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FOREWORD

Myroslav I. Zhaldak Symposium on **Advances in Educational Technology** (AET) is a peer-reviewed international conference focusing on research advances and applications of combined use of computer hardware, software, and educational theory and practice to facilitate learning. Today, AET is the premier interdisciplinary forum for learning scientists, academicians, researchers, professionals, policymakers, postgraduate students, and practitioners to present their latest research results, ideas, developments, and applications.

AET topics of interest are:

- Artificial Intelligence, knowledge engineering, and intelligent tutoring systems
- Aspects of environmental augmented reality security and ethics
- Augmented reality gamification
- Augmented reality in professional training and retraining
- Augmented reality in science education
- Augmented reality social and technical issues
- Cloud technologies for informatics learning
- Cloud technologies for mathematics learning
- Cloud technologies for physics learning
- Cloud technologies of mobile learning
- Cloud technologies of open education
- Cloud-based and mobile learning technologies for teacher and VET
- Cloud-based e-learning platforms, tools and services
- Cloud-based learning environments
- Cloud-based learning management systems
- Computer simulation in science and mathematics learning
- Design and implementation of augmented reality learning environments
- Development of Soft Skills for teachers of institutions of professional, special before higher and higher education in the context of digitalization
- Educational data mining and learning analytics
- ICT in higher education for a sustainable future society
- ICT in secondary education for a sustainable future society
- Learning environments models
- Learning technology
- Machine learning, robot learning and artificial learning
- Management of professional development of specialists in the digital space of formal and non-formal education

- Massive open online courses
- Methodology of informatization in education
- Methods of using cloud-oriented learning tools
- Mobile and blended learning
- Mobile technology of augmented reality
- Modelling systems in education
- Open learning systems and virtual conferences for training professionals
- Psychological safety of participants in the educational process in the digital educational environment
- Seamless learning and holistic education modelling and design
- STEAM education
- Supporting the development of 21st century skills through ICT
- Training and professional development of specialists in the digital twin of the educational institution
- Training of managers of a socio-political profile in the context of society digitalization: a humanistic aspect
- Virtualization of learning

This volume represents the proceedings of the 2nd Myroslav I. Zhaldak Symposium on Advances in Educational Technology, held in Kyiv, Ukraine, on November 11-12, 2021. It comprises 65 contributed papers that were carefully peer-reviewed and selected from 200 submissions. Each submission was reviewed by at least 3, and on the average 3.1, program committee members. The accepted manuscripts provide an up-to-the-minute appraisal of successful cases and delineate guidelines for prospective research.

We express our gratitude to all the scholarly authors who submitted their works and the participants who graced the occasion with their presence and interest in AET as a platform for sharing their ingenious ideas. We are profoundly grateful to the program committee members for their unwavering guidance, while the peer reviewers, by offering constructive criticism, commendations, and corrections, have tremendously contributed to the quality of the publications. We extend our appreciation to the developers of HotCRP, whose exceptional conference management system provided us with a wealth of resources, from the call for papers and reviewer invitations to handling paper submissions and communication with the authors. Lastly, we acknowledge the SCITEPRESS team for their cordial and fruitful cooperation in assembling and publishing the symposium proceedings.

Editors
Serhiy Semerikov
Viacheslav Osadchyi
Olena Kuzminska

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The Graph-Based Approach to Creating a System of Educational Management Based on Labour Market Demand in Terms of STEM and Science Education

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Keywords: Ontologies, IT Polyhedron, Labour Market, STEM, Education, New Ukrainian School.

Abstract: The educational system in modern society is required to provide a fast reaction to real-life challenges. Also, the growing role of IT skills in labour market requires to provide changes in educational systems related to enhancing the role of IT. This study aims to provide the development of a system that considers real-life requirements of labour market and defines competencies it requires (including IT skills) and provides the possibility to take them into account during the development of the educational programs. In the paper, the system that provides a correspondence between the demand on competencies provided by employers and delivering that request to Methodists that developing educational programs is described. The main actors in the proposed systems are Employers, Job Seekers, and Ministry specialists (Methodists). The proposed concept may be implemented using simple basic tools such as MS Excel and as well by specialized tools such as CIT Polyhedron and Phyton. A graph-based system using CIT Polyhedron has been developed. In this case, each entity is represented in form of nodes. Proper links have been provided between entities (nodes). Characteristics and descriptions of each specific entity were added in form of semantic and numeric nodes' metadata. An example of CIT Polyhedron's specific tools (rank) usage is described.

1 INTRODUCTION

The problem of building digital-based sociality is relevant today. However, development tendencies are very high, and education is one of the fields that may not provide the required digital-based changes (Mahyoob, 2020; Saminathan, 2021). Moreover, especially digitalization has come sharply during COVID-situation, leading to some problems related to its implementation (Eutsler et al., 2020; Trubavina et al., 2021).

Sure, there were many attempts to provide digital approaches. For example, it is using of cognitive IT platform Polyhedron (Stryzhak et al., 2018; Velychko et al., 2017; Strizhak, 2014) with its functions auditing (Stryzhak et al., 2014; Globa et al., 2015, 2019) and ranking (Nadutenko et al., 2022), virtual educational experiments (Slipukhina et al., 2019), using mobile Internet devices (Modlo et al., 2019) and augmented reality (Leshko and Rykova, 2017), distance learning in vocational education and training institutions (Petrenko et al., 2020), on-line courses (Vlasenko et al., 2020; Yahupov et al., 2020). Also, there are many approaches to providing STEM (Cheng et al., 2021, 2020; Badmus and Omosewo, 2020; Stryzhak et al., 2017).

However, its usage cannot be widely provided if it is not declared in the educational programs. Now, the New Ukrainian School is used to provide modification to the educational process (Elkin et al., 2017; Budnyk, 2018; Zhorova et al., 2022). It contains a list of the competencies that should be taught during education.

Currently, job seekers' search uses web-based services that require not standardized experience, skills and competencies. For example, such services are work.ua, rabota.ua, djinni.co (specialised in IT), etc. Moreover, it seems that the labour market required more digital-based skills than it declared in the New Ukrainian School and educational programs in Ukraine. Also, it seems more relevant to use the results of employers' requests on vacancies compe-

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tencies to include them in educational programs and forecasting requests in future.

Considering what was noted before, it seems relevant to develop approaches that takes to account job requirements for specialists during projecting of educational courses. Therefore, the study aims to describe an information system that provides data transfer on real-life required competencies from employers who demand job seekers' competencies to specialists in the Ministry of education and science to take them into account. Therefore, the object of the study is an approach that provides taking to account real-life required competencies during providing educational programs.

2 METHODS

To provide study and develop solving approaches, the concepts developed by the Ministry of Education and Science of Ukraine were used to define the problem and provide background research. Also, considering growing the role of digital skills (competencies) in digital sociality, the proposed approach focuses on digital competencies but is not limited by them.

The UML schemes were used to describe the informational system that may solve the problem of improving considering required real-life competencies during the development of educational programs. A use case diagram is developed to describe the main actors of the proposed system. Next, a class diagram is developed to describe the database, the main classes in it, and data for each class. Finally, the ways of implementation and some of its features are described.

The cognitive IT Polyhedron was used to create graphs as it was described before (Shapovalov and Shapovalov, 2021). Both graphical and excel-based approaches were used to form graphs. The excel-based approach to constructing a graph is shown in figire 1.

3 RESULTS

3.1 Analysis of Nonconformity of Competency Provided by Education and Requirements by Employers

As noted before, there is the problem of nonconformity of competencies given by teaching and required by employers. It means that some educational time is wasted. The competencies taught during the modern educational process of Ukraine in middle school are declared by the New Ukrainian School concept and its implementation in specific educational programs. However, employers require competencies, and those declared by New Ukrainian School were not compared.

Employers are seeking a person who can solve specific tasks he needs. For example, such skills are knowledge of using MS Office, English level B2, Adobe Photoshop, or using the textile machine. Also, the employer may require some measurable experience in some field (5 years working on environmental projects, three years of C++ coding). These competencies are very static, specific and easy to determine. Such requirements (competencies) may be named as "specific" and can be divided into "static skill-based" and "static experience-based".

However, the competencies declared by New Ukrainian School have different essential nature, and it is instead "abstract", "wide", and "relatively static". Using the term "abstract", we mean competencies that include more specific (in our classification – "static") competencies. In this group, we propose to include mathematical competence, essential competencies in natural sciences and technologies, and information and digital competence. For the term "wide", we mean that it is not provided specific knowledge or skill but rather some dynamic abstract level. Also, the "wide" means that competencies are used in each decision-making. The analysis of competencies declared by the New Ukrainian School is shown in table 1.

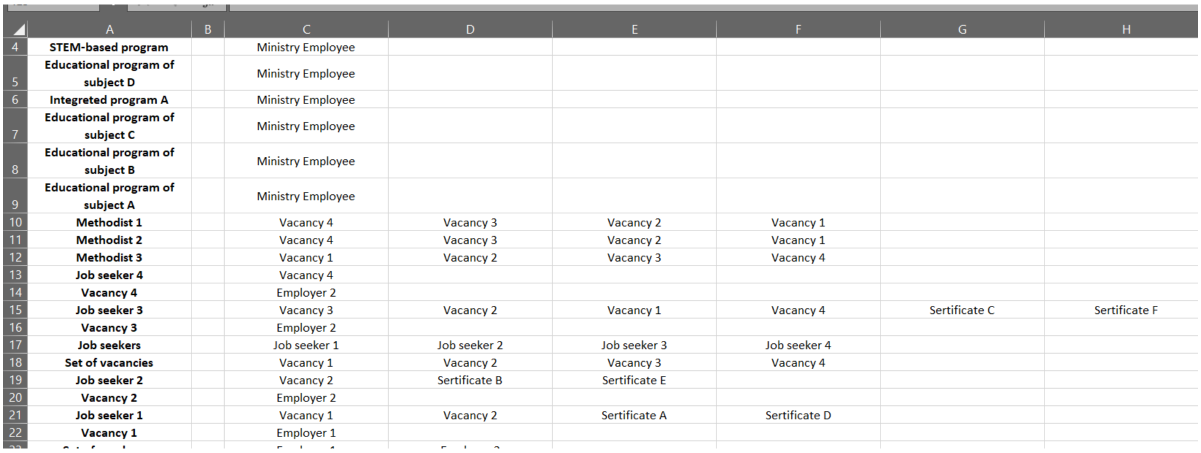
As seen from table 1, the competencies declared by New Ukrainian School may not be used by the employer.

All noted before makes the gap between skills provided by education and used in real-life work. However, it seems that it may be solved by standardisation, defining of values of each competency and using simple well-known ranking mechanisms. Sure, the proposed method is not dedicated to violating market-based society, but it allows for prioritising the competencies that have not been taken to account before. Also, the idea of standardisation can be used to define a median salary for jobs that require specific skills. Then, students can use that to decide on skills required by digitalised sociality.

3.2 Proposed Approach

3.2.1 Using Ranking Tools to Evaluate the Digital Competencies of the Job Seekers

To solve the problem, it seems relevant to use measurable competencies (such as "static skill-based"



	A	B	C	D	E	F	G	H
4	STEM-based program		Ministry Employee					
5	Educational program of subject D		Ministry Employee					
6	Integreted program A		Ministry Employee					
7	Educational program of subject C		Ministry Employee					
8	Educational program of subject B		Ministry Employee					
9	Educational program of subject A		Ministry Employee					
10	Methodist 1		Vacancy 4	Vacancy 3	Vacancy 2	Vacancy 1		
11	Methodist 2		Vacancy 4	Vacancy 3	Vacancy 2	Vacancy 1		
12	Methodist 3		Vacancy 1	Vacancy 2	Vacancy 3	Vacancy 4		
13	Job seeker 4		Vacancy 4					
14	Vacancy 4		Employer 2					
15	Job seeker 3		Vacancy 3	Vacancy 2	Vacancy 1	Vacancy 4	Sertificate C	Sertificate F
16	Vacancy 3		Employer 2					
17	Job seekers		Job seeker 1	Job seeker 2	Job seeker 3	Job seeker 4		
18	Set of vacancies		Vacancy 1	Vacancy 2	Vacancy 3	Vacancy 4		
19	Job seeker 2		Vacancy 2	Sertificate B	Sertificate E			
20	Vacancy 2		Employer 2					
21	Job seeker 1		Vacancy 1	Vacancy 2	Sertificate A	Sertificate D		
22	Vacancy 1		Employer 1					

Figure 1: Excel-based approach to graph forming.

Table 1: The analysis of competencies declared by New Ukrainian School.

Competency type title	Description of competency type	List of competencies
Abstract	Impossible to measure, are very abstract and includes some more specific competencies	Mathematical competence; Basic competencies in natural sciences and technologies; Information and digital competence
Wide	Impossible to measure, is used during solving any of practical based-problems	Ability to learn throughout life; Initiative and entrepreneurship; Awareness and self-expression in the field of culture; Social and civic competence; Environmental literacy and healthy living
Relatively static	Possible to measure, but still relatively hard. However, accepted international levels may be used to measure	Communication in the state (and native in case of difference) languages; Communication in foreign languages

and "static experience-based") that may be processed. Their processing may be used to obtain a general integrated score of the corresponding person to the vacancy.

Also, it seems relevant to use the importance of competency for vacancies description. As for digital specialisations, such skills will provide a core score for Job seekers' evaluation, but for other specialisations in digitalisation of sociality, it may provide up to 50% of the ranking score.

Such a ranking approach will provide a win-win situation during the job-seeking process. Employers will decrease the role and load on the company's HRs. Job seekers will be evaluated objectively and receive reasonable estimates based on the general skills of job seekers, including digital. It will not provide a waiver of HRs, but it significantly decrees their work amount and provides a more accurate, fair candidates selection. As a standard to create a relevant system of ranks inputted by the user, the document "job responsibilities" may be used.

So, the employers will use a well-known raking tool that the modified equation of graph-based ranking can describe:

$$RANK_{abs(i)} = \sum (IMP_i \times \frac{v_i}{v_{max}}) \qquad (1)$$

where $RANK_{abs(i)}$ – ranking rank in absolute value for i's node; IMP_i – importance coefficient for data of i's object; v_i – the value i's object; v_{max} – maximum value of the dataset.

For this, the class name of each data will be the name of the competency (skill); its numeric data (v_i) will correspond to the mastery level of that skill; the importance (IMP_i) is a level of such competency requested by the employer. So, each job seeker will obtain his personal $RANK$ of corresponded for a specific vacancy. Such an approach will be also useful for job seekers due they will obtain the matrix of the $RANK$s for the vacancies they choose and define by themself work that they are fitted and comfortable to do.

As it was noted before, in the digitalized sociality, the role of digital competencies will be always high. To prove it, the example the IT profession (junior front-end programmer) and non-IT professions (enterprise economist) vacancies $RANK$s is shown in table 2 and table 3, respectively. For the examples, approximations of ranks and levels will be used to simplify understanding. The competency level will be used in form of relative values (%).

As shown from Table 2, Jobseeker 1 with *RANK* of 480 is more suited for vacancy than Jobseeker 2 with *RANK* of 400. Also, digital skills are valuable for non-IT specialists as it is shown in table 3.

As it is shown in table 3, Jobseeker 2 has higher hard Bookkeeping skills, but low IT skills and generally it will be less suitable for the vacancy than Jobseeker 1. That proves that the proposed approach will be helpful to IT specialists and non-IT specialists in the digitalised world. However, it requires providing a certification program to define the competency level (numeric data).

3.2.2 Using of Competency Importance Data to Develop Educational Programs

The developed approach will collect the employer's requests on competencies they need. So, it will be possible to use such data sets to generate real-life required skills and competencies.

The most valuable is a set of Importance (IMP_i) requested by the employer for each skill data to analyse the labour market requirements in competencies and modify the educational process. So, it may be represented as further:

$$<CN_{edu}, IMPC_{edu}> = RANK(<CN_n, IMP_n>) \quad (2)$$

where

$<CN_{edu}, IMPC_{edu}>$ – cortege of skills and its values recommended for education;

$RANK(<CN_n, IMP_n>)$ – ranking results of each element of cortege of skills and their importance for the employer ($<CN_n, IMP_n>$).

The general workflow is using such a system provides obtaining of data set (cortege) of required by Employer competencies and its importance. Such data is processed by the system and it provides both, the results of corresponding of Job Seeker to the vacancy and obtaining a set of importance competencies values used for the development of education programs (figure 2).

3.3 Practical Developments

To simplify, the approach will be described in short form. The main actors of the proposed system are an employer that generates demand on competencies and a methodist that uses that demand on competencies to lay down it into educational programs. Also, there is an actor called Jobseeker. That actor is already an educated person who is already characterised by some stack of competencies.

Each actor has many functions, but only the most important actions will be described. The employer creates the vacancies and adds required competencies with the importance of the job. The required vacancy competencies and their importance are used to rank the corresponding specific job seeker with its stack of competencies with a vacancy. Ministry specialists use such ranking results to analyse them and lay down the most required competencies in educational programs. The use case diagram of the proposed approach is shown in figure 3.

The classes that correspond to actors and actions are used to create such a system. First of all, some classes describe actors themselves, and they are Jobseeker, Employer and Ministry Employee. Each of such classes has person identifiers due they describe actors. Each Job seeker has its personalised set of competencies called the "Job seeker's set of the competencies". Each Job seeker's set of competencies consists of competencies (skills), competency's (skill's) level and certificates that prove it.

Each Employer is looking for a Job seeker, and finding it creates a vacancy. Each employer can create multiple numbers of Vacancies, and it creates a library of them called Set of Vacancies. Each vacancy has data about competencies and their importance to provide Vacancy's activities well. Job seeker's set of competencies provides a ranking that defines corresponding of its to Vacancy's RequiedCompetency and CompetencyImportance.

Set of Vacancies with its data CompetenciesAndImportance is used by Ministry employees (Methodists) to modify the educational program with an array of StudiedCompetenices. The list of database entities in the form of a class diagram is shown in table 4 and figure 4.

The proposed Use case diagram and Class diagram will be useful to developing real-life systems.

3.4 Implementation

3.4.1 Possible Approaches

The proposed concept may be implemented using simple basic tools such as MS Excel and by specialised tools such as KIT Polyhedron (Tarasenko et al., 2021; Shapovalov et al., 2021) and by using Python.

Also, the proposed approach seems relevant to use in a stack with modern semantic graph-based technologies (Paschke and Schäfermeier, 2018; Schäfermeier et al., 2021) and neural networks to provide analysis and predictions.

Table 2: Example of *RANK*ing the junior front-end programmer.

Class name (competency name)	Mastery level of the skill (v_n) (numeric data), %	Importance (IMP_n) requested by the employer	$RANK_n$ of the skill	General *RANK* score
Job seeker 1				
CSS coding	50	5	250	100
HTML codding	30	4	120	
MS office skills	50	2	100	
Business analysis	10	1	10	
Geography skills	10	0	0	
Job seeker 2				
CSS coding	20	5	100	83
HTML codding	70	4	280	
MS office skills	10	2	20	
Business analysis	0	1	0	
Geography skills	50	0	0	

Table 3: Example of *RANK*ing the enterprise economist vacancy.

Class name (competency name)	Mastery level of the skill (v_n) (numeric data), %	Importance (IMP_n) requested by the employer	$RANK_n$ of the skill	General *RANK* score
Job seeker 1				
Bookkeeping	80	5	400	100
Bookkeeping Law understanding level	40	5	200	
MS office using level	60	3	180	
Analysis and reporting	60	4	240	
General skills of PC using	20	4	80	
Job seeker 2				
Bookkeeping	90	5	450	85
Bookkeeping Law understanding level	60	5	300	
MS office using level	10	3	30	
Analysis and reporting	30	4	120	
General skills of PC using	10	4	40	

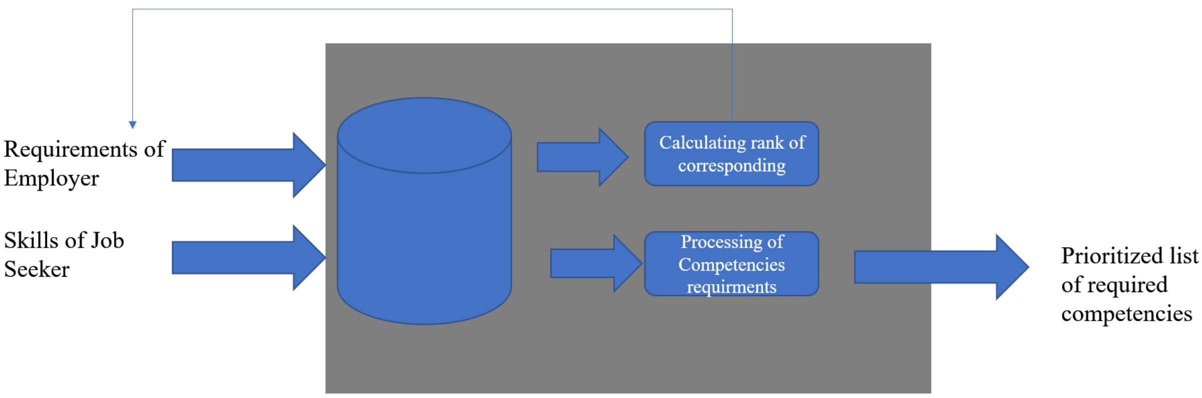


Figure 2: Workflow of data in proposed system.

Sure, while using simplified tools such as MS Excel or Google Sheets, it will not be an informational and communicational system, and it will not be possible to communicate with it using API. However, it will be possible to provide all required functions. For the Excel-based approach, libraries of skills "CompetencyName" will be located in a separate sheet and used as a drop-down list.

Also another vital question to be solved is data collection. Using google forms to create vacancy profiles and cortege on importance and competencies is the simplest way. Such google form can collect

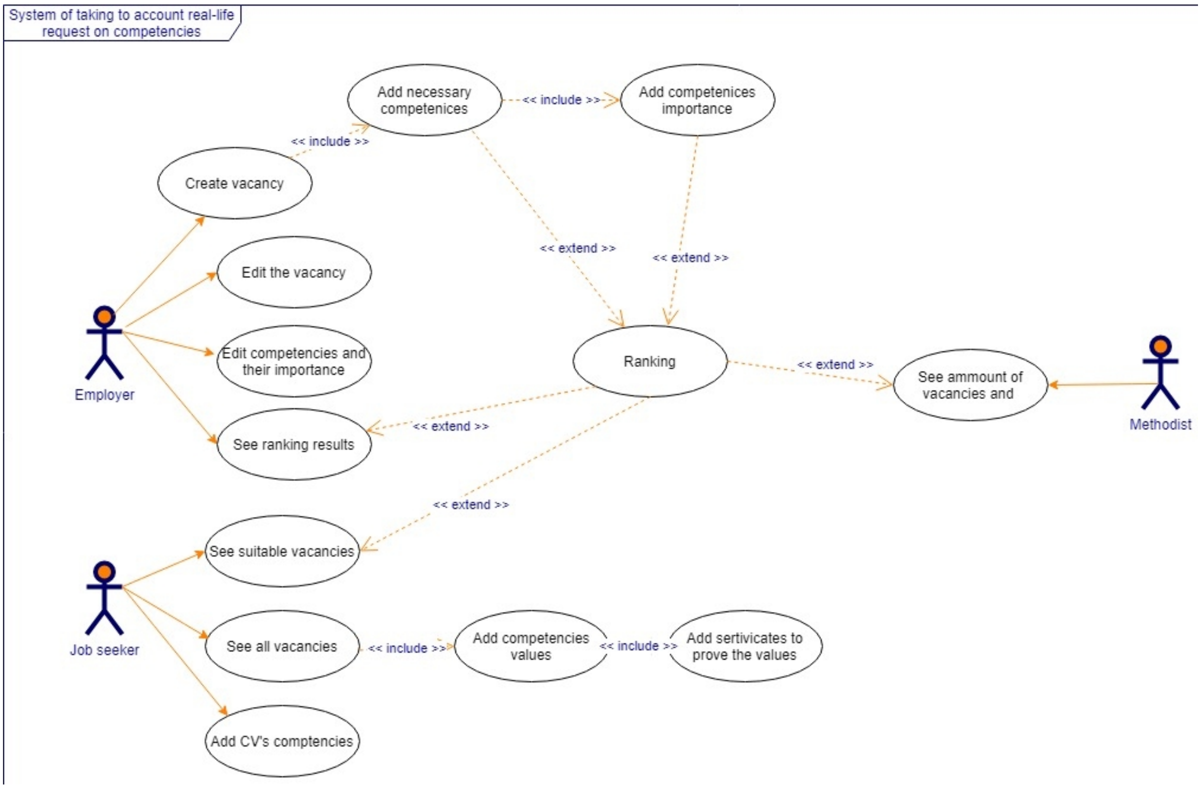


Figure 3: Use case diagram of proposed approach.

Vacancy's "name", "Description", "RequiedCompetenices", and "CompetenicesImprotance". Another form may be used to collect data on a Job seeker's set of competencies.

Sure, it is the most common and straightforward way. The system will be created using full-stack (back end and front end) development in real life. However, MS Excel-, Graph- and Phyton-based tools will be developed to make concept proof tests in further studies.

In any form of its implementation, the proposed approach will be helpful and provide an effective way to consider real-life required competencies. Comparing approaches to create a system that takes to account job requirements for specialists during projecting of educational courses educational programs with real-life labour market demand is shown in table 5.

As seen from table 5, the Excel-based approach is simple to provide, but it does not provide possibly to provide noted database structure in full-scale. On the other side, a python-based approach is a full-scale approach that gives the possibility to provide any system, but it requires a vast number of resources. Thus, the most perspective to use is a no-code cognitive IT Polyhedron to provide such a system. Also, the advantage of Polyhedron has integrated audit and ranking tools.

3.4.2 Graph-Based Approach

One of the advantages of the graph-based approach is a visualisation of entities (in the form of nodes) and their links. Thus, it is possible to implement a UML diagram to represent the database in the form of a graph in full-scale. Also, taking into account the specificity of graphs built using cognitive IT Polyhedron (however, it will be relevant for most graph-based approaches), some classes will be represented not in the form of nodes but in the form of semantic or semantic numeric data of some entities. For example, competency (skill) and its level will be represented in the form of metadata of nodes vacancies or job seekers (depending on the variant of realisation). For this case, competency (skill) will be the class name of the node, and its value will be the value of such a class. Such an approach provides the possibility to provide a ranking. However, competencies (skills) also will be represented in the form of nodes (separate entities) to provide additional structurisation.

The first data structural component is a set of competencies. Each specific competency has been directed on the "Set of competencies" link to represent its dependence on this class. A general view of the

Table 4: Description of the classes of UML class diagram of proposed system.

Name of Class	Attributes of Class
Job seeker	+ ID: int + name: string +Job seeker's set of the competencies: array(Competency (skill), Competency's (skill's) level) AddNewCompetency(string): text AddCompetency's(skill's)Level: int AddCertificate:link display(set of the competencies): list(set of the competencies)
Competency's (skill's) level	+ ID: int + value: int
Competency (skill)	+ ID: int + name: string
Certificate	+ ID: int + name: int +file: link +authority:name
Job seeker's set of the competencies	+sertificates: list(certificates) + SetOfCompetencyLevel: array Competency (skill); Competencies(skills)level
	Display(Competency(skill)): list(Competency(skill)) Display(Competency's(skill's) level): Competency's (skill's) level
Ranking	++ ID: int + rank: int
Employer	+ get(Job seeker's set of the competencies):array (Job seeker's set of the competencies) + get (RequiedCompetenices): array(RequiedCompetenices): + get (CompetenicesImprotance) array (CompetenicesImprotance) + Id: int + name: text
	+create(Vacancy):array(Vacancy) +display(Job seeker's set of the competencies)
Vacancy	+ Id: int + name: text + Desription: text + RequiedCompetenices:array + CompetenicesImprotance:array
Set of the vacanieses	+Vacancynames(Vacancyname): array +CompetenciesAndImportance (VacancyRequiedCompetenices);VacancyCompetenicesImprotance:array
Ministry employee	+ Id: int + name: text + displayRequiedCompetenices:array + displayCompetenicesImprotance:array + modify
Educational program	+ users: list(User) + TextOfProgram: text + StudiedCompetenices:array

structural component "set of competencies" is shown in figure 5. Each competency is linked with the Job seeker whom it owns, a certificate that it proves and a vacancy that is required.

The built graph also represents Job seekers and Vacancies branches. All specific Job seekers are

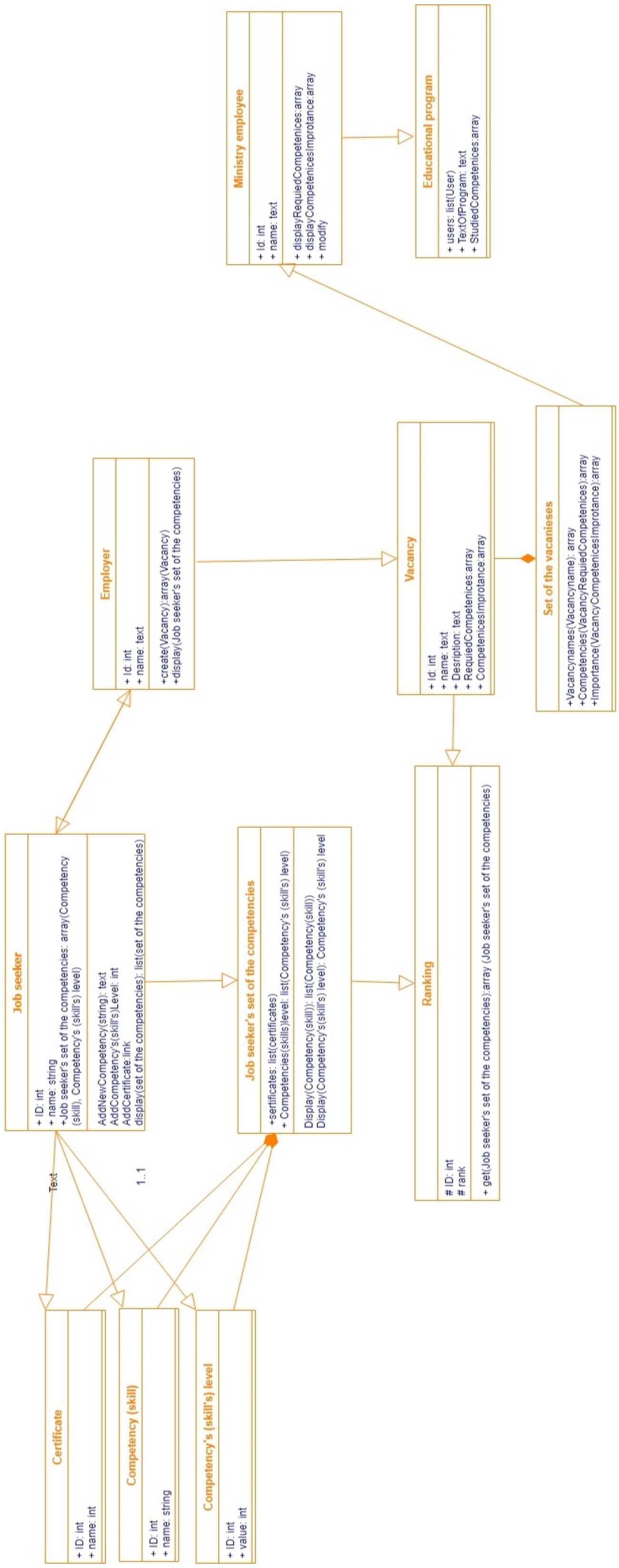


Figure 4: UML Class diagram of the proposed system.

Table 5: Comparing approaches to create a system that takes to account job requirements for specialists during projecting of educational courses educational programs with real-life labour market demand.

Name of approach	Requiring to write specific code	Possibility to provide noted database structure in full-scale	Integrated ability to provide raking without writing specific code
Excel-based	No	No	No
Graph-based	No	Yes	Yes
Python-based	Yes	Yes	No

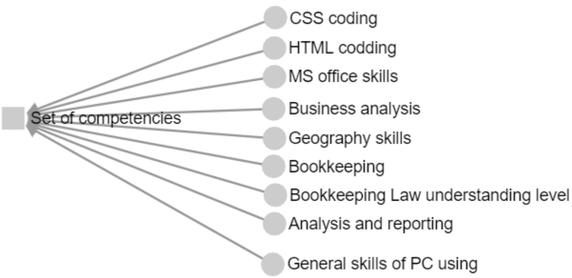
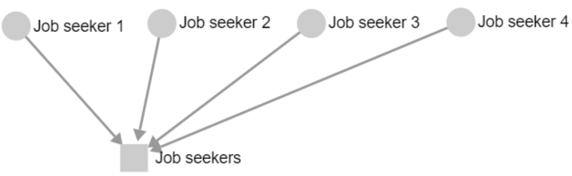


Figure 5: Element "Set of competencies" of proposed graph-based system.



(a)

(b)

Figure 6: Element "Set of vacancies" (a) and "Set of employers" of the proposed graph-based system.

linked to the "Job seekers" node (figure 6a). Each vacancy is linked with the "Set of vacancies" node to show its belonging and a specific employer who provided such vacancy. All employers are linked with the Set of employers node (figure 6b).

The primary users of demand analysis shown at graph's node "Education management institution". Vacancies are linked with members of education management institutions. Education management institution is the root node linked with ministry employee that in turn linked with Methodists who develop educational programs. Ministry employees form all educational programs. That is why they are linked. Each multiplicity of educational programs is linked to the "Educational programs" node. Educational programs additionally may be represented as a form of nodes of this graph that represents elements of specific programs themselves or have a link to the specific ontology-based educational program (figure 7).

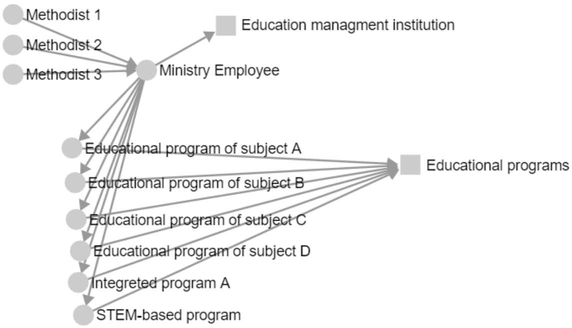


Figure 7: Elements "Educational management institutions" and "Educational programs" of the proposed graph-based system.

The proposed system is integral is maybe used for decision making. All entities in the form of graph's nodes are linked as noted before:

- Job seekers with vacancies and with competencies and certificates that it proves;
- competencies with certificates that prove job seekers and vacancies
- vacancies with job seekers, required competencies, employers who provide it and methodists who form educational programs;
- job seekers are linked with competencies and certificates and with vacancies they responded on;
- methodists are linked with vacancies that describe real-life demand on competencies and with ministry employees who form educational programs.

A general view of the proposed graph-based solution for taking to account real-life required competencies is shown in figure 8.

Both job seekers and vacancies have metadata. Job seekers' metadata are the skill level that job seekers own, and vacancies' metadata are skills and competencies that are required (figure 9a and b).

The ranking is possible to provide in both ways, to evaluate which vacancy fits the best chosen by a specific job seeker and to evaluate which job seeker fits the best for the proposed vacancy. The type of ranking depended on users' requests. The user chooses factors that he requires to rank and their importance for him.

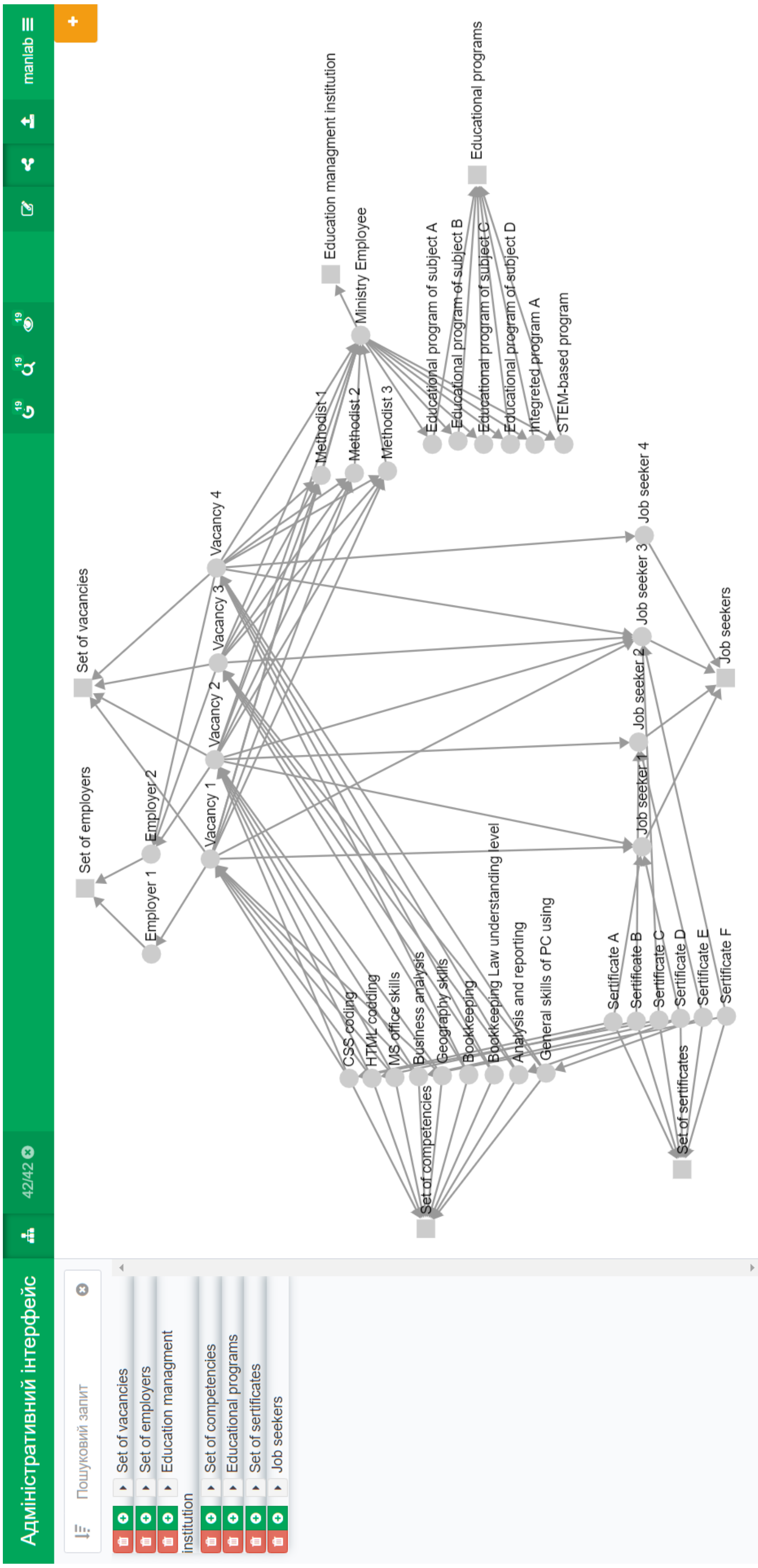
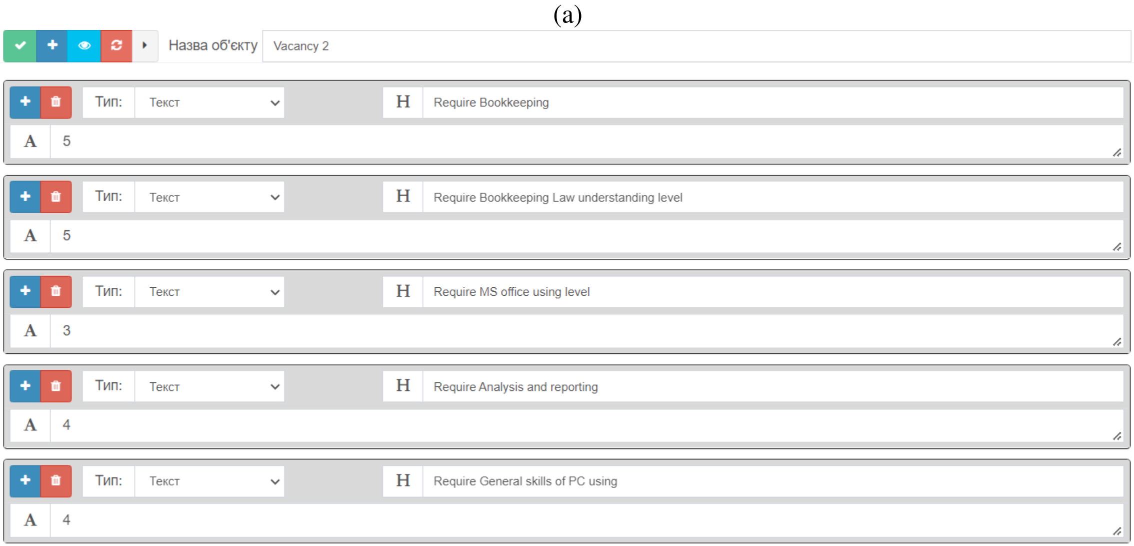


Figure 8: Developed a graph-based approach to taking to account real-life demand in the labour market.

(a)



(b)

Figure 9: Metadata in graphs' elements.

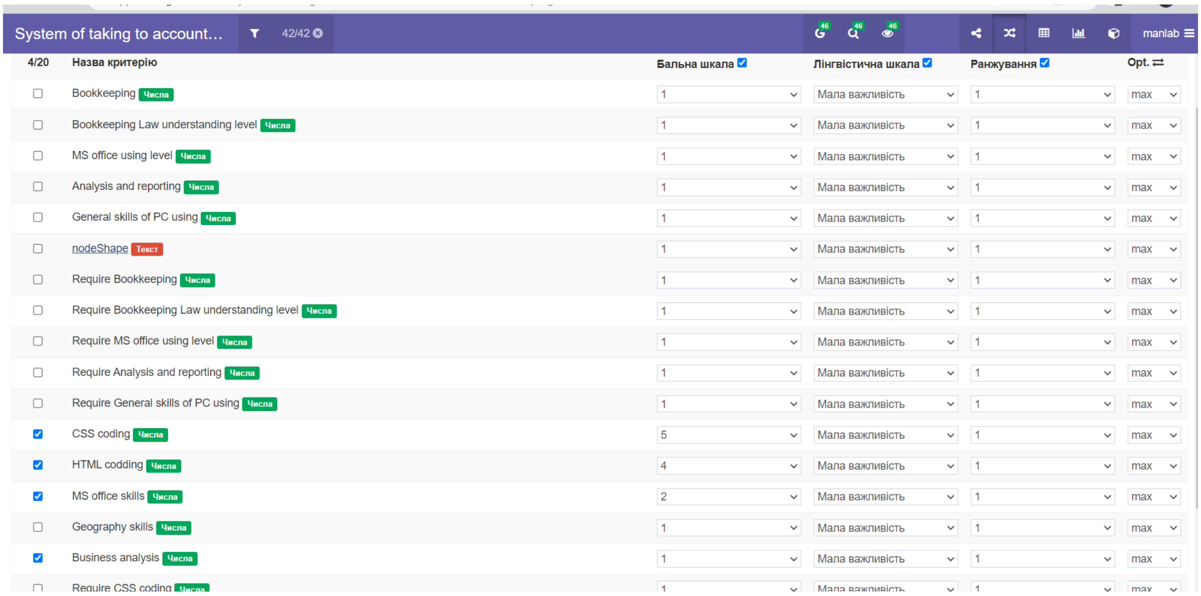
So, if he chooses the factors that correspond to competencies that require vacancy and chooses the importance of such factors for this job, the system will rank job seekers to their relevance to this vacancy; on the opposite, if the job seeker chooses competencies that require for jobs (for example, Require HTML codding), he will rank existing vacancies and find which of them fits him best (figure 10).

Methodists and Ministry employees may use a table view of the graph with or without filtering the data. A table view of the generated graph used by the Methodists and Ministry employees is shown in figure 11.

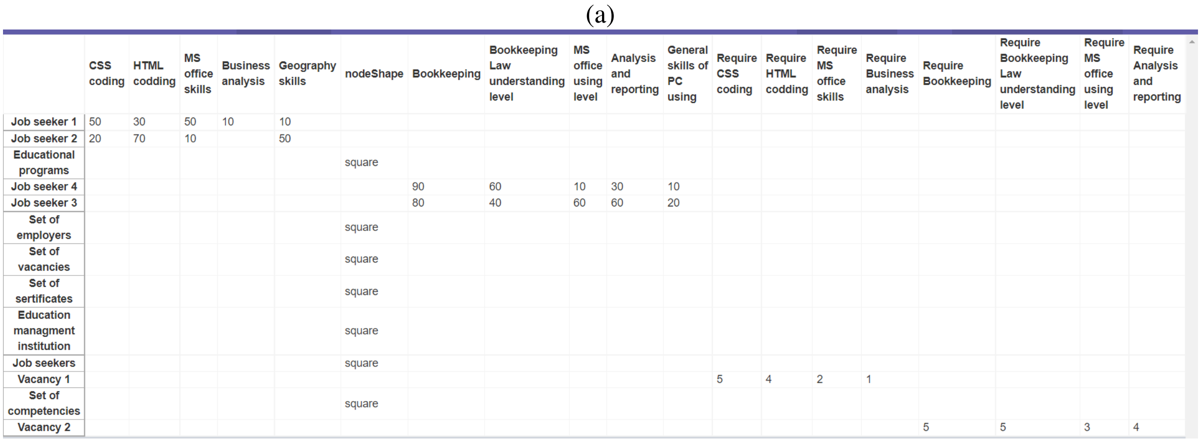
Therefore previously, the connection between education and the practical labour market was not provided systematically. And now it is proposed to use ontologies to produce such connections. In this case connection will be provided by connection relative nodes by graph's edges. The proposed approach will be much more efficient in case of its usage in complexes with forecasting systems such as regression or neurolar networks. However, it is important to collect such data to forecast and ontologies are used to provide it.

4 DISCUSSION

Currently, the labour market requires specialists with soft skills, hard skills, critical thinking, creativity,



(a)



	CSS coding	HTML codding	MS office skills	Business analysis	Geography skills	nodeShape	Bookkeeping	Bookkeeping Law understanding level	MS office using level	Analysis and reporting	General skills of PC using	Require CSS coding	Require HTML codding	Require MS office skills	Require Business analysis	Require Bookkeeping	Require Bookkeeping Law understanding level	Require MS office using level	Require Analysis and reporting
Job seeker 1	50	30	50	10	10														
Job seeker 2	20	70	10		50														
Educational programs						square													
Job seeker 4							90	60	10	30	10								
Job seeker 3							80	40	60	60	20								
Set of employers						square													
Set of vacancies						square													
Set of sertificates						square													
Education managment institution						square													
Job seekers						square													
Vacancy 1												5	4	2	1				
Set of competencies						square													
Vacancy 2																5	5	3	4

(b)

Figure 10: Metadata in graphs' elements.

project management and other skills. The approach that provides it is STEM/STEAM, but no trivial (as for the Ukrainian educational system) approaches that foresees not-project based and not-real-life based education. The proposed graph will be very effective to modernise both trivial educational programs (as it will highlight the skills and knowledge that are not used in employing process) and STEM-based education.

The skills and their values will prioritise the skills to teach based on market demand. As STEM is more fluent compared to traditional ones, it will be possible to use for STEM-based programs to develop the most required skills. Also, it can develop required real-life skills even during not-specialised subject learning. For example, the task was given to students during chemistry maybe project that foresees using coding, project-management or business analytical skills if such is defined as the most demanded by the labour market.

For example, the task that develops business analysis during chemistry discipline may foresee analysing of current business process and technological process of production of ammonia (for example; it can be related to any production; related to the technology aspect of STEM); find the laws, fundaments and existing modern scientific studies that related to the field (related to science aspect of STEM); provide calculation of the existing production and propose technology that optimises the production (related to science aspect of STEM); find or develop equipment to provide proposed optimised technological approach (related to engineering aspect of STEM). As it can be seen, it provides both STEM-approach and development required for the current state of

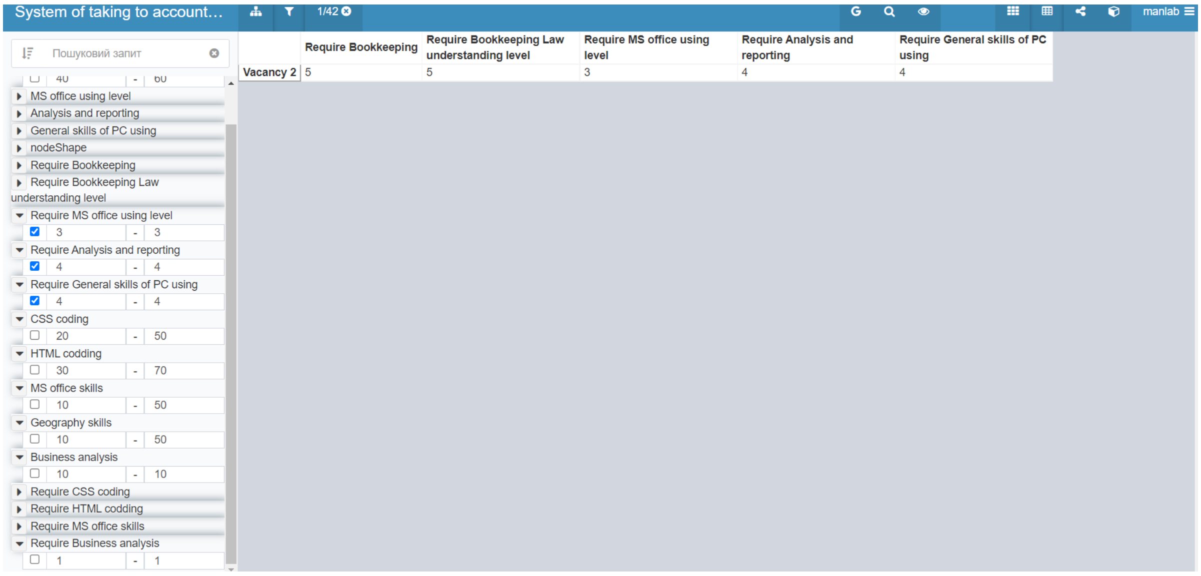


Figure 11: Table view of the generated graph to use by the Methodists and Ministry employees.

marked skill (for example, business analysis).

5 CONCLUSION

It is shown that some competencies that are required in real life are not prioritised in educational programs. The study describes an information system that provides data transfer on real-life required competencies from employers to specialists in the Ministry of education and science and Methodists consider them.

The main actors in the proposed systems are Employer, Job Seeker and Ministry specialist (Methodist). The main classes in proposed systems are Jobseeker Competency's (skill's), level Competency, (skill) Certificate, Job seeker's set of the competencies, Ranking Employer Vacancy, Set of the vacancies, Ministry employee, educational program. Each of these classes has the data that describes it.

The proposed concept may be implemented as well using simple basic tools such as MS Excel and as well by specialised tools such as KIT Polyhedron and as by using Phyton. In further studies, MS Excel-, Graph- and Phyton-based tools to make concept proof test.

It is shown that the graph-based approach is characterised by advantages, and it was chosen to build the system's prototype. It represents the graph's root nodes are a Set of competencies, Job seekers, a Set of Vacancies, a Set of employers, educational management institutions and educational programs. It is proven that the most perspective approach during which such a system can be used is STEM because a high level of flexibility characterises it.

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Professional Stress Prevention Program for Employees Working Remotely in Crisis

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Keywords: Professional Stress, Crisis, Remote Work, Mental Health, Psychological Safety.

Abstract: This article highlights the problem of professional stress of workers in the mass transition to remote work caused by the difficult conditions of our time in a pandemic COVID-19. Based on the results of theoretical analysis of scientific literature, the classification of the main models of stress is given. The content, features, factors, consequences of professional stress of workers working remotely in general in a pandemic in particular are highlight. Personal indicators of professional stress of employees are revealed. The role of personal qualities of employees in the emergence of professional stress as a buffer that mediates the impact of stressors, enhancing their action, or inhibiting it, negatively affecting the mental health, psychological safety of employees and the quality of their professional activities are shown. The results of an empirical study show that the influence of stressors, which is significantly enhanced in the forced transition to remote work, causing violations in the communicative, emotional, volitional and need-motivational spheres of personality of employees in general and depending on gender and age and professional features of employees in particular. The expediency of taking into account the personal characteristics of employees to prepare them for the prevention and overcoming of professional stress, developing the ability of employees to conscious and active stress management and counteracting stressors is stated. The article presents the components of the program of professional stress prevention for employees working remotely in crisis (cognitive, motivational, volitional, communicative). The data on approbation of the program is given, which testify to its positive influence on the dynamics of stress subjective perception. Prospects for further research aimed at large-scale implementation of the program in postgraduate education are outlined.

1 INTRODUCTION

The dynamic changes observed in Ukrainian society are caused by a significant number of stressors in professional activities, which, combined with the personal characteristics of employees, contribute to professional stress, which negatively affects the effectiveness of professional activities and well-being. This problem is especially vital in today's crisis when a significant number of professionals went to work re-

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motely under the pressure of external circumstances (pandemic COVID-19, martial law), which led to a radical change in the usual way of life and, consequently, the emergence of new, additional stressors. Given this, developing programs for professional stress prevention of specialists deserve particular study.

Analysis of the literature shows that the problem of stress is the subject of research by many scientists. Intensive research of the phenomenon of stress began after the publication of the works of Selye (Selye, 1976) in the 1950's, in which the main attention was focused on physiological changes in the body under the influence of stressors. Later, the psychological component of stress development was singled out and, accordingly, the concept of "psychological stress" was introduced as a product of the subject's cognitive processes (Lazarus, 2001; Pilkey et al., 2020; Cooper and Quick, 2017).

The problem of professional stress as a factor influencing the ability to work, quality of work and health of employees of organisations, devoted to the research of (Burke et al., 1996; Vodopyanova, 2013; Greenberg, 2008; Edwards et al., 1998; Karamushka and Gnuskina, 2018; Cohen and Wills, 1985; Cooper et al., 1994; Leonova, 2016; Beehr and McGrath, 1992; Pankovets, 2006; Zhou and Salvendy, 2019; Sharit and Salvendy, 1982). There are investigated some aspects of the specifics of the organization of effective work of remote virtual teams online (Pazos, 2012; Orti and Middlemiss, 2019) and the possibility of obtaining the psychological safety in such teams (Lechner and Tobias Mortlock, 2021; Costello, 2020), including crisis (Sandoval-Reyes et al., 2021; Horton and Jacobs, 2022).

Some approaches to employee skill improvement, psychological stress relief, work-family balance, and company culture reinforcement from an HRM perspective are considered because of the impact of work-from-home patterns during the COVID-19 crisis (Chen, 2021).

At the same time, the peculiarities of professional stress prevention of specialists who work remotely in general and are forced due to a pandemic or martial law, in particular, have not previously been the subject of a particulatr study. The urgency and insufficient study of the problem determined the purpose of the study – to theoretically justify and test the program to prevent professional stress of employees who were forced to switch to remote work in a crisis.

2 LITERATURE REVIEW

An in-depth analysis of stress models was made by Ukrainian researcher Pankovets (Pankovets, 2006), who classified such models depending on the factors that cause stress and ways to manage it.

Thus, the models based on biological stressors include P. Parson's Model of Predisposition (Bodrov, 2000), H. Selye's physiological model (Selye, 1976; Pankovets, 2006; Bodrov, 2000), J. Fuller's genetic-constitutional model (Bodrov, 2000). Psychological factors are taken into account primarily in the cognitive model of R. Lazarus (Lazarus, 2001; Bodrov, 2000) and models of mental tension of N. Naenko (Nayenko, 1976). Complex (biological and psychological) factors are considered in the integrative model of R. Scott (Wong et al., 2006) and the model of Greenberg (Greenberg, 2008), and socio-psychological - in the interdisciplinary model of H. Basovich et al. (Bodrov, 2000), D. Dooley's theory of conflict (Bodrov, 2000) and D. Dorenvend's model (Bodrov, 2000). In addition, the scientist distinguishes models of stress depending on the methods of stress management through the mechanisms of adaptation (model D. Mechanic (Bodrov, 2000)), systemic self-regulation (system model of D. Ford and G. Schwart (Bodrov, 2000), or coping (model of coping R. Lazarus and S. Folkman (Lazarus, 2001; Greenberg, 2008; Bodrov, 2000).

Based on the analysis of these models, we can conclude that the occurrence and development of stress depend on both the constantly changing external environment and the individual psychological characteristics of the individual (Bodrov, 2000). The latter is caused by the fact that a difficult situation can be stressful for one person and not for another. It depends on how threatening the person is. The emergence of negative effects of stress is due primarily to the peculiarities of cognitive assessment of the environment and their own resources, in case of noncompliance of the latter with the requirements of the environment in which the person is.

To explain and describe the stressors associated with work, use close but not synonymous concepts: "work stress", "organisational stress", "professional stress", which carry different content loads (Pankovets, 2006; Kulikov, 2000; Nikiforov et al., 2003; Vasilieva et al., 2004).

Thus, work stress (job stress, stress at work), according to researchers, occurs as a result of complications related to the work environment (features of the workplace, working conditions, etc.). Organisational stress arises as a result of the negative impact of the characteristics of the organisation in which the entity operates. These concepts are close, but not synonymous. Therefore, it is vital to use them adequately following the objectives.

Professional stress is often understood as such a negative mental state, which is caused by the peculiarities and requirements of the profession itself, in its narrow sense (Bodrov, 2000; Knorring, 2001; Huhtala et al., 2021; Moreno Fortes et al., 2020; Kendall et al., 2000). These are complications:

- arise in the organic and psychological spheres in the performance of functional duties (according to the requirements of the profession) by the subject of professional activity and depend on the specifics of each profession;
- arising in the absence of a role balance between the professional sphere and the personal sphere: role overload, fuzzy role definition, role conflicts (Pankovets, 2006);
- due to the low level of satisfaction of the needs of the subject of professional activity in the process of performing this professional activity and the emotional attitude of the subject to the same work (Pankovets, 2006).

Currently, there are three main approaches to the study of professional stress: environmental, transactional and regulatory (Vasilieva et al., 2004; Hassard and Cox, 2015). The main task of the environmental approach is to find links between the content of work, the characteristics of the professional environment, the individual characteristics of staff and the violation of the health and psychological well-being of employees.

In the transactional approach, a great role is given to cognitive assessment by employees of professional situations and their own resources. *Proponents of the regulatory approach* (Leonova (Leonova, 2016), G. Hokki (Bodrov, 2000)) emphasise the mechanisms of regulation of activity and the mental state of specialists under the influence of various factors. Based on this, professional stress can be defined as a specific form of violation of the physiological and mental activity of the individual, which is due to individual and personal characteristics and occurs in response to the negative impact of the professional situation.

Both the features of the organisational and professional environment and the personal qualities of employees have a great influence on the development of stress, due to which they, when perceiving such influence of stressors, can reduce their significance or, conversely, strengthen them. In the latter case, there are complications in the psychophysiological state and psychological health and well-being of employees.

During the crisis phenomena that cause the forced transition of several employees to remote work, additional stress factors arise. It is the compulsion of remote work that restricts people's freedom and, despite the understanding of the need for such a state of affairs for survival, at the same time causes internal resistance due to the heavy psychological, emotional and financial burden for people. Employees working at home, especially in small rooms where they are forced to stay with other family members, may feel angry, irritated by the inability to adapt to the conditions and to cope with the difficult current situation. As a result, there is a risk of deteriorating mental health, the spread of symptoms of psychological distress and disorders, and so on (Hawryluck et al., 2004; Parmet and Sinha, 2020; Rubin and Wessely, 2020; Wu et al., 2005; Xiang et al., 2020).

In remote mode, employees receive basic information about the course of events from the media and social networks, which, unfortunately, often broadcast messages that update the perception of danger, threat and risk to life, often against the background of unclear information about the course of events, their uncertainty, etc. (Lechner and Tobias Mortlock, 2021; Pinchuk et al., 2022).

As for social networks, they often talk about spreading unverified rumors or just misinformation, fakes which causes unfounded fears among many people (Bontcheva et al., 2013; Oksanen et al., 2021).

An equally important factor in professional stress is the threat of reduced working hours and job losses in unstable business conditions, reduced payments, risks of housing destruction, etc., which negatively affects the financial capacity of employees due to limited or lost income and, as a consequence – on their emotional state, mental and physical health (Furedi, 2015; Page et al., 2006; Toffler, 1984; Zhou et al., 2020).

The main physiological symptoms of stress include (Pankovets, 2006):

- dysfunction of the nervous system;
- cardiac dysfunction;
- dysfunction of the gastrointestinal tract;
- respiratory dysfunction;
- sleep disorders.

Among the psychological symptoms are (Williams, 2001; Kamenyukin and Kovpak, 2004):

- decreased activity of the cognitive sphere: decreased attention; memory impairment; violation of the adequacy of perception and logic of thinking;

- disorders of the emotional sphere: increased anxiety; increase emotional rigidity; an increase in the number of generalized negative emotional reactions such as anger, guilt, shame;
- changes in the behavioural sphere: "stuck" on the problem; difficulty in performing official and domestic duties, etc.

Remote work in pandemic times increased perceived stress, reduced work-life balance, and work satisfaction and increased productivity and engagement. Researchers also found a partial moderating effect, competitive and complementary, of perceived stress, and one significant gender difference: when working remotely, perceived stress affects men's productivity more acutely than women's productivity (Sandoval-Reyes et al., 2021).

Therefore, prevention and coping with professional stress (stress management, according to Greenberg (Greenberg, 2008)) is based on the ability of employees to consciously and adequately use methods and techniques of stress management, in particular, the establishment of personal barriers at all stages of stress in order to combat stressors. In our opinion, such a barrier can be a personal resource as a specific set of personality qualities, which determines the inner readiness to overcome challenging situations.

3 ORGANIZATION AND PROCEDURE OF RESEARCH OF PERSONAL RESOURCE OF PROFESSIONAL STRESS OF EMPLOYEES WORKING REMOTELY

3.1 Research Methods

In situations of change, uncertainty, and the impact of stressors, the role of personal resources becomes especially significant. The features of such spheres are decisive here, such as: motivational (active motivation in overcoming adverse external circumstances, focus on success despite all obstacles and challenges), volitional (personal endurance, control over life situations) and communicative (ability to interact effectively with others and maintain social contacts).

The following methods were used in the study: a questionnaire of interpersonal relations (author – V. Schutz, modification of A. Rukavishnikov) (Krylov and Manichev, 2006), a questionnaire for self-assessment of patience (authors – E. Ilyin, E. Feshchenko) (Ilyin, 2009), the method "Motivation for success and fear of failure" (author – A. Rean) (Fetiskin et al., 2009), method "Level of occupational stress" K. Weiman to study the characteristics of professional stress (Greenberg, 2008), as well as the author's questionnaire for self-assessment of professional stress of employees working remotely.

The questionnaire of interpersonal relations (author – V. Schutz, modification of A. Rukavishnikov) was used in our study to assess the communicative sphere of personality (Krylov and Manichev, 2006) in conditions of professional stress.

The test measures personal characteristics and evaluates relationships between people. The type of behaviour is diagnosed in three areas:

1) an inclusion (the need to create and maintain satisfactory relationships with other people (psychologically acceptable), based on which there is interaction and cooperation, considered in two directions: the first - from individual to other people in the range from "establishing contacts with all people" to "does not establish contact with anyone", the second – from other people to the individual in the range from "always establish contact with him" to "never establish contact with him/her"),
2) a control (the desire to create and maintain a sense of mutual respect, based on competence and responsibility, to feel competent and responsible person, ranging from the desire for power, authority and control over others to the desire to be controlled, to lose responsibility),
3) an affect (the need to create and maintain a satisfying relationship with other people based on emotional attachment, the desire to create and maintain a sense of mutual warm emotional relationship, the individual's need to feel worthy of love is considered in the range: behaviour expected by the individual from others in the range of "always establish a close personal relationship" to "never establish a close personal relationship with an individual").

In the process of the stressor's influence on the personality, its initial cognitive evaluation takes place by cognitive mental processes, such as thinking, memory, attention, imagination, will, etc. Based on this assessment, the situation is considered threatening or favourable, respectively, the analysis is carried out whether there are enough resources to cope at the emotional and volitional level or not.

That is why to assess the emotional and volitional sphere of employees we used the questionnaire for self-assessment of patience (authors – E. Ilyin, E. Feshchenko) (Ilyin, 2009). Under the latter E. Ilyin understands the quality of personality for a long time with the help of strong-willed efforts to withstand adverse situations (Ilyin, 2009). The questionnaire is aimed at studying the volitional component of personality, personal self-assessment of personality opportunities to perform work or perceive any situation.

The method “Motivation for success and fear of failure” (author – A. Rean) provided an assessment of the severity of motivation to achieve in situations of professional stress, its impact on the effectiveness of employees who are forced to work remotely (Fetiskin et al., 2009).

Analysis of the data by the method allows you to assess which desire mainly determines the behavior: the desire to succeed or avoid failure. The advantage of one of these two options largely determines the level of our aspirations – whether the person is ready to set difficult tasks to experience significant success, or chooses more modest goals so as not to be disappointed.

K. Weimann’s method “Level of occupational stress” (Greenberg, 2008) is aimed at studying the degree of manifestation of professional stress in employees of the organization. The methodology contains 15 statements, which respondents are asked to rank in terms of the frequency of experiencing difficult situations.

As a fundamental characteristic of the cognitive component of the personal resource for the prevention of professional stress was chosen features of the subjective perception of professional stress by employees, which were determined by the author’s questionnaire. The questionnaire consisted of 10 questions related to various manifestations of professional stress, the presence of which respondents noted in the following gradation: 1 point – manifestations are almost absent, 2 – minor manifestations, 3 – moderate manifestations, 4 – severe manifestations, 5 – pronounced manifestations.

The sample consisted of 156 people, of whom 55.8% were employees with telework, who worked stably outside the headquarters and 44.2% were employees at distance work, who were forced to work remotely due to crisis conditions.

The age composition of the sample is presented as follows: employees under the age of 30 – 51.9%; at the age of 35-45 years – 15.4%; at the age of 45-55 years – 25%; over 55 years – 7.7%

The organisation of employees of organisations was also divided according to the record of professional activity: up to 5 years (25%); 5-15 years (30.8%); 15-25 years (15.4%); more than 25 years (28.8%) of the respondents.

Regarding the organisational and professional composition of the sample, it is distributed as follows: managers – 25%, employees – 75%. Among them: 5.8% – top managers, 32.7% – middle managers, 61.5% – specialists.

The experimental array of data obtained during the experiment was subjected to quantitative and qualitative analysis. Data processing was performed using the computer package of statistical programs SPSS (version 23.0) Criterion χ^2, correlation analysis of variance, and K-means cluster were used to identify statistically significant differences and the relationship between different groups of respondents and data.

3.2 Features of the Cognitive Component of the Personal Resource of Professional Stress Prevention for Employees Working Remotely

According to the results of an empirical study based on the author’s questionnaire, the distribution of the studied employees according to the subjective perception of professional stress was revealed. It was found that the manifestations of professional stress are virtually absent or insignificant for only 11.1% and 20.4% of respondents, respectively. 37.0% of employees rated the manifestations of professional stress as moderate, 25.9% – as severe, and 5.6% – as pronounced. Thus, the vast majority of respondents (68.5%) perceive the situation of professional activity as stressful.

At the same time, the results of the analysis of variance revealed the features of the subjective stress assessment of employees depending on status (figure 1).

It was stated that managers, regardless of gender, perceive the situation of professional activity as more stressful than ordinary employees, which may be due to their greater overload and responsibility for the results of the case ($p < 0.05$). At the level of the trend ($p = 0.1$) it was found that with the increasing length of service in women, regardless of position, the subjective assessment of professional stress deteriorates significantly compared to men.

Thus, in general, the insufficient level of the cognitive component of the personal resource for the prevention of professional stress was stated in a significant part of the respondents, especially in female managers who have a significant length of service.

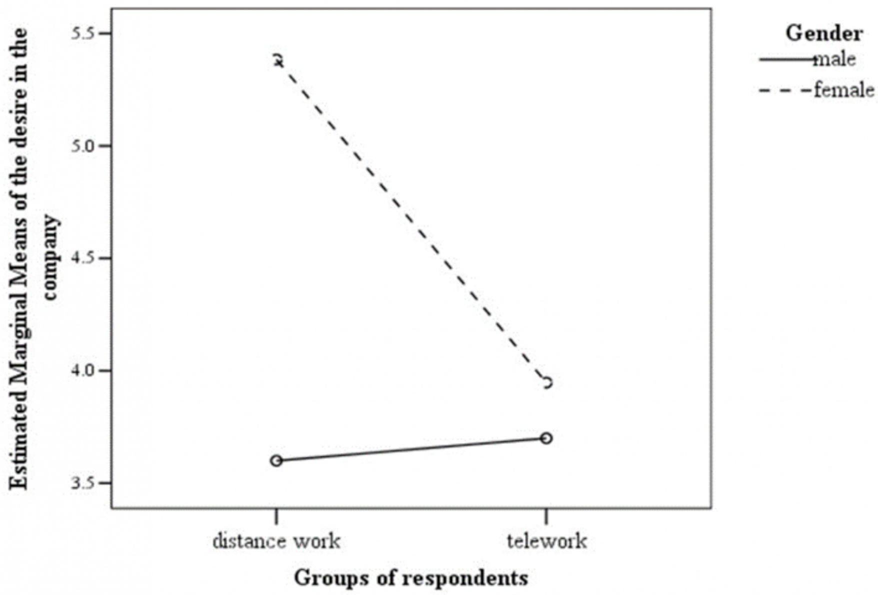

Figure 1: Features of the subjective stress assessment of employees depending on status.

3.3 Features of the Communicative Component of the Personal Resource of Employees Working Remotely

At the first stage, the study of the communicative component of the personal resource of the employees with telework and distance organisation of work with the help of a questionnaire of interpersonal relations (author – V. Schutz, modification of A. Rukavishnikov) (Krylov and Manichev, 2006).

As follows from the data given in table 1, a significant number of respondents (42.2%) have a low desire to belong to different social groups, avoid large and frequent communication with others; do not feel very comfortable among others. Moreover, they do not require others to be involved in active communication (48.0%).

At the same time, regarding the need for affect, it was found that more than half of the respondents (65.4%) feel very careful in establishing close, intimate relation-ships, based on love and emotional attachment. Only 13.4% of employees have a strong need to create and maintain a feeling of mutual warm emotional attitude.

Regarding the need for control, it was stated that more than half of the respondents (65.4%) seek to build and maintain satisfactory relationships with others based on a sense of mutual respect, competence and responsibility. In fact, we can talk about the expressed need for this category of workers to feel competent and responsible person.

The next step was the analysis of the communicative component of the personal resource of employees with a remote of labour organisation by gender and organisational and professional characteristics.

Thus, according to the results of analysis of variance (figure 2) found statistically significant differences ($p < 0.05$) gender characteristics of employees in the desire to establish friendly relations with others depending on the form of work organisation. As Figure 2 data shows, men, both at telework and distance work, show a low tendency to be in the company of people, while women at distance work are characterized by a greater desire to maintain relationships with others for interaction and cooperation. For women at telework, this need is relatively less important. In our opinion, this picture shows that women, having experience in the office with constant communication with employees, remain more oriented to psychologically satisfactory interaction with people.

In general, it should be stated that women, regardless of the forms of labour organisation, are more inclined to close emotional contacts with a partner and need a relatively greater feeling and confirmation in the love of a partner, in contrast to men.

Regarding the professional and organisational features of the communicative component of the personal resource of employees, we revealed statistically significant differences ($p < 0.01$) in the desire for control in communication. Thus, employees in manage-

Table 1: Features of interpersonal needs and behavior of employees of organisations with different forms of work.

Trends in interpersonal interaction	The level of severity of the trend, %		
	low	medium	high
to be in the company of other people	42.2	38.5	19.3
the desire for others to show interest in the individual and accept him into their society	48.0	19.4	32.6
control relationships with others	21.1	13.5	65.4
to obey others in relationships	34.6	38.5	26.9
to establish close relationships with others	65.4	21.2	13.4
the desire to establish deep emotional relationships with other	38.5	26.9	34.6

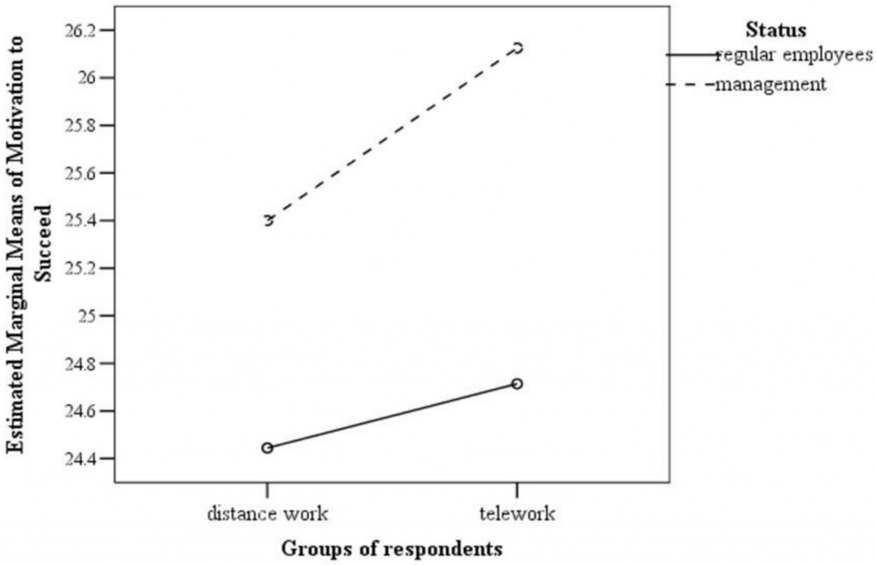

Figure 2: Features of the desire in the company of employees depending on gender and form of labour organisation.

rial positions show a greater need for authority, influence over others, and are more likely to show responsibility and dominance over others, in contrast to ordinary employees. Instead, the tendency to obey others is more pronounced in ordinary employees, while managers are less likely to avoid responsibility and obey others.

3.4 Determining the Indicators of the Emotional and Volitional Component of the Personal Resource of Employees Working Remotely

The next stage of the empirical study of the psychological characteristics of the impact of professional stress on employees of organizations involved the analysis of the features of the volitional component of the personal resource using a questionnaire for self-assessment of patience (authors – E. Ilyin, E. Feshchenko) (Ilyin, 2009).

It was found that absolutely all the surveyed employees rated their patience at a high level, which indicates a tendency to highly appreciate the strong-willed qualities associated with purposefulness.

Regarding gender-age and organisational-professional features of subjective assessment of volitional ability to regulate activities, it was found that employees (women and men) of telework form of labour organisation evaluate their patience relatively higher as opposed to employees of the distance work form of employment.

Based on the results of the analysis of variance, the statistically significant differences ($p < 0.05$) were found in the level of subjective assessment of patience from the record of service.

The group of employees of the distance work form of labour organisation with work experience up to 15 years tends to have higher values of volitional assessment; the group of employees with work experience from 15 to 25 years evaluates volitional qualities much lower; and in the group of employees working more than 25 years increase again. A group of respondents from a distance work form of labour organisation is characterized by a relatively high level of assessment of volitional qualities, regardless of the record of professional activity.

Such differences, in our opinion, can be explained by the fact that in the extreme situation of recent years, associated with the spread of coronavirus and martial law and, consequently, a sharp change in living conditions, for a group of workers with experience of distance work, there were significant limitations of career prospects, which affected the level of endurance in contrast to the group of employees of telework, for whom, in general, the changes had less impact.

3.5 The Results of the Study of the Indicators of the Motivational Component of the Personal Resource of Employees Working Remotely

The analysis of the study results of the features of the motivational sphere of the employees' personality was carried out using the method "Motivation for success and fear of failure" (author – A. Rean) (Fetiskin et al., 2009).

Summarizing the results, it was found that only 25.0% of employees are motivated to succeed, which indicates a desire in the process of setting and achieving goals to focus on the successful completion of tasks and getting a positive result. The vast majority of respondents (67.7%) show a tendency of motivation to succeed, which indicates a lower level of their activity in achieving results. In addition, 7.7% of respondents show a tendency of motivation to fail, which can lead to a decrease in self-confidence and, consequently, the level of demands.

At the same time, a detailed analysis revealed the peculiarities of the motivational component of employees depending on gender, position and record of professional activity.

Regarding the peculiarities of the manifestation of motivation for success depending on gender, a statistically significant difference ($p < 0.05$) was recorded in employees with telework and distance work forms of labour organisation.

Men with a distance work form of labour organisation have higher rates of motivation to succeed than women. While for employees with telework form of activity of both male and female, the indicators of positive motivation are almost indistinguishable. There is a more active desire of men without experience of telework to realize themselves in a new place, in new conditions, with new employees.

Further analysis of variance allowed determining the features of the motivational component of resource depending on the position and form of labour organisation (figure 3).

Figure 3 shows that employees in management positions show higher motivation to succeed than regular employees, both during telework and distance work.

This state of affairs, in our opinion, can be explained by the fact that managers of different levels (top, middle management) have greater access to information about the prospects and plans for the company development, project implementation, are more involved in the financial aspects of the activities of structural divisions and the organisation as a whole, which contributes to the confidence that they are more involved in the process of achieving the company's success and have a direct influence on it.

Next, the study performs the analysis of variance of the positive motivation of employees depending on professional experience during telework and distance work forms of labour organisation. Regarding it, the study established that employees during telework form of labour organisation are characterized by consistently high rates of positive motivation, i.e. they are focused on achieving constructive, positive results. While in contrast to employees with a distance work form of organisation of activities, it shows a decrease in motivation to succeed with work experience from 15 to 25 years.

Thus, both with the general level of patience and with the peculiarities of the motivational sphere, employees with experience of 15 to 25 years have certain difficulties, which may be associated, in our opinion, with crisis experiences related to the age characteristics of this category of respondents. We can assume that external complex circumstances acted as a catalyst for internal fears. However, the positive fact is that the lower values of this group of respondents by professional experience fluctuate within the positive motivation, i.e. employees look to the future with hope.

According to the results of the K-means cluster, the distribution of the surveyed by the levels of personal preventional resources concerning professional stress was established. Previously, the indicators (the distribution of which, despite all the peculiarities, did not differ statistically enormously from the normal distribution curve) were transformed by McCall's T-scale in order to present individual test results in a way that is easy to interpret. As a result, 3 clusters

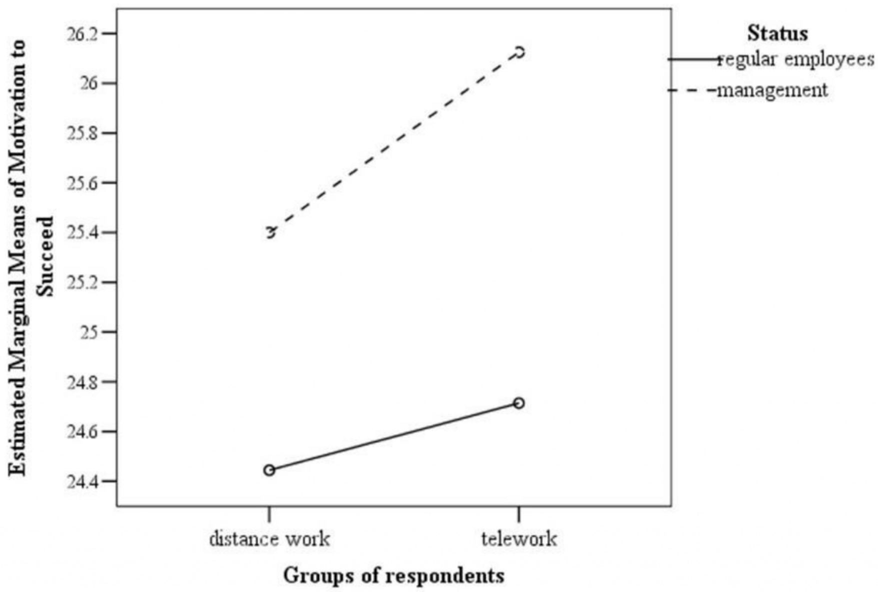

Figure 3: Features of the motivational sphere of employees depending on the position and form of labour organisation.

were identified, the analysis of which allows us to determine the presence of groups of subjects with levels below average, average and above-average (table 2).

Cluster 1 (34.6% of respondents) included employees with mostly low indicators of personal resources, including a high subjective assessment of professional stress. At the same time, given the sufficient indicators of patience and balance of interpersonal relationships in terms of inclusion in interpersonal relationships, their level of personal resources can be considered as below average.

Cluster 2 (50.0% of respondents) consisted of employees with mainly average indicators of personal resource, which gives grounds to define the level of personal resource in general as average.

Cluster 3 (15.4% of respondents) includes employees with mostly high indicators of personal resources. At the same time, taking into account the subjective assessment of stress and a certain imbalance of interpersonal relations according to the indicator of control in interpersonal relations, their level of personal preventional resources of professional stress can be considered higher than average.

At the same time, according to the results of variance analysis, it was found that higher levels of personal resources correspond to lower indicators of professional stress ($p < 0.01$). This indicates the expediency of its development as a significant factor in preventing professional stress of employees.

4 CONTENTS OF THE PROGRAM

Therefore, there was a need to develop and approve a program to prevent professional stress of employees who work remotely in crisis conditions, which is based on the development of personal resources. For this purpose were identified and implemented the main principles and psychological conditions for the development of personal resources of employees working remotely. Thus, the main principles include:

- systemic (mutually determining influence of psychological components on the development of the individual's personal resources);
- comprehensiveness (orientation on the integral development of the personality of employees by using a set of complementary methods of corrective and developmental influence);
- individualization (development of a positive attitude towards oneself, belief in one's own abilities by taking into account the individual characteristics of the development of remotely working employees);
- individual activity (overcoming developmental barriers takes place due to strengthening the internal potential of the individual and including it in joint activities);
- objectification of behavior (providing constructive feedback leads to occurring of transforma-

Table 2: Distribution of employees of organizations by levels of personal resources.

Indicators of personal resources	Cluster		
	1 (lower than average)	2(average)	3 (above average)
Subjective stress assessment	60.0	41.5	50.7
Motivation to succeed	48.2	48.7	53.2
Patience	49.6	49.1	53.8
Inclusion in interpersonal relationships			
Tendency to be in the company of other people	41.2	52.5	61.9
The desire for others to show interest in the individual and accept him into their society	41.6	52.4	61.1
Control of interpersonal relationships			
Tendency to control others in relationships	42.7	54.3	52.4
Tendency to obey others in relationships	51.2	46.2	59.6
Intimacy in interpersonal relationships			
Tendency to establish close relationships with others	43.5	48.8	68.4
The desire to establish deep emotional relationships with others	41.8	51.5	63.4

tional changes of the personality in perception, attitude and behavior towards oneself and others);

- research position (activation of self-regulatory strategies due to the application of reflective analysis of one's own activity);
- partner communication (development of reflection, tolerance, recognition of the value of another person, his thoughts, interests, preferences).

These principles were clarified in the psychological conditions of the development of personal resources of employees working remotely in crisis conditions:

1) ensuring the correspondence of methods and techniques to life experience and the level of personal development, through a systematic reflective analysis of needs, values and meanings in all types of interactions within the program;
2) creation of a safe virtual space for personal changes, based on the feelings, experiences, states, and interests of the participants, admitting the value of their personality, as well as joint development and adoption of the rules of the group and ontime feedback;
3) promotion of self-discovery, self-disclosure and self-realization of employees through the discussion of personally significant professional and life situations and the development of a common vision of emerging problems and ways of their solutions;
4) maintaining an active position towards a new, developing experience, which allows each participant to discover opportunities for expanding the perception of the situation, oneself and one's resources, and the vision of others;
5) the organization of problem-meaningful creative space, which is aimed at cooperation and joint creativity in solving complex professional and life tasks;
6) the use of interactive learning methods as a means of promoting the development of personal resources of employees of organizations that work remotely in crisis conditions;
7) stimulation of personal responsibility, which increases involvement in the process of group interaction, increasing motivation for internal changes and becoming personally meaningful.

The program "Prevention of professional stress for employees who work remotely in crisis" is designed for 30 hours (of which – 12 classroom hours and 18 hours for independent work) and was implemented in the format of a special training course on the basis of the Ukrainian Open University of Postgraduate Education (UOUPE) https://bit.ly/3a2PBSe. It consists of four modules, which involve remote individual and group processing of selected components of personal resources (communicative, volitional and motivational). Forms and methods of the program are aimed at the development of all its components and were selected according to the results of the diagnosis of the personal resources of employees who work remotely (Bondarchuk and Pinchuk, 2020).

Taking into account the identified features of the development of the personal resource of employees who work remotely in crisis, we consider the most optimal forms and methods of its development to be active group methods adapted to the specifics of a remote form of interaction in a virtual learning space. These are thematic group discussions (rooms in Zoom), brainstorming (online boards Google Jamboard, Mentimeter), mini-lectures (Zoom, BigBlueButton, Google Meet), situational role-playing games, individual and group exercises (Zoom), tasks for individual independent works (Google Classroom), etc.

Exercises that ensured the development of personal resources of employees who work remotely in crisis, in accordance with the components we identified and were included in the modules, developed by us personally or borrowed from other authors and modified by us in accordance with the goals and objectives of the program (Greenberg, 2008; Karamushka and Gnuskina, 2018; Leonova, 2016; Pankovets, 2006; Pinyuhina et al., 2015).

To create a comfortable, trusting atmosphere of interaction and communication, relieve emotional tension, and unite the group at the organizational and preparatory stage, techniques were used to get to know the group members, determine the goal and tasks, develop and approve the rules of interaction, and study the expectations from participation in the program. This was achieved by the use of icebreaker exercises, during which, for example, the participants, answering the questions: "I think that I...", "Others think that I...", "Actually, I...", invented three imaginary characters, heroes, animals and then introduced themselves in a circle.

Elaborating on the content of the first module "Cognitive component of personal resource as a factor of prevention of professional stress", the participants were asked to describe and analyze problematic situations of professional activity concerning the main factors of the development of stress, using the following questions:

- regarding the "significance of the situation": What is valuable for me that I will lose if I refuse to perform this activity or from being in this situation?
- regarding "uncertainty": What do I not know about this situation? What information do I need? What am I missing to cope? How should I act?
- regarding the "load": What resources (effort, funds) will I lose or do I need to cope with the situation? At what cost can I succeed in this dish?
- regarding "risk": What valuable for me will I lose if I take the wrong steps?
- regarding the "rush": How much time do I need to deal with the situation? How much time am I willing to devote to this matter? (significance of the situation, uncertainty, load, risk, rush).

This approach helped carry out a detailed cognitive analysis of professional situations in crisis conditions to reduce emotional tension and awareness of ways and personal opportunities to solve difficult circumstances.

Within the deployment of the second module "The role of the communicative component of a personal resource in overcoming professional stress in crisis conditions", the work was aimed at finding and developing means of social support. Thus, the participants were invited to join mini-groups in Zoom Breakout rooms and discuss and write down what are the positive and negative aspects of communication in a remote format in these challenging conditions.

Self-study of this module consisted of the tasks of providing and asking for social support. For example, talking to someone close to them about a difficult situation they are in, talking about their experiences using the I-statement technique, and providing constructive feedback.

Self-regulation techniques, goal-setting techniques and others were suggested for the development of the willpower and perseverance of employees. Thus, performing the "Fortress" technique, the participants were offered, divided into small groups of 4-5 people, to create a security fortress in Google Jamboard, using any of the board's available tools. During the task, it was necessary to think of a group answer to the following questions: "What emotions and feelings accompanied the process of creating the fortress?", "What material is the fortress built from?", "How strong are the walls of your fortress?" If it is not enough – "Who can help make them stronger? / How can they be strengthened?", "Who (or what) does the fortress protect?", "What resources/things make the inhabitants of the fortress stronger?", "Who defends the fortress from enemies?", "What will you take with you to the fortress?".

The setting goals and developing steps to achieve them technique was also used. For this, the participants independently determined the best result they enjoy to gain (the best purpose) in four areas: health, work, family (relationships with a loved one, children) and personal development. If desired, the spheres could be changed in accordance with one's own priorities. Next, on a scale from 1 to 10, the current level of satisfaction with each area was recorded. After that, it was necessary to write down 3-5 easy, real steps that will help move one position closer to the goal.

The basis of tasks for self-study in this module was based on the statement that repeated mental states gradually change the corresponding personality properties (Maksymenko et al., 2015). And the main principle of managing mental states is the analysis, selection and use of self-regulation methods. Accordingly, the participants were offered to independently compile a list of available and desirable methods of self-regulation, using the list: autogenic training (self-suggestion), breathing techniques, muscle relaxation, physical exercises, meditation, visualization (use of positive images), etc.

In the process of mastering the tasks of the fourth module "Development of the motivational sphere of personal resource as a factor of preventing professional stress of employees", it was suggested to individually perform the exercise "I want, I can, I will be in professional activity' (Kamenyukin and Kovpak, 2004) when each participant continued unfinished sentences about his/her professional activity:

- "I want to work..." (desire).
- "I can at work..." (abilities and opportunities, unique ability).
- "I will be at work..." (plans).

After that, there was a discussion about the participants' analysis of the correspondence between their desires and opportunities for self-realization in the professional sphere. The value and relevance of the proposed exercise lie in finding and identifying one's own internal resources that will help achieve success in professional activities.

The independent work on this module included the task of analyzing the motives of professional activity in crisis conditions, answering the question: "Why do I work in such difficult times?". Another task was to recall some stressful events that happened in the last year and analyze the motives of one's own behaviour under the influence of a challenging situation.

The developed program for the prevention of professional stress for employees who work remotely in crisis was based on a combination of the following components:

- educational, training and development components;
- agreement and compliance with the rules of group interaction;
- determination of the goals of each stage of the program;
- creation and maintenance of greeting and farewell rituals unique to the group;
- verbal reflection, which created favourable conditions for the development of cognitive, communicative, volitional and motivational components of the personal resource in countering challenging circumstances.

60 employees who were forced to work remotely took part in the approbation of the program, of which 30 were in the experimental group and 30 were in the control group.

At the end of the approbation of the program, the participants were asked to answer the questions of the questionnaire again regarding the determination of the level of subjective perception of professional stress, the results of which are presented in table 3.

Table 3: Distribution of respondents of the experimental regarding the levels of individual perception of professional stress before and after approbation of the program.

Levels of individual perception of manifestations of professional stress	Number of respondents in %	
	Before approbation (I stage)	After approbation (II stage)
practically absent	10.0	23.3
insignificant	23.3	30.0
medium	36.7	26.7
pronounced	20.0	20.0
great pronounced	10.0	0.0

As shown in table 3, a comparative analysis of the individual perception of the manifestations of professional stress of employees working remotely in crisis conditions, as a result of the preliminary approbation of the program, testifies to the effectiveness of the proposed program for participants (statistically significant differences at the level of $p < 0.01$ according to the sign criterion). At the same time, no statistically significant differences were found in the indicators of individual perception of professional stress in the control group. The obtained results indicate the need its wider implementation with different categories of employees in the postgraduate education system.

5 CONCLUSIONS

Stress as a reaction to a difficult life situation is seen as a result of individual interaction with the environment, individual adaptive response to the complication of the situation or a special class of states that reflects the mechanisms of regulation of activities in difficult conditions.

Professional stress can be defined as a specific form of violation of physiological and mental activity, which occurs in response to the negative impact of the professional situation, and which is due to individual psychological and personal characteristics of employees.

Personal qualities of employees play a very important role in the occurrence of professional stress. They are the buffer that mediates the impact of stressors, increasing their action, or inhibiting it, negatively affecting the mental health of employees and the quality of their professional activities.

The influence of stressors is significantly enhanced in the forced transition to remote work, causing violations in the cognitive, communicative, volitional and motivational components of personality resources of employees of the organization, which acquire their specifics depending on gender, age and professional characteristics of employees.

Therefore, personal factors should be taken into account in the prevention and coping of professional stress, developing the ability of employees to consciously and actively manage stress and counteract stressors.

A program for preventing professional stress for employees who work remotely in crisis has been developed, and several principles and psychological conditions for its implementation have been substantiated.

The approbation of the program, which consisted of four modules corresponding to the cognitive, communicative, volitional and motivational components of the personal resource, proved its effectiveness. The results of the analysis of the distribution of respondents regarding the levels of individual perception of professional stress before and after the approbation are evidenced. Accordingly, the need for broader implementation for various categories of workers in crisis is actualized.

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Differentiated System for Digital Professional Development of University Teachers

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Abstract: The article highlights the issues of designing a system for teacher digital competence development. The paper describes the research that resulted in the development and implementation of a differentiated system for digital professional development of university teachers at the Borys Grinchenko Kyiv University. The principle of system differentiation is realized in two directions: to time possibilities of testing and minicourse passing; to needs of teachers according to professional direction and disciplines taught. A model of organization of this system based on self-assessment, self-education and micro-teaching principles has been developed. The main structural elements of the differentiated system are a diagnostic test and sets of mini courses. The approaches to the formation of the diagnostic test, including ensuring its integration, variability and validity, as well as the principle of its use in order to establish the level of digital competence of teachers in accordance with the developed corporate standard of digital competence were applied in detail. The content of the levels is analyzed on the example of the levels Analyst-Researcher (A), Integrator (B1) and Expert (B2). For the levels Leader (C1) and Innovator (C2) the structure based on the formative assessment process is offered. The system allows teachers to build their own professional development trajectory as a digital footprint reflected in a personal study, and the use of embedded business intelligence tools provides a visualized holistic picture of digital professional performance.

1 INTRODUCTION

The objectively necessary mass transition to e-learning during the quarantine and martial law periods has become a global challenge for the whole educational environment of Ukraine, including higher education institutions and teachers in particular.

An important issue is the quality of e-learning, as noted, for example, in the 2021 EDUCAUSE Horizon Report (Pelletier et al., 2021). This focuses specifically on the quality of online learning as a technology, the use of analytics, open resources, a mix of blended and hybrid learning models. At the same time, the requirements for information and digital competence, which is the basis for effective use of digital tools for online learning arrangement, are increasing.

For this reason, the issue of implementing an effective professional development system that contains research, didactic, leadership and digital components is of particular relevance. Teacher trainings play an important role in educational systems of many developed countries. In Finland teacher trainings are organized at the working place by the educational institution, by The National Board of Education, by The National Centre for Professional Development in Education, by teacher training departments and at higher education institutions with credit system of study (OECD, 2011).

In Great Britain teacher trainings are arranged using one of two models: course model on the basis of higher education institutions and school based in-service education (Machin and Vignoles, 2005). The process of teacher training in Canada is provided by different educational institutions including universities, departments of education, school boards, regional centres of education, volunteer organisations, teachers communities and privat professional development companies (Thomas, 2013). Professional development of American teachers takes place at higher

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educational institutions of different levels (Darling-Hammond et al., 2010).

This leads us to the question of a higher educational institution as a teacher training provider. The aim of the paper is to describe a differentiated system for digital professional development of university teachers implemented on the basis of Borys Grinchenko Kyiv University. In particular, the authors consider the question of teachers digital competence level determination and providing a differentiated approach to learning through the system of mini courses for personalization of teachers learning trajectory in digital sphere. The structure and the topics of the courses are offered to meet the needs of teachers at different levels. Also the possibility of formative assessment implementation at advanced levels is taken into consideration for high quality learning provision.

The analysis of current research has shown that a significant number of scholars pay a lot of attention to this issue. Seel and Zierer (Seel and Zierer, 2019) stress that the implementation of digital technologies in education will be effective if it is teacher and pedagogy rather than technology that takes the lead: "The main focus of educational responsibility has always been human development. The human being in pedagogy is both the starting point and the end result. This approach must also be applied to the digitalisation of education. Digital technologies cannot become a substitute for the pedagogical component of the educational process. Moreover, digitalization must be subordinated to pedagogy". Meyers et al. (Meyers et al., 2013) believe that the development of digital technologies and tools requires new knowledge and skills from the educator; the educator should ensure that applicants for education master digital tools in order to be ahead of the younger generation and help them master the necessary competencies to increase the availability of new knowledge.

Yarbro et al. (Yarbro et al., 2016) stresses that in the digital space it is the teacher who determines the pace of learning, organizes the topics that implement subject knowledge, and is responsible for students' learning progress.

The Digital Competence Profile of Educators (DigCompEdu, 2017) proposed in 2017 describes 22 competencies, the focus of which is not on technical skills, but on the teacher's ability to use digital technologies to provide high quality education.

Kluzer and Pujol Priego (Kluzer and Pujol Priego, 2018) describe the implementation practices of the European Digital Competence Framework (DigComp) consisting of 50 case studies and tools.

Ottestad et al. (Ottestad et al., 2014) define the digital competences of an educator as a set of components: general, which includes general knowledge and skills that teachers should have; didactic, which reflects the digital specificity in each discipline and professional oriented with a description of digital rice.

According to the 2021 EDUCAUSE Horizon Report (Pelletier et al., 2021) at the beginning of the pandemic, educational institutions started to develop portals/hubs that included different educational resources and use new teaching strategies. The educational reference materials presented on them to help teachers move quickly from traditional to online learning. One of the best examples was the training of teachers at Indiana University and its partners. The developers actively developed the site's resources, allowing them to quickly review and redistribute materials to meet faculty needs. The site, its structure and content have also been used in the future not only by colleges and universities in the United States but also by other higher education institutions.

The pandemic and martial law require new pedagogical approaches for educators to rethink the ways and methods of delivering educational content to applicants, motivating them, establishing electronic communication and collaboration, performance assessment, interactive tasks preparation and formative assessment.

At the same time, an important point in defining quality is standardization, which is a complex multifactorial process.

The Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) (Tomas and Kelo, 2020), standards for quality assurance in higher education: internal and external, based on the experience of quality assurance in the Western European countries, set the only European format for quality assurance systems and the creation of a single European educational area. The documents stipulate that HEIs should have certain procedures and criteria to validate the qualifications and professional level of teachers. Given that Ukraine is a party to this space, higher education institutions implement these standards, which are specifically stated in the Law of Ukraine on Higher Education (On Higher Education, 2017).

The professional standard for the group of professions "Teachers of Higher Education Institutions" (Standard, 2021) defines the conditions for the professional development of teachers and specifies a list of their job functions, each of which provides a detailed description of professional competences, noting the necessary knowledge, skills and abilities, a considerable part of which require a sufficiently high level of digital competence.

Taking into account the above-mentioned requirements in the professional standard of a teacher at Borys Grinchenko Kyiv University the "Teacher Profile" was developed, which reflects the manifestation indicators and learning outcomes of a university teacher in the context of such qualities: didactic, research, leadership and digital competence.

2 DIGITAL PROFESSIONAL DEVELOPMENT OF UNIVERSITY TEACHERS

Professional development at the University is implemented in five modules: digital competence module, research competence module, leadership competence module, didactic competence module, professional competence module (Borys Grinchenko Kyiv University, 2015; Morze et al., 2022).

The digital competence module is offered to teachers to develop information and digital competence, namely an introduction to modern educational trends in the process of digital transformation, ways of introducing innovative pedagogical technologies based on various digital instruments into the educational process, 21st century skills, the peculiarities of blended and online learning arrangement. Participants explore digital tools for creating high quality e-content, implementing formative assessment, effective communication and collaboration. Learning takes place in a blended learning format using the e-learning course "Digital Module" located in the university's e-learning system.

In order to improve the teacher professional development system, teacher satisfaction with the process and the learning results is constantly monitored. To analyze the dynamics of professional development indicators analytical data is tracked in real time using a modern business intelligence tool – Microsoft Power BI, which is a set of business intelligence services with cloud support for data analysis and visualization. The main advantage of this tool is the ability to build interactive dashboards, with key performance indicators that are available for viewing from any device connected to the Internet (Microsoft, 2022).

The availability of reports enables the top management of the University to analyse the development of the teaching staff in dynamics, and for the teacher to rationally build a trajectory of further self-development.

3 THEORETICAL BACKGROUND AND PRACTICAL IMPLEMENTATION

According to the Concept of Digital Competence Development to improve the system of professional development the Corporate Standard of Digital Competence of University Teacher was developed, introduced to increase the level of digital competence of teachers, which is recognized as one of the key competencies of successful person of the 21st century, to improve the quality of educational process, actualization of competitiveness of teachers by mastering new digital competences. The spheres of application of digital competence at Borys Grinchenko Kyiv University are determined by the main types of teacher's activities: teaching, research activities, professional communication and cooperation; digital self-management. Five levels of digital competence are defined:

- Analyst-Researcher (A), which is mandatory;
- Integrator (B1) Expert (B2) – sufficient
- Leader (C1) Innovator (C2) – high.

As teaching and research activities are the prevailing ones for HEI teachers, the courses covering corresponding topics receive more attention especially at lower digital competence levels (figure 1).

The volume of a level varies from 50 to 60 academic hours. The average duration of a mini-course is between 2 and 6 academic hours. Some topics are introduced at different levels so that any gap in the knowledge on the topic could be covered. For example, at the Analyst-Researcher level there is a course "Basics of e-communication and e-collaboration". At the Integrator level the topic is presented by two courses: "Collaboration arrangement using digital instruments" and "Digital instruments for communication". That means that a teacher with a higher level of digital competence could return to the basics on the specific topic when needed.

3.1 Model of a Differentiated System for Digital Professional Development of University Teachers

According to the approved digital competence standard, the systems for enhancing teachers' digital competence have been amended and the practice of compulsory university-wide testing of teachers has been abolished. Instead, a differentiated system of professional development has been developed, which is

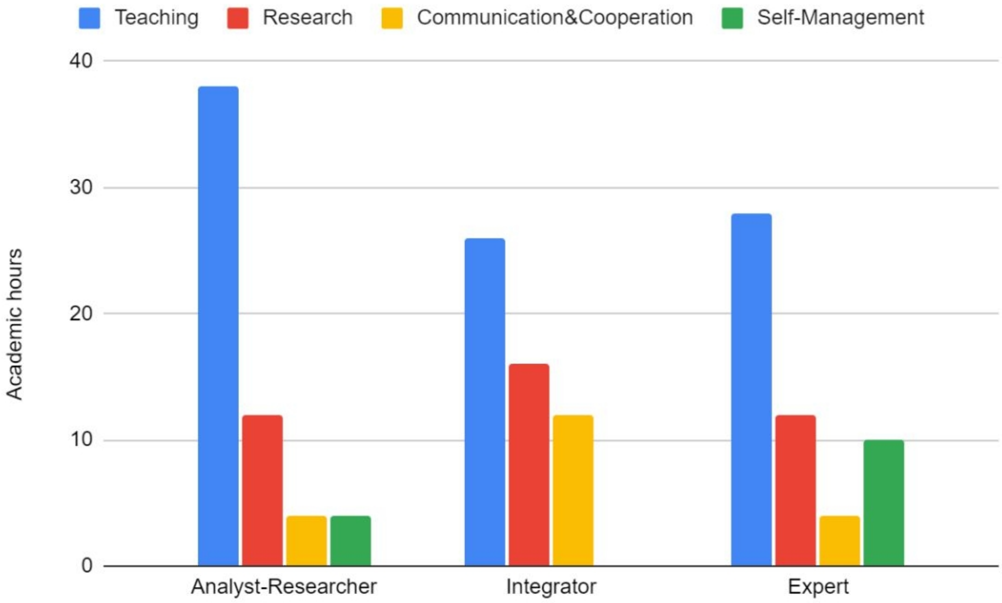

Figure 1: e-Courses by the types of activities.

based on self-assessment, self-study, the principles of microlearning, e-learning, etc.

The differentiated professional development system contains a diagnostic test and a structured set of mini-courses that are presented according to the levels of digital competence.

The differentiation of the system is provided with the help of micro modules placed in the e-learning system of the university. Online storage means that teachers are not limited in the choice of time and location to work with the courses. Such organization also makes it possible to build your own professional development trajectory by choosing the sequence of learning. Teachers are not forced to take all the topics presented in the level. They are also allowed to return to lower levels to refresh their knowledge. That is the content can be adapted to the professional needs of a teacher at the moment.

The model of the differentiated professional development system is shown in figure 2.

The developed model allows the teacher to be aware and self-motivated to improve their skills, including in the digital skills, using a diagnostic test and passing mini-courses.

First of all, the level of digital competence of a teacher is determined by the results of a diagnostic test, mastery of level mini-courses with the possibility of building an individual trajectory of professional development and the marking in a personal office of the achievement of the appropriate level – the digital footprint.

3.2 Diagnostic Test to Determine the Level of Digital Competence of a Teacher

The development of a diagnostic test to determine the level of digital competence of a teacher was carried out in several stages. Firstly, the goals of the test were defined – self-assessment of the level of digital competence and determining the need for its further improvement. It is self-assessment that lies at the heart of a teacher's motivation to choose their own trajectory of professional development and improvement of digital resource skills. Traditionally, goal classification has been implemented similar to Bloom's taxonomy (Bulakh and Mruha, 2006), but according to the levels of digital competence defined in the Corporate Standard, and the domain is described, will be diagnosed. It is defined that this test will assess the cognitive domain, i.e. knowledge and attitudes towards aspects of digitalization in the areas: learning activities, research activities, professional communication and cooperation; digital self-management. Indirectly the psychomotor domain is assessed, because the passing of the test takes place using a digital tool in a differentiated system developed. The objectives do not include and consequently do not offer tasks for the assessment of the personal emotional domain.

The choice of testing as a measurement method offers a number of advantages given the rapid response in the self-assessment process. The diagnostic test determines the level of digital competence of teachers, i.e. the competences that colleagues have

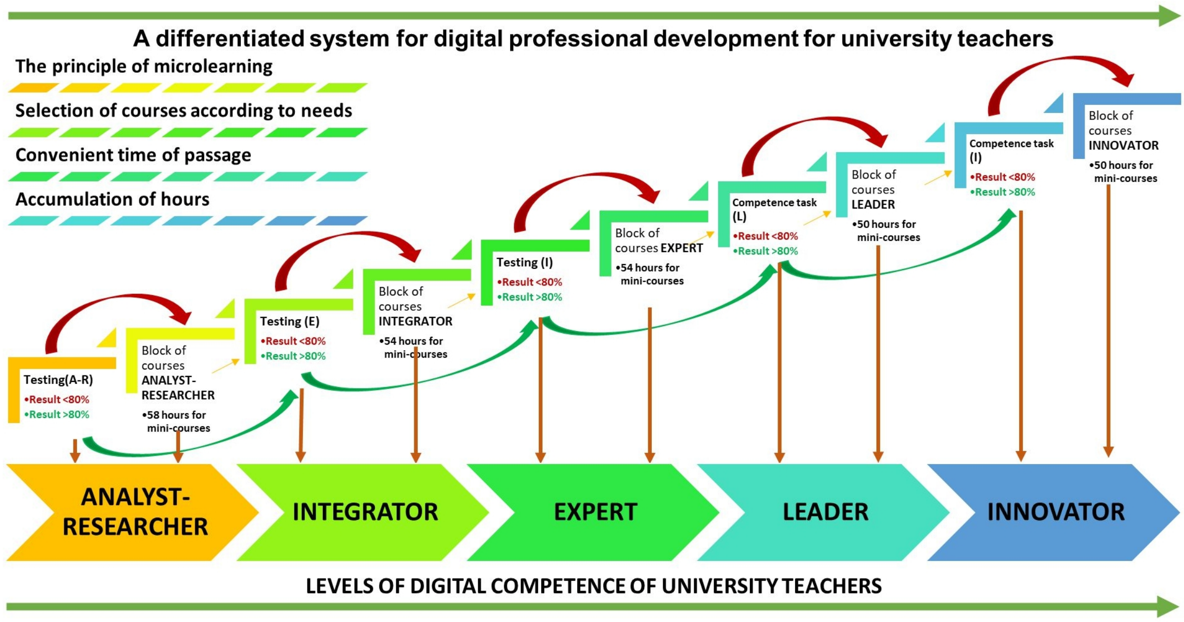

Figure 2: Model of a differentiated system for digital professional development of university teachers.

or do not have now according to the given descriptors of the corporate standard, detailing the skills of university teachers according to the levels of digital competence and the areas of application.

Secondly, a base of test tasks is created according to the matrix, which is developed based on the structure of digital competence standard and 97 descriptors. The matrix is three-dimensional 1 dimension is one of the four activities of a university teacher; 2 dimension is one of the five levels of digital competence; 3 dimension is conditional horizontal lines of development of a certain competence, which are formed according to the content and aspects of the activity.

In order to be able to provide a variable diagnostic test to determine the level of digital competence 3-5 alternative test tasks to each descriptor are provided.

The choice of test item formats is limited by the capabilities of the chosen tool, i.e. LMS Moodle. We use test tasks of the following types: multiple choice with one or more correct answers, yes/no questions, establishing logical sequences or correspondences. Graphic objects of a certain quantity are used in the test tasks, but more textual materials.

Thirdly, in the process of shaping the test its integrated nature is taken into account and in connection with those two lines are defined, i.e. the test has subtests in accordance with the activities of university teachers and on the other hand it is integrated according to the levels of the CC. A decision was made at the physical conclusion of the test and accordingly it was taken into account in its specification, the subtests of the activities to be concluded into a test for the specific level of the GC. Thus, a separate test for the confirmation or non-confirmation of the Analyst-Researcher level is created. The results will be processed as soon as a statistically relevant number of participants is achieved for the analysis and the summarising. There is no need to equalise the test when concluding it for a particular GC level, because its balance in terms of difficulty has already been taken into account, and consideration of the logical coverage of meaningful questions is provided by including test items in accordance with the matrix for the establishment of comprehension of the competence described by each descriptor without exception.

The validation process to establish the validity and reliability of the test results will take place in parallel. The participants will be informed of these nuances. The passing score is provisionally set at 80%. However, the feasibility of such a limit to determine the pass/fail result will also be tested and adjusted if necessary.

For professional development using the differentiated system the teacher is firstly invited to take the test to prove the compulsory level of digital competence “Analyst-Researcher”. If the teacher enters 80% of points, he/she can receive a certificate of confirmation of this level, or take the test of the highest level. If the compulsory level is not confirmed, the teacher can take the mini-courses directly in the differentiated professional development system. The list of mini-courses on offer generally enables the teacher to practise all areas of digital activity in accordance with the requirements defined in the standard.

3.3 Multi-Level Mini-Courses in an Differentiated System for Digital Professional Development of University Teachers

The title of each course indicates the number of hours that are allocated to studying the material and what will be entered into the accumulation system, there are also marks on the percentage of completion of the course and its completion.

The courses in the system are built on the basis of microlearning which allows personalization achievement of teachers learning path by several indicators including time framework, level of knowledge, conformity to teachers needs in digital technologies implementation.

Mini-courses contain educational materials, including mandatory ones with the appropriate mark, and a final test (for the levels Analyst-Researcher – Expert) (figure 3).

At the levels Leader and Innovator formative assessment is used to track the courses participants progress. As at the above mentioned levels users have become not only educational content consumers, but also its authors and distributors, they are capable of assessing their own progress according to the set criteria as well as assess the results of the co-learners activities. According to CCSSO formative assessment (Formative Assessment for Students and Teachers (FAST) State Collaborative on Assessment and Student Standards (SCASS), 2022) is a planned, ongoing process used by learners and teachers in the educational process to reveal and use results of student learning to improve student understanding of intended learning outcomes and support students in their individual learning path. Effective formative assessment process (figure 4) includes the following steps: identifying learning goals and the ways to achieve them, analyzing student's achievements within their learning path, providing self-assessment and peer feedback, using received feedback to improve further learning strategy.

At different steps of learning formative assessment can be performed using various digital instruments including those available in Moodle. Steps 1 and 2 can be implemented by Checklists in Moodle or with the help of whiteboards. In the activity Checklist students there might be a list added by the course designers, but students can be allowed to add their own items. To encourage students to work with checklists, grades and activity completion options might be set up, so that a course won't be completed unless this activity is done. Implementation of such activity makes learners analyze their expectation from the course and estimate afterwards what is achieved and plan further steps for improvement.

Step 3 has the widest variety of activities and instruments for implementation.

Quizzes still remain one of the options. However, at Leader and Innovator levels those activities, which allow not only to check the knowledge but also to analyze, widen and implement it, should be given preference. For example, it can be such activities in Moodle as Forum and Wiki or external instruments such as whiteboards, mind maps can be used.

There are different forum types available in Moodle (figure 5) which can serve different purposes: standard forum for general use, a single simple discussion, each person posts one discussion, Q and A forum, standard forum displayed in a blog-like format.

Standard forums are the most suitable for connectivism learning application, when students learn from each other. This type of forum allows learners to create an unlimited amount of topics as well as leave comments on existing topics. A student can read answers of co-learners before giving their own answer, which contributes to their understanding of a theme. Standard forums are also the best option for a help forum as previous questions and answers can be studied before adding your own one, so the answer might be found even without questioning. Each person posts one discussion forum is similar to a standard forum, but it lets one user create only one topic. Q and A forum requires a student's answer before viewing other learners' posts. This type of forum makes a student find their own solution to a given task and then gives an opportunity to compare it with other options.

A single simple discussion is a forum where students cannot create their own topics, but only give answers to the existing one. This type of forum might be used for assessment criteria discussion or feedback on some topic.

Feedback is important both for a learner to improve their learning strategy and for course authors to apply changes to the course. Moodle provides several options for feedback implementation. First of all, a checklist created at the beginning of the course is helpful for a learner to estimate whether they achieve their goals or their learning path requires some changes. Secondly, Questionnaire and Feedback activities can be used. Feedback answers might be shown to all participants or available to the course creators only depending on the goals; it can also be anonymous. Feedback templates can be created to be

Analyst-Researcher	Integrator	Expert
Basics of e-communication and e-collaboration (2 hours)	Collaboration arrangement using digital instruments (4 hours)	Theory and practice of digital tools utilisation in different kinds of activities (6 hours)
Basics of netiquette and corporate culture (2 hours)	Digital instruments for communication (4 hours)	Interactive learning resources design (4 hours)
Work with scientific profiles (2 hours)	Methodology of statistical data processing (4 hours)	Digital tools for professional self-presentation (6 hours)
Checking a scientific publication for uniqueness (2 hours)	Use of advanced search in scientometric databases (4 hours)	Means for students'project (group) work arrangement (4 hours)
Collection and analysis of statistical data (4 hours)	Video filming and editing (4 hours)	Design and utilisation of interactive videos (4 hours)
Quotation rules in scientific publications and bibliographies (4 hours)	Use of bibliographic managers and cross-references (4 hours)	Different types of web-conferences arrangement depending on needs (4 hours)
Gradebook maintenance (2 hours)	Infographics utilisation for learning materials design (4 hours)	Implementation of scientific statistical data analysis using digital instruments (4 hours)
Assessment of students' study achievements in the e-learning system (2 hours)	Implementation of peer assessment in ELC (4 hours)	Adaptive educational activities arrangement (6 hours)
Use of digital instruments with corporate account (4 hours)	Use of ELC for microlearning implementation (4 hours)	Layout of publications in Latex (4 hours)
Work with ELC (10 hours)	Use of ELC for blended learning implementation (4 hours)	Professional YouTube channel creation and editing (4 hours)
Video design and utilisation (4 hours)	Interactive quizzes (4 hours)	Work with international scientific communities (4 hours)
Infographics design and utilisation (4 hours)	Intergration of MOOCs into educational process (2 hours)	Systematic utilisation of innovative pedagogical methods in ELC (4 hours)
Structuring and visualising theoretical materials (4 hours)	Arrangement of work with colleagues using corporate accounts (4 hours)	
Use of digital instruments for planning work (4 hours)	Arrangement of students interaction during a web-conference (4 hours)	
Online classes arrengement using web-conference tools (4 hours)	Layout of publications (4 hours)	
Main types of quizzes design (4 hours)		

used in all courses of the system.

Thus, courses of Leader and Innovator level (figure 6) follow all steps of the formative assessment process from setting up goals to feedback and further learning strategy planning.

The system provides tracking of tasks and own learning progress (figure 7, 8).

The full completion of the mini-course is displayed in the block "Status of completion of the course" of the mini-course, and the points scored, i.e. hours, are automatically displayed in the Gradebook of a certain level of digital competence (figure 9).

The analysis of data from the additionally installed plug-in block "Progress of completion" and the report "Activity completion" for each level of digital competence separately allows to evaluate the progress of each teacher in mastering mini-courses of a certain GC level, to identify which mini-courses are most or least in demand for further consideration in the process of improving the system as a whole (figure 10).

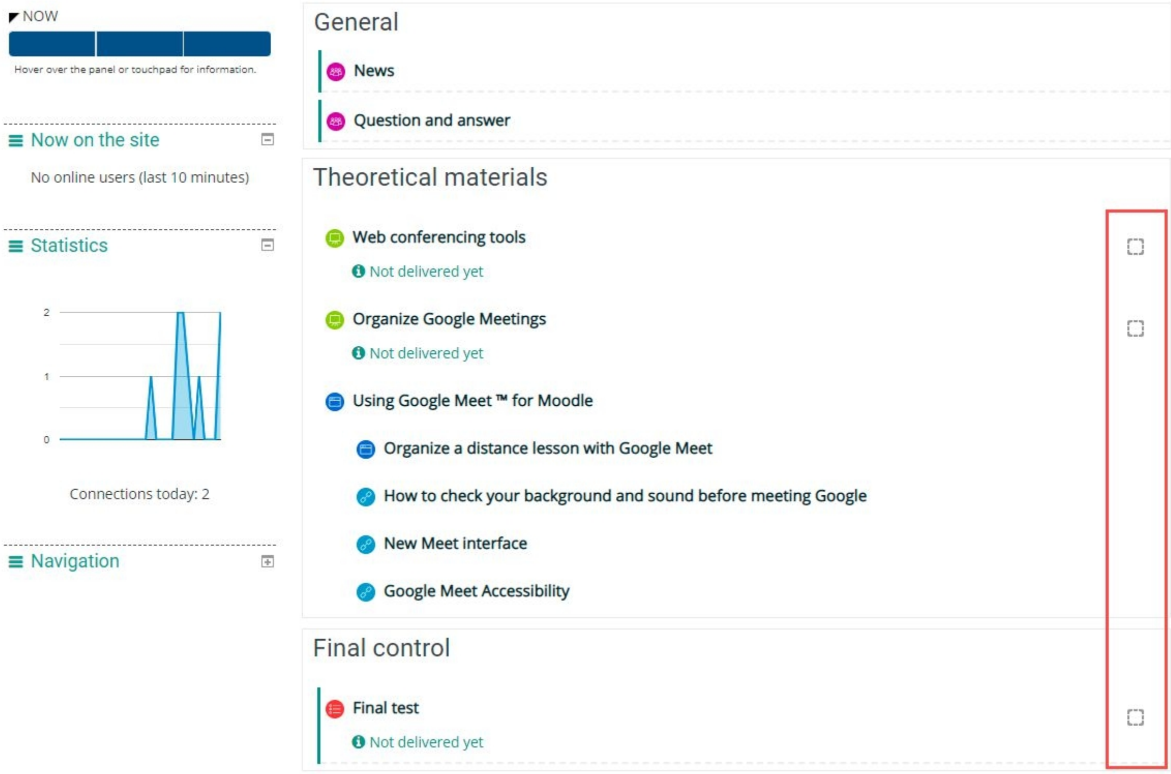

Figure 3: Example of the mini-course for Analyst-Researcher level.

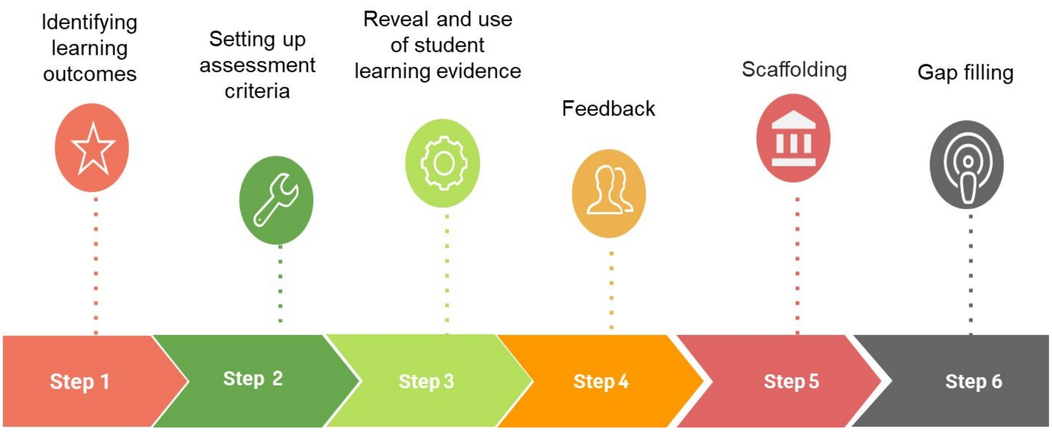

Figure 4: Formative assessment process.

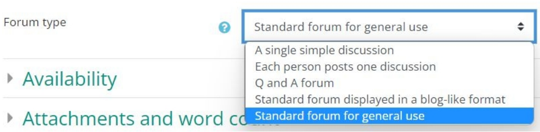

Figure 5: Forum types in Moodle.

4 CONCLUSIONS AND FURTHER RESEARCH PERSPECTIVES

Today's requirements and normative documents adopted at different levels prompted the research participants to review approaches and methods of professional development. Thus, a differentiated system for digital professional development of university teachers was designed in accordance with the model presented in the paper, where the main parts are digital competence levels, diagnostic test, sets of mini courses for each level of digital competence.

The designed diagnostic test considers the need for integration of digital instruments implementation skills in all kinds of teachers activities: research, teaching, professional communication and

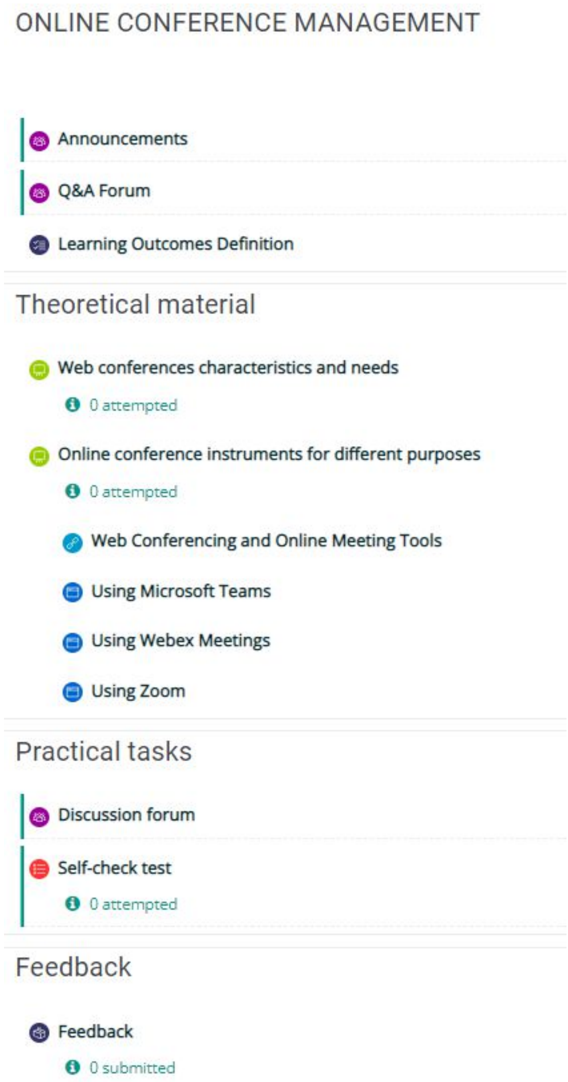

Figure 6: An example of Leader level course.

Figure 7: Tracking the performance of mini-course activities.

digital self-management. It is aimed at the current level of teacher digital competence definition.

Level mini-courses, arranged according to the levels of digital competence of the teacher, declared in the developed Corporate Standard of Digital Competence, contain materials according to the defined descriptors by types of activities. Teacher qualification improvement in the differentiated system begins with passing a diagnostic test, based on the results of which redirection is made to take mini-courses of the appropriate level.

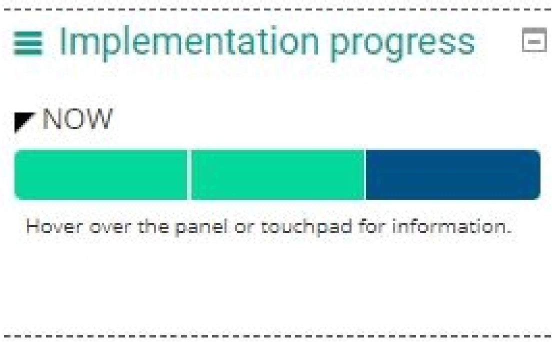

Figure 8: Progress of implementation.

Figure 9: Course completion status.

The designed differentiated system for digital professional development allows to personalize teacher's learning path by providing possibility to choose courses within the determined level or below according to the teacher's needs, gaps in the knowledge and topics of interest. Related topics are placed at different levels which provides learners with an opportunity to widen and deepen their knowledge on the most required themes as well as to return to the previous level. As the courses are built for self-learning, the participants are not limited to a certain time or location. Altogether these promote the self-motivation of teachers to increase the level of digital competence and, accordingly, the quality of providing educational services in general.

Implementation of formative assessment at the advanced levels of the system provides learners with wider study options as they not only consume information presented in the course, but also identify their own goals, track their progress, learn from each other and perform self assessment and peer assess-

Figure 10: Activity Completion Report.

ment. Such activities available in Moodle as Forum, Checklist, Feedback, Questionnaire and others can be used to arrange formative assessment.

In the future, it is planned to expand the system of teacher training in other areas: research, didactic, leadership, professional. This will allow teachers to acquire additional knowledge and constantly improve their skills to perform their professional duties.

The experience of the differentiated system for digital professional development implementation might be useful for other universities which can take the offered system as a basis and adapt it to their conditions and needs.

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Learning Environment Design for Teaching Foreign Languages by Means of Instrumental Pedagogical Technologies

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Keywords: Pedagogical Foreign Language Learning Technologies, Instrumental Technologies, Technologies of Technical Teaching Aids Application, Computer Learning Technologies, Ergonomic Approach, Learning Environment Design.

Abstract: The paper reveals the content of the research aimed at studying the possibilities of computer-oriented technologies in the intensification of teaching foreign languages to students of non-linguistic specialties. The content of pedagogical foreign language learning technologies has been characterized; their classification has been carried out. The role, place and advantages of instrumental technologies in teaching methods update of a foreign language in the digital society have been shown. The main types of instrumental technologies that allow to increase the efficiency of teaching foreign languages have been identified, among them the following ones have been mentioned: technologies of technical teaching aids application, computer learning technologies, telecommunication technologies, and hybrid model of instrumental technologies. The leading part of ergonomic principles and methods for designing a learning environment that provides the most optimal ratio of modern digital and traditional intensive technologies for learning foreign languages have been emphasized. The criteria have been formulated, the methodology for diagnosing the level of ergonomics of the educational environment using the method of expert assessments has been disclosed. The positive dynamics in the level of ergonomics of the educational environment, which is designed on the basis of the use of instrumental technologies for teaching foreign languages, has been shown. The conclusions regarding the effectiveness of methodological approaches to designing an ergonomic educational environment using instrumental technologies for teaching a foreign language have been formulated.

1 INTRODUCTION

In connection with Ukraine entry into the European educational space, European integration, internationalization of business relations and professional activity, the problem of personal development and professional success is singled out, which today is undoubtedly associated with fluency in foreign languages, learning intercultural communication through the latest technologies.

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In the context of modern educational concepts, in terms of democratization of society and socio-economic reforms in Ukraine, higher education is based on the principles of fundamentalization, systematization and humanization of knowledge, competency and cultural approaches and involves social determination of target guidelines. The dominant place among the educational goals belongs to the creation of conditions for the formation of personal qualities of students, in particular communicative, as well as traits mediated by the level of their foreign language communicative competence – ability to academic mobility, autonomous learning and lifelong learning.

Meanwhile, taking into account the specifics of teaching foreign languages to students of non-language specialties and the uniqueness of the cur-

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rent stage of development of digital and globalized society, a number of unresolved *contradictions* still remain. They are, in particular, between the urgent needs of society for professionals capable of intercultural foreign language professional communication, the growing amount of professionally oriented information in foreign languages and the possibilities of educational systems, limited time and extensive type of foreign language training of students in institutions of higher education.

The *purpose* of the paper is to research the possibilities of computer-based technologies in teaching foreign languages to students of non-linguistic specialties and ergonomic foundations in the design of the appropriate educational environment with the use of these technologies. The authors are going to reveal the classification of pedagogical technologies for teaching foreign languages, among them they will focus on characteristics and types of instrumental technologies applying for goals of intensification of teaching students of non-linguistic specialties. Yet another task of the paper is producing the sense of ergonomic analysis, as well as the methods of its use to design an environment for teaching foreign languages. In addition, the criteria and diagnostic tools for evaluation of designing the educational environment for learning foreign languages will be illustrated and clarified; the results of their approbation in real educational process will be shown and analyzed.

2 MATERIALS AND METHODS

The experience of studying foreign languages for special purposes in non-language institutions of higher education contains a lot of thorough work on the use of modern methods, forms, techniques of activating the educational process, increasing its efficiency. Thus, the theory and methodology of communication in a foreign language are disclosed in (Bartosh et al., 2020; Lyakhovitsky and Koshman, 1981; Nikolaeva and Synekop, 2020; Tarnopolsky et al., 2020; Zimnyaya, 2021); problems of students' foreign language communicative competence and foreign language culture formation – in (Amelina et al., 2022; Bondar et al., 2022; Buzhykov and Buzhykova, 2020; Chorna et al., 2022; Holiver et al., 2020; Kravtsova et al., 2022; Tokarieva et al., 2021).

The results of leading scientists and teachers-practitioners work analysis show that the reduction of the volume of foreign language learning in non-language institutions of higher education to a critical value has led to the loss of its effectiveness. This primarily influences the level of competitiveness of graduates, reduces academic and professional mobility, the inability of most bachelors to continue their studies at the next level of higher education. That is why in the scientific literature there are more and more works on the conceptualization of empirical developments in the application of the latest pedagogical technologies that are able to ensure the process of intensive learning of foreign languages by students of non-language specialties (Bespalko, 1960; Klarin, 2016; Strelnikov, 2002), in particular, using digital technologies (Burov and Pinchuk, 2021; Buzhykov, 2006; Bykov and Shyshkina, 2018; Gurevich et al., 2016; Hodovaniuk et al., 2022; Kramarenko et al., 2022; Kukharenko, 2017; Tkachuk et al., 2019).

The works of researchers on the theoretical substantiation of methodological bases, genesis and experience of pedagogical technologies application (Driscoll, 2002; Lynch, 1996; Molnar, 1997; Negoescu and Bostina-Bratu, 2016; Skinner, 1931; Stanford, 2009; Thorndike, 1932) also make an important basis for scientific research; as well as their adaptation to modern conditions and development on this basis of new pedagogical technologies for teaching foreign languages (Lozynska et al., 2021; Rozhkova, 2014; Serdyukov, 1997).

Researchers also constantly emphasize the need for qualitative changes in the methodology of teaching foreign languages. In particular, it means the transition from extensive to intensive studying, in so far as in the process of extensive studying the capabilities of the brain are used by only 15–20%. At the same time, methods based on intensive teaching require excessive expenditure of mental energy. Thus, the discrepancy between the modern requirements of the digital society to improve the efficiency of learning and the shortcomings of modern methods of knowledge mastering raise the problem of developing such educational systems, which would be commensurate with the intensive work of lecturers, but without their excessive workload. These and other related issues are taken care of by pedagogical ergonomics, taking into account the achievements of which provides an opportunity to significantly increase the effectiveness of pedagogical technologies for teaching foreign languages (Gervas, 2011; Karapuzova et al., 2012; Lavrentieva, 2019; Okulova, 2011; Skydan, 1999).

Pedagogical ergonomics as a scientific discipline arose on the basis of ergonomics, the subject of which is a specific human activity (group of people) using machines (technical means) (Gervas, 2011, p. 3–4). Ergonomic analysis of the learning environment involves the movement in two directions – from human requirements to technical means of learning and the conditions of their optimal use, and vice versa –

from the requirements of technology and conditions of its operation to a human. Our special attention is drawn to such a direction as cognitive ergonomics, which was started and is developing in connection with the development and improvement of computer technology. Cognitive ergonomics takes care of the levels of interaction in the human-machine system – from physical interaction (angle, focus, colour perception, background, animation) to abstract (lexical, syntactic, semantic and conceptual levels), which are worth noting in the context of efficiency teaching foreign languages to students using pedagogical technologies (Gervas, 2011).

The basis of pedagogical ergonomics is a set of achievements of the complex of sciences in pedagogical work and student activities, educational environment and advanced pedagogical experience, modern technical means and pedagogical technologies used in the educational process. In this case, any phenomenon that occurs in the educational process has its meaning and is assessed through the functional structure of the system "educator – student – learning environment" (Skydan, 1999, p. 12).

Therefore, the above overview of modern foreign language learning technologies allows us to focus on the study of such issues as: classification of existing pedagogical foreign language learning technologies, the role, place and importance of instrumental technologies updated in the digital society, as well as ergonomic principles and methods of designing a learning environment that provides the most optimal ratio of modern digital and traditional intensive technologies for learning foreign languages.

3 THEORETICAL BACKGROUND

Content development research of "pedagogical technologies" concept by many researchers (Daniushenkov, 1994; Esnault, 2007; Guerrero, 2005; Petersson et al., 2007; Polat, 2004) singled out its long evolution. The genesis of pedagogical technologies can be found in technical teaching aids. For the first time the principle of manufacturability was formulated by Thorndike (Thorndike, 1932). The scientist noted that first there is a machine that can provide certain sensorimotor stimuli, then it is introduced into the educational process as a didactic tool and finally create a technological scheme of application (Thorndike, 1932). However, the mechanism of technologicalization of the educational process – its construction with rigidly planned, fixed results, was outlined by Skinner (Skinner, 1931) in the concept of programmed instruction (Young, 1961). Thus, the level of implementation of pedagogical technologies in the educational process is subject to the vector of pedagogical systems development, is determined by the type of social thinking and is associated with scientific and technological progress of society and the introduction of new techniques.

In general, the development of the technological approach can be outlined by the following scheme: from the use of technical teaching aids and on their basis technologies in education to educational technologies and finally to the actual pedagogical learning technologies, when the educational process is based on the principles of systematization, scientificity, structure and procedurality.

It is established that the modern theory and practice of introduction of the technological approach in training offers numerous interpretations.

The conducted semantic analysis allowed to find out that *pedagogical technology* is a system category, which functions autonomously at three semantic levels (scientific, procedural-descriptive and procedural-activity), at the same time is in systemic interrelations and takes its place in the hierarchy of educational, upbringing and didactic technologies. Pedagogical technology is not identical to the type, method, teaching methods, didactic model and the methodology itself (Kuts, 2021).

We consider *pedagogical technologies of teaching* as types of concepts from generic "pedagogical technologies" and consider them as being based on modern positions of professional development of the person and directed on achievement of the educational purposes. In the process of learning foreign languages, such technologies are a way of step-by-step system organization of communicative interaction between lecturer and student in terms of prompt feedback between them through the use of specific methods, forms and means of learning. The leading class of pedagogical technologies for teaching foreign languages is communicatively oriented technologies.

The conceptual basis of pedagogical technologies of teaching foreign languages is the communicative-activity approach; leading idea – modelling a real foreign language professionally oriented communication in the educational process, principles – speech orientation, individualization and the primary role of the personal aspect, situationality and novelty, professionalization.

Approach systematization for the content problem in pedagogical technologies of teaching foreign languages made it possible to develop their classification based on different methodological principles (figure 1).

A special place among the variety of pedagogical

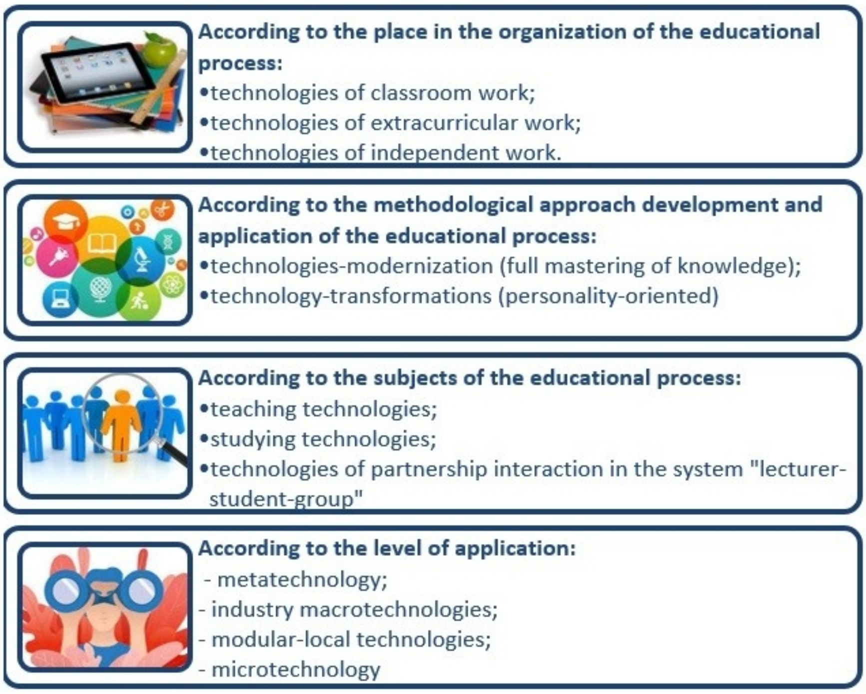

Figure 1: Classification of pedagogical technologies for teaching foreign languages.

technologies of foreign language teaching belongs to instrumental technologies. Next, we proceed directly to the analysis of their content and role in the intensification of the educational process.

4 ERGONOMIC BASES OF USING INSTRUMENTAL TECHNOLOGIES FOR DESIGNING EDUCATIONAL ENVIRONMENT FOR LEARNING FOREIGN LANGUAGES

4.1 Characteristics of Instrumental Technologies of Foreign Language Teaching

Technological approach to creating an artificial foreign language environment is one of the important issues of modern methods of teaching foreign languages. As a retrospective analysis of existing concepts shows, scholars and educators are constantly looking for tools that intensify the process of learning foreign languages.

Thus, *instrumental technologies of foreign language teaching* are considered as a process of development and application of special teaching aids, which is based on the language training method and is aimed at achieving educational goals.

Depending on the didactic purpose of instrumental technologies of foreign language teaching can be used as: sources of foreign language knowledge, means of organizing their learning under the guidance of a teacher or independently, means of visualization, practice, repetition and systematization of foreign language knowledge for all types of speech activity.

Based on the research of Serdyukov (Serdyukov, 1997), we include in instrumental technologies such interdependent components as:

1) technologies of technical teaching aids application;
2) computer learning technologies;
3) telecommunication technologies based on the use of telecommunication tools and networks.

Our vision of the types of instrumental technologies of foreign language teaching is presented in figure 2.

Considering the first component – the technology of modern technical teaching aids application, we should note the following. Despite the fact that

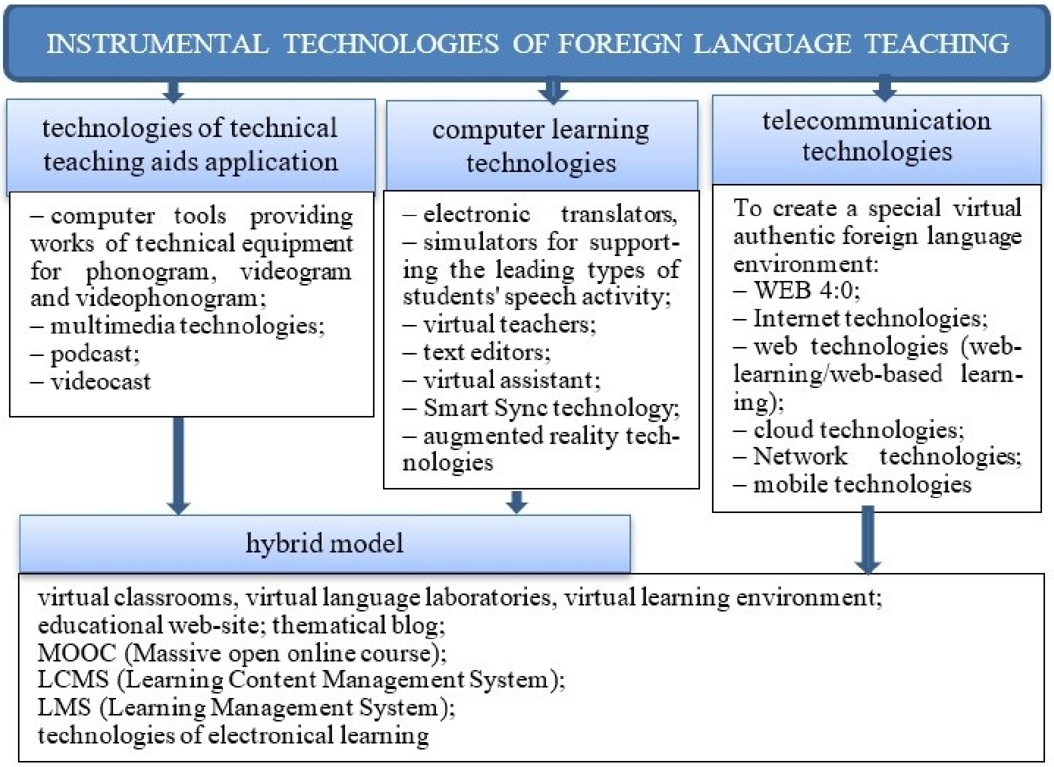

Figure 2: Family of instrumental technologies for teaching foreign languages.

modern technical teaching aids are almost entirely digital technical devices, the technologies of their application are based on the approaches developed by Lyakhovitsky and Koshman (Lyakhovitsky and Koshman, 1981). They names teaching aids in foreign language learning as a technical means that requires the use of technical equipment for phonogram, videogram and videophonogram (Lyakhovitsky and Koshman, 1981, p. 60). This generally accepted of technical teaching aids classification reflects the main means of supporting the leading types of students' speech activity.

Auditory technical teaching aids are used to teach listening, speaking through the use of speech patterns (emphasis, pronunciation, intonation); rational presentation of speech samples and their consolidation (for example; models, clichés, typical structures); introduction of speech material in dialogic form; demonstration of songs, folklore and artistic reading performed by native speakers; analysis of audio recording of students' statements; sound accompaniment of visual aids. In this way, audio technical teaching aids allow clarity for all types of sound and the presentation of educational information in natural language form (Rozhkova, 2014). The work, depending on the didactic goals, can be organized according to one of the following three basic schemes: audiopassive, audioactive or audiocomparative (Lyakhovitsky and Koshman, 1981, p. 55).

The value of *on-screen videograms* lies in visual support, which increases the emotional perception of students of educational information and helps to focus and concentrate their attention on the objects of study. In addition, on-screen tools allow students to practice their reading and translation skills. As screen tools in the study of a foreign language can be used: illustrations of local lore and special professional material, authentic texts, various tables, schemes for studying grammatical material, etc.

Dynamic means of visualization, in comparison with static ones, allow to stimulate students' creative thinking. Sensory images, which consistently change and clearly reflect the logic of mental actions, facilitate the assimilation of all phases of educational material, contribute to the transformation of involuntary attention into a stable and consciously controlled one (Prykhodko et al., 2019). Dynamic screen tools include slide shows, which, with the correct didactic design, serve as a kind of screen story, which involves the plot organization of the material. For slides with pictures, you can select or use ready-made subtitles, questions and answers according to the logic of learning the material. The image should appear on the screen only when it requires methodical design. This contributes to the maximum correspondence between the story and the visual image. Individual phases demonstration of dynamic processes development allows teachers, based on the imagination of students, to use their ability to think out on intermediate stages. This approach in the study of foreign languages stimulates interest, increases attention, helps to find logical connections in the material, to learn dialogic units (Rozhkova, 1987).

Screen technical teaching aids, videograms provide, first of all, the supply and processing of visual information, which during training can perform a variety of functions: 1) to serve as a support for understanding the language structure; 2) combine the semantic and sound side of the word and thus facilitate memorization; 3) to model language, speech situations; 4) perform the role of feedback in the form of keys to tests, tasks (Rozhkova, 1987, p. 46).

Slideshows with sound accompany combine two main means of creating a situation – an image and a word, they are characterized by flexibility and mobility. Soundtrack is the standard on which students adjusts their speech. At the same time, it is a kind of key or control text with which the answer can be correlated. This function is implemented by fragments that include tasks based on the visual series, drawings (Rozhkova, 1987, p. 58).

Today's technical teaching aids are developed and applied on the basis of computer technology. To use them effectively, integrated computer-based technologies are being developed that significantly intensify foreign language learning. In particular, these are technologies of *podcast* (audio material) and *videocast* (video material), which the author sends by subscription via the Internet, as well as hub technologies.

With the development of equipment and related technologies, it became possible to create fundamentally new *technical teaching aids* – multimedia ones in foreign languages. Their valuable characteristic is the high quality of reproduction of all constituents of its data components, as well as the possibility of their interdependent or complementary use. For example, a combination of video with text and sound; audio fragments with text data on the content of the audio series; images with music and text. The minimal set of multimedia system in addition to the multimedia projector, equipped with a video camera, microphone, headphones, pedagogical software – performs in full the functions of language equipment. In this case, the possibility of manipulating information (stop-frame, repetition, increase-decrease, transfer, etc.) allows teachers to organize learning at the pace necessary for students and at a level accessible to them (Molnar, 1997). Modern computer-based *technical teaching aids* also helps to master foreign language writing, grammar and spelling skills with automatic control by special programs (Polat, 2009).

Didactically correct use of modern *computer-based technical teaching aids* allows intensification of foreign language learning due to the maximum load of students' language and auditory channels, activation of their mental and speech activities, optimization of knowledge of special professional, intercultural and foreign language phenomena (Buzhykov, 2006).

A special class of tool technologies are Internet, web (web-learning/web-based learning) and cloud technologies. Their significance lies in the ability to use online services for learning a foreign language and work with authentic materials of cultural and scientific kinds. Pedagogical technologies in teaching, built on foreign language Internet information, contribute to the most effective formation of students of all types of foreign language communicative competence, allow to use language as a means of real communication. In addition, the information competence of students, the ability to organize communication by interests in oral and written forms is further developed. It is clear that working with authentic sources involves the level of formation of foreign language communicative competence of students is not below average. At the same time, lecturers are required to be able to organize such activities of students on a technological basis (Tkachuk et al., 2019).

It seems impossible to ignore the growing prevalence of computer-based foreign language teaching technologies, which allow to form all aspects of foreign language communicative competence. Among them are the following: electronic translators (including network), simulators for learning vocabulary, training of pronunciation, writing and speaking; virtual teachers, interlocutors and assistants; text editors with built-in checking and proofing tools and much more with the use of virtual and augmented reality. Smart Sync technologies provide students with quick access to up-to-date educational information under the guidance of lecturers.

Today, the computer in teaching foreign languages is also a technical means of interpersonal communication based on multifunctional network multimedia learning systems and automated learning systems – *telecommunications technology* (Buzhykov and Buzhykova, 2020), which creates a special virtual authentic foreign language environment.

Varieties of instrumental technologies can be used both separately and in combination, simultaneously or sequentially combining different technical, educational, developmental and upbringing capabilities during the performance of pre-explanation exercises by students during explanation, training, repetition and consolidation of educational material. Modern computer-based *teaching aids* are fully capable of compensating for and modelling the natural foreign language environment for individual and differentiated foreign language learning according to academic achievement and the level of cognitive interest and professional needs of students.

Given the characteristics of the above subspecies of instrumental technology, Serdyukov (Serdyukov, 1997) quite rightly identifies areas of their application, in particular: technologies for the application of modern *teaching aids* are appropriate in the educational process with a group form of education under the guidance of a teacher; computer technologies – mostly in the organization of independent work and self-education, but also in the system of group classroom learning; telecommunication technologies – mainly in individual training, extracurricular activities and self-education. Computer technology can also be used autonomously and over a network (such as on-line services or cloud and Smart Sync technologies, LMS, LCMS, Web 4.0, MOOC).

The widespread use of modern digital technologies contributes to the emergence of *hybrid models* of instrumental technology for teaching foreign languages. Technologies of electronic learning are in their heart.

Let us consider further how the educational environment which allows effective use of pedagogical technologies of foreign languages teaching should be designed.

4.2 Ergonomic Approach to Intensify Foreign Language Teaching

First of all, we should note that *pedagogical ergonomics* is the direction of modern pedagogy, which aims to comprehensively study and design the pedagogical activities of lecturers and students in the system "educator – student – learning environment" to ensure its effectiveness and optimality. The most essential feature of pedagogical ergonomics is the consideration of phenomena in the relationship of the human factor with the factors of the learning environment (Gervas, 2011, p. 22–23). At the same time, pedagogical ergonomics is able to design appropriate options for specific activities related to the use of new technology; to formulate requirements to technical teaching aids, to a level of readiness of teachers and students concerning use of instrumental pedagogical technologies of training, means of intensification of educational process in general (Karapuzova et al., 2012).

This becomes possible due to the fact that from the standpoint of pedagogical ergonomics a lecturer and a student are considered as carriers of activity, and the learning environment as one that ensures the integration of teaching and learning by the most optimal consideration of sanitary, psychophysiological, aesthetic and socio-psychological factors (Skydan, 1999, p. 11–12). The learning environment is interpreted in two ways: as an *external physical environment* that surrounds the subjects of educational activities and provides external information processes, as well as an *internal environment*, which initiates internal information processes, affects the inner world and thus enables educational and developmental impact on students and faculty. External information processes characterize the relationship between lecturer and student with sources of information, in particular with help of digital technologies. Internal information processes determine the psychophysiological side of studying – the proper course of the processes of perception, information processing and storage, knowledge and skills formation. Therefore, the effectiveness of application of pedagogical technologies of foreign language teaching depends on the appropriate design of the learning environment, where the activities of teaching and studying take place in externally and internally plan. This requires taking into account the production, sanitary, anthropometric, psychophysiological and aesthetic factors of study work, which is organized using pedagogical technologies of foreign language teaching (Gervas, 2011) (figure 3).

The means of pedagogical ergonomics make it possible to determine the appropriate relationship between "traditional" methods and teaching foreign language and computer-oriented instrumental technologies. In particular, pedagogical leaning technologies, introduced from ergonomic positions, take into account the motives, temperament, employment of students, allow students with special needs to study, activate students' perception of information, increase their emotional tone. Pedagogical teaching technologies, based on pedagogical ergonomics, improve the quality of work through the possibility of proper distribution of time, transfer of routine functions to instrumental technologies, promote the stability of working postures and rational movements, prevent overload, including the language apparatus of foreign language teachers.

The technologies of partnership interaction in the system "lecturer – student – group", based on the principles of ergonomic approach, provide the opti-

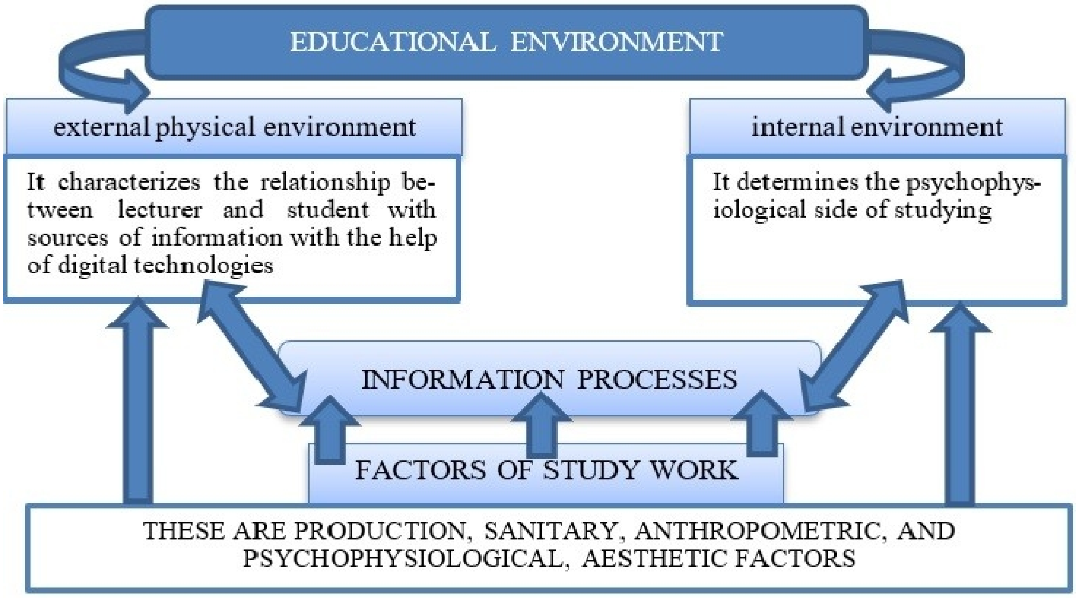

Figure 3: Ergonomic characteristics of educational environment.

mal way to organize educational activities, intensify it, but at the same time prevent fatigue by setting a certain pace, rhythm of educational work and proper feedback. Taking into account the requirements of ergonomics when using instrumental technologies is a guarantee of convenience, reliability and safe use of equipment in the educational process, reducing the intensity of educational work. Didactically correct use of instrumental technologies allows intensification of foreign language learning due to the maximum load of the language and auditory channels of learners, activation of their mental and speech activity, optimization of knowledge of intercultural and foreign language phenomena (Lavrentieva, 2019).

Designing the learning environment from the standpoint of pedagogical ergonomics requires the construction of a special language environment for students. Continuing the traditions of pedagogical ergonomics and didactics, we distinguish *two types of learning environment – material and virtual*. The subject-material part of the learning environment of foreign languages consists of: classrooms, language laboratories and students' workplaces, where educational equipment is located, teaching aids, multimedia equipment, mobile interactive devices, etc., as well as virtual laboratories created by modern platforms for remote teaching students using computer and network technologies (Skydan, 1999). It is pedagogical ergonomics that makes it possible to take into account the physical characteristics of sources of foreign language knowledge and the psychological features of their assimilation by means of pedagogical learning technologies.

4.3 Methods of Designing an Ergonomic Environment for Teaching Foreign Languages

We proceed from the fact that the design in terms of pedagogical ergonomics affects the organization of teachers and students in a specially created language laboratory – directly in a classroom and in a virtual laboratory.

Today, the concept of "foreign language classroom" is a special audience (class), equipped with a set of sound, projection and film projection equipment, which allows audio-visual methods to create optimal conditions for students' independent work to master non-native language skills, native language speech culture and professional – performing skills in students' specialty (Lozynska et al., 2021).

Under ergonomic requirements, the working space of students, teachers and groups in the classroom in general should be designed for a certain number of study seats (from 10 to 25), and so that each lesson can be organized both individually and in a group, and change forms of work would not cause overload, delays, inconveniences, unnecessary movements of both teachers and students.

We have taken into account that the widespread use of multimedia teaching aids and instrumental technologies based on them makes it possible to properly design the workspace of foreign language teaching in the language laboratory so as to achieve the required level of functional comfort for lecturers and students. Multimedia technologies organize the teaching of foreign languages on the basis of psychologically correct modes of functioning of attention, memory, mental activity of students, reconstruct the learning process from the standpoint of integrity. In particular, they allow to take into account the physiological basis of information perception, to provide the appropriate angle, focusing students' eyes, based on psychological features in the perception of colour, background, the rate of change of information flow for the person working.

As it is known, the minimum set of multimedia system consists of a computer, projector, screen and speakers. Equipped with a video camera, microphone, headphones, supplemented by a smartboard, it successfully implements the task of creating a natural functionally comfortable foreign language environment (Tokarieva et al., 2021). At the same time, from the point of view of pedagogical ergonomics, it is important to ensure proper processing of information presented by multimedia, in particular – to organize active language practice of students, work on learning foreign languages, solving educational problems. Therefore, in the language laboratory we consider it appropriate to combine the screen on which the image of the learning task is projected, and the board on which such a task can be performed quickly (close test, restored scheme or sequence, support scheme, speech pattern, crossword puzzle, text, etc.) (Lynch, 1996). Such board should be white, have magnetic properties for attaching any illustrative material and be appropriate for work with coloured markers.

A full-fledged language laboratory should provide autonomous and network work of the group, prompt feedback between lecturers and students. This is facilitated by placing the group in a semicircle so that everyone has the opportunity to exchange information while working in a group, during frontal work with the blackboard in both real and online communication. A properly designed learning environment should use Internet communications, including Wi-Fi.

A review of the existing literature revealed the leading software tools for the organization of electronic, combined and blended learning of students in the language laboratory, namely:

1) tools of communication: SMS, smartphone, e-mail, chat, instant messaging, voice and video conferencing, forums;
2) means of presenting educational materials: electronic textbooks, text, hypertext, audio, video (including those located on websites, blogs, wikis, video repositories, podcast servers, slide hosting, electronic libraries, file servers, cloud services);
3) means of practicing skills: simulators, virtual classes, electronic translators and dictionaries, multimedia materials, etc.;
4) collaboration tools (webinars, wikis, virtual classes, cloud services, web quests, collaborative projects, etc.);
5) means of assessment of educational achievements, monitoring and management of the learning process (survey, planning, testing) (Driscoll, 2002; Lavrentieva et al., 2021).

The proposed *pedagogical software* (PS) of foreign language teaching was based on a number of requirements, namely: 1) general didactic requirements (individualization, activity, student independence, scientific character, visualization of educational information, etc.); 2) linguistic requirements (correctness and normativeness of the language used); 3) methodical requirements (communicative and professional orientation of PS); 4) electronic-didactic requirements (interactivity, modular construction of the content of the material, multimedia presentation of study information, friendly interface) (Buzhykov and Buzhykova, 2020).

In our research, as a basis for the organization of active language practice, we use tools provided by well-known services, including Google, Office 365, Facebook, Edmodo, Studyboard and distance learning platforms such as LMS Moodle. The leading idea in their application was to create a semantic basis for the technology of the *teacher's website* – an interactive didactic tool that allows the organization of interaction between all participants in the educational process. Analysis of advanced pedagogical experience shows that the teacher's website is a holistic information and communication technology that can provide pedagogical guidance in teaching foreign languages to students (Holiver et al., 2020). In our practice we use such models of application of the teacher's website technology as: *subject site, educational site, thematic blog, portfolio site*.

Among other existing opportunities for organizing students' work, we chose the LMS Moodle platform, which allows convenient organization of the entire foreign language course, in particular: presents students with curriculum, schedules, provides teaching materials in electronic and multimedia format (Stanford, 2009). With the help of the LMS Moodle platform, even a teacher who is not well versed in computer technology can independently form their own strategy for foreign language teaching, which includes the necessary amount of educational material in text, graphics and multimedia forms, audio and video database, a list of hyperlinks to achieve specific learning objectives. In general, for the implementation of feedback between lecturer and student, the system supports the exchange of files of any format, allows to organize joint studying activities, energetic foreign language communication through a blog, forum, workshop etc. This significantly intensifies the learning process, ergonomically organizes the students' study activities and allows the implementation of many pedagogical technologies for teaching foreign languages – training, design, interactive, game, test, etc., as well as hypermedia, media, multimedia technologies.

According to the results of the analysis of scientific and methodical literature, we came to the conclusion that the structure of the network electronic methodical complex is not regulated. The *electronic complex* developed within the limits of our professional activity includes both the volume obligatory for studying (electronic educational materials, audio and video applications, test materials, podcasts and videocasts, links to them), as well as additional one, constructed on the principle of complex differentiation (glossary of professional terms, materials for independent project activities, additional scientific, technical and linguistic resources, links to reference materials). In addition, the complex combines the advantages of a text editor, e-mail, e-journals and many other attributes of modern information and communication technologies, represented by the LMS platform like Moodle. The object orientation of the platform provided individual adjustment of certain elements of the training course to the needs of lecturers and students.

The educational complex we used for the study of foreign languages is structured in a module, in accordance with the curriculum of the discipline. The structural components of each module are: a text page, a list of links, a book, an explanation, a workbook, a forum, an exercise, a test, a webinar. Each of them consists of such sections as: Reading, Vocabulary, Listening and Video. Materials for study are presented by topics and content training modules. An important part of the complex is a system of test tasks that are processed automatically using the built-in Moodle services. The "Forum" option is used by us for the formation and development of oral and written speech skills, as well as for the organization of foreign language communication (Rymanova, 2013).

At the same time, we practice the means of a *thematic blog* – a specially created resource, which contains relevant information for students of scientific, technical, cultural, linguistic and professionally significant nature, mostly in a foreign language (Polat, 2009).

In authors' opinion, the effective teaching of foreign languages and its intensification is facilitated by the use of relevant media materials in shaping the content of the teacher's website and its varieties. In particular, the texts of such British newspapers as: "The Guardian", "The Observer", "The Times", "The Sunday Times", "The Daily Telegraph", "The Sunday Telegraph", "The Independent", "The Independent on Sunday", "The Financial Times". We believe that the British press is a classic example of a comprehensive coverage of the processes taking place in the country and abroad in various spheres of political, socio-economic and cultural life (Tokarieva et al., 2021).

The appropriate content of the teacher's website is all kinds of professionally important information provided by means of tool technology. In particular, *TED (Technology Entertainment Design)* presentations are widely used in the work of lecturers of the Department of Foreign Philology, Ukrainian Studies and Social and Law Disciplines of the Mykhailo Tuhan-Baranovsky Donetsk National University of Economics and Trade and Department of the English Language with Methods of Teaching of the Kryvyi Rih State Pedagogical University. *TED* is a private non-profit foundation in the United States that has held annual conferences since 1984 to promote unique ideas. Some of the lectures on science, art, design, politics, culture, business, global issues, technology and the entertainment industry are available on the conference website (https://www.ted.com/). Lectures are usually held at a high methodological and linguistic level, their topics concern, in particular, issues of subject specialization of students, as well as their culturological, socio-cultural, linguistic needs. As of today, more than 400 video recordings of lectures in different languages are available online. The translations are available in subtitle format. Therefore, videocasts from this site can serve as a semantic basis for the organization of foreign language teaching in non-language institutions of higher education.

Now, there are a lot of websites offering similar services. We are intended to mention some of them. The *Learn Out Loud* provides the podcasts and other educational materials in the 16 directions (https://www.learnoutloud.com). The *Artana* spreads the lectures about Art for free (https://artanablog.com). The *Englishcentral* contains interesting audio and video materials to study various topics equipped with subtitles (https://www.englishcentral.com). *English Listening Lesson Library Online (ELLO)* permits acquainting students with issues of modern society (https://www.elllo.org/). And this is not to mention the numerous foreign language educational channels on *YouTube*.

In the practice of teaching foreign languages, we usually use two modes of operation. *Synchronous mode* of management of students' study activities involves the use of network technologies and real-time communication, in particular through video conferencing, web conferencing, virtual classrooms, chats etc. (Bykov and Shyshkina, 2018). Access to Internet resources, the possibility of authentic communication, acquaintance with the latest advances in science and technology, participation in international discussions significantly increases the level of motivation of students to learn a foreign language. At the same time, there is an intensification of educational activities, when students replenish their vocabulary, improve their receptive and productive skills, form and improve skills of dialogic speech, get acquainted with the culture and traditions of the language they are studying in a convenient time and space format (Negoescu and Bostina-Bratu, 2016).

Asynchronous communication allows us to exchange time-delayed information via the Internet. The possibilities of podcast and videocast technologies, e-mail correspondence, forums, chats, specialized sites, blogs, and electronic libraries can be widely used here. Foreign forums, joint projects with foreign students, quests, postponed conferences, work on foreign language sites, and communities on social networks have significant opportunities in the formation of foreign language communicative competence.

4.4 Effectiveness Evaluation of Designing the Educational Environment for Learning Foreign Languages

An important criterion for the effectiveness of pedagogical technologies in teaching foreign languages, along with the level of formation of foreign language communicative competence, is the *ergonomics of the learning environment*, which reflects the degree of influence on lecturer and students of psychophysiological, physiological, anthropometric and hygienic factors. This means assessing the effectiveness of foreign language teaching using pedagogical technologies (accuracy, reliability, productivity of their application) and compliance with human psychophysiology (safety for lecturer and student health, level of tension and fatigue, emotional impact on the process of lecturer and student) (Skydan, 1999, p. 11–12).

Ergonomic criterion serves three main factors of influence of pedagogical technologies on the educational environment – technological, labour and organizational ones (Skydan, 1999).

The *technological factor* involves the assessment of teaching aids, technical equipment, content and procedural parameters of applied pedagogical technologies. This involves, first of all, taking into account the anthropometric and biomechanical characteristics of the applied technical teaching aids, which should reduce the cost of muscular and mental energy, replace manual processes with automated, reduce static and dynamic load of information channels of students and lecturers. At the same time, in pedagogical ergonomics it is important to assess the degree of manufacturability of the educational process: algorithmicity, conceptuality, expediency, subjectivity, purposefulness, reproducibility, effectiveness, controllability, design, statefulness, etc. A certain level of manufacturability should provide a certain quality of educational material (depth, effectiveness, strength, system) compared to "non-technological" approaches.

Pedagogical ergonomics also takes care of the degree of workload of students and lecturers. Insufficient workload of students due to prolonged automatic execution of monotonous actions and operations or insufficient level of problems or overload due to rapid rate of presentation of information or exceeding its volume dramatically reduce the effectiveness of foreign language studying. The state of functional comfort is also provided by external factors: the aesthetics of the room, the norms of the work environment, the workplace, the teaching aids offered by the lecturer (Karapuzova et al., 2012).

The labour factor considers the rhythm and intensity of study work, the correctness of individual actions with maximum economy of movement and prevention of awkward position during the work, its compliance with speed, energy, visual and other capabilities of students and lecturers. To the kinetic characteristics of the labour factor adds aesthetic – the conformity of the design of jobs, objects of labour, components of pedagogical technologies to the aesthetic needs of students and lecturers in the process of foreign languages learning (Okulova, 2011).

The organizational factor, first of all, takes into account the organization of the workplace of students and lecturers in the educational environment (in the classroom and virtual language laboratory). This involves a certain functional organization for a student or group of students to perform certain educational work with the use of pedagogical technologies. Properly organized workplace includes the availability of sufficient workspace; basic and auxiliary language equipment, convenient approach and access to them;

the ability to establish physical, visual and auditory connections between the subjects of the educational process; safety priority; compliance with the norms of the working environment (permissible noise level, temperature, light, humidity, etc.), the possibility of remote autonomous studying.

Thus, the *indicators on ergonomics criterion of the educational environment* include: functional comfort of the student; technological, labour and organizational parameters of the educational environment of learning foreign languages with the use of pedagogical technologies and modern technical teaching aids, the quality of learning foreign language knowledge by students, the degree of their sensitivity to new technologies of educational activities.

Ergonomic analysis of the level of functional comfort of students in teaching foreign languages with the use of pedagogical technologies was conducted using the method of expert evaluations (figure 4).

Based on the testing of the card above in the pre-quarantine period, it was found that the reason for most of the failures of students is their failure to master at the appropriate level of pedagogical technologies for studying foreign languages, especially instrumental technologies. Unformed ability of individual students, especially freshmen, to concentrate, quickly switch attention, engage in work in the classroom, organize their work space, which affects the working environment in the language laboratory. Quantitative indicators are shown in table 1.

Table 1: Degree development dynamics of students' study work ergonomics (in %).

Indicators	Study year		
	I	II	III
Elementary	40,0	31,3	25,0
Intermediate	40,0	31,3	31,3
Upper-Intermediate	12,0	20,8	22,9
Advanced	8,0	16,6	20,8

Thus, we singled out the *contradiction* between the existing potential of foreign language teaching pedagogical technologies in the direction of intensification of learning, complex impact on the motivational, cognitive and linguistic spheres of students' personality and the existing average level of effectiveness of their use in the educational process at a non-language higher education institution. A number of *difficulties* have been identified, including: objective difficulties due to economic factors – extremely small amount of time for learning a foreign language in a non-language free economic zone, lack of funding for extracurricular activities and elective courses; insufficient hardware and software of instrumental technologies, limited direct communication with native speakers. There are also difficulties of semantic nature – imperfect development of the educational environment in terms of its ergonomics and functional comfort of students in the language laboratory, as well as procedural nature – insufficient level of mastery of some foreign language lecturers of instrumental educational technologies, especially computer and network; the advantage of technology-transformations in the educational activities of students, uniformity in their use; low share of communicative activity of students, their participation in extracurricular activities for professional interests during their studies in higher education institutions.

At the same time, the experience of application and widespread use of instrumental technologies during quarantine measures, balanced approach and hard work of foreign language teachers in the development of professional skills allowed to achieve significant changes in the levels of ergonomics of the educational environment (table 2).

Table 2: Ergonomic factor dynamic of students' study work (in %).

Levels	December	September
	2019	2021
Elementary	40,0	20,0
Intermediate	40,0	30,0
Upper-Intermediate	12,0	30,0
Advanced	8,0	20,0
Pearson's χ^2-criterion	$20{,}952 > 11{,}345$, $\rho = 0{,}001$	

This became possible due to the design of the learning environment taking into account the requirements of pedagogical ergonomics, which intensifies the teaching of foreign languages by means of instrumental pedagogical technologies.

5 CONCLUSIONS

Having considered the features learning environment design that provides intensive teaching of foreign languages to students of non-linguistic specialties, we came to the following conclusions.

1. The pedagogical technologies of teaching should be considered as types of concepts from generic "pedagogical technologies". In the teaching methods of foreign languages such technologies are based on the communicative-activity approach; their leading idea is modelling a real foreign language professionally oriented communication in the educational process, principles are speech orientation, individualization and the pri-

Parameter	Feature	Evaluation zones	Grade
Technological factor: technical perfection; compliance with anthropometric data; functionality, quality, sufficiency	Language / linguistic laboratory, its equipment	0-10	
	Virtual language laboratory, its completeness	0-10	
	Educational content	0-10	
	Didactic teaching aids	0-10	
	Computer-based technical teaching aids, local area network, Internet	0-10	
	Pedagogical software for teaching foreign languages	0-10	
Labour factor: aesthetics, compliance with psychophysiological and psychological characteristics of a human; requirements of labour protection and hygiene	Classroom design	0-10	
	Virtual lab interface	0-10	
	Rhythm, regularity of the educational process	0-10	
	Ease of use of technical teaching aids, equipment	0-10	
	Labour intensity	0-10	
	Educational and methodical complex of teaching the discipline	0-10	
Organizational factor: time indicators; functionality of educational work, authenticity of content	Student workplace in the classroom	0-10	
	Student workplace in a virtual laboratory	0-10	
	Organization of independent study work	0-10	
	Organization of extracurricular activities (clubs, electives, events)	0-10 and additional 2 points	
	Organization of communication with native speakers	0-10	
	Research work in the specialty by means of a foreign language	0-10 and additional 2 points	

Figure 4: Expert card for assessing technological, labour and organizational parameters of educational environment.

mary role of the personal aspect, situationality and novelty, professionalization. The pedagogical technologies of teaching foreign languages can be classified based on different methodological principles, namely: according to the place in the organization of educational process, under the methodological approaches to their development and application, according to the subjects of the educational process, under the level of application. A special place among them belongs to instrumental technologies.

2. The instrumental technologies of foreign language teaching are considered as a process of development and application of special teaching aids, which is based on the methodology of foreign language teaching and is aimed at achieving educational goals. The instrumental technologies include such interdependent components as 1) technologies of technical teaching aids application; 2) computer learning technologies; 3) telecommunication technologies based on the use of telecommunication means and networks as well as 4) hybrid models of instrumental technology, where the technologies of electronic learning are in their heart.

3. Pedagogical ergonomics is the direction of modern pedagogy, which aims to comprehensive study and design the pedagogical activities of lecturer

and students in the system "educator – student – learning environment" to ensure its effectiveness and optimality. These features permit the use of ergonomic approach to design education environment for intensive learning foreign language by means of digital technologies. The effectiveness of the application of pedagogical technologies of foreign language teaching depends on the appropriate design of the learning environment, where the activities of teaching and studying take place in external and internal plan. Designing the learning environment from the standpoint of pedagogical ergonomics requires the construction of a special language environment for students – material and virtual. This requires taking into account the production, sanitary, anthropometric, psychophysiological and aesthetic factors of study work, which is organized using pedagogical technologies of foreign language teaching including instrumental technologies.

4. The widespread use of multimedia teaching aids and instrumental technologies based on computer makes it possible to properly design the workspace of foreign language teaching in the physical or virtual language laboratory in order to achieve the required level of functional comfort for teachers and students. In this purpose it should consider organization of physical space, availability of the necessary set of computer equipment and technical teaching aids, pedagogical software, rhythm of study work, mode of study activities (synchronous, asynchronous), available opportunities in the use of educational Internet resources. In any case, design of the process of foreign language learning by means of instrumental technologies should be realised through the prism of functional structure of the system "lecturer – student – learning environment", and to do the ergonomic analysis of the learning environment in two directions – from human requirements to technical teaching means of learning and the conditions of their optimal use, and vice versa – from the requirements of instrumental technologies and conditions of their operation to a human.

5. Ergonomic model of learning environment organisation reflects the degree of influence on lecturer and students of psychophysiological, physiological, anthropometric and hygienic characteristics of study work. Degree of influence of instrumental technologies on the educational environment of foreign languages learning can be defined with help of ergonomic criterion, which estimates three main factors – technological, labour and organizational ones. The indicators on ergonomics criterion of the educational environment include: functional comfort of the student; technological, labour and organizational parameters of the educational environment of learning foreign languages with the use of pedagogical technologies and modern technical teaching aids, the quality of learning foreign language knowledge by students, the degree of their sensitivity to new technologies of educational activities. Ergonomic analysis of the level of functional comfort of students in teaching foreign languages with the use of instrumental technologies can be conducted using the method of expert evaluations and special expert card.

The positive dynamics in the levels of ergonomics obtained as a result of approbation of the method of learning environment design for teaching foreign languages by means of instrumental pedagogical technologies allows us to consider it as appropriate and effective one.

Given the fact that in a modern digital society, new technological approaches are constantly being developed, the prospect of further research seems in the development of a methodology for the use of smart-technologies, augmented reality technologies, technologies for mobile learning for foreign language teaching.

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Implementation of a Single Information and Educational Environment of the University "NMU Digital"

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Keywords: Digital Transformation, Information and Educational Environment, Distance Learning, Automated Control System.

Abstract: The publication considers theoretical and practical approaches to the design and creation of a single information and educational environment of the Bogomolets National Medical University. The main factors that were taken into account in the development of information and educational environment of the university are identified and substantiated. The basic educational and methodical resources that ensure the functioning of the information and educational environment of modern Medical (Pharmaceutical) Higher Educational Establishment (M(P)HEE) are given. The peculiarities of the educational process at the university are analyzed and the scheme of interaction of the educational-methodical department with the faculties of the university is given. In the process of research, it was developed a model of information and educational environment of the Bogomolets National Medical University "NMU Digital". The list of works related to the educational process performed by the structural units of the university in the automated control system is highlighted. The main advantages of use and functionality of the automated control system, electronic document management system and distance learning platform are revealed and analyzed. The results of an online survey of research and teaching staff and students of different faculties on determining the level of digital orientation are analyzed. Presented a comparison of the results of the survey in 2020-2021 and 2021-2022 academic years on the quality of the organization of a single information and educational environment at the Bogomolets National Medical University.

1 INTRODUCTION

Today, every governmental institution (health care is no exception) requires qualified professionals who have a high level of digital skills and are able to work with new technologies. Digital transformation (digitalization) of all spheres of public life, including education and science, is an important area of higher education not only because of the pandemic, but also in general through global trends and national policy (Morze and Strutynska, 2021).

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According to the draft of the Concept of digital transformation of education and science for the period up to 2026 (Concept of Digital Transformation, 2021), the resolution of the Cabinet of Ministers of January 30, 2019 No. 56 (Cabinet of Ministers of Ukraine, 2019) and priority areas and tasks of digital transformation for the period up to 2023 approved by the Cabinet of Ministers of Ukraine dated February 17, 2021 No. 365-r (Cabinet of Ministers of Ukraine, 2021) the existing system of education and science must undergo radical digital changes and meet global trends in digital development for the successful realization of each person's potential. Acquisition of digital competencies is a basic need of a modern specialist, so the education system (Medical (Pharmaceutical) Higher Educational Establishment – M(P)HEE) should ensure the formation of digital competencies of students and research and teaching staff (Kuzminska et al., 2019), as well as initiate the introduction of

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digital infrastructure and electronic services.

The digital transformation of higher medical education is an integral part of the digital society as a whole, where there is a rapid filling of the world with digital technologies, systems, as well as with their help to establish communication and data exchange. These processes contribute to the development of digital competencies of the subjects of the educational process and are aimed at building an innovative, open and secure digital environment of the university.

Problems of design, implementation and use of an open cloud-oriented educational and scientific environment of a higher education institution have been the subject of research by (Bezverbnyi and Shyshkina, 2022; Bykov et al., 2019; Glazunova et al., 2022; Kolgatin et al., 2022; Oleksiuk and Spirin, 2022; Oleksiuk et al., 2021; Osadcha et al., 2022; Spirin et al., 2019). The researches of (Fedorenko et al., 2019; Kartashova et al., 2022a,b; Hurzhii et al., 2018) are devoted to the analysis of informatization of general secondary and higher education in Ukraine. The study of some features of informative terminology is revealed in (Zhaldak, 2019). Morse and Varchenko-Trotsenko (Morse and Varchenko-Trotsenko, 2015) considers the design of the model of effective learning environment of the university using information technology. The research of Spirin and Vakaliuk (Spirin and Vakaliuk, 2017) is devoted to the definition of criteria and establishment of appropriate indicators for the selection of open web-based learning technologies, Trius and Sotulenko (Trius and Sotulenko, 2017) talks about problems of creating distance learning support systems for health professionals. Franchuk (Franchuk, 2020) analyzes and systematizes the most common web-based computer systems in higher education. Stuchynska et al. (Stuchynska et al., 2021) consider approaches to the design and creation of a cloud learning environment for medical students. Marin (Marin, 2021) describes different practices which attempted to enact a digital university: MOOCs and videoconferencing apps used for lecturing. Michaeli et al. (Michaeli et al., 2021) investigate the digital changes that have taken place in medical school that are related to the pandemic COVID-19. Rosenman and Swanson (Rosenman and Swanson, 2020) discusses the advantages and disadvantages of using digital platforms and wearables, as well as the problems of "Digital Health" in Medical School. Maltese (Maltese, 2018) offers new methodologies, data models, authority control mechanisms, and system infrastructures that are able to support a broader range of services in digital university.

Purpose of the article is presentation of design experience and general approaches to creating a single information and educational environment of Bogomolets National Medical University "NMU Digital".

2 METHODS

Theoretical and empirical methods of scientific research were used to perform the set tasks, namely:

- method of system analysis, comparison and generalization for theoretical substantiation and development of information and educational environment of the Bogomolets National Medical University "NMU Digital";
- bibliosemantic method – for the study of psychological and pedagogical, scientific literature, regulations on the design of information and educational environment, the use of automated control systems and distance learning technologies;
- empirical methods – conversations with students and teachers, analysis of ways to use learning materials management systems;
- questionnaire – in order to determine the level of digital orientation of students and research and teaching staff of the university;
- modeling – to develop the information and educational environment of the university and analyze its functionality.

3 RESULTS AND DISCUSSION

First of all, it is necessary to consider the essence of the concepts of "digital competence" and "digitalization of education" to understand the need for the formation of certain skills in the subjects of the educational process when working in the information and educational environment. In the Recommendations of the European Parliament and of the Council (Council Recommendation, 2018), digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking. Carretero et al. (Carretero et al., 2017) defines the digital competence not only as the ability to use the latest digital technologies, but also as the ability to use these digital technologies in a critical, collaborative and creative way. In particular, this publication identifies five main structural components of digital competence, namely:

1. literacy of information operations (viewing, searching, filtering data, information and digital content; evaluation of data, information and digital content; data, information and digital content management),
2. communication and cooperation (interaction through digital technologies; sharing of digital technologies; involvement in active public activities through digital technologies; cooperation with the help of digital technologies; network etiquette; digital identity management),
3. creation of digital content (digital content development; integration and processing digital content; copyright and licenses; programming),
4. security (device protection; protection of personal data and privacy; protection of health and well-being; protection of the environment),
5. problem solving (solving technical problems; identifying needs; creative use of digital technologies; defining spaces in numbers competence).

According to (Bykov et al., 2020), digitalization of education "is a modern stage of its informatization, which involves saturation of information and educational environment with electronic-digital devices, tools, systems and electronic communication between them, which actually allows integrated interaction of virtual and physical, that is, it creates a cyberphysical educational space". In turn, the information and educational environment will be understood as a continuum of spatio-temporal, socio-cultural, activity, communicative, informational and other factors that appear as conditions for interaction between the developing individual and the objective world of higher education, which are purposefully created and arise spontaneously. Obviously, for effective interaction between the user and the information and educational environment, the subject of the educational process must have established digital competencies.

The results of the analysis of scientific and pedagogical literature allow us to interpret concept of "informational and educational environment" as a continuum of spatio-temporal, socio-cultural, activity-oriented, communicative, informational, and other factors that appear as conditions of interaction between the developing individual and the objective world of higher education that are purposefully created and arise spontaneously. Kasatkin and Tverezovska (Kasatkin and Tverezovska, 2011) gives another interpretation of this concept, namely as a system-organized set of tools, information resources, interaction protocols, hardware and software, and organizational and methodological supports, focused on meeting the educational needs of users. In particular, the educational environment of M(P)HEI is a necessary component of the holistic mechanism of professional socialization, life, and professional situations that ensure the entry of students into professional life.

The results of the analysis of scientific and pedagogical literature allowed to identify the main factors that were taken into account in the design and creation of information and educational environment of the university, namely: widespread use in the educational process of computer-based learning technologies; practical implementation of distance learning technologies; providing ICT support for research; wide introduction of digital technologies in education management at different levels; use of cloud technologies; taking into account the features of different computer technology platforms. In the course of digitalization, it is necessary to consider such principles as:

- ensuring access to data and knowledge;
- compliance with the system;
- focus on the development of a single information and educational environment;
- organization of communication, partnership and international cooperation;
- ensuring digital security and management priorities.

Analyzing the experience of organizing training with the help of distance technologies in institutions of higher medical (pharmaceutical) education, it can be stated that important educational and informational and methodological resources for the formation of the educational environment are:

- official portal of the institution of higher education;
- structured media library;
- thematic collection of video, audio materials, printed materials, methodical materials that provides the maximum visualization of educational, scientific and methodical activity, satisfies the interests of real and potential consumers of educational services in terms of the content of educational activities;
- virtual library – an electronic library with educational, educational and methodical, methodical literature, catalogs of other electronic libraries;
- distance learning courses or their elements as a form of organization and implementation of educational activities and self-education of students using ICT.

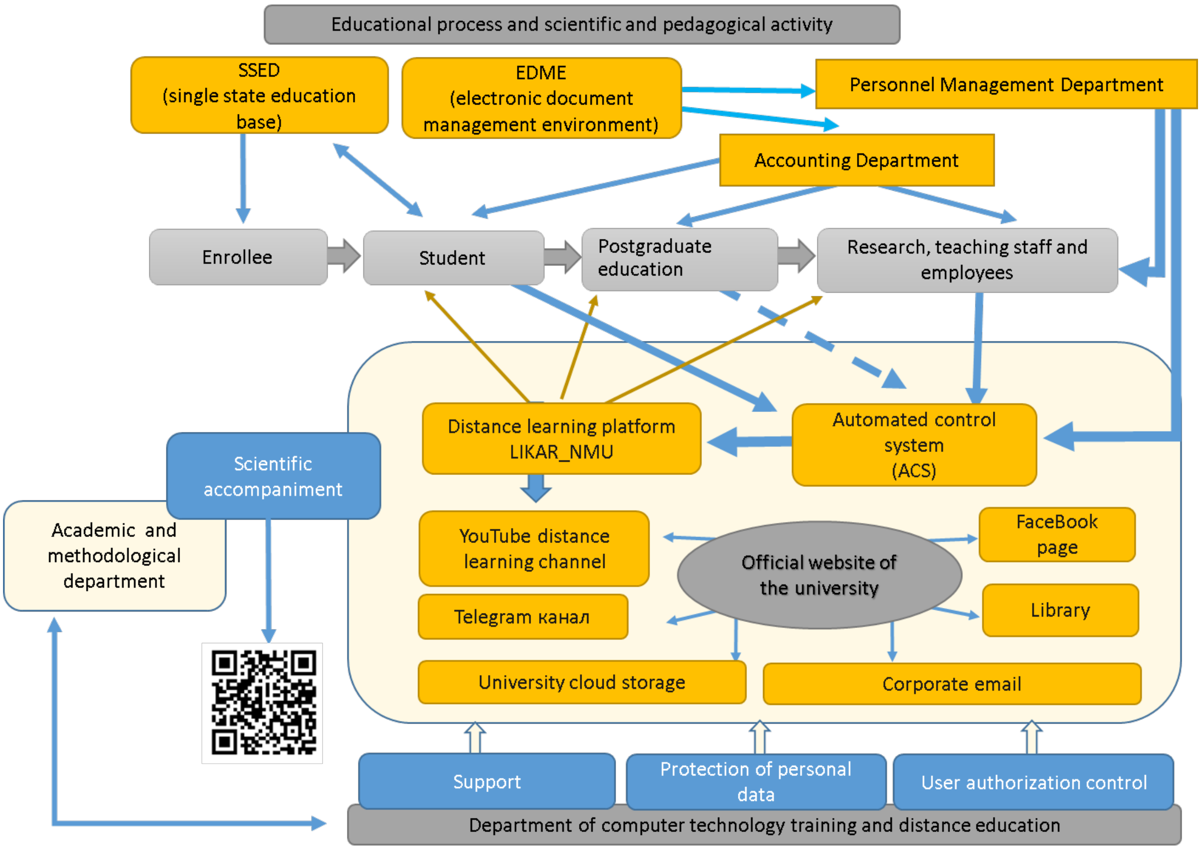

Figure 1: Model of information and educational environment of the Bogomolets National Medical University “NMU Digital”.

Information and educational environment of the Bogomolets National Medical University is based on the use of the latest technologies and provides the educational process with electronic textbooks and teaching aids in relevant disciplines, guidelines for the use of various web services, resources, and creates conditions for: introduction of pedagogically balanced learning models, use of cloud and mobile-oriented learning environments, use of various virtual laboratories, monitoring of academic achievements and disclosure of personal abilities of students.

The modern educational environment of M(P)HEI must meet a number of conditions, namely:

- to have the aesthetic appeal of the elements of the environment;
- to ensure compliance of the content and means of education with modern requirements for medical (pharmaceutical) education;
- to provide professional, psychological, and pedagogical needs of scientific and pedagogical workers and students; to have a positive image that contributes to the successful positioning of M(P)HEI in Ukraine and abroad;
- to have a high level of pedagogical skills, general and social culture of the teaching staff;
- to provide conditions for the formation of a competitive specialist in the medical (pharmaceutical) industry.

Thus, the informational and educational environment M(P)HEI in distance learning can be understood as a systematically organized set of modern educational and other information resources focused on meeting the needs of participants in the educational process and its scientific and educational support, as well as a set of hardware and software for storing, processing, and dissemination of educational materials and communications interaction to achieve educational aims, in particular in order to form the necessary professional competencies.

In figure 1 shows a model of information and educational environment of the Bogomolets National Medical University “NMU Digital”. First of all, all electronic data of entrants are entered by the staff of the Admissions Committee into the Unified State Electronic Database on Education (USEDE) and as soon as the entrant is enrolled in the number of university students, he/she immediately becomes part of the digital environment. All data of the entrant goes to the ACS, and thanks to the integration of the ACS with the university distance learning platform LIKAR NMU, students of our university will have access to video and teaching materials on the YouTube distance learning channel in the disciplines taught to them this or that semester. Orders on the movement of the contingent (enrollment, transfer, deduction or academic leave) of students are formed in the ACS and transferred to the electronic document management environment (electronic management system – EMS), and from there to the necessary departments.

Based on distance learning technologies, it is possible to provide access to a wide range of information resources – from assistance in performing specific practical work and autonomous training courses downloaded to the student's mobile device, to fully networked training courses with problem-oriented software running on the server. It is also important that distance learning solves the problem of professional development of those who live and work in remote areas and helps to solve cost problems. Distance learning is currently impossible to imagine without systems of software products (distance learning platforms), through which remotely, via the global internet, the student can master the material, and the teacher in turn can create distance learning courses and conduct distance learning. The use of such platforms provides an interactive connection between teacher and student; distribution and verification of control tasks; keeping an electronic journal of records of assessments and visits; setting up various course resources; integration with cloud technologies. Using the latter opens up new learning opportunities, provides almost unlimited storage space, and most importantly – provides access from various devices to server resources and does not "tie down" the user to the workplace.

Let's consider the features of training at Bogomolets National Medical University, which are due to the "specific" organization of both the educational process and its structure. These features include: different duration of initial classes (1, 2, 3 and 5 hours); availability of monodisciplines (the department of a certain faculty teaches the same discipline for students of different faculties); academic disciplines for students of the faculty are taught by scientific and pedagogical employees of the departments belonging to other faculties. Analyzing the scheme of interaction of the educational and methodical department with the faculties of the university (figure 1) it can be traced that the students of the pharmaceutical faculty have academic disciplines taught by different departments, which in turn belong to different faculties, for example:

- faculty of training of foreign citizens (disciplines: "Information Technology in Pharmacy", "Higher Mathematics and Statistics", "Latin");
- medical faculty No. 1 ("Human Anatomy");
- medical faculty No. 4 ("Hygiene and Ecology").

Sometimes one department is taught by several departments, for example, the discipline "Life Safety, Fundamentals of Bioethics and Biosafety" will be divided between the Department of Hygiene and Ecology No. 3 of the Medical Faculty No. 4, and the Department of Philosophy, Bioethics and History of Medicine.

In accordance with figure 2, the logical sequence of interaction is as follows: the educational and methodical department calculates the pedagogical load and forms the schedule of educational classes; faculties (dean, deputy dean, methodologists, dispatchers, inspectors) form lists of student groups, monitor academic performance, make curricula into the automated control system (ACS), etc. Having received the previously mentioned information from the educational and methodical department and faculty, the responsible persons from the department assign teachers in the schedule by groups, publish thematic plans for disciplines (calendar-thematic plans of lectures, practical and seminar classes, as well as independent work of students) syllabuses and regulations. classes, final modular controls. In addition, they fill in grade journals, attend lectures, and fill in information on academic performance.

During the period of adaptive quarantine and digitalization of education it is important to ensure not only students' access to educational and methodical material, but also a reliable communicative component between students, departments, faculties and educational and methodical department and other structural units of Bogomolets National Medical University, as well as automation of processes related to the placement or completion of information. Especially important is the support and assistance to research and teaching staff of the university in organizing the provision of quality educational services.

At present, it is important to install a new ACS module, namely its synchronization with the ACTION application. In particular, the following documents are available for "sharing":

- Passport of a citizen of Ukraine in the form of an ID card;
- Biometric passport;
- Registration number of taxes;
- Internally Displaced Persons (IDP) certificate;

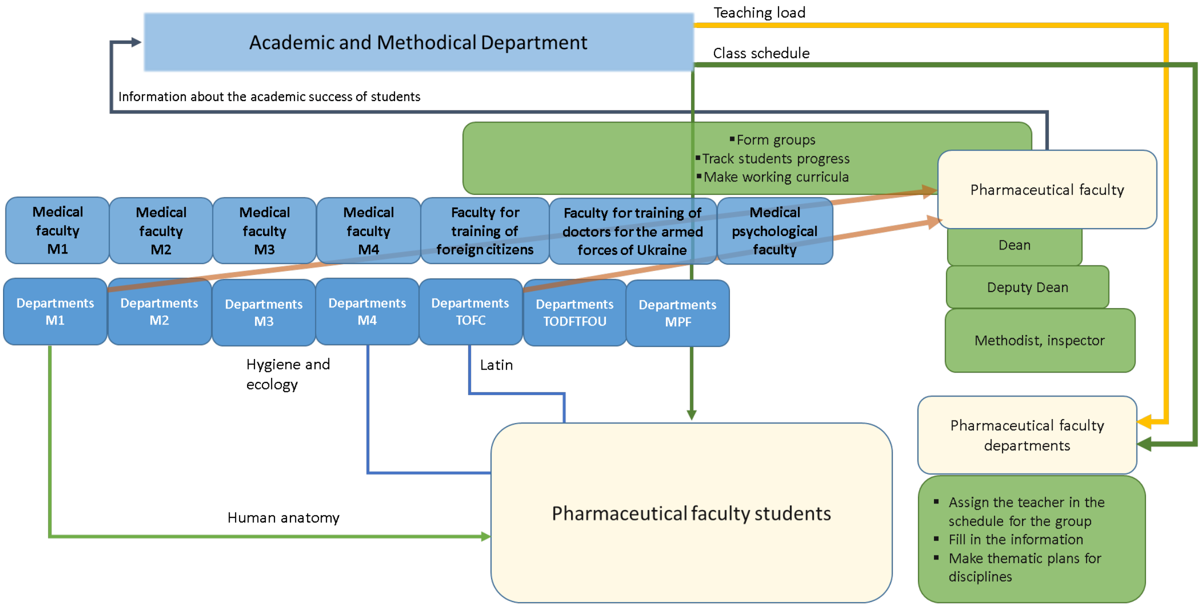

Figure 2: Scheme of interaction of the educational and methodical department with the faculties of the university.

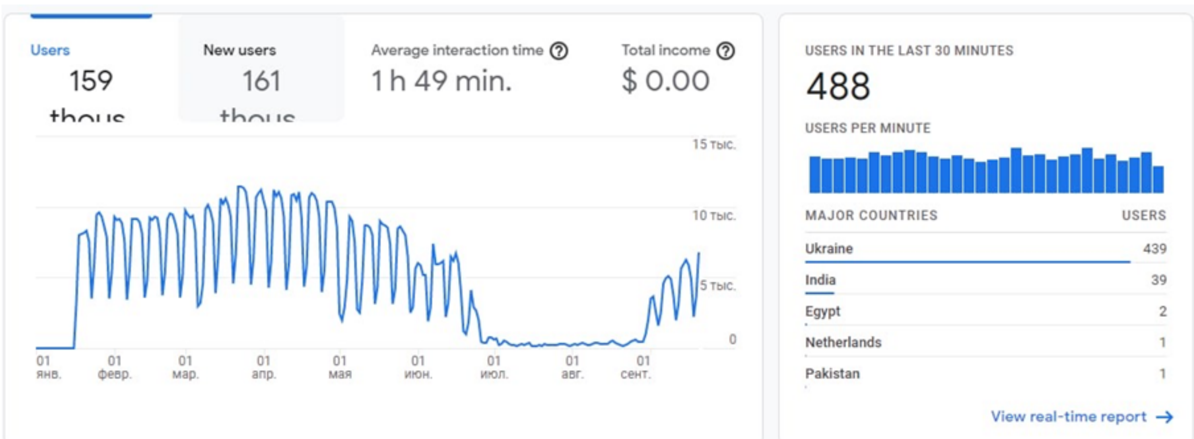

Figure 3: Attendance statistics of the LIKAR NMU distance learning platform.

- Child's birth certificate.

In addition to working in the ACS, research and teaching staff carry out organizational and pedagogical activities on the distance learning platform LIKAR NMU (develop and fill distance learning courses and YouTube distance learning channel). Three modules are available on the LIKAR NMU distance learning platform: distance learning; deanery; the organizational structure (figure 3).

The scientific and pedagogical staff of the university developed almost 2000 video recordings of lectures and video recommendations for practical and laboratory work, which were uploaded to the YouTube distance learning channel of Bogomolets National Medical University. The mantis is placed (figure 4). The channel currently has more than 3,000 subscribers.

In order to optimize the information support and counseling of higher education students, teachers, course managers and faculty members responsible for educational work, support chats were created in Viber and Telegram messengers. In addition to the organizational and control function, the university administration together with the educational and methodical department and the department of computer technology of learning and distance education provides constant scientific support, updating instructions, publishing methodical materials and scientific articles placed in the rubric "Distance learning" on the official website of the university, as well as step-by-step video

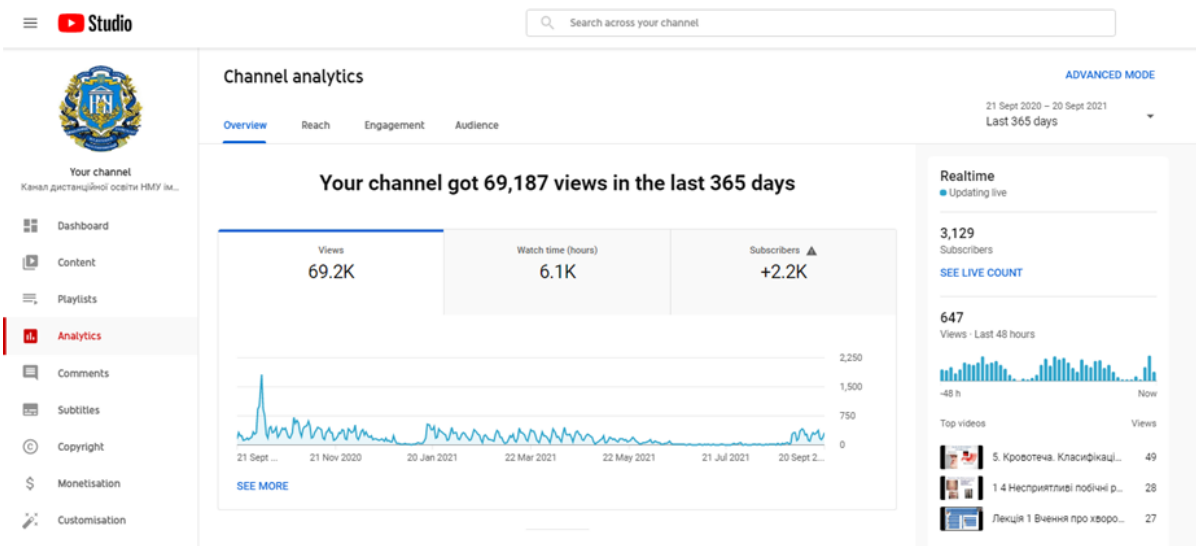

Figure 4: Analytics of views of the YouTube distance learning channel of Bogomolets NMU.

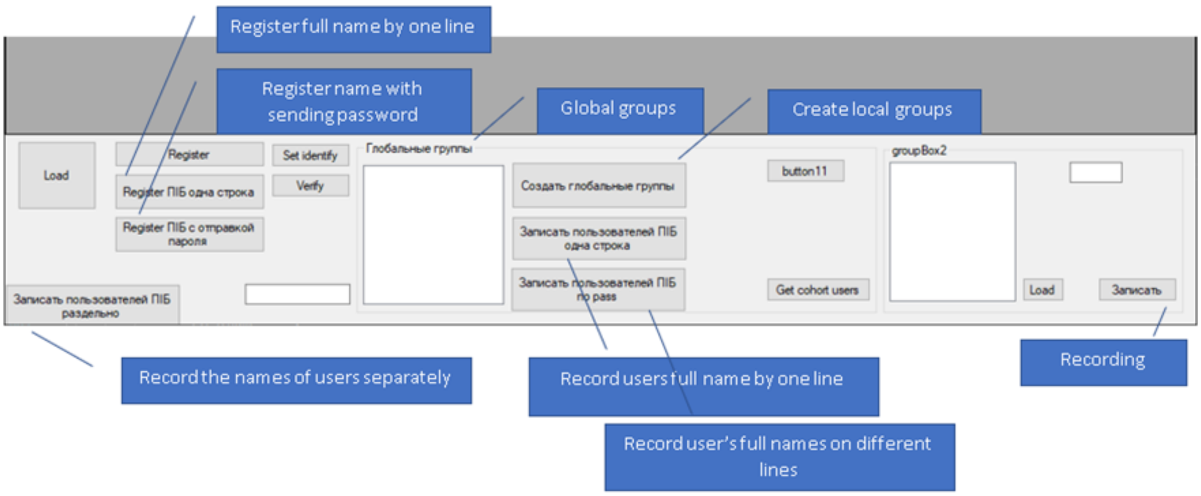

Figure 5: Application window for optimizing user registration without an ACS account.

instructions for teachers were recorded and posted on the distance learning channel.

With regard to postgraduate education, this includes interns and students of advanced training or technical improvement courses. In fact, we have former students of our university, information about which was stored in the ACS and on the platform LIKAR NMU and new users. Data on graduates is stored on the distance learning platform, and software was developed for unregistered users, which solved the problem of fast data transfer from the spreadsheet, and registration of users absent in the ACS (figure 5). This software application is designed for local use.

In addition, a special module on the LIKAR NMU platform has been developed for advanced training and technical improvement courses, which allows generating certificates confirming the completion of training courses. These certificates indicate the educational institution, name, subject of the training course and the date of completion.

An important role in the interaction between structural units is played by the environment of electronic document management (EMS). Thanks to EMS, the hierarchy of management actions of the university administration, structural units and faculties is clearly traced and adhered to. Quite convenient is the fact that the order or order of the university can be immediately sent to all necessary users for review, signature or review. The head of the structural unit has the opportunity to review the status of execution of the order and find out whether all colleagues are performing their duties properly. This is quite convenient, especially when there is a powerful institution and structural units are located in different parts of the city, you do not need to spend time and resources on the way to the office building and waiting in line for signatures under offices, most importantly to have constant access to the Internet.

In the process of designing an information and educational environment of the university, it was expedient to establish the readiness of the teaching staff and students of different faculties to use digital technologies in their activities. In order to determine the level of digital orientation of research and teaching staff and students of Bogomolets National Medical University a questionnaire was conducted. A total of 939 respondents took part in the survey, of which 87 were faculty, 817 were full-time students and 38 were part-time students.

Respondents were asked to rate their own components of digital competence on a 5-point scale:

- Respondents rated information literacy as follows: 37% – by 5 points, 46% – by 4 points, 14% – by 3 points, 2% – by 2 points, 1% – by 1 point.
- Respondents rated communication and cooperation as follows: 45% – by 5 points, 38% – by 4 points, 13% – by 3 points, 3% – by 2 points, 1% – by 1 point.
- Respondents rated the creation of digital content as follows: 25% – by 5 points, 36% – by 4 points, 27% – by 3 points, 8 – by 2 points, 4% – by 1 point.
- Respondents rated data protection as follows: 29% – by 5 points, 33% – by 4 points, 27% – by 3 points, 7% – by 2 points, 4% – by 1 point.
- The solution of technical problems was assessed by the respondents as follows: 23% – by 5 points, 33% – by 4 points, 30% – by 3 points, 9% – by 2 points, 5% – by 1 point.

Table 1: Distribution of respondents depending on the position.

Academic title	2020-2021 a.y.	2021-2022 a.y.
Professor	1.5%	2.3%
Docent	3.3%	7.3%
Senior Lecturer	0.2%	0.9%
Teacher	0.3%	1%
Assistant	3.8%	6.6%
Full-time student	86.5%	72%
Part-time student	4.1%	7.7%
Intern	0%	1.7%
Postgraduate	0%	0.3%
Other	0.3%	0.1%

As can be seen from the results of the answers to this question, most respondents assess themselves at a sufficient level of digital competence. It was also suggested to assess one's own level of interest in the use of digital tools:

- Work on the global Internet: 65% respondents have a high level, 30% respondents have a medium level, and 5% respondents have a low level.
- Visualization: 63% respondents have a high level, 34% respondents have a medium level, and 3% respondents have a low level.
- Ensuring cybersecurity: 45% respondents have a high level, 38% respondents have a medium level, and 17% respondents have a low level.
- Scientific communication: 51% respondents have a high level, 40% respondents have a medium level, and 9% respondents have a low level.
- Electronic documents: 53% respondents have a high level, 38% respondents have a medium level, and 9% respondents have a low level.
- Mobile devices: 71% respondents have a high level, 24% respondents have a medium level, and 5% respondents have a low level.

It can be stated that the majority of respondents are interested in using digital tools when working on the global Internet and with mobile devices, at least in ensuring cybersecurity of data.

In response to the questionnaire “In your opinion, what are the main requirements to be met during the digital transformation of education?”, distance learning technologies were identified in the first place, research learning and blended learning in the second and third, respectively (figure 6).

To the question “Do you have the skills to create digital content?” the following answers were received: 51.9% of respondents have a basic level (I create simple digital content (text, tables, images, audio files) in at least one format), 39.5% of respondents have a medium level (I create complex digital content in different formats (for example, text, tables, images, audio files) and have the skills to create web pages or blogs); 8.6% of respondents have a high level (I create complex multimedia content in different formats, using a variety of digital tools and environments, I can create a website).

To the questionnaire question “Do you have the skills to create digital content online in cloud storage (for example, Google Drive or Dropbox)?” such answers were received, 58.4% indicated that “yes”, 41.6% – “no”.

To the question “Do you have the skills to use e-mail and messengers (for example, Viber, Telegram or

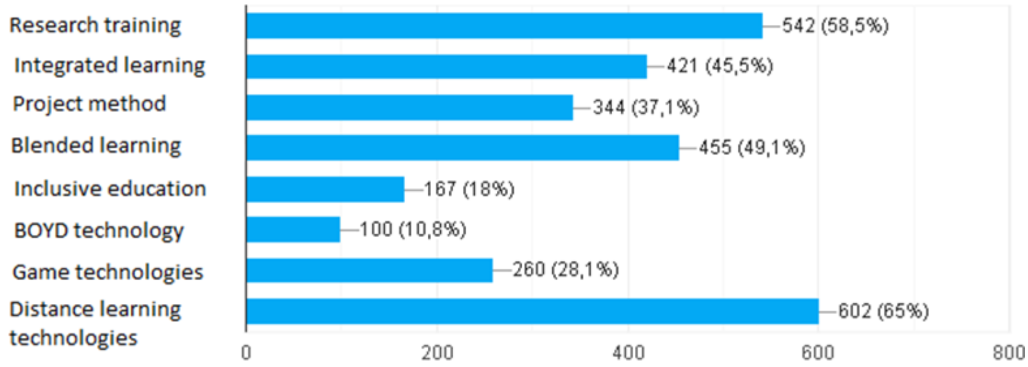

Figure 6: Distribution of respondents' answers to the main requirements should be provided during the digital transformation of education.

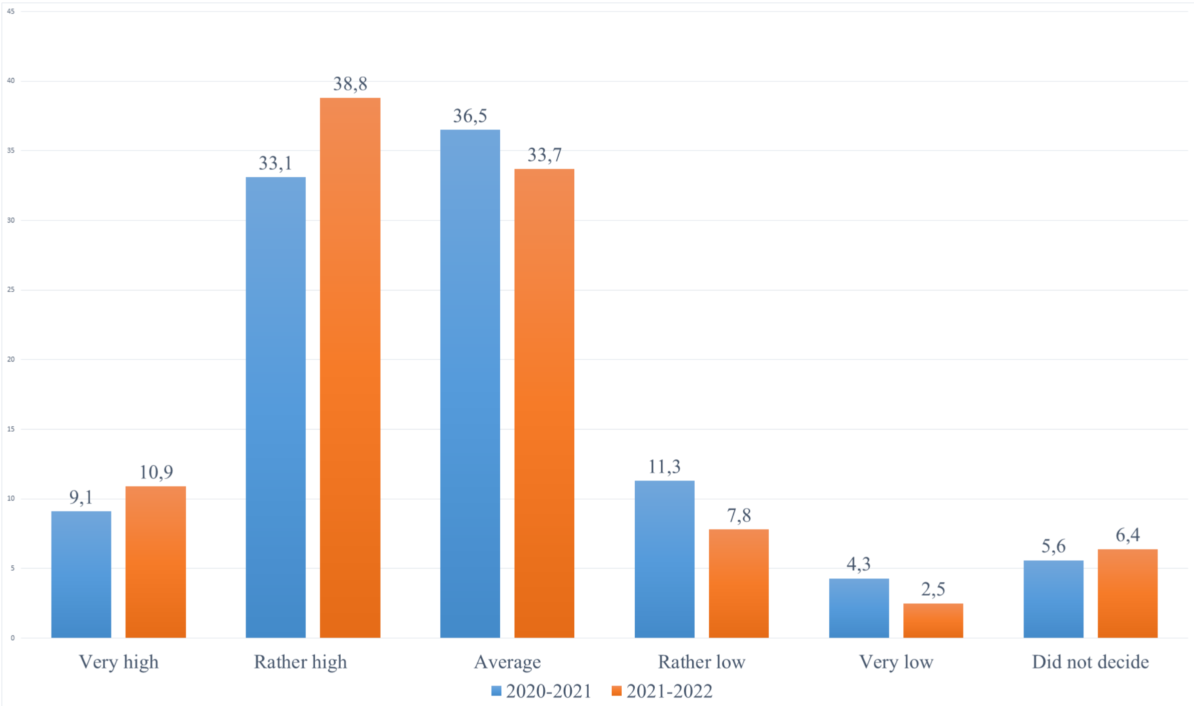

Figure 7: Distribution of respondents' answers to the question "How would you assess the quality of education at the Bogomolets National Medical University?"

WhatsApp) in professional activities?" the following answers were received, 97.1% – said "yes", 2.9% – "no". Having studied the attitude of respondents to the organization of the educational and information environment of Bogomolets National Medical University we can note that 44.4% are completely satisfied, 37.9% are undecided, and 17.7% are dissatisfied. Analyzing satisfaction with the quality of information support, the following results were obtained: 44.5% were completely satisfied, 35.5% were undecided and 20% were dissatisfied.

In order to study the quality of the organization of a single information and educational environment at the Bogomolets National Medical University for the last 2 years has been conducting online surveys of research teaching staff and students of various faculties. In 2020-2021 academic year 4610 respondents took part in the survey, and 2021-2022 academic year 3940 respondents (table 1). The following results were obtained after the survey. To the question of the questionnaire "How would you assess the quality of education at the Bogomolets National Medical University?" (figure 7) in 2020-2021 a.y. 78.8 % of respondents answered positively, 15.6 % of respondents considered the level of education rather low or very low and 5.6 % did not decide on the answer. In 2021-2022 a.y. the distribution of respondents answers was as follows: 83.4 % of respondents answered positively, 11.2% of respondents considered the level of education rather low or very low and 6.4 % did not decide on the answer.

To the question “How would you assess the quality of education at the Bogomolets National Medical University for distance learning in adaptive quarantine?” 2020-2021 academic year the following answers were received: 45.3% – very high and high, 35.3% average quality score; 16.2% – low and very low and 3.2% of respondents did not decide on the answer. Since 2021–2022 a.y. training was carried out according to the classroom–distance form of education, the question of assessing the quality of the form of education was posed as follows: ”How would you assess the quality of education at the Bogomolets National Medical University the classroom–distance form of education in the conditions of adaptive quarantine? ” respondents’ answers are divided as follows: 44.3% – very high and high, 35.9% average quality score; 15.8% – low and very low and 4.9% of respondents did not decide on the answer. However, regardless of the form of student learning, whether distance or mixed, the issue of improving the quality of distance learning at the Bogomolets National Medical University. The worshiper remains relevant today. Last educational year, 57.2% of respondents believed that this issue is a priority, this year 42.4% share this opinion.

In 2020-2021 academic year answering the question ”Do you agree with the statement that distance learning puts everyone on an equal footing?” The opinion of the respondents was divided: 30% – said they completely agreed, 29.6% – mostly agreed, 13.5% – mostly disagreed, 16.2% – completely disagreed and 10.6% did not decide on the answer. In 2021-2022 a.y. The distribution of respondents’ answers was as follows: 29.3% – said they completely agreed, 31.1% – mostly agreed, 15.2% – mostly disagreed, 14.4% – completely disagreed and 10% did not decide on the answer. In addition, it is appropriate to determine the form of organization of the educational process that most puts students in a level playing field.

In 2020-2021 academic year 68.9% of respondents were satisfied with the organization of distance learning, 13.1% – rather dissatisfied and 17.9% found it difficult to determine the answer. This year we had a task to determine how many respondents are satisfied with different forms of education at the university (figure 8): classroom, mixed, distance. It should be noted that the combination of classroom and distance learning has become commonplace for teachers of the Bogomolets National Medical University. Answering the question “Can distance learning affect the reduction of corruption?” 64.1% of respondents indicated that ”rather yes”, 16% – “probably not”, 19% – did not decide on the answer. In 2021-2022 a.y. respondents’ answers were divided as follows: 57.4% of respondents indicated that “rather yes”, 19.9% – “probably not”, 22.7% – did not decide on the answer. As for the use of additional tools to provide distance and classroom distance learning, it is the same as last year – Zoom and GoogleMeet are preferred. As the epidemiological situation in the country is constantly preparing new challenges for the education and health care system, students and teachers have to adapt to change. It is important, regardless of the form of classes to convey the necessary information to students, and get a positive result of its assimilation. Constantly improve pedagogical skills, following modern methods and teaching methods.

4 CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The designed single information and educational environment “NMU Digital” unites all participants of educational and scientific activity, providing space for communication and data exchange, simplifies and modernizes management processes at the university. The implementation of the proposed concept aims to ensure: a qualitatively new level and effectiveness of the university; development of a unified information educational environment of the university; high level of quality of training and advanced training of students; increasing the efficiency and effectiveness of research; high level of digital competence of university employees.

The information and educational environment developed at the university consists of many components. Its organization involves not only the use of modern digital technologies, such as automated document management system, distance learning platform, automated control system, YouTube, telegram channel, official website, but also establishing communication between all structural units of the university, creating conditions for the formation of digital competence in order to work in the information and educational environment of the university. Analysis of the results on the level of digital orientation of teaching staff and students of Bogomolets National Medical University gives grounds to conclude that a significant number of respondents need to improve

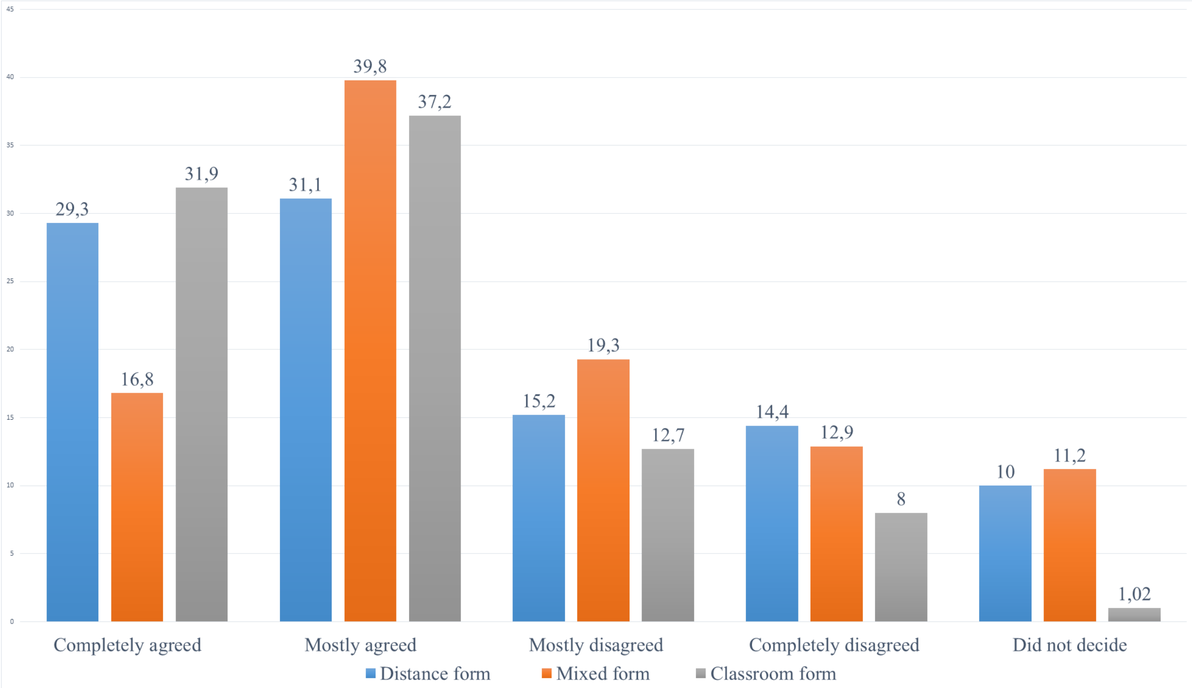

Figure 8: Distribution of respondents' answers to the question "Can distance learning affect the reduction of corruption?"

their digital competence. Most users have high skills in working on the Internet and with mobile applications, this applies mainly to students. In our opinion, it is possible to expand knowledge in other directions by updating the content of computer science disciplines. As for the teaching staff, web training's and seminars should increase their digital competence. Tracking the dynamics of digital competence changing is a prospect for future research, as the process of creating information and educational environment of the university is long and is implemented in stages. The results of the conducted sociological research will contribute to the creation of new opportunities for adjustment, development, and functioning of the informational and educational environment of the university. As we can be seen from the results of the comparison of 2020-2021 and 2021-2022 academic years, the percentage of respondents who positively assess the quality of education at the university has increased. Most likely, this is due to the introduction of a mixed form of education and the establishment of mechanisms for interaction between students and teachers.

Prospects for further research are aimed at developing proposals for ways to develop digital competence of students and research and teaching staff of the university. The proposed concept for the design of information and educational environment of the university needs constant improvement and in our opinion, the results of sociological research will help create new opportunities for adjustment, development and functioning of the information and educational environment of the university.

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Responsibility and Digital Competence of Future Socionomic Professionals: Relationship and Features of Development

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Abstract: The article dwells on to the study of the relationship between responsibility and digital competence of future professionals in socionomic professions and the study of the features of their development. The role of responsibility as a vital indicator of digital competence of future specialists of socionomic professions was determined, which determines their conscious and responsible activities in the context of obtaining and disseminating information in the digital space, promoting both their own psychological safety alongside psychological safety of other members of the digital community. The results of an empirical study were highlighted, which revealed an insufficient level of both responsibility and cognitive-operational components of digital competence for a significant number of future specialists in socionomic professions. Gender differences in the manifestations of responsibility of future specialists depending on the gender are characterized according to which the female respondents were slightly more responsible for the consequences of dissemination of information than male specialists. The expediency of promoting the development of responsibility of future specialists of socionomic professions as an indicator of their digital competence is stated, which can be provided in a specially organized psychological training. The program of responsibility development as a component of digital competence of future specialists of socionomic professions and the results of its approbation are presented, which testify to the effectiveness of this program.

1 INTRODUCTION

The development of the digital society in today's complex conditions leads to the growing role of information and digital technologies, in general, and in professional activities, in particular. This, in turn, requires the development of digital competence, the creation of conditions conducive to effective work with a variety of information sources, the identification of factors that ensure these processes, and so on. Today, the infrastructure of the metaverse is still evolv-

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ing. Researchers, educators, policymakers and digital designers have the chance to use the potential of the metaverse as a three-dimensional, global, interconnected, exciting and online space in real-time. Therefore we need new ways to connect the physical virtual reality (VR) (Hirsh-Pasek et al., 2022). The digital competence is recognised by the EU as one of the 8 key competencies for a full life condition and activity, which according to the updated Digital Competence framework (DigComp 2.2) contains 5 main blocks of competencies (Adz, 2016) (information literacy and data literacy; communication and interaction; digital content; security; problem-solving). Digital competence is especially important for specialists in socionomic professions who work in the human-human system, and their activities support and develop the human capital and intellectual potential of the country. This imposes special requirements on the training of future specialists in socionomic professions, providing their ability to navigate independently in the digital space, strive for self-regulation, search for professionally vital information, and be able to analysing and systematising, use digital technologies as a set of professional solutions, be responsible for the consequences of information dissemination, help prevent cyberbullying, mobbing and other negative phenomena that accompany the formation of a digital society. Digital competence combines knowledge, skills, motivation and responsibility. Thus, taking into account these components, the following components should be distinguished: information and media literacy – knowledge, skills, motivation and responsibility due to the searching, organization, archiving of digital information and its critical thinking, as well as the creation of information objects using digital resources (text, graphics, audio and video); communicative competence – knowledge, skills, motivation and responsibility necessary for various forms of communication (e-mail, chats, blogs, forums, social networks, etc.); technical competence – knowledge, skills, motivation and responsibility which allow effectively and safely using the hardware and software to solve various problems; consumer competence – knowledge, skills, motivation and responsibility in making it possible to solve with the help of digital means and the Internet various everyday tasks that involve meeting needs, solving specific life situations, etc. (Soldatova et al., 2013, p. 5). However, scholars point to several specific difficulties coming from what was originally considered the upside of the whole idea – the lack of rigid rules, the lack of controlling teachers, and the lack of conditions forced upon students. Electronic training of future professionals, in many cases, are simply neither ready nor even aware of their lack of readiness to take control over how what and when they learn (Postek et al., 2010, p. 105). Moreover, in our opinion, there is an additional confirmation of the development of responsibility as a vital component of future professionals' digital competence.

2 LITERATURE REVIEW

It should be noted that some aspects of the research problem have already been the subject of attention of researchers. Thus, there were investigated the following: the psychological aspects of computer literacy those contribute to the effective use of digital technologies in both educational and professional activities (Balakhtar, 2018; Balakhtar et al., 2022; Bondarchuk et al., 2022b; Meshko et al., 2020; Osadchyi et al., 2020); information personality culture of specialists (Voitovych et al., 2022); the problem of digital competence and its separate components (Balyk et al., 2019; Bezverbnyi and Shyshkina, 2022; Burov et al., 2020; Kartashova et al., 2018; Kiv et al., 2019; Klochko and Fedorets, 2022; Nosenko and Sukhikh, 2019; Semerikov et al., 2021; Shokaliuk et al., 2020; Yevtuch et al., 2021; Soldatova et al., 2013; Riezina et al., 2022), in general, and future specialists of various profiles: teachers (Mintii et al., 2021; Oleksiuk and Spirin, 2022; Spirin and Vakaliuk, 2019; Zaika et al., 2021), economists (Hlushak et al., 2020), specialists in agronomy (Yevstratiev, 2020).

The investigations were conducted on the studies of the socio-psychological consequences of the development of digital technologies on the personality of a specialist or a user (Vakulich, 2006; Yeung, 2019), including in the context of responsibility for the consequences of using digital technologies (Aguilera et al., 2007; Aguinis and Glavas, 2012; Rupp et al., 2013; Glavas, 2016).

There are studies of CSR (Corporate social responsibility) which are focused on the macro and institutional levels (Aguilera et al., 2007; Aguinis and Glavas, 2012; Rupp et al., 2013), and some studies are focused of how CSR influences employees – micro level (Glavas, 2016).

On the other hand, many works are devoted to the study of various aspects of psychological and pedagogical problems of professional and personality development of future specialists, including in the context of responsibility and professional ethics (Bezrukova, 2015; Meshko et al., 2021; Vinoslavskaya, 2002, 2005) et al. The Digital Competence Framework for Citizens (DigComp 2.2), mentioned in the Digital Competence Framework for Citizens, highlights responsibility as an important indicator of digital competence, but the content of responsibility, in our opinion, is somewhat generalised as the ability to apply and adapt different communications in digital environments alongside the various forms of behaviour, know-how, aspects of cultural and age diversity, using digital technologies (Dig, 2021).This, in turn, requires the responsible use of ICT and includes issues of privacy and copyright, ethical issues and the ability to evaluate digital information (Hatlevik et al., 2021).

We read, write, listen and communicate differently than we did 500 years ago (Coiro et al., 2008). It is quite reasonable in our information society (Martin and Grudziecki, 2006) to understand digital competence as a basic need if we are to function in society (Chapman, 1999), as an essential requirement for life (Bawden, 2008) or even as a survival skill (Eshet, 2004).

The specificity of the professional activity of specialists of socionomic professions determines the increased requirements for their professional competence, in general, and digital competence, in particular. This is a significant number of factors that are directly dependent on the more general problem of the relationship between science, morality and ethics. Socionomists deal with social relations at different levels of their implementation in accordance with legal documents (Constitution, Law of Ukraine "On Information", norms, rules, etc.), which define the concepts of information, information relations, objects of these relations, rights and responsibilities of their participants, information ownership (Law, 1992).

Currently, many codes of ethics have been developed, which contain relevant rules, including on the responsible use of information, protection of information systems from viruses and artificially created errors in them. Within the ethics of the media, a separate area of digital ethics is identified and designed to address a number of issues due to the needs of selection and evaluation of information, contextualisation of information, information control, information security and reliability of information (Nazarov, 2005, p. 222). However, compliance with these rules is not enough. In particular, decision-making in the process of information retrieval requires an appropriate level of formation in the personality of the future specialist of socionomic professions of responsibility, which will allow ensuring the regulation of activities based on ethical norms and principles (Papakitsya, 2014, p. 36). At the same time, it is digital competence according to the National Council on Curriculum and Assessment (NCCA) (National Council for Curriculum and Assessment, 2004) that contributes to learning, the growth of achievements and motivation of professionals, and the spread of technology in everyday life, which will allow all citizens to be functional in our knowledge society (Ferrari, 2012). Higher educational institutions should provide the necessary skills and knowledge to determine the social, ethical and environmental impacts of entrepreneurship (Bampton and Maclagan, 2005), moreover, integrate ethical and social responsibility aspects in curriculum design (Nelson et al., 2012; Stonkutė et al., 2018; Rodríguez-Gómez et al., 2020).

Modern psychological science has accumulated considerable theoretical and practical material on various aspects of personal responsibility, in general (Bezrukova, 2015; Kosulya, 2010; Nazarenko, 2016; Papakitsya, 2014).

The study is *aimed* at theoretical and empirical research of psychological features of responsibility of future specialists of socionomic professions as an indicator of their digital competence.

3 THEORETICAL SUBSTANTIATION OF RESPONSIBILITY AS AN INDICATOR OF DIGITAL COMPETENCE OF FUTURE SPECIALISTS OF SOCIONOMIC PROFESSIONS

The ratio of freedom and responsibility, the ratio of social and personal responsibility, understanding of responsibility as a moral category, action and an important component of education are being significant in the study of responsibility in the context of digital competence of future specialists of socionomic professions (Kartashova et al., 2018).

Scientists interpret the concept of responsibility in different ways, namely: the presence of freedom because only free beings can recognize a sense of responsibility (Agazzi, 2009); the possibility of fulfilling an obligation or a duty; quality, which is an indicator of reliability and trust; an element of government, responsibility for something, certain obligations to others (Dic, 2022); "The ability of the individual to understand the compliance of the results of his/her actions with the goals set, recognised in a society or the collective by the norms, as a result of which there is a feeling of complicity in a common cause, and in case of non-compliance, a feeling of unfulfilled duty; the individual's readiness to admit that he or she himself/herself is the cause of the consequences of his/her behaviour and activities" (Prykhodko and Yurchenko, 2020, p. 34), etc.

Henceforward, on the one hand, responsibility is inconceivable without freedom, but on the other hand, freedom without responsibility becomes arbitrariness. Behind the solution of this dilemma is the freedom of choice, in general, for everyone in society. Thus, a person always has a choice, however, only a person should be responsible for this choice (Kosulya, 2010; Prykhodko and Yurchenko, 2020). Therefore, a person has the right to make decisions and act in accordance with his/her opinion, but he/she must also be personally responsible for the results of his/her actions, and not shift the blame for the negative results of his/her decisions and actions to others. This indicates the phenomenon of "personal responsibility". In addition, in the framework of social responsibility, the latter is seen as a certain relationship between the individual and society, aimed at the benefit of society as a whole, making decisions that meet the goals and values of mankind.

Responsibility in the social context is a certain concept that integrates common human values, ethical norms of behaviour of the government agencies employees, public organisations, research institutions, different levels of business structures etc.

Worth noting the concept of responsibility is formed on the basis of the international standard of social responsibility ISO 26000, developed in 2003 by the Strategic Advisory Group on Social Responsibility from around the world (Lazorenko and Kolyshko, 2008). Ukraine was among these countries. This standard makes clear the relationship between the principles of social responsibility and organisational governance structures.

A significant contribution to the study of aspects of social responsibility in the educational sphere in Ukraine also was made by Vinoslavskaya (Vinoslavskaya, 2002). Responsibility from the standpoint of action or not action, but conscious, is considered through a personal form of behaviour – an act (Bondarchuk et al., 2022a; Zinchenko and Meshcheryakova, 2003). Investigating the act, Rubinshtein (Rubinshtein, 2002) considered it as a special kind of action. The content of the act determines the moral behaviour of the individual, his/her value attitude not only to the results of his/her work but also to the information itself; has the following properties: axiological, responsibility, eventfulness (Bakhtin, 1986). Romenets created in modern Ukrainian psychological science the so-called action paradigm, according to which "an action becomes … not only a subject but also a methodical basis for the study of the psyche" (Tatenko et al., 1999, p. 181). An act is a "way of personal existence in the world" (Romanets, 2006, p. 13).

The concept of action allows the assessment of actions performed by the subject in information retrieval activities, which requires the adoption of certain criteria according to which this assessment can be carried out and determine the degree of responsibility of future socionomic specialists in the implementation of information retrieval activities. In particular, such a criterion may be the result of the performed action (aftereffect), its impact on the well-being of the environment. This requires the definition of some motivation as a motive and the identification of the degree of its morality. After all, a moral act is a holistic act and is manifested in the unity of motive, action and result (Rogozha, 2010).

Considering the above, it is worth noting that decision-making in action always testifies to freedom of choice, and this choice lies in the moral and ethical plane of the personality of a specialist of socionomic professions, forming a responsible attitude to information as a value based on predicting possible consequences for the use of this information and, however, be prepared to be held accountable for these consequences.

With regard to digital competence, the concept of "competence" should be understood in the sense proposed by European educational experts. Digital competence is "a set of knowledge, skills, values and attitudes, as well as strategies needed to use information and communication technologies and digital media for effective, critical, creative, independent and ethically-oriented learning" (Ferrari et al., 2012). Digital competence involves the confidence and, at the same time, critical application of digital technologies for the creation, retrieval, processing, exchanging of information at work, in public space and in private communication respectively. At the same time, information and media literacy, basics of programming, algorithmic thinking, working with databases, acquiring Internet and cybersecurity skills, understanding the ethics of working with information (copyright, intellectual property, etc.) are essential too (Zaporozhtseva, 2019).

Thus, digital competence implies the continuous ability of future specialists of socionomic professions to master competencies (knowledge, skills, motivation, and responsibility), confidently, critically and safely choose and apply various information and communication technologies in professional activities. The activity and attitude to it should be based on a sense of responsibility, understanding of the rights and rules of behaviour and activity in the digital world (Soldatova et al., 2013). At the same time, responsibility is correlated with the problem of the safety of modern technologies in the information world.

4 RESEARCH METHODOLOGY

In order to study the characteristics of the responsibility of future specialists of socionomic professions, their attitude to information as a value and willingness to be responsible for its use alongside the impact on the formation of digital competence, we conducted an empirical study. Accordingly, we used the methods of Papakitsa (Papakitsa, 2013) "Responsibility for the use of information" and the authors modified questionnaire "Information" (Law, 1992), aimed at determining the level of awareness of future specialists of socionomic professions, content and properties of information, responsibility for its dissemination, and adapted methodology "Index of digital competence" (Soldatova et al., 2013) – digital competence, blocks "Knowledge" and "Skills", which determine the cognitive and operational components of digital competence of the individual.

The observational stage of the study (2019-2020) was attended by 748 students – future specialists in socionomic professions of the 1st, 3rd and 5th courses. At the formative stage (2021) – 60 people, 29 of them formed an experimental group (divided into 2 subgroups of 14 people each for the convenience of training, providing and receiving feedback from all participants within the appropriate time frame) and 31 – control. The research was carried out based on the University of Education Management and the Yuriy Fedkovych National University of Chernivtsi. Respondents were distributed according to gender: 40.1% – men, 59.9% – women. Statistical processing of the obtained data was carried out using the computer program SPSS (version 23.0).

5 ANALYSIS OF THE RESULTS OF EMPIRICAL RESEARCH

At the first stage of the empirical research, based on the results of the analysis of the data of the "Information" questionnaire, an insufficient level of awareness by future specialists of socionomic professions of the content and properties of information, responsibility for its dissemination, and the like was found.

At the ascertaining stage of the empirical study based on the results of the analysis of the data of the questionnaire "Information" revealed an insufficient level of awareness of future specialists of socionomic professions content and properties of information, responsibility for its dissemination and more.

Thus, regarding the first question "Information is. . . ", only 22.2% of respondents answered in the affirmative and agreed with the proposed interpretation of the concept of "information". In particular, there were such answers as the following: facts understandable to a person; information about the world around us that is understandable to humans; information that carries a semantic load; a set of symbols or drawings that are accessible to human perception; information presented in any form and understandable to a person, etc. At the same time, 77.8% of respondents gave answers that may be grouped into two groups. The first group (59.6%) consisted of such answers as, for example, the following: information – this is what you can receive something new, data, knowledge, skills, everything new that surrounds us, the properties of the world. As you can see from the above example, respondents take information for data or ready-made knowledge. The second group (24.4%) – such answers as the like: method of development, means, source of development, method of governing society, means of achieving the goal, and so forth. The answers obtained indicate that this group of respondents considers information as a tool of achieving goals. Besides, there were 2.8% respondents who found it difficult to answer the first question.

Regarding the second question "The main sources of information for me are ...", the answers of the respondents according to the semantic units of content analysis have the following distribution: Internet – 91.4%, books – 64.0%, subject expert – 38.9%, mass media – 47.5%. At the same time, 8.2% of respondents gave such answers as, for example, the world around them, data, personal life conclusions, practice. This suggests that respondents understood the questions but were unable to classify their answers. Furthermore, 0.5% of respondents found it difficult to answer in general.

Moreover, 6.8% of respondents understood the essence of the third question "Digital competence is. . . ", giving complete, detailed answers such as the following: the degree of readiness to work in a digital environment, the ability to perceive and process information for their needs using digital tools, possession of digital technologies and their use for successful activity in the modern world, etc. At the same time, other respondents gave incomplete, fragmentary answers, primarily related to the level of knowledge of digital technologies ("know how to act on the Internet, social networks"), mastering modern innovations in the digital world (43.8%) or skills use the Internet, the ability to find certain information, etc. (42.1%).

Besides, 7.3% of respondents found it difficult to answer the third question.

The answers to the fourth question "Information has the following properties ..." according to the semantic units of content analysis have the following distribution: adequacy – 4.4%, relevance – 8.2%, reliability – 6.4%, accessibility – 6.7 %, objectivity – 3.8% and completeness of information – 2.5%. Furthermore, 11.1% of respondents found it difficult to answer.

Nevertheless, the respondents answered not only according to the semantic units of content analysis but also to several additional answers. We grouped these additional answers into two groups. The first group (64.1%) includes such answers as, for example: cognitive, developmental, usefulness, harmfulness, variability, instability, influence. The second group (35.9%) includes the following answers, e.g.: by content, by volume, by place, by quality, technical and professional. Although these examples of properties cannot be attributed to the group of semantic units that are compiled for this study based on accepted properties of information in the scientific and educational literature, they reflect different aspects of the category of property as a whole in the philosophical plane, and the accepted answer within the framework of this study does not fully express the meaning determined by the semantic units of content analysis.

Only 22.5% of respondents gave the correct answers to the fifth question "Digital technologies are ...". These are, for instance, the following: information processing technology, where the tool is a computer and various digital tools; technologies that allow receiving, processing, transmitting and storing information using a computer; computer technologies that allow the user to effectively search and further process information. At the same time, 76.5% of respondents gave incorrect answers, which can be grouped into two groups. The first group (38.7%) includes the following answers, for instance, as the like: computer, Internet, technical base, technology that creates information, digital technology. As can be seen from the given example, it can be assumed that this group of respondents believes that information and computer technologies are generally a technique, or a separate device or a network itself, while not indicating which particular technique and the subject of processing, without focusing on key words – technology, information – and work will be carried out based on some technical device (computer). From the dictionary of philosophy of science and technology (Gub, 2003), the term technology – is a set of various devices, mechanisms and devices that do not exist in nature and are made by human to meet socio-cultural needs. Thus, the answers of the respondents indicate either a misunderstanding of the term "technology" or a misunderstanding that technology can be tools that do not belong to the so-called new information technologies.

The second group (29.8% of the respondents) includes the following answers, for instance, as the like: type of activity aimed at developing technical means; a set of knowledge that is used to create and use computer technology; the ability to correctly find and use information in their activities. As can be seen from the given examples of answers, the respondents believe that information and computer technologies are a certain amount of knowledge or the abilities and skills of a person to perform any actions. Besides, 9.7% of the respondents found it difficult to answer.

Exclusively 11.3% were able to justify their choice a search engine, answering on the sixth question "I used a search engine to find information. I argue my choice by the fact that ...", e.g.: a user-friendly interface, no advertising, and the ability to search on English-language sites, access speed, and ease of search. Worth noting, the name of the search engines corresponded to the given arguments of the respondents, like the following: the Google search engine is the speed of indexing pages, the absence of advertising.

Moreover, 88.7% of respondents could not argue their choice and answered very superficially, for instance: the most popular, convenient, well-known, familiar, used by my friends, and the like. Besides, 0.5% of the respondents found it difficult to answer.

Thus, the analysis of the given as examples answers showed that there is a certain dissonance between the high level of development of digital technology in general and the low level of knowledge of the content of the information concept, the patterns of its existence, understanding of the variability of information sources, including methods of searching for information in the network, using search engines and the responsible attitude to its distribution.

The latter conclusion was confirmed by the analysis of the data of the "Responsibility" questionnaire, aimed at studying the attitude to information as a value and the willingness to bear responsibility for the consequences of its use.

The results obtained indicate that only 17.0% of the respondents have a high level of responsibility in the context of receiving and disseminating information (table 1). Other respondents do not fully (56.7%) or do not understand at all (27.3%) that the possession of information is already valuable. This indicates that information that satisfies the need for personal development, learning new things to prepare for a future profession, and is not of value for the respondents. They also do not realise the possible negative consequences of using the information in their activities and, as a result, do not fully realise their responsibility for the consequences of using this information, in general. In addition, these respondents often underestimate the negative consequences of spreading unnecessary information about themselves, which can negatively affect their psychological and even, sometimes, physical safety.

Table 1: Distribution of researched future specialists of socionomic professions by levels of responsibility.

Levels of responsibility	Development indicators (number of respondents, in%)
Low	27.3
Average	56.7
High	17.0

At the same time, according to the criterion χ^2, the peculiarities of the responsibility of *future specialists of socionomic professions of different genders* are stated (table 2).

Table 2: Features of responsibility of future specialists of socionomic professions depending on gender.

Gender of the respondents	Levels of responsibility (number of respondents, in%)		
	Low	Average	High
Female	19.9	56.9	25.2
Male	34.7	56.5	8.8

As follows from table 1, a high level of responsibility was found in 25.2%, future female specialists against 8.8% of future male socionomic professions, while a low level of competence was found in 34.7% of male, and among female – only in 19.9 % ($p < 0.05$). Thus, the future specialists of socionomic professions of the female gender have a slightly higher rate of development of digital competence than males.

Differences in the development of responsibility of the respondents depending on gender are consistent with the position of the gender approach, which states that women strive for social activity, are more responsible for their actions, seek to control their behaviour in accordance with social expectations (Burn, 1995).

The obtained data also correlate with those obtained by Pryadein (Pryadein, 2001). He highlights that "in the implementation of responsible cases in female students to a greater extent than in male students, the desire to adhere to ethical norms prevails. More often than students, they prioritize the public over the personal". Thus, when analysing the benefits of meaningful signs of responsibility by young people, the scientist received the following data according to the following components: "The desire to comply with ethical standards" (female students – 78%, male students – 68%), "Guidance of duty" (female students – 69%, male students – 62%), "Priority of publicity over personal" (female students – 62%, male students – 51%) (Pryadein, 2001, p. 171).

Thus, according to the results of empirical research, responsibility needs special development for a significant number of future specialists in socionomic professions.

On the other hand, in accordance with the purpose of our study, the levels of development of cognitive and operational components of digital competence were established by the relevant blocks "Knowledge" and "Skills" of the methodology "Index of Digital Competence" – authors –(Soldatova et al., 2013).

Hence, 9.3% of respondents have a high level of development of the cognitive component of digital competence, are able to use the Internet for education, install their own software update settings on the device used to work on the Internet. At the same time, 30.5% of the respondents are characterised by an average and 60.2% – a low level of development of the cognitive component of information readiness. The results showed that the respondents are not awareness enough about the various mobile applications and the possibilities of its usage; the Internet is used only to maintain relationships with friends, make purchases, payments and more (table 3).

Table 3: Distribution of researched future specialists of socionomic professions by levels of development of cognitive component of digital competence.

Levels of development of the cognitive component digital competence	Number of respondents, in%
Low	60.2
Average	30.5
High	9.3

Examining the operational component of digital competence of future specialists of socionomic professions, difficulties in understanding the content and analysis of the semantic structure of the text, in constructing questions about missing information, finding a piece of information from another text. Thus, only 9.8% of respondents are able to use special search engine settings (operators) to find specific information; make payments using electronic payment systems and Internet banking, use cloud technologies to store and work with own content (for example, Google Docs, Etherpad, Microsoft Office Live), check the reliability of software sources, etc. 52.6% of respondents are able to browse the network in order to search people with whom they would like to communicate, find inaccurate information, mark ("Check") in those places where they have been (e.g., in a social network or through special services), etc. Moreover, 37.6% of respondents can only post their photos, posts, statuses on social networks and special services (Twitter, Tumbrl, Instagram), find the most profitable offers of goods and services on the Internet, interact with members of various Internet communities (via Twitter, forum, wiki, etc.), create and post videos on a special service (e.g. YouTube), etc.

Regarding the second question of the questionnaire "Give your name to the text", 52.7% of respondents formulated the title of the text according to its content and gave the following answers: information inequality in the world, opportunities for social networks to study and work, setting up antivirus programs, cookies files, to protect personal information. There was not found the respondents who would hesitate to answer. However, 47.3% of respondents could not create and post videos on a special service (e.g., YouTube), create multiple user accounts for a particular computer, change their passwords, settings for accessing their information on social networks for different user groups etc.

47.3% of respondents coped with the task and in accordance with the content of the text formulated queries on the third question "Please formulate a query for the search engine for the missing, in your opinion, information in the text", for example the following: methods of combating information inequality, with information crime in Ukraine, information terrorism in the world, problems of access to information in Ukraine, digital gap and measures to eliminate it. From the given answers to this question of the questionnaire it should be noted that future specialists of socionomic professions are interested only in the question concerning information processes in the world, and Ukraine respectively. 11.6% of the respondents hesitated with the answer. At the same time, 41.1% of respondents formulated queries that do not relate to the content of the text. Accordingly, it can be assumed that the respondents either did not understand the instructions or did not understand the content of the proposed text, for instance: earnings on the Internet, globalization (not understanding the term – author's note) in Ukraine, whether these problems can be solved (what problems – author's note) and in what ways.

To the fourth question "Did you notice information that is not related to the topic of the text? If so, indicate the number of the sentence or paragraph", only 26.1% of respondents were able to find and indicate this fragment, 8.2% found it difficult to answer. At the same time, 65.7% of respondents could not find and accordingly indicated that they did not have such information, or pointed to an incorrect fragment of the text.

According to the generalization of the obtained results, the levels of development of the operational component of digital competence are determined (table 4).

Table 4: Distribution of researched future specialists of socionomic professions by levels of development of operational component of digital competence.

Levels of operating room development component of digital competence	Number of respondents, in%
Low	37.6
Average	52.6
High	9.8

As it follows from the data given in table 4, a small number of respondents have (9.8%) a high level of development of the operational component of digital competence

Hence, 52.6% and 37.6% of the respondents characterise, respectively, the average and low levels of development of the operational component of digital competence of future specialists in socionomic professions.

Thus, we can conclude that future specialists of socionomic professions are insufficiently prepared to develop "normal" information literacy and skills of semantic analysis of information as the basis of their digital competence in professional activities and responsibility for its use and dissemination, which in our opinion may be explained by gaps in the modern education system.

6 RESPONSIBILITY DEVELOPMENT PROGRAM AS A COMPONENT OF DIGITAL COMPETENCE OF FUTURE SPECIALISTS OF SOCIONOMIC PROFESSIONS AND RESULTS OF ITS APPROBATION

In our opinion, the development of digital competence and responsibility for the use of information dissemination in professional activities may be facilitated by the creation of an educational environment taking into account this need in the modern education system, alongside the organization of specially organized training. The patterns and mechanisms of development of information competence and responsibility should be taken into account, defining the principles, content, methods and forms, as well as the expected result. In addition, the development of information competence requires the creation of special psychological conditions as a mechanism that takes into account and implements favourable psychological factors (figure 1).

Favourable psychological conditions for the development of responsibility and digital competence of future specialists in socionomic professions include:

- organization of special socio-psychological training with emotional comfort and creative freedom, which will expand awareness of the essence of the responsibility and digital competence, ways of their development and role in future professional activities;
- orientation of future specialists on the value attitude to digital competence and its development, alongside the responsibility for its use and dissemination;
- formation of beliefs about one's value, ability to use information resources responsibly;
- the desire for personal self-development, self-regulation of emotional state, reflexive and prognostic abilities;
- formation of motivation for search activities, focus on success in educational and professional activities;
- development of the ability to be reflective on the way to achieving information competence, understanding the possibilities and conditions of its development in today's challenging conditions;
- development of abilities to use information resources in educational and professional activities, be successful and independent in solving complex professional problems in the future professional activity area, purposeful and able to responsibly manage the information environment;
- the need for constant personal and professional growth, expanding the information, business and psychological field, enabling the emergence and development of complex subjective relationships, exchange of experience, knowledge, skills and abilities based on moral values of society and personality of the future specialist, according to his focus on self-realization (Onoprienko-Kapustina, 2021, p. 124);
- introduction of innovative forms and methods in the process of professional training of future specialists, modelling future professional activities in higher education, quality and effective cooperation with practice bases to reach the top of professional maturity as the main condition for self-realization, as an opportunity to realize their social potential (Sotska, 2017, p. 388).

The creation of such conditions in higher education institutions is carried out by implementing the process of training a psychological program for the development of responsibility and digital competence of future specialists in socionomic professions, built on the following basic principles:

- "taking into account the needs of the individual in self-organization, self-determination and self-development; recognition of the priority of individuality and self-worth of the individual" (Zeer, 2005, p. 269);
- reflexivity (self-analysis of their behaviour and activities, as well as the behaviour of other participants in the program, providing mandatory feedback during the completion of all stages of training and practical classes);
- purposefulness (observance of the purpose, awareness and perception by future specialists of the development of their information competence in the process of professional training);
- adherence to uniform ethical principles in the use of information resources (Dustin, 2007) because every person has the right to freedom, happiness, development and expression of all abilities, and good is a criterion for assessing social phenomena, equality, justice, humanity as a desirable norm in society;
- efficiency, predictability and control (Lyons and Lovelock, 2004, p. 37-54);
- creativity and creative position (openness to new experiences, generating innovative ideas, modelling, designing ways to develop information competence, responsibly using the features of interpersonal interaction, which approves and supports any initiative, expression of any position (Balakhtar et al., 2022), experimenting with personal resources, finding non-standard solutions;
- the principle of partnership (creating an atmosphere of security, trust, openness, which allows future professionals to experiment with their behaviour without being ashamed of mistakes);
- activity and autonomy (aimed at achieving success in educational and professional activities, self-realization and self-realization, developing

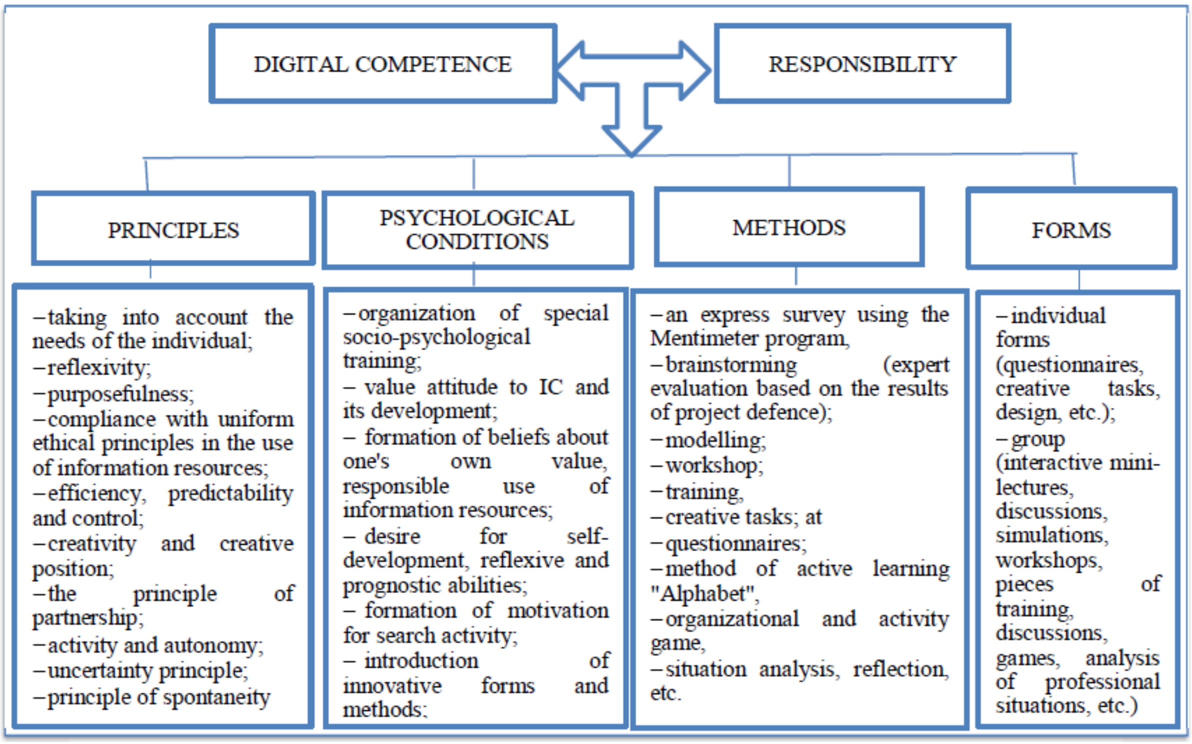

Figure 1: The program of development of responsibility as an indicator of digital competence of future specialists of socionomic professions.

the ability to autonomy by performing specially designed exercises, playing situations that allow all members of the group to actively participate in them);

- the principle of uncertainty (set in the instructions, where in most cases there are no clear rules for the task, future professionals are free to find solutions);
- the principle of spontaneity (spontaneity makes it possible to change the usual behavioural stereotypes with further activation of the individual creative potential).

Among the forms and methods of development of responsibility and digital competence of future specialists of socionomic professions, it is worth noting: express survey using the Mentimeter program, brainstorming (expert evaluation based on the results of project defence); individual and group exercises; modelling; practicum; training, creative tasks; questionnaires; method of active learning “Alphabet”, organizational and activity game, situation analysis, reflection etc.

Forms of development of responsibility and digital competence of future specialists of socionomic professions: individual (questionnaires, creative tasks, design etc.) and group (interactive mini-lectures, discussions, modelling, discussions, games, analysis of professional situations etc.) as in general halls on the ZOOM platform and in session halls, as well as work on the online board (Google Jamboard, Padlet etc.).

Methods and forms of work were selected in such a way as to ensure the development of responsibility and digital competence of future specialists in socionomic professions based on their individual qualities and abilities. They will develop mental strategies, search activities and motivation to carry out information retrieval activities as close as possible to the professional, alongside providing an opportunity to develop practical knowledge, skills and abilities to work with information in conditions of uncertainty.

This approach, in our opinion, will help ensure the development of digital competence of future socionomic professionals and responsibility for the use and dissemination of information in professional activities due to the implementation of certain psychological conditions, principles, forms and methods and prove its effectiveness by predetermined criteria. The specifics of this work combined theoretical and practical-reflective components that allowed gaining new knowledge, master new tools and the experience their use in future practice. In particular, informing future specialists about the work procedures was carried out at the ZOOM conference, alongside – being acquainted with the instructions for the use of digital services and ways to connect them.

The study of participants' expectations was carried out using an online board (Google Jamboard, Dashboard etc.), followed by a group discussion in ZOOM). Participants answer the following questions: "Why do I strive to develop information competence?"; "What is the importance for me of information for professional activities and personal life, in general, and the possibility of negative consequences during the process of finding and using information?"

Defining the rules of group work "Brainstorming" (group form of developing rules for the process of finding information as an opportunity to achieve a certain level of professional and personal development). Multimedia presentation: "What will our training be like? (definition of the purpose and tasks of training)".

Team building (5-7 people): grouping; announcement of tasks for presentation; immersing participants in the problem (micro discussion on the development of the ability to predict the consequences of the use of information, along with the willingness to take responsibility for it). Presentation of teamwork.

The theoretical aspect was an interactive lecture: "The essence of information and features of working with it: thinking and its styles, behavioural strategies, professional responsibility etc.", which allowed participants to be more active (argue on problematic issues, give interesting examples, draw conclusions etc.). For example, instructing and activating the knowledge of the group - participants were asked to express in one word "What does it mean to be responsible?" Clear instructions were provided to demonstrate the Mentimeter screen. The discussion took place after the exercise.

The practical-reflexive component included a workshop, training, the elements of which were: mini-presentations, diagnostic, analytical and psychogymnastic exercises, discussion, brainstorming (exercise "16 associations"), role play, project tasks, modelling, modelling, creative homework ("My responsibility: past, present and future", "What are the typical mistakes, problems that arise in the process of finding and using the information in professional activities?"), the method of active learning "Alphabet", organizational and activity game, situation analysis, reflection and others. The work was carried out in groups in the session halls on the ZOOM platform using an online board (Google Jamboard, Miro etc.). In particular, the diagnosis of responsibility, the search for opportunities and conditions for its development. To do this, future specialists were informed about the tasks and conditions of the activity: 1) to identify the main contradictions and problems in the development of responsibility; 2) to analyze the possibilities of developing responsibility; 3) to determine the conditions for the development of responsibility. After the announcement of the tasks, the participants were divided into groups and the work was carried out in the session halls. The speakers of the teams presented the results of the work in the main hall (2 minutes for each team. Brainstorming in groups in session halls on the ZOOM platform using an online board (Google Jamboard, Miro etc.) involved the development of a program to empower and develop responsibilities as part of information competence.

Creative homework, such as "My responsibility: past, present and future", included an analysis of their life situations. Drawing up a summary table of factors which are conducive to the development of compliance and the following scheme: which you used in the past, use today and factors that could be used in the future.

In the process of program implementation, we paid considerable attention to future specialists' reflections on their actions, statements, actions, opinions, solving practical problems, analysis of the situations of educational and professional activities of future specialists in socionomic professions that require responsibility. After all, it is impossible to achieve success in professional activities without reflexivity as the most important regulatory component of personality, which allows him/her to consciously build his/her life. This encouraged us to use reflection, completing each exercise, action, session and training, in general.

Analysis of the results of the approbation of the program showed its effectiveness (table 5). In the experimental group, the implementation of the program of development of responsibility of future specialists was carried out following psychological conditions, principles, methods and forms of work that provided holistic and systematic work aimed at developing responsibility as part of information competence of the experimental group members.

In the control group, classes were conducted traditionally, according to the requirements of the educational-professional program and the curriculum of professional training of future specialists, with only two sections before and after the approbation of the program.

In both the experimental and control groups, sections were performed according to the same methods as at the ascertaining stage of the empirical study. Statistical processing of the results of approbation of the program "Development of responsibility as a component of digital competence of future professionals

Table 5: Distribution of respondents of experimental and control groups on the levels of responsibility development before and after the approbation of the program.

Levels of responsibility development	Groups, the number of respondents in %			
	Before the approbation (I stage)		After the approbation (II stage)	
	Control group	Experimental group	Control group	Experimental group
low	38.5	42.9	38.5	7.7*
average	53.8	53.6	50.0	65.4*
high	7.7	3.5	11.5	26.9*

*– differences are statistically significant at the level $p < 0.05$

of socionomic professions" was carried out using the SPSS version 23.0. Criterion χ^2 was used to compare the results between the experimental and control groups and the G-criterion of signs to assess the statistical significance of differences in the results separately in the experimental and control groups.

Table5 shows that before the approbation (I stage) there were no significant differences between the experimental and control groups in the levels of responsibility development. After the approbation (second stage) in the experimental group, in contrast to the control. The expressed positive dynamics of levels of development of responsibility are fixed. Thus, the number of studied future specialists with a low level of responsibility decreased from 42.9% to 7.7%, and with a high level, on the contrary, increased from 3.5% to 26.9%.

It is equally important that positive trends in the development of the cognitive component of digital competence were identified. In particular, the positive, statistically significant dynamics of the levels of the cognitive component of digital competence of the participants of the experimental group after the approbation were noted (table 6).

Table 6 dwells on the statistically significant differences in the levels of the cognitive component between the results of the first and second stages in the experimental group participants.

In particular, it is an increase in the number of respondents with a high level of development of this component from 17.8% to 50.0%, and a decrease with a low level from 28.6% to 3.6% ($p < 0.05$). Instead, in the control group according to the results of the first and second sections, small differences were found, which, in general, do not affect the levels of the cognitive component of the digital competence of the experimental group participants. Thus, the number of studied future specialists with a low level of self-efficacy decreased from 23.1% to 19.20%, and with a high level, on the contrary, increased from 19.2% to 26.9%. At the same time, the identified differences are not statically significant.

Such a positive dynamics of the levels of the cognitive component was due to the growth of awareness of the essence of the component of digital competence, knowledge of late mobile applications and the possibilities of their use in socionomic professions, increasing opportunities to use the Internet.

There was also an increase in the number of participants in the experimental group with a high level of the operational component of digital competence (table 7).

Table 7 shows among the participants of the experimental group between the results of the first and second sections recorded statistically significant differences in the levels of the operational component of digital competence: a reduction of low from 50.0% to 15.4%, while an increasing high development from 7.7% to 23.1% ($p < 0.05$).

In the control group, the results of the first and second sections showed minor differences: the number of low-level specialists decreased from 48.0% to 40.0% (although the differences are not statically significant) and generally do not affect the levels of operational competence of digital competence.

Thus, the comparative analysis of the results of approbation of the program allowed making conclusions about positive changes in the growth of information literacy and skills of semantic analysis of information as the basis of their digital competence in professional activities and responsibility for its use and dissemination.

7 CONCLUSIONS

Responsibility is an important indicator of the digital competence of future specialists in socionomic professions, which determines their conscious and responsible activities in the context of obtaining and disseminating information in the digital space, contributes to their own psychological safety and psychological safety of other members of digital community.

The results of the empirical study revealed an insufficient level of both responsibility and cognitive-operational components of digital competence for a

Table 6: Distribution of respondents of experimental and control groups by levels of the cognitive component of digital competence before and after the approbation of the program.

Levels of the cognitive component of digital competence	Groups, the number of respondents in %			
	Before the approbation (I stage)		After the approbation (II stage)	
	Control group	Experimental group	Control group	Experimental group
low	23.1	28.6	19.2	3.6*
awerage	57.7	53.6	53.8	46.4*
high	19.2	17.8	26.9	50.0*

*– differences are statistically significant at the level $p < 0.05$

Table 7: Distribution of experimental and control groups by levels of operational component of digital competence before and after the approbation of the program.

Levels of the operational component of digital competence	Groups, the number of respondents in %			
	Before the approbation (I stage)		After the approbation (II stage)	
	Control group	Experimental group	Control group	Experimental group
low	48.0	50.0	40.0	15.4*
awerage	48.0	42.3	56.0	61.5*
high	4.0	7.7	4.0	23.1*

*– differences are statistically significant at the level $p < 0.05$

significant number of future specialists in socionomic professions.

Furthermore, statistically significant differences in the manifestations of responsibility of future specialists depending on gender were found: female respondents were slightly more responsible for the consequences of information dissemination than male ($p < 0.05$). Such differences appear to be gender in nature, as women live in a more controlled and rigidly structured world than men. Therefore, women are more focused on complying with regulations on their activities, in this case, educational and professional.

There were no statistically significant differences in both responsibility and digital competence, depending on the profession of the representative of the socionomic profession.

Men are more likely to be characterised with concepts of independence and initiative, and reinforced with the norms of "anti-emotionality" (Burn, 1995) which determines their greater autonomy and self-control.

The expediency of promoting the development of responsibility of future specialists of socionomic professions as a component of their digital competence, which can be provided in specially organized psychological training, is stated.

The program of responsibility development as an indicator of digital competence of future specialists of socionomic professions, which includes psychological conditions (organization of special socio-psychological training; values of IC and its development; formation of beliefs about self-worth, responsible use of information resources; desire for self-development, reflective and prognostic abilities; gaining motivation for search activities, etc.), principles (taking into account the needs of the individual; reflexivity; purposefulness; adherence to uniform ethical principles in the use of information resources; efficiency, predictability and control; creativity and creative position; principle of partnership; principle uncertainties, etc.), methods (express survey using the Mentimeter program, brainstorming (expert evaluation of project defence results); modelling; workshop; training, creative tasks; questionnaires; method active learning "Alphabet", organizational and activity game, situation analysis, reflection, etc.) and forms (individual forms (questionnaires, creative tasks, design, etc.) and group (interactive mini-lectures, discussions, modelling, workshops, trainings, discussions, game, analysis of professional situations, etc.) work.

The results of approbation of the program testify to its effectiveness: after the conduction of the formative experiment, the participants of the experimental group, in contrast to the control, recorded statistically significant positive dynamics of responsibility as an indicator of digital competence. Accordingly, it is possible to use the responsibility development program as an indicator of digital competence in the process of their professional training and refresher courses.

The study does not cover all aspects of the relationship between responsibility and digital competence of future specialists in socionomic professions and the peculiarities of their development. In our opinion, an in-depth study of the factors of development of specialists' responsibility, as well as study of the psychological readiness of teachers of higher education institutions to responsibility and digital competence of future specialists of socionomic professions in the process of training in the mental network, work in virtual environment and practical psychologists education – to the psychological support of such training.

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The Methodology for Using a Business Simulator with Elements of Machine Learning to Develop Personal Finance Management Skills

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Abstract: Any person, not even a financier, should be knowledgeable in the field of personal finance management. As a result of the survey, it was concluded that schoolchildren and students should be interested in the study of personal finance, even within other disciplines in the form of separate sections. Successful personal experience and knowledge of the teacher in the field of personal finance is an important component of the effectiveness of the formation of competence of pupils, students, and adults in the field of personal finance. Business simulators come in handy here. That is why the authors developed a business simulator for the development of personal finance management skills, which was developed in the form of a web service. The article presents a methodology for using the use of a business simulator with elements of machine learning to develop personal finance management skills, its main components are given: content, purpose, forms, methods and means. The main features of this simulator, which are presented in different sections of the simulator, are considered. It is shown what skills of personal finance management are developed using this business simulator. Since this simulator was designed to develop personal finance management skills, an attempt was made to apply machine-learning elements to make this business simulator work even better. The proposed simulator can be used in the future to teach the elements of personal finance management to people who are not sufficiently knowledgeable in the field of such finance. Moreover, the web application can be useful even for school-age children, so the simulator can complement the educational process within the economic courses not only in higher education institutions but also in secondary education institutions of Ukraine.

1 INTRODUCTION

Almost every day, each person spends money on housekeeping, utility bills, payment for services and purchases. It also includes debts on loans, or just borrowed money from friends. Personal finance includes all the funds available to us and the ability to manage them, so the topic of personal finance is relevant and worthy of attention for everyone who cares about their financial well-being. That is why any person, not even a financier, should be knowledgeable in the field of personal finance management. As a result, a survey was conducted to find out certain aspects of the financial literacy of first-year students as individuals who have their financial resources. In 2019, 167 respondents took part in the survey, in 2020 – 214 respondents (first-year students of the Faculty of Information and Computer Technologies of the Zhytomyr Polytechnic State University).

As a result, it was found that in 2019, 70.7% of respondents consider themselves financially literate, ready to consciously and effectively manage their own and family financial resources; in 2020 – 74.3%. At the same time, 29.3% of respondents in 2019 do not consider themselves sufficiently aware in this regard; in 2020 – 25.7% (see figure 1, a).

It was also found that in 2019 45.5% of respon-

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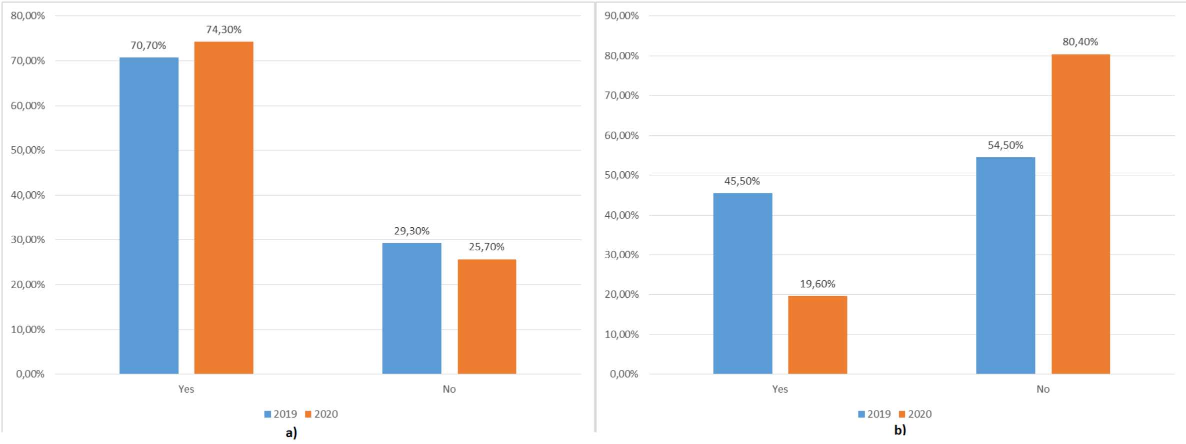


Figure 1: Financial literacy education results.

dents studied the basics of financial literacy in at least one form, in 2020 – this figure dropped to 19.6%, in 2019 54.5% – did not study in any form, in 2020 – this figure is 80.4% (see figure 1, b).

In addition, by the results of the survey, it was found that in 2019 14.4% of respondents at the highest level assess their level of readiness for conscious and effective management of own and family financial resources, in 2020 – 10.7%, 38.3% of respondents in 2019 – indicated the level of readiness "good" and "satisfactory", while in 2020 46.7% indicated the level of readiness "good", 35% - "satisfactory". All others either rated the level at the lowest level or an unsatisfactory level.

As a result of the survey, it was concluded that schoolchildren and students should be interested in the study of personal finance, even within other disciplines in the form of separate sections. Successful personal experience and knowledge of the teacher in the field of personal finance is an important component of the effectiveness of the formation of competence of pupils, students, and adults in the field of personal finance. Business simulators come in handy here.

1.1 Theoretical Background

The need for personal finance competency development was analyzed in the research internationally. The challenge is relevant for both developed and developing countries. Influence of the financial literacy on the well-being of people worldwide and the need to recognize it as the fundamental right and universal need was discussed by Lusardi (Lusardi, 2019). Another research by Lusardi et al. (Lusardi et al., 2017) shows that in the USA 30–40% of retirement wealth inequality is associated with the level of financial literacy alone. As for the initial personal finance management, knowledge, and skills formation, the study concludes significant influence of the high school financial literacy courses on the lower default rates and better credit scores (Urban et al., 2020).

Using business simulations in education is a shared practice now. Simulations are being used in practical training, such as flight or combat simulations as well as in economic, managerial, and financial areas. Researchers study the pedagogical significance of this type of technology-enhanced educational method. Hernández-Lara et al. (Hernández-Lara et al., 2019) concluded the positive impact of business simulations on the generic competencies. Farashahi and Tajeddin (Farashahi and Tajeddin, 2018) conclude the effectiveness of business simulations in their comparative study. The study of business simulations in economic or finance evolves with the evolution of technologies available to develop immersive, attractive, and highly functional experiences. The range of use-cases differs from elementary schools to life-long learning establishments. Korgin (Korgin, 2015) provides evidence of the effectiveness of the simulation games for kids with basic arithmetical operations literacy. Palan (Palan, 2015) studied the criterion and approaches to select business simulation software for asset market experiments to use in the higher education establishments.

The analysis provides evidence of the effectiveness of business simulation usage in education in general and the need to further development of business simulation for the economy and finance literacy development, assessment, and study of its behavioral aspects.

The *purpose of the article* is to describe the methodology for using the business simulator with elements of machine learning to develop personal finance management skills.

2 RESULTS

The analysis of the analogues (Antoniuk et al., 2019, 2020) revealed that most part of the simulation software is appropriate for a specific area of the finance in the countries with developed financial markets. Based on the conclusions above this work represents the experiment in developing more generalized simulator for the countries with less developed market of financial instruments.

That is why the authors developed a business simulator for the development of personal finance management skills (Antoniuk et al., 2022a,b), which was developed in the form of a web service (10, 2020).

The methodology for using a business simulator with elements of machine learning to develop personal finance management skills is presented in the next part of this work.

The methodology for using a business simulator with elements of machine learning to develop personal finance management skills, like any other methodology, includes the purpose and content of the application, forms, methods, and tools.

It is focused on the expected result – the improved personal finance management skills because of using a business simulator with elements of machine learning.

The purpose of using a business simulator with elements of machine learning is to develop personal finance management skills.

The content of using is the improvement of the process of teaching normative disciplines using a business simulator with elements of machine learning.

The proposed methodology includes the following methods for using a business simulator with elements of machine learning:

1. *Adaptive learning*. In the simulator, a process is created in a game form, which in the literature is called the examination cycle. At each stage of the simulator, the user is faced with a list of problems corresponding to the current level of competence. In the process of passing the simulation, the user is allowed to use new tools available in the field of personal finance management, which could not be effectively used at previous levels of the formation of the relevant competence. This approach requires the user to iteratively master new knowledge, skills, and abilities that are more complex from a theoretical and psychological point of view, and the ability to use them in situations close to real ones. In the process of passing the simulation and the corresponding stages of the formation of competence, the user gets the opportunity to work out tools and situations that were previously unfamiliar to him or are of additional interest to him, taking into account the stage of the life cycle, the field of activity or current problems and interests.
2. *Situational modeling*. The simulator proposed for use in this work is based on a realistic simulation of common and more specific situations in the process of managing personal or family finances. The initial stage is modeling the creation of a diversified currency and forms of storing the user's financial basket. In the future, to move to more complex personal finance management tools, credit and deposit operations with a different set of time parameters, payment schedules, and forms of provision are added to the simulated situations. The realism of the simulation is ensured by the presence of probabilistic events with a positive or negative impact of different monetary values on the user's personal finances. Non-financial investment transactions are the next step in familiarizing and developing the user's competence in the field of personal finance management.

Here are the main forms of conducting training sessions using a business simulator with elements of machine learning within the framework of this methodology:

- Introductory classes for teachers and facilitators on the functionality, modes, and features of using the simulator, the analytical capabilities of the platform, and the means of scientific research on the effectiveness and adaptability of the process of developing user competence;
- autonomous and group independent work with the simulator, aimed both at independent in-depth or a convenient pace through the training and game plot of the simulator and at the joint learning activities of user groups and facilitators of such classes either with elements of the competition or without such elements;
- an in-depth analysis of the situations of the simulator can take place in face-to-face or remote format with individual students or groups. This form of interaction is aimed at additional elaboration of situations, behavioral and psychological aspects or financial instruments, the work with which causes difficulties, misunderstanding, or attracting additional interest of users.

The tools for developing personal finance management skills provided in the proposed methodology using a business simulator with machine learning elements include computers, smartphones, tablets with Internet access, a business simulator with machine learning elements; teaching materials.

The result of the proposed methodology: the skills of managing personal money are formed at a high level; acquired skills to successfully apply a business simulator with elements of machine learning to perform practical work.

Within the framework of this methodology, we offer different forms and methods of using a business simulator with machine learning elements to develop personal finance management skills: organization and development of a business simulator with machine learning elements to develop personal finance management skills; sessions of using a business simulator with elements of machine learning to simulate socio-economic situations that correspond to the topic of the lesson; organization of thematic economic training using a business simulator with elements of machine learning; visualization of economic and behavioral concepts; using a business simulator with elements of machine learning as a means of targeted in-depth problem-based learning; using a business simulator with elements of machine learning as a means of organizing an assessment.

At the same time, the organization and development process of a business simulator with elements of machine learning for the development of personal finance management skills ensures the use of knowledge needed to complete a project in the field of professional activity of students of IT specialties as an incentive for obtaining new knowledge in the field of economics. In the process of developing a business simulator with elements of machine learning, the acquisition of skills and abilities is ensured, as well as the formation of a personal attitude to the problematic issues of the economic industry.

Sessions of using a business simulator with elements of machine learning to simulate socio-economic situations that correspond to the subject of the lesson material provide students with interest, provide the necessary theoretical information in the field of the lesson, organize the possibility of obtaining skills in this topic, and initiate the formation of students' personal attitude to the socio-economic situation, considered by focusing on a specific economic law, principle or concept, which reduces the complexity of understanding.

The organization of thematic economic training using a business simulator with elements of machine learning contributes to motivation and increased attention to the knowledge of the lesson material. Obtaining the skills and abilities of rational behavior in the problematic area of training is an integral part of the training, providing one's own experience, close to practice and the formation of a stable personal attitude, provoked by the experience of mastering problematic material and the active generation of relevant conclusions.

Visualization of economic and behavioral concepts allows students to be motivated to perceive the lesson material. When using a business simulator with elements of machine learning with dynamic parameters or dynamic content, provides students with the skills and abilities to manage an object of a socio-economic nature. Visualization and selection of topics relevant to the audience contribute to the formation of one's own attitude towards the object of knowledge. The use of a business simulator with elements of machine learning as a means of targeted in-depth problem-based learning basically contains the need for independent work on organizing such a lesson. This approach allows for the development of personal finance management skills, initiating the independent study of the lesson material. Supplementing this method with an assessment in the form of an essay, including questions on the relevance of the subject of the simulation conducted for the student who conducts it, and the group as a whole, contributes to the formation of a personal attitude to the problems of the studied material.

A separate object of study in the process of using such a simulator can be the results of comparing the optimality of decisions made by a person and a model using machine learning algorithms. Such a comparison complements the learning process with visual data on the causes and consequences of applying various approaches to managing personal finances.

Consider the main features of this simulator, which are presented in different sections of the simulator (figure 2):

1. Current account management options.
2. Savings management options.
3. Deposit management options.
4. Credit management options.
5. Non-financial investment management options.
6. Information on changes in current accounts that have occurred in the last week.
7. Analytical information on the dynamics of changes in current account funds, savings, and investments.
8. Information on current exchange rates.
9. List of recent transactions that have been made on current accounts.

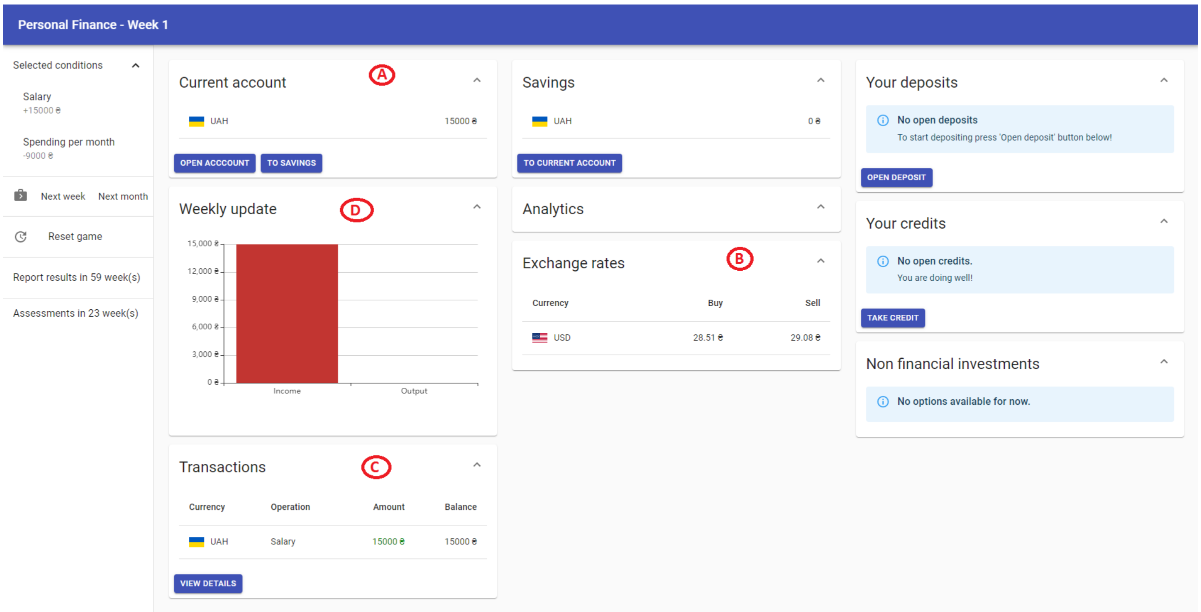


Figure 2: Business simulator.

Consider in more detail the section with current account management options (figure 2, A). The "Current account" section contains a list of current accounts in the form: code and available amount.

The user has the opportunity to open a new account. To do this, click on the "Open account" button, then a window will appear where you need to select the currency in which you want to open a new account (figure 3). Each user action in the simulator (for example, opening a new account) is accompanied by a message that appears in the lower right corner of the page.

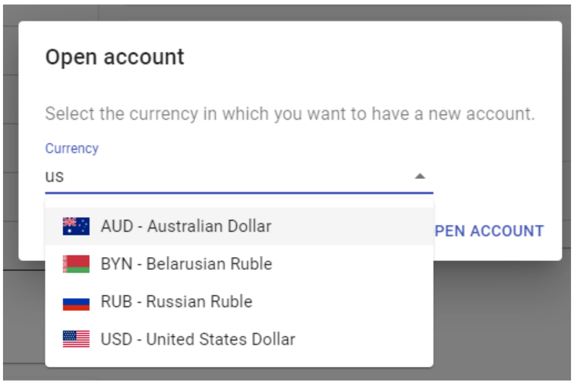


Figure 3: Example of opening a new account.

After opening a new account, the "Exchange" option will be available in the "Current account" section, which allows you to exchange currencies at the rate that can be viewed in another section "Exchange rates" (figure 2, B).

To exchange currencies, the user can enter the amount he wants to sell and the amount in the currency to be purchased will be filled in automatically. The user can also enter the amount to purchase and the amount required for the purchase will be filled in automatically. The user can also change currencies and the amounts will be automatically transferred.

In the process of performing all actions by the user, a real-time section is available with information about changes in current accounts that have occurred in the last week (figure 2, D). The user can choose the currency of the account for which he wants to see the relevant data (figure 4).

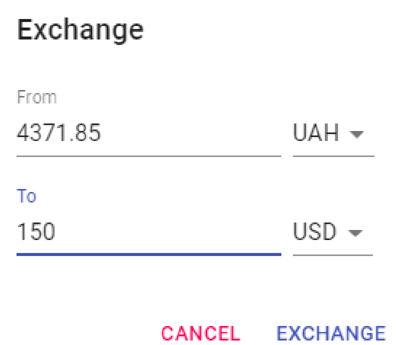


Figure 4: Example of currency exchange.

In addition, in the simulator, there is a section with analytical data on the dynamics of changes in current account funds, savings, and investments since the beginning of the simulation (figure 5). The user can select the currency of the account for which he wants to see the information. By default, to visualize the dynamics of funds in all accounts, the option “Accounts total amount in USD” is selected, which displays the total amount of funds in all accounts converted into USD.

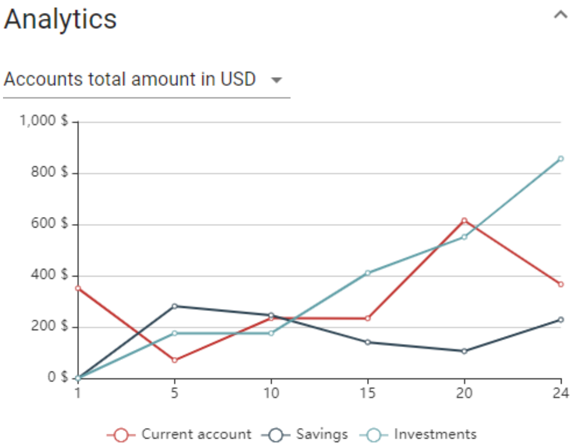
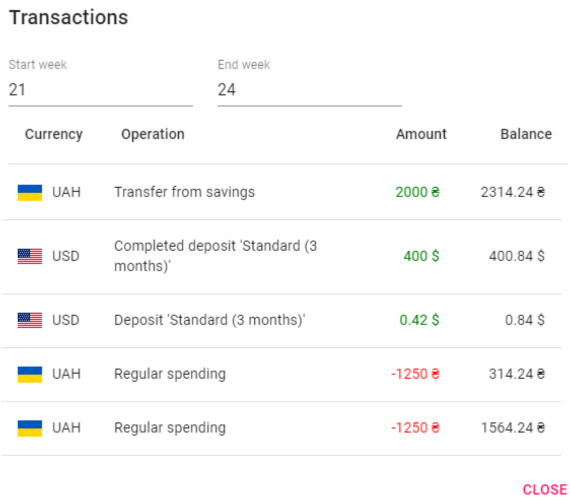


Figure 5: Analytical information on the dynamics of changes in current account funds, savings, and investments.

The user also can view transaction information on all current accounts (figure 2, C). The corresponding section contains a list of the last 5 transactions. In this case, the user can view all transactions or filter them by specific weeks in the details window (figure 6).


Transactions

Start week: 21   End week: 24

Currency	Operation	Amount	Balance
UAH	Transfer from savings	2000 ₴	2314.24 ₴
USD	Completed deposit 'Standard (3 months)'	400 $	400.84 $
USD	Deposit 'Standard (3 months)'	0.42 $	0.84 $
UAH	Regular spending	-1250 ₴	314.24 ₴
UAH	Regular spending	-1250 ₴	1564.24 ₴

CLOSE

Figure 6: List of transactions with the filter by weeks.

At the beginning of the 4th week of the simulation, a window with a test question appears, in which the participant is asked what the amount is enough to save for savings from a monthly salary per month. This question is part of the assessment, and the user is obliged to answer it.

To sometimes distract the user from financial instruments and bring more of the reality into the simulation process, random events were added to the system, including various diseases, repairs, the birth of a child, and so on. Most random events last for some time and additional costs for the entire period of validity. Some events are constant, so costs are made every week, such as the birth of a child. You can't cancel any random event, you can just accept it and close the window (figure 7).

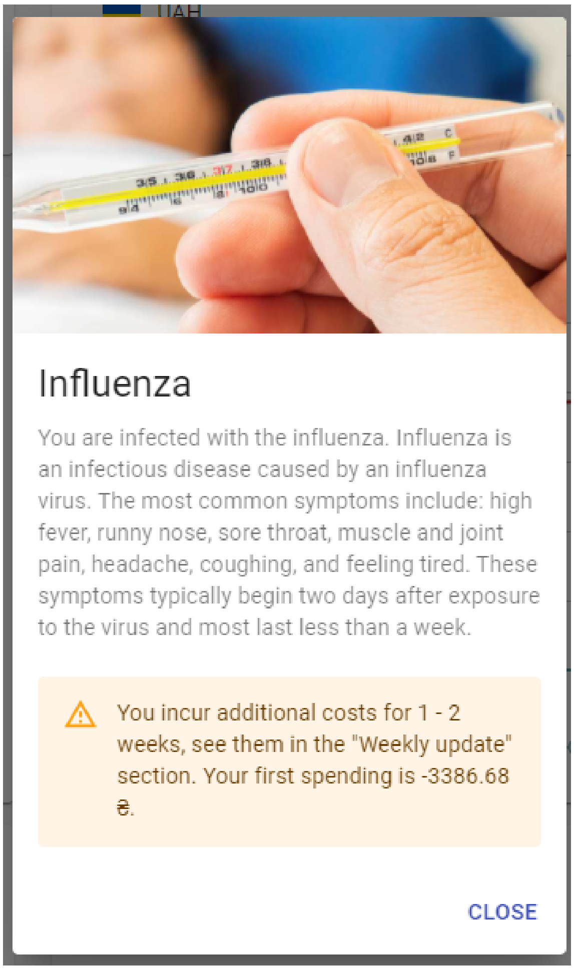


Figure 7: An example of a random event.

Upon reaching the 60th week of the simulation, the user will be shown a page where the participant can view analytical data on the dynamics of changes in funds on all current accounts, savings, and investments since the beginning of the simulation (figure 8). Funds on all accounts, savings, and investments are converted into USD and shown in one chart. On this page, the user can compare their results with the results of other participants in their country, as well as from other countries, in addition, they can share their thoughts or ideas about the simulator by filling in the field at the bottom of the page.

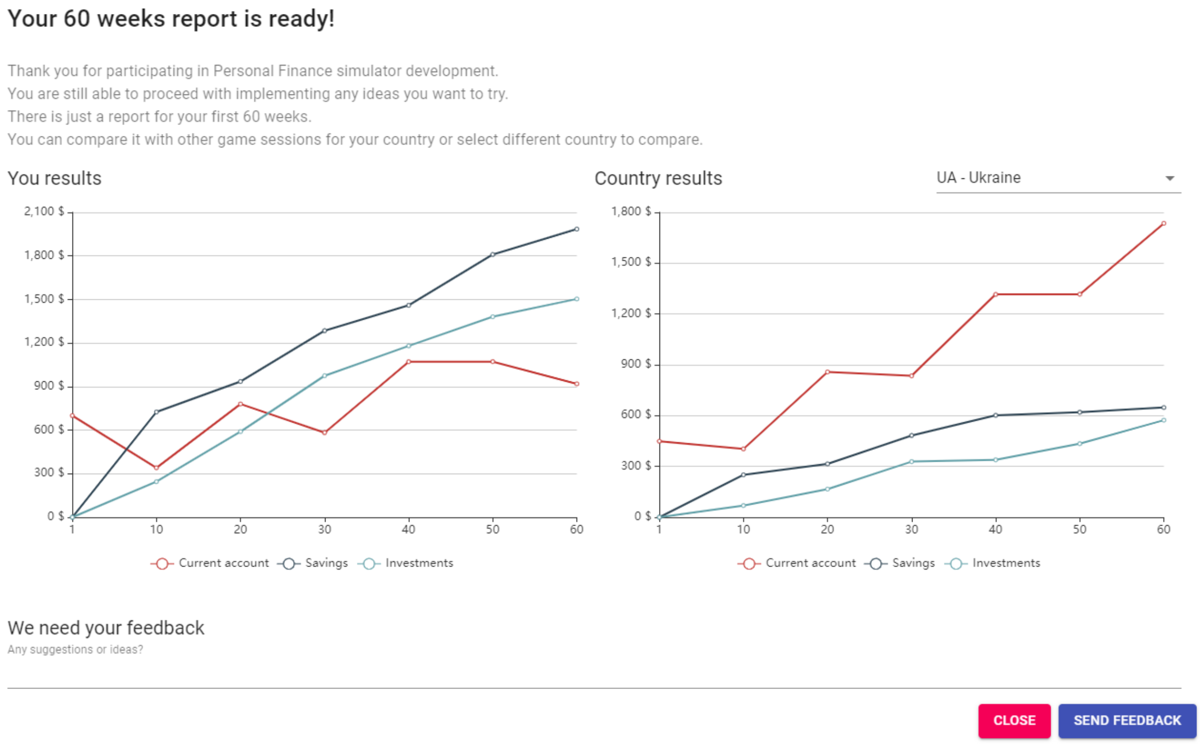


Figure 8: Example of simulation results.

The use of the Simulator facilitates forming of the following knowledge, skills, and competencies as well as the personal attitude towards:

- Using the diversified list of currencies.
- Forming widely-acknowledged standard of emergency savings and assessing readiness for longer-term investment.
- Using basic saving and investment instruments available in a wide range of countries such as deposits (deposit certificates), real estate, and business investments. Experiencing different types of instruments and understanding their specific.
- Debt-management and forming personal behavioral attitude to using debt as constructive investment leverage.

Since this simulator was designed to develop personal finance management skills, an attempt was made to apply machine-learning elements to make this business simulator work even better. This requires the creation of a system that could determine for the user an effective strategy of action in the simulator because the amount of real data of simulation participants is extremely small for analysis and identification of hidden dependencies using cluster analysis. This task is suitable for those that are solved by the latest approach in machine learning, namely reinforcement training.

Reinforcement learning (RL) is a type of machine learning in which the agent directly examines environmental data, receives rewards, and sets policies for optimal action. The goal of RL is to find the optimal policy that maximizes the expected amount of future rewards (Sutton and Barto, 2015).

Reinforcement learning focuses primarily on how to obtain the optimal strategy (Sutton and Barto, 2015) (figure 9). Ideally, the system should determine what will be financially optimal, as well as understand what is inherent in man, given its characteristics. For example, if a person has never used investment instruments, it is not worth building a strategy for him with too aggressive investment behavior, because it is unlikely that a person will follow it.

Reinforcement learning includes an agent, a set of states S, and a set of actions by states A. By acting $a \in A$, the agent moves from state to state. Acting in a certain state provides the agent with a reward. The agent's goal is to maximize his overall (future) reward. He does this by adding the maximum reward that can be achieved from future states to the reward for reaching his current state, thus influencing the current action with a potential future reward. This potential reward is the sum of the rewards of all subsequent steps, starting from the current state.

Formally, reinforcement learning is modeled as a Markov decision-making process (MDP). MDP pro-

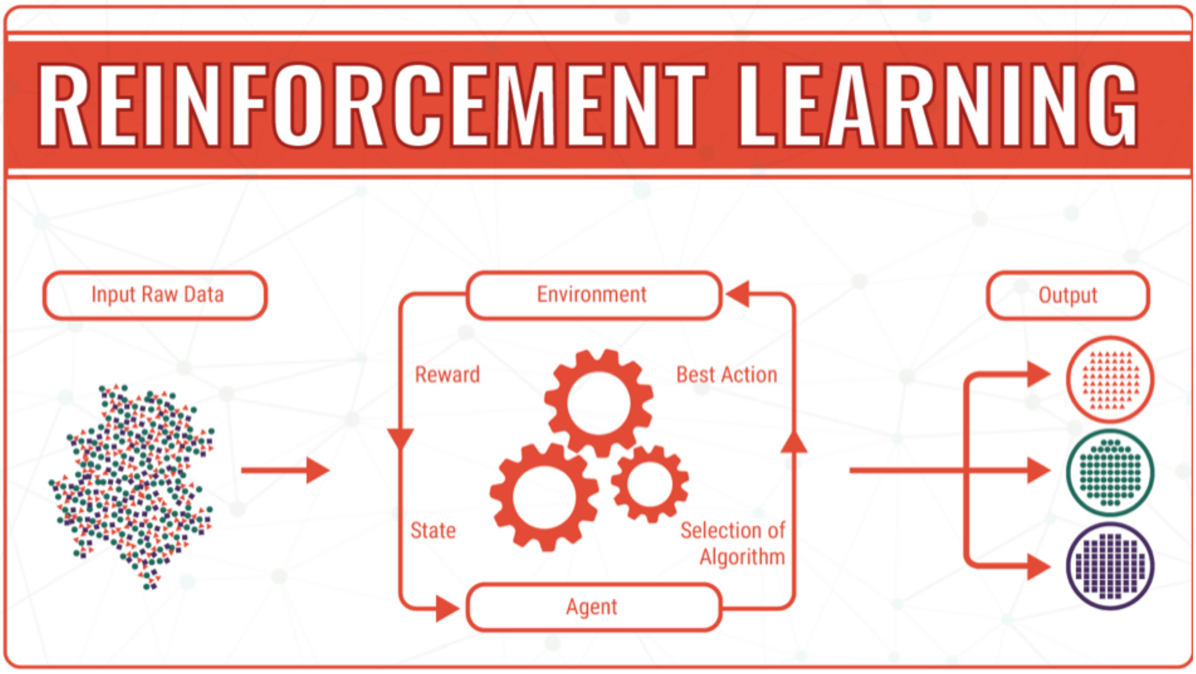


Figure 9: The principle of operation of the model of training with reinforcement (Sutton and Barto, 2015).

vides a mathematical basis for modeling decision-making in situations where the results are partly random and partly controlled by the decision-maker (Puterman, 2008).

One of the algorithms of reinforcement training is Q-learning. The purpose of Q-learning is to learn a strategy that gives the agent information about which step is best to perform in a particular state S.

The algorithm contains the following elements:

- r_t the reward received in the transition from state s_t to state s_{t+1};
- α – the pace of learning, which determines the extent to which new information will override old information;
- γ – depreciation ratio, which gives the effect of valuing rewards received earlier, higher than those received later (figure 10).

Before training, Q is initialized with an arbitrary fixed value (selected by the programmer), for example, 0. Then, at each point in time t, the agent selects an action a_t, receives a reward r_t, moves to a new state s_{t+1} (which may depend on both the previous state s_t and the selected action), and table Q is specified. The core of the algorithm is the Bellman equation as a simple update of values by iteration, using the weighted average old value and new information (Watkins and Dayan, 1992).

As a result, the open-source library SharpRL was chosen (Jansson, 2015). This library provides basic functionality for developing a learning environment with reinforcement based on the Q-learning algorithm. The program for defining personal financial strategies is a console application. Running this program involves setting certain parameters, including:

- number of simulation passes in training mode;
- the number of simulations in the mode of compliance with the model policy after training;
- duration of the simulation in weeks;
- monthly income and expenses of the user in a certain currency, which will be determined as the main currency of this user.

At the end of the training process, the screen will display the maximum reward that was achieved during the program; data on the user in the last week, which include: funds in current accounts, amounts invested in deposits and savings of the user; the best way that was found during the operation of the system. Each step of the path is an action that is recommended for the user to perform in a particular week. For more information, user data is displayed next to each step after performing the specified operation.

To have more opportunities to analyze the results, the program saves them in a CSV file, which can be used to compare the data with data from other launches of the program.

The generated file has only two columns: the first – indicates the week of the simulation, the second – the reward received by the user this week.

$$Q^{new}(s_t,a_t) \leftarrow \underbrace{Q(s_t,a_t)}_{\text{old value}} + \underbrace{\alpha}_{\text{learning rate}} \cdot \overbrace{\bigg(\underbrace{\underbrace{r_t}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(s_{t+1},a)}_{\text{estimate of optimal future value}}}_{\text{new value (temporal difference target)}} - \underbrace{Q(s_t,a_t)}_{\text{old value}} \bigg)}^{\text{temporal difference}}$$

Figure 10: Q-learning algorithm.

As a result, the operation of the system with different initial parameters was analyzed and it was found that a small number of iterations is the cause of an untrained model, which results in unstable results. Experiments were conducted and it was hypothesized that the optimal ratio of initial parameters, namely: the number of simulation passes in the training mode and the number of simulation passes in the mode of adherence to the model policy after training, is close to 1000. It was found that best results. After attempts to increase these figures, the results remained within the statistical error. For example, figure 11 shows the result of increasing the number of training epochs to 2000, which, compared to the results of 1000 epochs, remained almost unchanged. As a result of the study, it was concluded that with the current set of possible actions in the system (for example, to open a deposit of 10% of profits, etc.), increasing the number of training epochs does not improve the result.

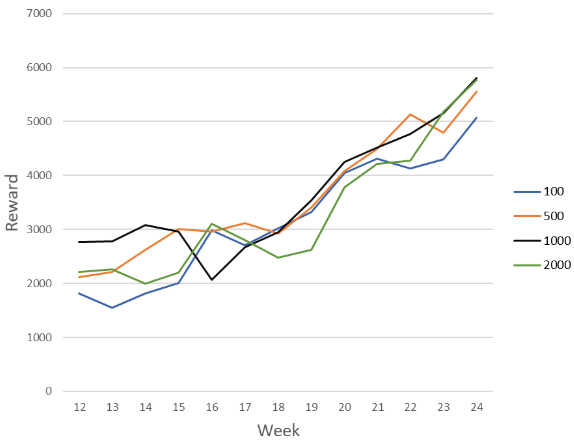


Figure 11: Results with different number of epochs of training in the mode of adherence to the trained model.

To test the trained model, a method of comparing the results of the system with the average values of the results of the passage of real users in the developed simulator was chosen. Thus, it was decided to take a certain period, for example, 54 weeks, and collect user data using the available functionality of the simulator. Based on the collected user data and the results of the trained model, several comparative graphs with different indicators of income and expenses were constructed.

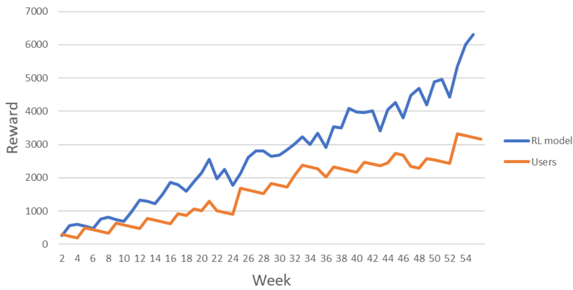


Figure 12: Comparison of model and user results with parameters of UAH 10,000. income and 6,000 UAH costs.

It was found that for 54 weeks, the system shows consistently better results than the average results of users who underwent the simulation. From the graph, you can see that the performance of the model is growing from week to week, which means that the system adapts to the environment.

After increasing the parameters of profit and expenses, the difference in the graphs becomes more significant in favor of the trained model. This is shown in figure 13, 14, 15.

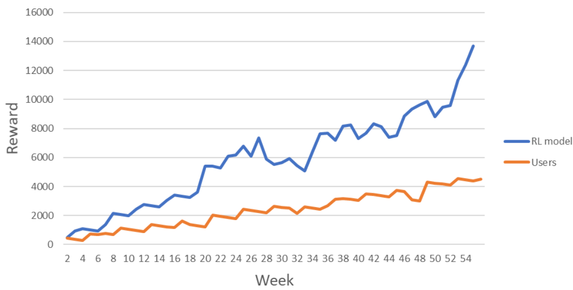


Figure 13: Comparison of model and user results with parameters of UAH 15,000 income and UAH 9,000 costs.

Jumps can be seen in the graph showing the results of the reinforcement learning model. They can be seen more often on charts where higher incomes and a large difference between income and expenses. This is the effect of specific rules that are described to train the model so that the virtual agent system follows the best path. For example, if an agent has opened a deposit for 3 months, after this period the deposit will be closed automatically and this closing

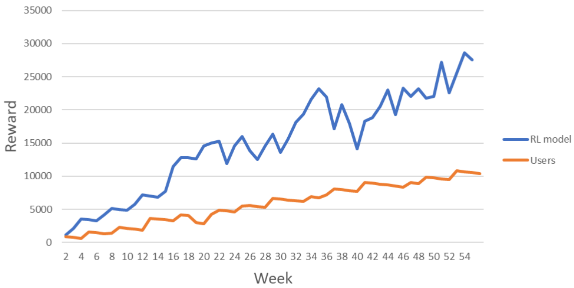


Figure 14: Comparison of the results of the model and users with the parameters of UAH 30,000 income and UAH 15,000 costs.

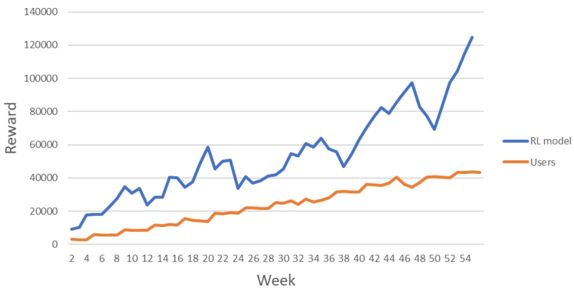


Figure 15: Comparison of the results of the model and users with the parameters of UAH 100,000 income and 30,000 UAH costs.

of the deposit will significantly affect the user's reward for this week. However, the system learns and "understands" where to invest or save. As a result, this leads to sharp increases in performance, as seen in the graphs. In the graphs responsible for the results of real users, such behavior is not observed, which indicates the ignorance of users with effective ways to manage personal finances within the developed simulator.

3 CONCLUSIONS

Currently, economic processes are a new topic for research into the possibilities of applying the full potential of machine learning. Scientists from around the world are just making the first attempts to reproduce such processes programmatically to use artificial intelligence to find solutions and answer various economic questions of humanity.

The proposed developed software package consists of two parts: a personal finance management simulator and a system for determining effective financial strategies, which uses reinforcement learning opportunities.

The proposed simulator can be used in the future to teach the elements of personal finance management to people who are not sufficiently knowledgeable in the field of such finance. Moreover, the web application can be useful even for school-age children, so the simulator can complement the educational process within the economic courses not only in higher education institutions but also in secondary education institutions of Ukraine.

The prospects for further research include testing the effectiveness of the proposed simulator of personal finance as a learning tool.

When constructing a methodology for using a business simulator with elements of machine learning to develop personal finance management skills, it is advisable to take into account: various types, scopes, methods of placement, and purposes of using business simulators. The use of a business simulator with elements of machine learning is expedient and contributes to an increase in the efficiency of the educational process, the formation of personal finance management skills, and also forms a steady cognitive interest in students in educational activities. The application of the author's methodology will improve and supplement the educational process in higher education by including a business simulator with elements of machine learning.

In addition, the prospects for further study include the selection of different simulators of this type, the possibility of using simulators of this type to develop the managerial and financial competencies of students in various specialties, as well as the development of an appropriate methodology and testing its effectiveness. In the future, we plan to develop guidelines for teachers on using a business simulator with elements of machine learning to develop personal finance management skills in the educational process of higher education.

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Test Quality Assessment and Adaptive Algorithm Based on IRT Models

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Keywords: Adaptive Algorithm, Rasch Model, Item Response Theory (IRT), Information Function of Test, Latent Variables, Birnbaum Model.

Abstract: In this paper the algorithm for adaptive testing of students' knowledge in distance learning and an assessment of its effectiveness in the educational process has been proposed. The results of the study are based on the achievements of modern testing theory IRT. The objective of the study was to build test items that allow adequately assessing the student's achievements and automating the assessment process using an adaptive algorithm. To achieve this goal, mathematical models of modern testing theory IRT were used, namely, the Rasch model, 2-PL and 3-PL Birnbaum models. The important outcomes of this work are a thorough analysis of the developed test tasks, identification of their shortcomings and automation of the process of assessing students' knowledge using an adaptive algorithm based on the methods of modern testing theory IRT. The paper provides an overview of the results of the application of modern test theory, a description and block diagram of the proposed algorithm and the results of its application in the real educational process. The effectiveness of using this algorithm for the objective assessment of students' knowledge has been experimentally shown. The test quality has been assessed using the IRT models.

1 INTRODUCTION

1.1 Motivation and Research Challenges of the Study

Important components of the educational process are the quality control of the assimilation of knowledge in higher education and the assessment of the degree to which students achieve their educational goals. Recently, distance learning has become widespread, which has become especially relevant in connection with the COVID19 pandemic. In this regard, there is a problem of the adequacy of knowledge assessment with the help of computer testing. The solution to this problem is of great importance, because it allows you to reduce the time for knowledge control, facilitate the work of teachers, and immediately get the result of the assessment.

While solving this problem, we faced the following challenges:

1. Choice of research methodology.
2. Experimental verification of the research results.

Our studies were evaluated on the results of modern testing theory, which allows us to adequately assess the quality of test items and create effective adaptive knowledge assessment algorithms based on them. To test knowledge, test items of varying complexity were developed for the discipline "Higher Mathematics" to assess the level of students' knowledge of with different levels of training.

1.2 Problem Statement

Modern approaches to assessing students' academic achievements are based on the use of classical testing

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theory and Item Response Theory (IRT). The mathematical background of pedagogical measurement theory was created in the works of (Andersen, 1973; Andrich, 2021; Avanesov, 1980; Guttman, 1944; Lord et al., 1968; Maslak et al., 2005; Rasch, 1960; Wright and Linacre, 1987; Wright and Masters, 1982). In IRT, the concept of a latent variable is used. The term "latent variable (parameter)" is usually understood as a theoretical concept that characterizes a certain hidden property or quality (for example, the level of students' ability, the difficulty of the test task), which cannot be directly measured. The advantages of the classical testing theory are the provision of information about the indicators of the knowledge quality of the subjects, the clarity of the performed calculations and the simple interpretation of the processing data. The main disadvantage is the dependence of the results of evaluating the participants' parameters on the difficulty of the proposed tasks. Application of IRT, based on Rasch models, provides the possibility of the evaluation independence of the latent parameter "ability level" calculated values of participants α_i from the values of the "item difficulty" β_i. This helps to increase the objectivity of the obtained assessments of the students' ability level and allows to build effective algorithms for assessing knowledge.

The *purpose of this paper* is to develop an algorithm of adaptive testing for objective assessment of students' knowledge in distance learning, which becomes especially relevant in the quarantine of COVID-19.

1.3 State of Arts and Review

The educational standards of the new generation are based on a competency-based approach to assessing the quality of a student's training, when it is not his knowledge that is tested, first of all, but his readiness to apply it in practice and to act productively in a non-standard situation, the ability to create the required mode of action. Therefore, the quality of training is understood as the degree of the student's readiness to demonstrate the relevant competencies. The generalization of the world experience in the implementation of the competence-based approach to assessing learning outcomes allows us to make the following conclusions that determine the main approaches to assessing the level of competence mastery, the main of which are the following:

1. competencies are dynamic, since they are not an invariable quality in the structure of a pupil's personality, but are able to develop, improve or completely disappear in the absence of an incentive to manifest them. Therefore, we can talk about the level of competence, assess it quantitatively, and monitor it.
2. when assessing learning outcomes, it is necessary to consider them in dynamics, which requires diagnostics of the educational process using monitoring procedures
3. the level of possession of a competence is a hidden (latent) parameter of the pupil and direct measurement is not amenable. It can be estimated with a certain probability. Therefore, when evaluating it, a probabilistic approach should be used.

It follows from this that in order to create tools for the automated assessment of the learning outcomes, it is necessary, first of all, to solve two problems:

1. develop theoretical and methodological foundations for modeling and parameterization of the learning process and the diagnostic tools used to evaluate its results.
2. theoretically substantiate and implement software-algorithmic means for processing the results of participants' diagnostics (testing, questionnaires), as well as tools for assessing learning outcomes and the quality of diagnostic tools.

The theoretical and methodological basis for solving these problems was the study results, first of all, by such Brown (Brown, 1910), Cronbach (Cronbach, 1951), Guilford (Guilford, 1942), Gulliksen (Gulliksen, 1986), Guttman (Guttman, 1944), Kuder and Richardson (Kuder and Richardson, 1937), Luce and Tukey (Luce and Tukey, 1964), Lord et al. (Lord et al., 1968), Sax (Sax, 1989), Spearman (Spearman, 1910). They developed the theoretical foundations for the creation of diagnostic materials and the classical approach to processing, analysis and interpretation of diagnostic results: the conceptual apparatus of the classical test theory, criteria and indicators of the quality of diagnostic tools, methodological basics of their design and quality expertise. The issues of scaling and comparison of processing data have been deeply investigated.

The theoretical basis for the creation of tools for automatic assessment of the results of the educational process has received its further development due to the creation of the IRT (Item Response Theory) the foundations of which are set out in the works of (Andrich, 2021, 2005; Andersen, 1973; Bezruczko, 2005; Bond et al., 2020; Andrich et al., 2001; van der Linden and Hambleton, 1997; Ingebo, 1997; Eckes, 2011; Lord, 1980; Perline et al., 1979; Smith and Smith, 2004; Rasch, 1960; Fischer and Molenaar, 1995; Wilson, 2005; Wright and Masters, 1982; Wright, 1977; Wright and Stone, 1979; Wright and Linacre, 1987).

Currently, IRT mathematical models are widely used to assess the quality of test items. In (Tjabolo and Otaya, 2019) the quality of the questions of school exams was assessed using 1, 2,3-PL models. As a result of the study, school exam questions were classified into two categories(the good and the bad categories) based on the value of the difficulty level of the test items.

In (Amelia and Kriswantoro, 2017) the quality of items in chemistry was also assessed using 1-PL, 2-PL and 3-PL models. By these models, assessments of the students' ability level, the difficulty level of test items were obtained, and the difference in the obtained assessments was analyzed. Various adaptive algorithms based on the Rasch model have been proposed in the works (Al-A'ali, 2006; Zaqoot et al., 2021) Despite the large number of papers devoted to the creation of adaptive algorithms based on IRT models, we could hardly find any reference to works that would consider an adaptive algorithm selecting the model that best suits the test data. The adaptive algorithm proposed by us can use any of three IRT models: 1-PL, 2-PL and 3-PL.

2 ALGORITHM OF ADAPTIVE TESTING BASED ON RASCH MODEL

Adaptive testing is a type of testing in which the order of presentation of test items and the difficulty of the next task depends on the participant's answers to previous items. The basis of adaptive testing systems are statistical models. Very easy and very difficult tasks are automatically uninformative. Therefore, for most tests, the optimal level of difficulty is the item, to which the correct answer is given by about half of the test participants.

The difficulties of the test items is determined experimentally, and the measurement process consists of determining the percentage of participants who are able to give the correct answer to the task in previous experiments. The problem of developing adaptive algorithms has been considered in (Weiss, 1982; Al-A'ali, 2006; Weiss, 2004).

The Rasch model was used to construct the adaptive testing algorithm. This model is defined by formulas:

$$P_{ni} = \frac{\exp(\theta_n - \beta_i)}{1+\exp(\theta_n - \beta_i)} \qquad (1)$$

where P_{ni} is the probability that the participant $n, n = 1,\dots,N$ with the ability θ_n correctly performs the task $i, i = 1,\dots,I$, with the difficulty β_i.

To start the algorithm, it is necessary to determine the initial levels of difficulties. To this end, at the beginning of the testing session the accumulation of primary information about the level of preparation of the participant is carried out. To do this, participant receive N_p tasks with an average level of difficulty. Tasks to determine the initial level of the participant are chosen by the teacher. Then, using the received answers, the initial estimation of the ability level of the student is calculated, and also recalculation of the difficulty level current values of test items is carried out.

The initial assessment of the ability level of the i-th student (in logs) is based on the formula:

$$\theta_i^0 = \ln\left(\frac{p_i}{q_i}\right), \quad i = 1,2\cdots N, \qquad (2)$$

where N is the number of test participants, p_i is the proportion of correct answers of the i-th participant to all tasks, q_i is the proportion of incorrect answers ($q_i = 1 - p_i$).

The difficulty level of test items in logs is determined by the formula:

$$\beta_j^0 = \ln\left(\frac{q_j}{p_j}\right), \quad j = 1,2\cdots M, \qquad (3)$$

where M is the number of test items, p_j is the proportion of correct answers of all participants to the j-th test item, q_j is the proportion of incorrect answers.

At the next stage, the initial values in the logs of the ability level of participants θ_i^0 and the initial values in the logs of the difficulty level of the test item β_j^0 are reduced to a same interval scale (Lord et al., 1968). The formula for such transition is based on the idea of reducing the impact of the items difficulty on the assessments of test participants.

Pre-calculating the average value of the initial logits of the students' ability level

$$\bar{\theta} = \frac{\sum_{i=1}^{N} \theta_i^0}{N}$$

and the standard deviation V of the initial values distribution of the parameter θ

$$V^2 = \frac{\sum_{i=1}^{N} \left(\theta_i^0 - \bar{\theta}\right)^2}{N-1},$$

we obtain a formula for calculating the difficulty level logit of the j-th item

$$\beta_j = \bar{\theta} + Y \cdot \beta_j^0, \quad j = \overline{1,M}, \qquad (4)$$

where

$$Y = \left(1 + \frac{V^2}{2.89}\right)^{\frac{1}{2}}$$

Similarly, calculating

$$\overline{\beta} = \frac{\sum_{j=1}^{M} \beta_j^0}{M}, \quad W = \sqrt{\frac{\sum_{j}^{M} \left(\beta_j^0 - \overline{\beta}\right)^2}{M-1}}$$

we get the formula for calculating the ability level logit of the i-th student:

$$\theta_i = \overline{\beta} + X \cdot \theta_i^0, \quad i = \overline{1,N}, \tag{5}$$

where $X = \left(1 + \frac{W^2}{2.89}\right)^{\frac{1}{2}}$.

The obtained values allow to compare the level of students' ability with the level of test item difficulty. If $\theta_i - \beta_j$ is a negative quantity and is large in modulus, then the problem of difficulty β_j is too difficult for a student with the ability level θ_i, and it will not be useful for measuring the level of knowledge of the i-th student. If this difference is positive and large in modulus, then the task is too easy, it has long been mastered by the student. If $\theta_i - \beta_j$, then the probability that the student correctly completes the task is equal to 0.5.

The information function of the i-th problem for the Rasch model (1) $I_i(\theta)$ is defined as the product of the probability of the correct answer $P_i(\theta)$ to this problem on the probability of the incorrect answer $Q_i(\theta)$ (Lord et al., 1968)

$$I_i(\theta) = P_i(\theta) \cdot Q_i(\theta) \tag{6}$$

Figure 1 shows the information function of the i-th item. Figure 1 shows that the test item, the answer to which all students know, does not provide any information, as well as the item, the answer to which no one knows. We get useful information when some participants know the answer to the task and some do not.

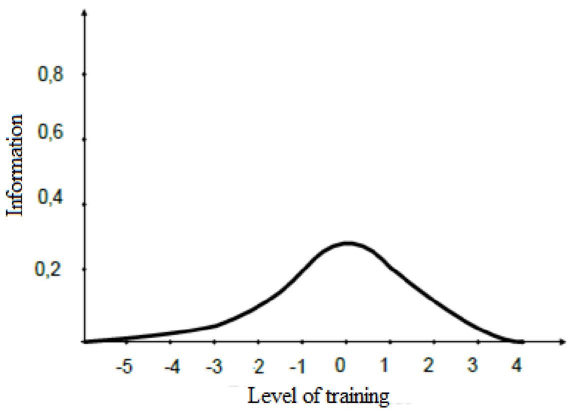

Figure 1: Information function of the test task.

The information function of the test is calculated as the sum of the information functions of the test items (Lord et al., 1968):

$$I(\theta) = D^2 \cdot \sum_{j=1}^{M} I_j(\theta) \tag{7}$$

where D is the correction factor (D = 1.7), necessary to approximate the distribution of logistic probability to the law of normal distribution.

After calculating the information function, the measurement error SE is calculated, the value of which is used to check the condition of the end of the test procedure.

In the Rusch model, the measurement error depends on the level of training θ and is calculated by the formula (Lord et al., 1968):

$$SE(\theta) = \frac{1}{\sqrt{I(\theta)}}. \tag{8}$$

If the error takes a value less than the threshold set by the teacher, the adaptive testing algorithm ends. Otherwise, the following test task is selected. To select the next task, use the value of θ_i, calculated by formula (5). The next task is the one whose difficulty level is closest to the current assessment of the ability level of the participant. This task has the largest information contribution and its choice reduces the total number of required test tasks.

Thus, the developed adaptive testing algorithm consists of the following stages:

1. Selection of 5 tasks of average difficulty from the bank of questions, which is determined by the teacher.
2. Finding the initial level of student's ability θ_i^0 and the initial difficulty level of items β_j^0 by formulas (2) and (3).
3. Summary of the obtained initial values θ_i^0 and β_j^0 to a single interval scale using formulas (5) and (4).
4. Calculation of the information function of test tasks to which the student answered by formulas (6) and (7).
5. Finding the measurement error by the formula (8).
6. If the measurement error is less than the threshold, the adaptive testing is completed.
7. If not, then the next task is selected from the condition $\left|\theta_i - \beta_j\right| = \min$.
8. Then the algorithm is repeated starting from point 3.

The block diagram of the algorithm is shown in figure 2. The proposed algorithm can use any of three models: 1-PL, 2-PL and 3-PL.

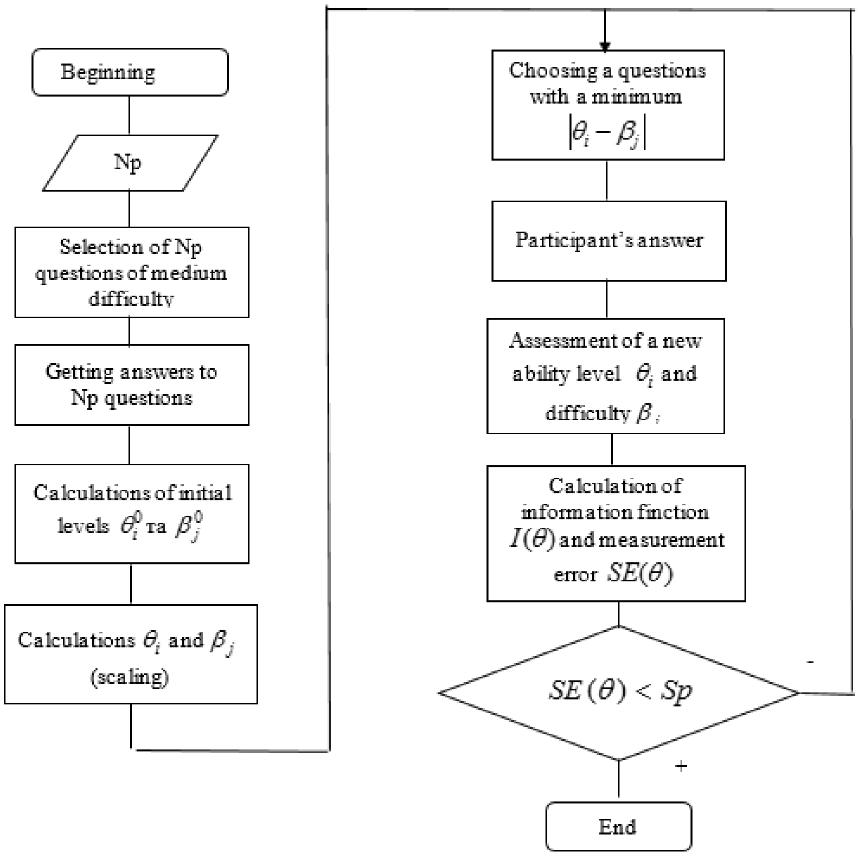

Figure 2: Block diagram of the adaptive testing algorithm.

3 RESULTS OF TEST ANALYSYS BASED ON THE RASCH MODEL

Let us consider the procedure for calculating the parameters of student ability level θ_i and item difficulty parameter β_i from empirical data. As initial data we will take results of testing of students in Moodle system on discipline "Higher Mathematics" of the Mathematics and Modeling Departement of the Donbass State Engineering Academy (table 1). Table 1 shows the records of the first 10 test participants. A total of 50 participants took part in the testing.

The test in this discipline consisted of 20 questions. First, it is necessary to calculate the proportions of correct p_i and incorrect q_i answers of participants. These values are calculated by formulas

$$p_i = \frac{R_i}{N}, q_i = 1 - p_i, \tag{9}$$

where R_i is the number of correct answers for the i-th test item, $= 1, 2, ..., n$, and n is the number of items in the test. For example, for the first participant of testing we have

$$p_1 = \frac{18}{20} = 0.9, \; q_1 = 1 - 0.9 = 0.1$$

The values p_i and q_i are given in columns 3 and 4 of table 1.

Next, calculate the initial values θ_1^0 of the ability level of participants by formula (2). For the first participant we have

$$\theta_1^0 = \ln \frac{0.9}{0.1} = 2.197$$

Using the statistical module Moodle, the following characteristics were obtained for test tasks: facility index (F), standard deviation (SD), random guess score (RGS), intended weight, effective weight, distinction, distinction efficiency.

These data are shown in table 2.

Based on the data in table 2, we can estimate the initial values of the item difficulty parameter. By formula (3) for the first problem we obtain

$$\beta_1^0 = \ln \frac{2}{98} = -3.891$$

Table 1: Test results in the Moodle system in the discipline "Higher Mathematics" of the Mathematics and Modeling Department of the Donbass State Engineering Academy.

Participant's number	Score	Number of correct answers	p_i	q_i	θ_i^0
1	90	18	0.9	0.1	2.197225
2	75	15	0.75	0.25	1.098612
3	85	17	0.85	0.15	1.734601
4	100	20	1	0	∞
5	75	15	0.75	0.25	1.098612
6	100	20	1	0	∞
7	90	18	0.9	0.1	2.197225
8	90	18	0.9	0.1	2.197225
9	70	14	0.7	0.3	0.847298
10	85	17	0.85	0.15	1.734601

Table 2: Statistical characteristics obtained using the statistical module of the Moodle system based on the results of final testing in the discipline "Higher Mathematics".

Q#	F	SD	RGS	Intended weight	Effective weight	Distinction	Distinguishing efficiency
1	98.00%	14.14%	33.33%	5.00%		-11.54%	-28.62%
2	94.00%	23.99%	33.33%	5.00%	3.41%	6.93%	11.28%
3	90.00%	30.30%	16.67%	5.00%	6.75%	44.07%	65.85%
4	94.00%	23.99%	20.00%	5.00%	4.66%	22.91%	39.11%
5	96.00%	19.79%	20.00%	5.00%	3.34%	11.72%	23.66%
6	90.00%	30.30%	14.29%	5.00%	3.18%	-1.53%	-2.22%
7	92.00%	27.40%	14.29%	5.00%	6.32%	43.38%	70.79%
8	84.00%	37.03%	20.00%	5.00%	6.48%	26.08%	35.44%
9	88.00%	32.83%	20.00%	5.00%	5.32%	17.26%	23.76%
10	74.00%	44.31%	20.00%	5.00%	9.75%	68.31%	84.84%
11	98.00%	14.14%	20.00%	5.00%	2.85%	14.64%	35.69%
12	100.00%	0.00%	16.67%	5.00%	0.00%		
13	94.00%	23.99%	33.33%	5.00%	4.93%	27.00%	45.87%
14	90.00%	30.30%	33.33%	5.00%	5.51%	23.81%	34.88%
15	88.00%	32.83%	25.00%	5.00%	5.32%	17.26%	23.76%
16	90.00%	30.30%	33.33%	5.00%	5.51%	23.81%	33.33%
17	42.00%	49.86%	20.00%	5.00%	5.23%	-2.60%	-3.57%
18	80.00%	40.41%	33.33%	5.00%	8.11%	45.46%	56.25%
19	56.00%	50.14%	20.00%	5.00%	7.01%	13.80%	17.23%
20	82.00%	38.81%	20.00%	5.00%	6.32%	21.10%	27.68%

The results of calculations of the initial values of the item difficulty parameter are given in table 3.

As can be seen from table 3, all participants in the quiz answered the 12th item, so the score was equal to infinity with a minus sign. But practically at β >-6 the probability value $P_i(\beta)$ close to one. These items are performed by all participants and they become redundant. Items with $\beta > 6$ are also useless. Such items will not be overcome by any participant and they do not carry any information about differences in the students' ability levels.

In tables 1 and 3, the parameter values θ_i^0 and β_i^0 are on different interval scales. In order to reduce them to a single scale of standard estimates, it is necessary to calculate the variances V_2 and W_2 using the data from tables 1 and 3. Infinite data are excluded from consideration.

Calculating the variance, we obtain

$$V^2 = \frac{\sum_{i=1}^{N}\left(\theta_i^0 - \overline{\theta}\right)^2}{N-1} = 0.634,$$

$$W^2 = \frac{\sum_j^M\left(\beta_j^0 - \overline{\beta}\right)^2}{M-1} = 4.873$$

Next, we calculate the angular coefficients (Lord et al., 1968):

$$Y = \left(1 + \frac{V^2}{2.89}\right)^{\frac{1}{2}} = 1.104$$

Table 3: Initial values β_i^0 of the item difficulty parameter.

Q#	Progress	p_i	q_i	β_i^0
1	98.00%	0.98	0.02	-3.89182
2	94.00%	0.94	0.06	-2.75154
3	90.00%	0.90	0.10	-2.19722
4	94.00%	0.94	0.06	-2.75154
5	96.00%	0.96	0.04	-3.17805
6	90.00%	0.90	0.10	-2.19722
7	92.00%	0.92	0.08	-2.44235
8	84.00%	0.84	0.16	-1.65823
9	88.00%	0.88	0.12	-1.99243
10	74,00%	0.74	0.26	-1.04597
11	98.00%	0.98	0.02	-3.89182
12	100.00%	1.00	0.00	-∞
13	94.00%	0.94	0.06	-2.75154
14	90.00%	0.90	0.10	-2.19722
15	88.00%	0.88	0.12	-1.99243
16	90.00%	0.90	0.10	-2.19722
17	42,00%	0.42	0.58	0.322773
18	80.00%	0.80	0.20	-1.38629
19	56,00%	0.56	0.44	-0.24116
20	82.00%	0.82	0.18	-1.51635

$$X = \left(1 + \frac{W^2}{2.89}\right)^{\frac{1}{2}} = 1.63$$

Next on the formulas

$$\theta_i = -2.103 + 1.104\theta_i^0$$

$$\beta_i = 1.86 + 1.63\beta_i^0$$

calculate the scaled values β_i and θ_i of the parameters.

In tables 4 and 5 scaled parameter values are provided.

For the analysis of test items quality we will create histograms of students' ability levels and levels of items difficulties on the basis of the received data. These histograms are shown in figure 3 and figure 4.

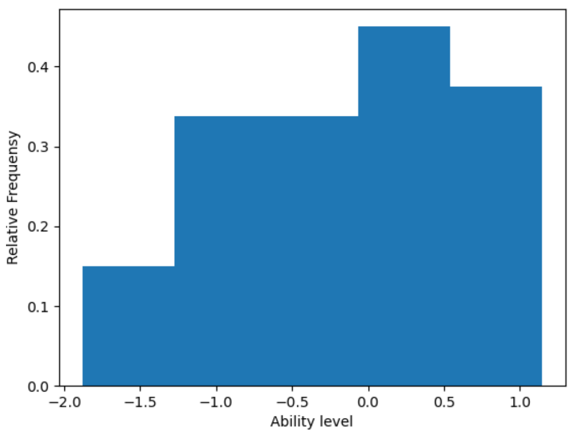

Figure 3: Ability levels histogram.

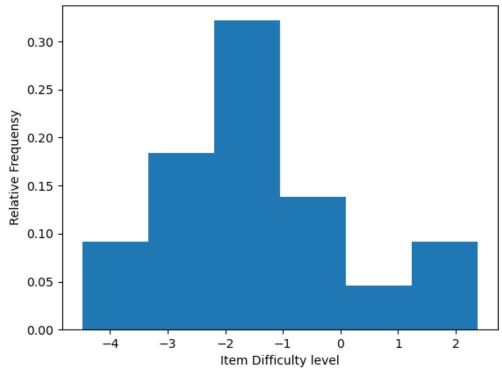

Figure 4: Items difficulty levels histogram

The histograms of the distributions of ability levels and difficulty levels of test items are visually similar to a normal distribution, which is typical for a good test. However, the distribution of difficulty levels of test items has a negative maximum, which indicates that there are more simple than difficult tasks in the test. The presence of a large number of easy tasks leads to the fact that assessments of the level of preparation of students will be inflated. This is clearly seen from the histogram of the training levels of the test participants, which clearly shows that the range of ability levels is from -1.8 to 2.3 logs, while the range of items difficulties levels is from -1.8 to 1.2 logs.

The sum of the scaled difficulty levels of test items is -27.93.

This means that the test items are very easy. This test is not balanced, it contains a lot of easy items. It is necessary to strive to ensure that this amount is close to zero. Thus, the assessment of latent parameters allows to determine noninformative items that should be excluded from the quiz. The use of the developed adaptive algorithm will allow to objectively assess the level of students' knowledge.

Now for all test tasks we construct characteristic curves using the relation (10)

$$P_j = \frac{1}{1 + \exp(-1.702(\theta - \beta_j))} \qquad (10)$$

where P_j is the probability that the participant with the ability θ correctly performs the task $j, j = 1, \ldots, M$, with the difficulty β_j.

The graph of these characteristic curves is shown in figure 5.

Figure 5 shows that the characteristic curves for the items 1-2, 4-6, 8-11, 12-13 coincide, and the curves for tasks 17-18, 18-19 are more than 0.5 log apart. Thus, the characteristic curves are uneven. Since tasks with the same level of difficulty do not provide additional information when measuring a

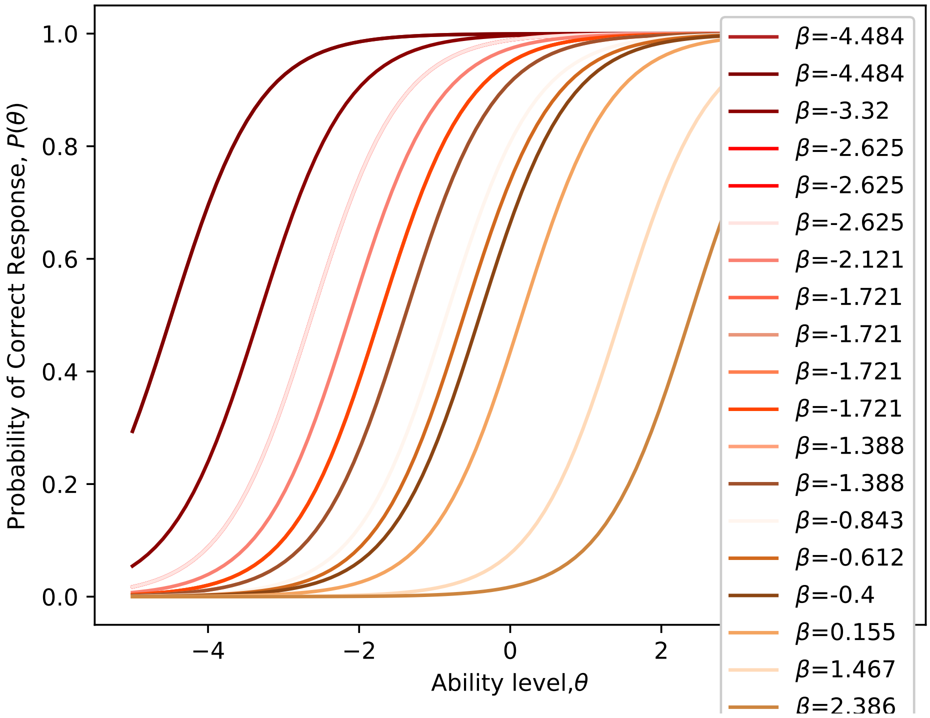

Figure 5: Characteristic curves of test items.

Table 4: Scaled values of item difficulty parameter β_i.

Q#	β_i^0	β_i
1	-3.89182	-4.48367
2	-2.75154	-2,625
3	-2.19722	-1.72148
4	-2.75154	-2.625
5	-3.17805	-3.32023
6	-2.19722	-1.72148
7	-2.44235	-2.12103
8	-1.65823	-0.84291
9	-1.99243	-1.38766
10	-1.04597	0.155071
11	-3.89182	-4.48367
13	-2.75154	-2,625
14	-2.19722	-1.72148
15	-1.99243	-1.38766
16	-2.19722	-1.72148
17	0.322773	2.386121
18	-1.38629	-0.39966
19	-0.24116	1.466906
20	-1.51635	-0.61165

Table 5: Scaled values of the ability level θ_i.

Participant's number	θ_i^0	θ_i
1	2.197225	0.322736
2	1.098612	-0.89013
3	1.734601	-0.188
5	1.098612	-0.89013
7	2.197225	0.322736
8	2.197225	0.322736
9	0.847298	-1.16758
10	1.734601	-0.188

given level of knowledge, one should be left out of the tasks that match in terms of difficulty, and the rest should be deleted. It is necessary to keep the item that is most different from the remaining items in the test. To create a quality test, it is necessary to remove tasks 1, 5, 6, 10, 11, 12 from the test and add to the test items with difficulty that is in the interval between the complexity of 17-18 and 18-19 items.

The graph of the information function of test items and the test as a whole, defined by formulas (6) and (7), is shown in figure 6. Figure 6 shows that the information function has one clearly expressed maximum. This is a sign of a "good" test. However, it can be seen that the test contains a lot of easy test items with difficulties in the interval (-3; -2), which can be excluded from the test. Also in the test there are many easy tasks with the same difficulties, which can also be excluded from the test without violation of its information content. However, the more difficult tasks (with difficulties of 1-2 logits) are clearly not enough in the test, so it is necessary to add more complex tasks.

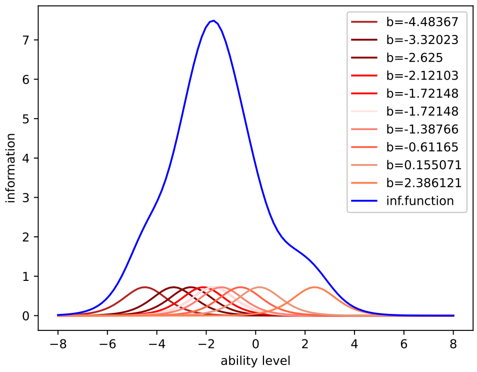

Figure 6: Information functions of the test and test items.

The graph of the measurement error, depending on the level of training, is shown in figure 7.

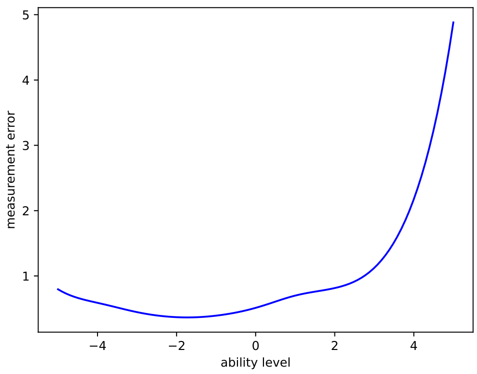

Figure 7: Measurement error graph.

It can be seen from the graph that the measurement error is large for the values of the ability in the interval (2, 4), which is associated with the lack of test items of increased difficulty.

4 RESULTS OF TEST ANALYSIS BY 2PL AND 3PL BIRNBAUM MODEL

The two-parameter (2PL) Birnbaum model differs from the Rasch model by the presence of the a_j parameter, which characterizes the differentiating ability of the j-th task. According to this model, the probability of a correct answer by an examinee with θ ability level to a test item with β_j difficulty is determined by the formula:

$$P_j(\theta) = \frac{1}{1+\exp(-1.7a_j(\theta-\beta_j))}$$

The a_j parameter is defined by the relation

$$a_j = \frac{(r_{bis})_j}{\sqrt{1-\left((r_{bis})_j\right)^2}}$$

where $(r_{bis})_j$ is the biserial correlation coefficient of the j-th task. Often, instead of this coefficient, a point biserial coefficient r^j_{ab} is used – correlation coefficient of each task with student individual score

$$r^j_{pb} = \frac{\overline{X_1}-\overline{X_0}}{s_x}\sqrt{\frac{n_1 n_0}{n(n-1)}} \tag{11}$$

Here n_1 is the number of students who completed this item;

n_0 – the number of students who did not complete it;

$n = n_0 + n_1$ – total number of students;

$\overline{X_1}$ – average individual score of students who coped with the given item (the ratio of the sum of individual scores of students who completed this item to n_1);

$\overline{X_0}$ – the average individual score of students who did not cope with this iten (the ratio of the sum of individual scores of students who did not completed this item, to n_0);

s_x is the standard deviation for the individual scores of all students.

So, we will assume that

$$a_j \approx \frac{r^j_{pb}}{\sqrt{1-\left(r^j_{pb}\right)^2}} \tag{12}$$

The parameter a_j is directly proportional to the slope of the characteristic curve at the inflection point. The greater the value of this parameter, the greater the steepness of the characteristic curve and, therefore, the greater the differentiating ability of the item. Therefore, to compare the levels of student's knowledge among themselves, it is important to select items depending on the values of the parameter a_j.

The table 6 shows the values of the point biserial coefficient r^j_{pb}, the parameter a_j and the difficulty of the items β_j. These parameters are calculated by formulas (4), (11), (12) respectively.

To obtain a test with a good distinguishing ability, we will use the following recommendations for selecting items. First of all, it is necessary to exclude tasks 7 and 3 from the test, which have a negative

Table 6: The values of the parameters r_{pb}^{j},a_j and β_j.

Q#	7	3	6	14	16	9	15	8	20	18	10	19	17
β_j	-2.12	-1.72	-1.72	-1.72	-1.72	-1.39	-1.39	-0.84	-0.61	-0.40	0.16	1.47	2.39
r_{pb}^{j}	-0.01	-0.14	0.00	0.26	0.43	0.40	0.64	0.26	0.59	0.65	0.65	0.49	0.35
a_j	-0.01	-0.15	0.00	0.27	0.47	0.43	0.84	0.27	0.73	0.84	0.85	0.56	0.37

value of the discrimination parameter. This is due to the fact that examinee with a low level of knowledge respond well to them and poorly – with a high level of knowledge, which is contrary to common sense. This is due to guessing, when a student with a low level of knowledge randomly selects the correct answer. In addition, it is necessary to select tasks with sufficiently large values – from the interval (0.5; 2.5). In the test, from this point of view, tasks 6, 14, 8 will be the worst. Further analysis involves the selection of tasks with the greatest differentiating ability with equal difficulty.

Consider tasks 9 and 15, which have the same difficulty and differ in the parameter a_j:$a_9 = 0.43$, $a_{15} = 0.84$. According to the one-parameter Rasch model, both tasks have the same probability curve for the correct answer of the subjects (curve 1, figure 8), that is, from the point of view of the differentiating ability of the tasks, they are indistinguishable. In the case of a two-parameter model, we obtain two different characteristic curves: steeper (2) for task 15 and less steep (3) for task 9. Thus, when minimizing the length of the test, task 15 is preferable.

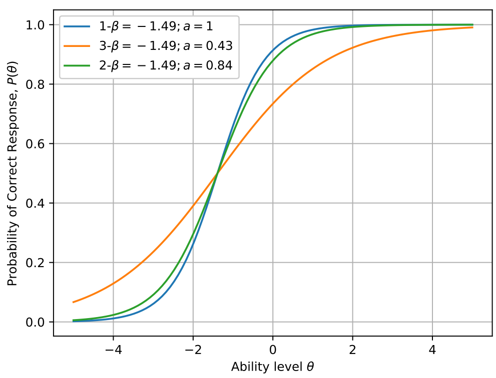

Figure 8: Comparison of the Rasch model and the two-parameter Birnbaum model for items 9 and 15.

The test in question is a closed-type test with the choice of a single correct answer out of five offered for each task. In such cases, in order to reduce the guessing effect, it is proposed to use the three-parameter Birnbaum model.

This Birnbaum model contains one more parameter c_j, which characterizes the probability of a correct answer to the task j if this answer is guessed and not based on knowledge. In this case, the probability of the correct answer of the subjects to the task of the j test is expressed by the formula

$$P_j(\theta) = c_j + (1 - c_j)(1 + \exp(-1,7a_j(\theta - \beta_j)))^{-1},$$

where $c_j = \frac{1}{k_j}$, k_j is the number of responses to task j. In the test under consideration $k_j = 5$, $c_j = 0.2$.

The characteristic curves of these tasks cross the line $P_j(\theta) = c_j$, so the characteristic curves themselves become flatter, which leads to a decrease in the differentiating ability of the test.

The figure 9 shows the probability curves for the correct answer of the subjects to item 5, depending on the ability level θ, corresponding to the Rasch model(curve 1),the two-parameter model (curve 3) and the three-parameter model (curve 2).

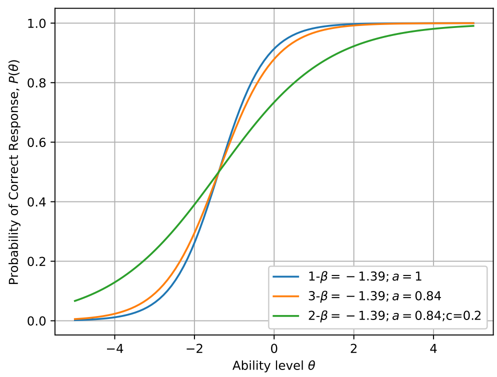

Figure 9: Characteristic curves for item 15 according to Rasch and Birnbaum models.

Let us compare the information functions for the Rasch and Birnbaum models. For the Rasch model, the information function is determined by relation (6). For the two-parameter Birnbaum model, the information function is given by the expression

$$I_j(\theta) = 2.89{a_j}^2 P_j(\theta) Q_j(\theta).$$

For the three-parameter Birnbaum model, the information function has the form

$$I_j(\theta) = \frac{2.89{a_j}^2(1 - c_j)}{R_i(\theta) Q_i(\theta)},$$

where $R_i(\theta) = (c_j + \exp(1.7a_j(\theta - \beta_j)))$ and $Q_i(\theta) = (1 + \exp(-1.7a_j(\theta - \beta_j)))^2$.

The maximum value of the information function for the Rasch model and the two-parameter Birnbaum model is reached at the inflection point of the characteristic curve, that is, when the difficulty (in logits) is equal to the ability level. The maximum value of the information function for the Rasch model and the two-parameter Birnbaum model is reached at the inflection point of the characteristic curve, that is, when the difficulty (in logits) is equal to the level of knowledge (in logits). Thus, for θ_i, tasks with difficulty values β from the neighborhood of the point θ_i are the most informative (in logits). Thus, for θ_i, tasks with difficulty values β from the neighborhood of the point θ_i are the most informative.

In the figure 10, for items 9 and 15 of the test, information functions are shown: according to the Rasch model (curve 1 – common for two items), according to the two-parameter model for item 9 (curve 2) and for item 15 (curve 3). The difficulty of tasks is equal to -1.39, therefore these items are the most informative for values close to -1.39.

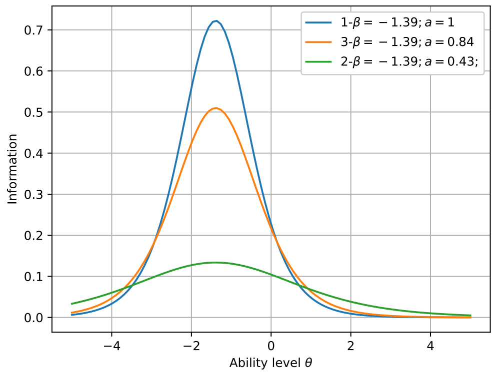

Figure 10: Information functions for items 9 and 15.

In the case of the three-parameter Birnbaum model, the maximum information function is reached at the point

$$\theta_{\max} = \beta_j + \frac{1}{1,7a_j}\left(0.5 + 0.5\sqrt{1+8c_j}\right).$$

For items 9, with difficulty $\beta = -1.39$, the maximum of the information function is reached at the point $\theta_{\max} = 2$, and for task 15, with the same difficulty, at the point $\theta_{\max} = 2$. The information function of the entire test is determined by the formula 7. The information function of the entire test must have one clearly defined maximum, otherwise the test needs to be improved, items with difficulties corresponding to the failure areas of the information function should be added to it.

The figure 11 shows the information functions of the entire test, based on the Rasch model, two-parameter (2PL) model, three-parameter (3PL) Birnbaum model. In the test under consideration, this condition is satisfied because each curve has one maximum point.

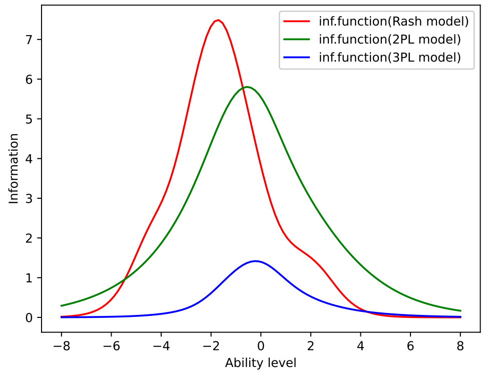

Figure 11: Information functions of test.

So, for the test in the discipline “Higher Mathematics”, two Birnbaum models were built: two- and three-parameter. If we consider that the test should correspond to these models, it is necessary to get rid of some tasks, and change others. In particular, from the point of view of a normatively oriented test, it should have a sufficiently high differentiating ability. Therefore, tasks 9 and 14 should be removed, which are identical in difficulty with tasks 15 and 16, respectively, and differ in lower differentiating ability. In addition, it is necessary to replace or change tasks 6, 8, 17 so that their differentiating ability increases. Tasks 7 and 3 with a negative value of the discrimination parameter should be removed. As regards the information functions, the graphs built according to the three models, including the Rasch model, did not reveal any contradictions between theory and experiment.

To use the IRT model for assessing the quality of test items, it is necessary that the test results are adequate to this model. To check this fact, the adequacy is assessed based on Pearson’s chi-squared test. To calculate the value $\chi^2_{\beta_j}$ for the j-th task, all test participants are divided according to the ability level into Q intervals, and for each interval the average value of their ability level $\bar{\theta}_q$ is found. The algorithm for dividing the range of change in the value of θ into intervals is constructed in such a way that if the level of ability of any participant coincides with the interval border, it shifts to the right so much that the value of this ability falls into the previous interval.

$\chi^2_{\beta_j}$ is calculated based on the expression (Baker and Kim, 2017)

$$\chi^2_{\beta_j} = \sum_{q=1}^{Q} \frac{(x_{qj} - T_q P_{qj})^2}{\delta^2_{\beta_j}}, \tag{13}$$

where x_{qj} is the number of test participants with ability level $\bar{\theta}_q$, who correctly answered the j-th test item; $T_q$is the total number of test participants with ability level $\bar{\theta}_q$; value δ_{β_j} is calculated by the formula:

$$\delta_{\beta_j} = \sqrt{T_q P_{qj} (1 - P_{qj})}. \tag{14}$$

P_{qj} is the probability expression of successful completion of j-th item with difficulty β_j by a participant with the ability level $\bar{\theta}_q$ and is defined by IRT models. To assess the adequasy of test results with IRT models, we will use the R language tools. To do this, we will load the test results saved in the input.csv file with the CSV extension using the call

```
data<-read.csv("input.csv")
```

For data analysis, we use the ltm library of the R language. To use this library, it must be installed and loaded using the commands

```
install.package("ltm")
library("ltm")
```

After that, the following commaands can be used to estimate Rasch model for test data.

```
f1<-rasch(data,constraint =
    cbind(length(data)+1,1)))
```

To view the results of estimation, we use the following command

```
summary(data.rasch)
```

As a result, we obtain the following output:

```
Call:
rasch(data = data,
      constraint = cbind(ncol(data) + 1, 1))

Model Summary:
   log.Lik      AIC      BIC
 -321.6515 681.3031 717.6315

Coefficients:
             value std.err  z.vals
Dffclt.v1  -4.3305  1.0338 -4.1888
Dffclt.v11 -4.3305  1.0338 -4.1888
Dffclt.v5  -3.5941  0.7533 -4.7712
Dffclt.v2  -3.1457  0.6323 -4.9751
Dffclt.v4  -3.1458  0.6323 -4.9751
Dffclt.v13 -3.1458  0.6323 -4.9751
Dffclt.v7  -2.8155  0.5619 -5.0104
Dffclt.v3  -2.5500  0.5151 -4.9510
Dffclt.v6  -2.5498  0.5150 -4.9509
Dffclt.v14 -2.5504  0.5151 -4.9511
Dffclt.v16 -2.5503  0.5151 -4.9511
Dffclt.v9  -2.3256  0.4813 -4.8319
Dffclt.v15 -2.3254  0.4813 -4.8318
Dffclt.v8  -1.9529  0.4355 -4.4842
Dffclt.v20 -1.7924  0.4193 -4.2750
Dffclt.v18 -1.6442  0.4060 -4.0502
Dffclt.v10 -1.2505  0.3775 -3.3122
Dffclt.v19 -0.2938  0.3435 -0.8552
Dffclt.v17  0.3859  0.3450  1.1184
Dscrmn      1.0000      NA      NA

Integration:
method: Gauss-Hermite
quadrature points: 21

Optimization:
Convergence: 0
max(|grad|): 0.0014
quasi-Newton: BFGS
```

The output contains the following information: log-likelyhood value (LogLik),the Akaike information criterion (AIC),Bayesian information criteria (BIC). AIC and BIC can be used to compare the relative fit of the models for the same data. The lower AIC and BIC value, the better the model fits the data. The output also include item difficulty estimates (Dffclt) with their standard error and z statistic. Using the functions ltm library, we can assess absolute model fit. This assessment can be conducted using chi-square test of the null hypothesis. The null hypothesis is that our model fits the data. To determine whether the model fit the individual items, we use the following command

```
item.fit(data.rasch,simulate.p.value=FALSE)
```

After using these command we obtain the following output:

```
Item-Fit Statistics and P-values

Call:
rasch(data = data,
      constraint = cbind(ncol(data) + 1, 1))

Alternative: Items do not fit the model
Ability Categories: 10

        X^2 Pr(>X^2)
v1  12.4481   0.0527
v11 12.4481   0.0527
v5  24.2183   0.0005
v2  35.3998  <0.0001
v4  18.3807   0.0053
v13 18.3807   0.0053
v7  12.7657   0.0469
v3  19.6667   0.0032
v6  17.7808   0.0068
v14  8.0073   0.2376
v16  9.8845   0.1296
v9  15.6480   0.0158
v15 15.6579   0.0157
v8  19.6375   0.0032
v20  9.4753   0.1486
v18 15.7466   0.0152
v10 24.7008   0.0004
v19 29.4453   0.0001
v17 19.5219   0.0034
```

Analysing this result, we can conclude that the model does not accurately fit responses for the individual tasks. Item 2 turned out to be the worst. Items 19,10 and 5 are also poorly consistent with the Rasch model. Similar results can be obtained for the 2PL Birnbaum model.

To obtain estimates of latent trait,we use the following commands:

```
data.2pl<-ltm(data~z1)
summary(data.2pl)
```

As a result, we obtain

```
Call:
ltm(formula = data ~ z1)

Model Summary:
   log.Lik      AIC      BIC
 -251.8978 579.7955 652.4524

Coefficients:
              value     std.err  z.vals
Dffclt.v1   -3.6349      6.5440 -0.5555
Dffclt.v11  -3.6349      6.5440 -0.5555
Dffclt.v5   -2.8923      4.1718 -0.6933
Dffclt.v2   -2.3626      3.3693 -0.7012
Dffclt.v4   -2.5588      3.4556 -0.7405
Dffclt.v13  -4.1300      5.4315 -0.7604
Dffclt.v7   12.4254     34.7564  0.3575
Dffclt.v3   -9.4923     24.8491 -0.3820
Dffclt.v6   10.1668     23.5444  0.4318
Dffclt.v14   2.9872      2.4793  1.2049
Dffclt.v16   1.7069      1.2336  1.3837
Dffclt.v9    1.6604      1.0279  1.6154
Dffclt.v15   0.7883    151.3151  0.0052
Dffclt.v8   13.1975     51.8541  0.2545
Dffclt.v20   0.9232      0.5943  1.5533
Dffclt.v18   0.6679   2601.7180  0.0003
Dffclt.v10   0.4715    439.4082  0.0011
Dffclt.v19  -0.0204     65.1284 -0.0003
Dffclt.v17  -0.6392    797.0869 -0.0008
Dscrmn.v1    1.3535      1.8244  0.7419
Dscrmn.v11   1.3535      1.8244  0.7419
Dscrmn.v5    1.5005      1.5262  0.9832
Dscrmn.v2    1.7745      1.6673  1.0643
Dscrmn.v4    1.5215      1.4152  1.0751
Dscrmn.v13   0.7628      0.8333  0.9153
Dscrmn.v7   -0.1942      0.5450 -0.3563
Dscrmn.v3    0.2395      0.5988  0.4000
Dscrmn.v6   -0.2130      0.4947 -0.4305
Dscrmn.v14  -0.7469      0.5524 -1.3522
Dscrmn.v16  -1.5396      0.8178 -1.8827
Dscrmn.v9   -1.3673      0.6043 -2.2627
Dscrmn.v15 -27.8310   2871.9894 -0.0097
Dscrmn.v8   -0.1238      0.4912 -0.2521
Dscrmn.v20  -2.2078      0.9535 -2.3155
Dscrmn.v18 -36.3006  70169.1000 -0.0005
Dscrmn.v10 -44.8844  17157.7715 -0.0026
Dscrmn.v19 -38.3693 122239.5199 -0.0003
Dscrmn.v17 -33.1395  20052.6276 -0.0017

Integration:
method: Gauss-Hermite
quadrature points: 21

Optimization:
Convergence: 0
max(|grad|): 0.012
quasi-Newton: BFGS
```

Comparing AIC and BIC for the Rasch model (AIC=681.3031, BIC=717.613) and for the 2PL Birnbaum model (AIC=579.7955,BIC=652.4524) we can conclude that 2PL model better fits the test data.

However, the function did not correctly calculate the difficulty level for some items, as evidenced by the std.err value. The presence of negative values of the discrimination coefficient indicates that these items does not fits the model. To assess the fit of each items, we use χ^2 test.

```
item.fit(data.2pl,simulate.p.value=FALSE)
```

The output of this command is shown below:

```
Item-Fit Statistics and P-values

Call:
ltm(formula = data ~ z1)

Alternative: Items do not fit the model
Ability Categories: 10

        X^2 Pr(>X^2)
v1  17.2949   0.0272
v11 17.2949   0.0272
v5   5.7470   0.6756
v2   8.6983   0.3684
v4   8.6199   0.3754
v13 18.0006   0.0212
v7  27.8472   0.0005
v3  32.8960   0.0001
v6  15.0469   0.0582
v14 19.2362   0.0136
v16 15.7731   0.0457
v9  19.5417   0.0122
v15  0.2435        1
v8  22.2559   0.0045
v20 11.2384   0.1886
v18  0.7094   0.9995
v10 23.5588   0.0027
v19 18.7206   0.0164
v17  2.4617   0.9635
```

From this output we see that the 2PL Birnbaum model did not fit items 3, 7, 10, 8, 19. Thus, by the R language tools, it was established which items correspond to the Rasch model and the two-parameter Birnbaum model.

5 DISCUSSION

The purpose of this paper was to automate the process of testing students' knowledge, which is especially relevant for distance learning. To achieve this goal an adaptive testing algorithm based on the Rasch model was proposed and the modeling of the students' knowledge assessment process using this algorithm was carried out. The results of testing their knowledge in the course "Higher Mathematics" obtained in the Moodle system were taken as the initial values of the tasks complexity and the levels of the students' ability.

As a result of modeling, the levels of students' abilities were recalculated. the information functions of the test tasks and the entire test as a whole were built. the standard measurement error was calculated. depending on the student's ability level. The analysis of the obtained results allows us to conclude that the test is not balanced and contains too many easy tasks. They are tasks with numbers 1, 3, 11. Removing them from the test will reduce the number of test items and speed up the process of determining the student's level of training.

A change in the assessment of the student's ability level as a result of testing indicates the need to introduce an adaptive testing system into the educational process which will improve the quality of assessment of students' knowledge.

These conclusions are confirmed by the works of other authors. So in this paper (Al-A'ali, 2006) it was shown that the use of adaptive testing based on IRT made it possible to reduce the number of test tasks and increase the reliability of determining the level of student readiness. The effectiveness of the use of adaptive testing to improve the quality of pedagogical measurements is evidenced by the works (Weiss, 1982, 2004).

6 CONCLUSIONS

In connection with the development of distance learning, the problem of automating the process of evaluating students' knowledge is becoming important. To solve this problem, the achievements of modern testing theory IRT were used. Mathematical models of IRT provide the basis for building an adaptive testing algorithm that allows you to automate the process of knowledge assessment.

As a result of this work, the following results were obtained:

1. An algorithm of adaptive knowledge assessment based on the IRT approaches was proposed. This algorithm consists of an initial assessment of the difficulty level of test items and students' abilities, scaling of these parameters, selection of the next question based on minimizing the module of their difference and estimation of the measuring error of the knowledge level by the information function of the proposed question.
2. The test parameters were evaluated on the basis of IRT theory, which identified non-informative test questions that should be excluded from the set of test items.
3. The correspondence of the experimental data to the Rasch and 2PL Birnbaum model was assessed based on the Pearson's chi-squared test by using the language R, which made it possible to identify tasks that require replacement or processing.
4. The quality of the test was examined using three IRT models (Rasch model, 2PL and 3PL Birnbaum model), which allowed for a more careful selection of test items.

The results of the study showed the effectiveness of using IRT to assess knowledge. An analysis of these results allows us to conclude that the use of the IRT methods to build an adaptive algorithm will automate the process of knowledge assessment and increase the objectivity of assessment in distance learning. The use of several mathematical models in the adaptive algorithm makes it possible to choose among them the one that best fits the experimental data, which will improve the accuracy of assessing the student's knowledge.

In the future, we plan to improve the adaptive algorithm for assessing educational achievements by combining the Knowledge Space (KS) and IRT (Muñoz-Merino et al., 2018).

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Development of the Certification System of Educational Resources

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Abstract: The article is devoted to the coverage of research on the development of system of internal certification of e-learning courses (hereinafter - ELC), which was carried out for several years with the aim of modeling the system of internal certification of educational resources for mixed and electronic learning in higher education and the creation of quality educational resources for blended and e-learning in Higher education. The authors describe the prerequisites for the internal certification system modeling and the features of recent changes in the process of internal certification of educational resources, approved by the university regulations, which is related to the requirements of the situation with COVID-19. The article describes the current model of the system of internal certification of educational resources, which is based on the approbation of the pilot model of ELC certification. The key components of the internal certification system are three mandatory expertise (professional, resource and technical). Based on the results of which, the methodological commission decides on the quality of educational resources of the ELC and its certification. Expectations from the current system of internal certification of ELC implementation were justified to a high degree, in particular, we have the following ad-vantages of their use: the creation of quality educational resources, expanding access to various categories of participants in the educational process to educational content; ensuring the individualization of the educational process under the needs, characteristics and capabilities of learners; improving the quality and efficiency of the educational process through the use of digital and innovative educational technologies; ensuring systematic monitoring of the quality of education, implementation of blended and e-learning in higher education.

1 INTRODUCTION

Students and teachers of Ukrainian universities are in a situation of limited access to classrooms due to active hostilities, and before that in connection with the COVID-19 pandemic. For higher education, the transition to blended and e-learning is the best way to organize learning. Today, all teachers understand and support changes in many dimensions of higher education and the transformation not only of approaches to the educational process, but also of their consciousness, psychological attitude and motivation to actively use e-resources in the implementation of blended learning and e-learning (Morze et al., 2018; Velykodna, 2021).

Also, general global trends in education need a transformation of pedagogical approaches, because, on the one hand, generations of students who need modern quality resources and greater use of digital tools, on the other hand, the challenges of the COVID-19 pandemic and the war of February 24, 2022 do not leave our country has alternatives in choosing the form of education (Hrynevych et al., 2020b,a). The implementation of blended and e-learning further stimulates the development of a system of certification of educational resources for the creation of quality educational materials in various electronic formats by introducing quality assessment of educational materials used by students.

Higher education institutions try in different ways to solve the issue of ensuring the quality of e-learning, including e-courses and e-content through the development of standards and the creation of e-learning systems (Abdel-Haq and Asfoura, 2021), implementing many-sided evaluation of e-learning and digital competences of teachers (Al-Hunaiyyan et al., 2021). An important factor influencing the quality of educational e-resources is determined by their students' assessment both in the process of use and upon completion of work in e-courses through various surveys (Kaewsaiha and Chanchalor, 2021; Sultan et al.,

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2021).

To develop an internal certification system of educational resources, it is necessary to develop criteria for creating quality educational resources and their comprehensive evaluation, which includes evaluation of e-course students, examination of e-resources and determining the technological feasibility of e-course components.

From this point of view, the preparation of quality educational resources for higher education can be provided by the university internal certification system of educational resources. The study, aimed at studying the impact of the system of internal certification of educational resources for blended and e-learning at the university took place in several stages:

1. Creating an internal certification system of educational resources:
   - Creation of a pilot model for certification of e-learning courses (hereinafter – ELC).
   - Approbation of the pilot model of certification of electronic training courses
   - Development of an internal certification system of educational resources for blend-ed and e-learning in higher education institutions
2. Active promotion of criteria for the quality of educational resources in e-courses through training for the vast majority of university teachers, depending on the level of their digital competence. For this purpose, the curriculum of the course "Digital Module" and the corresponding e-course in the e-learning system of the university have been created.
3. Creation of the Corporate standard of digital competence of the university teachers. The approbation pilot model for e-course certification, those ELC which teachers created as an additional resource to support academic disciplines, was tested by collectively discussing the results of the implementation. At the same time, trainings were held for teachers who wanted to be at the forefront of promoting blended and e-learning at the University. The research was managed by IT in Education Laboratory together with institutes and faculties of Borys Grinchenko Kyiv University.

The development of the system of internal certification of educational resources for blended and e-learning took place at the University level and resulted in the approval of the Regulations on the creation and certification of e-learning courses, which is the main tool for the internal certification of educational resources offer for University (Reg, 2020). It should be noted that until the approval of the internal certification system to ensure education at the University, only 9% of certified ELC were used for bachelor's degree, and 18% for master's degree (Buinytska and Vasylenko, 2020).

The current model of the internal certification system of educational resources is described in the articles (Morze et al., 2016; Buinytska and Vasylenko, 2022).

Research and intermediate results of the process of development of the internal system of certification of educational resources are described in the article below.

2 THE ELC DESIGN IN THE E-LEARNING SYSTEM

The university e-learning system is a special educational portal built on the Moodle platform (modular object-oriented dynamic learning environment), which allows you to create learning material that is stored as a structured ELC and through which is implemented as blended and e-learning links. The e-learning system is designed to provide the educational process at the university.

For effective work of teachers and students in the e-learning system were created personal digital cabinets of users (students, teachers, administrators), which provide quick access to useful digital resources: class schedule, means of communication and cooperation with colleagues and students, libraries (scientific materials, access to scientometric databases, etc.), electronic portfolio systems, search for scientific publications and checking student work for plagiarism, questionnaires for students to assess ELC, catalog of courses of choice for university students and other useful links (Ogneviuk et al., 2020; Buinytska, 2016).

In the personal cabinet, teachers have the opportunity to use filters to show the ELCs they are currently working with, view their own workload, work with the automated module "Individual teacher plan" and so on.

ELC are formed automatically in accordance with the curricula of higher education students in the academic/educational professional program of the university. The ELC is developed by authors, which can be a teacher or a team of teachers, who are appointed by the decision of the department of the university from among the academic staff/professors/lecturers/employees of the university. In the future, teachers are enrolled in the ELC and their role is defined: author, author-teacher, teacher with appropriate levels of access.

The developed ELC is the property and intellectual property of the University and must have a unified structure and meet the following characteristics:

- structured teaching and methodical materials;
- logical configuration of the discipline studies;
- a clear schedule for students to complete the curriculum;
- the system of interactive interaction of participants of educational process among themselves, means of resources of ELC and technologies of distance learning, during all time of studying of discipline is adjusted;
- high-quality training materials that allow the form of competencies declared in the working program of the academic discipline;
- system of control and evaluation of all types of educational activities of students.

Electronic resources included in the ELC have two types according to the level of student activity. Resources are designed to provide students with the content of educational material, such as structured electronic lecture notes, multimedia lecture presentations, audio and video materials (podcasts, videocasts, webcasts, etc.). And methodical recommendations, resources that ensure the development of the studied material, the formation of skills, acquisition of general and special (professional) competencies, self-assessment and evaluation of educational achievements of applicants, for example: tasks, testing, questionnaires, forums, etc. including the use of digital technologies. The digital learning technologies encourage the development of cognitive, creative, communicative and collaborative skills (Leshchenko et al., 2020; Buinytska and Vasylenko, 2019) using ELCs, which are developed for each discipline of the curriculum.

3 UNIFICATION OF THE ELC STRUCTURE

The structure of the ELC is unified for easy use by students. The structure of the ELC needs obligatory components of the ELC, approved by the Regulations on the procedure for creating e-learning courses, their certification and use in the e-learning system of Borys Grinchenko Kyiv University (Sultan et al., 2021):

1. The section with the description of ELC contains an indication of the Academic/Education Professional Program with title and educational level; contains the reference to the actual working program of educational discipline in the Institutional repository; general information about the discipline through resources: working program - syllabus; evaluation criteria; printed and Internet sources; glossary; announcements; information about the author (figure 1);
2. Teaching and methodical materials from each content module (figure 2):
   - theoretical material (structured electronic learning materials, manual in the form of resources Lecture or Book, multimedia presentations of lectures, audio, video, animation learning resources, a list of printed and Internet sources);
   - practical/seminars/laboratory works (content, methodical instructions on their performance, list of tasks, form of presentation of results of performance, terms of performance, evaluation criteria);
   - tasks for individual work of applicants (content, guidelines for their implemen-tation, list of tasks, form of submission of results, deadlines, evaluation criteria);
   - module control (control questions, tasks, form of work submission, deadlines, evaluation criteria);
3. Materials for the final control in the form of an examination (description of the procedure, examination program or references, indicative list of questions, evaluation criteria); in the resource Exam give a brief description indicating the procedure for the exam and evaluation criteria.
4. Additional materials.

   Special conditions: if the course is practical, it is advisable to present theoretical in-formation in at least one general resource Lecture or Book; for courses where listening, speaking, etc is obligatory, the form of submission of the completed work in the form of audio or video file, communication/interview in voice or video chat is allowed.

4 THE ELC INTERNAL CERTIFICATION SYSTEM

4.1 Model of the ELC Internal Certification System

The process of testing the pilot model lead to its significant modeling and design of a qualitatively new

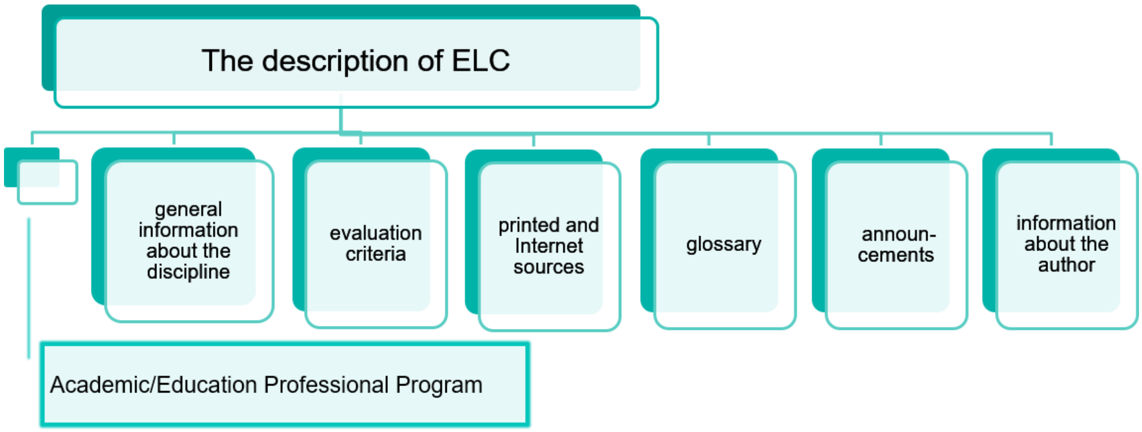

Figure 1: Description of ELC section.

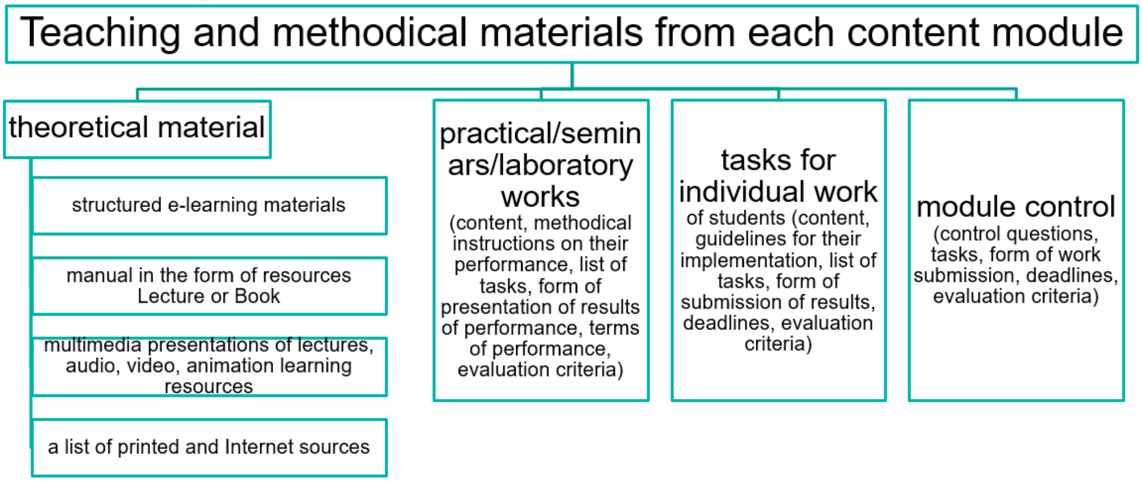

Figure 2: The module content.

integrated system of internal certification of educational resources for blended and e-learning (figure 3).

The ELC internal certification system is regulated by the approved Regulations and, accordingly, is carried out monthly following the decisions of the Academic Councils of the institutes and faculties of the university.

The main processes of the certification system presented in the model are: ELC design; organization and conduct of expertise; analysis of expertise results and certification decision-making.

During the professional expertise the scientific level of the course materials is determined, the correspondence of all created resources to the working programs, goals and objectives of the discipline. The relevance of the content, novelty of the submit-ted material, its completeness and logical consistency, content and methodological expediency of the created resources, methodological aspects of the course organization, pedagogical and psychological bases of organization of students' and pedagogical staffs' educational activity, their interaction, organization of control system are analyzed.

The procedure for managing a professional expertise includes the following steps:

- appointment of experts by the director dean of the structural unit;
- online expertise by appointed experts with conclusion;
- discussion of the results of the expertise at the meeting of the department.

The expertise of ELC resources is carried out by the ICT Assistant Director/Dean and involves the analysis of the availability of obligatory ELC components and the determination of the level of compliance of each component with the requirements specified in the regulation. The passing score for the expertise of ELC resources for further submission for technical examination is 70 (out of 130 possible).

The professional expertise and expertise of resources takes place in the first two weeks of the cur-

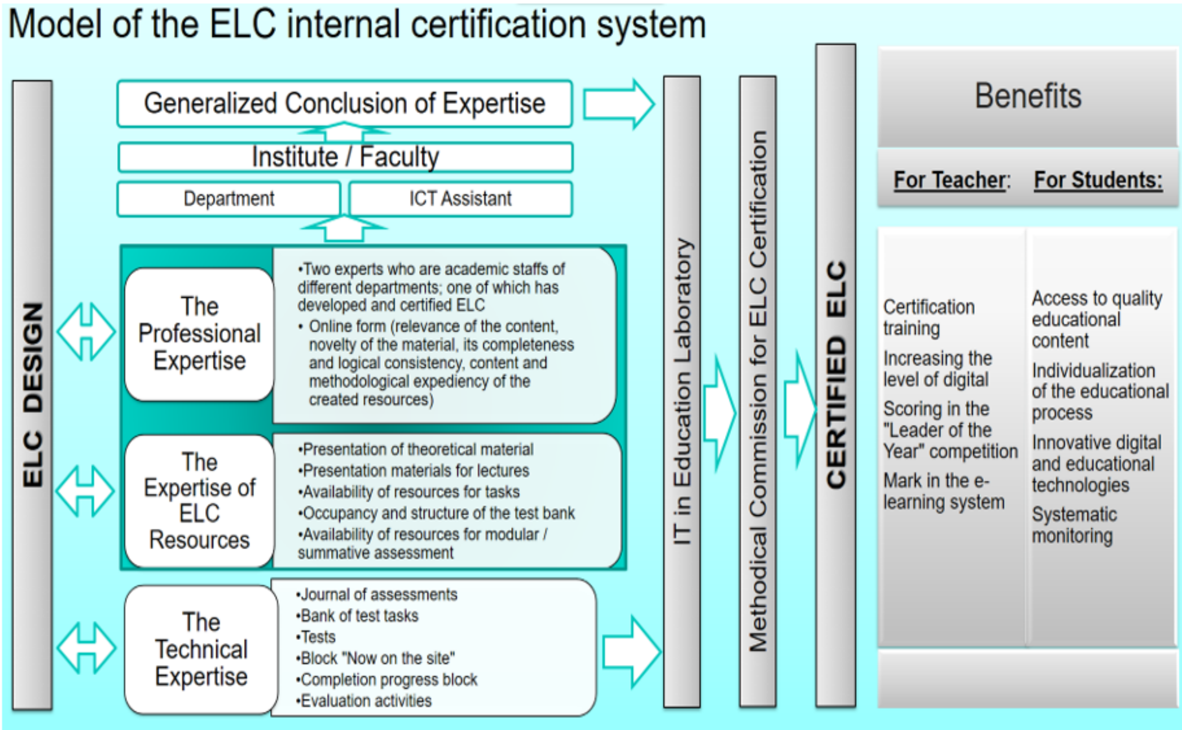

Figure 3: Model of the ELC internal certification system.

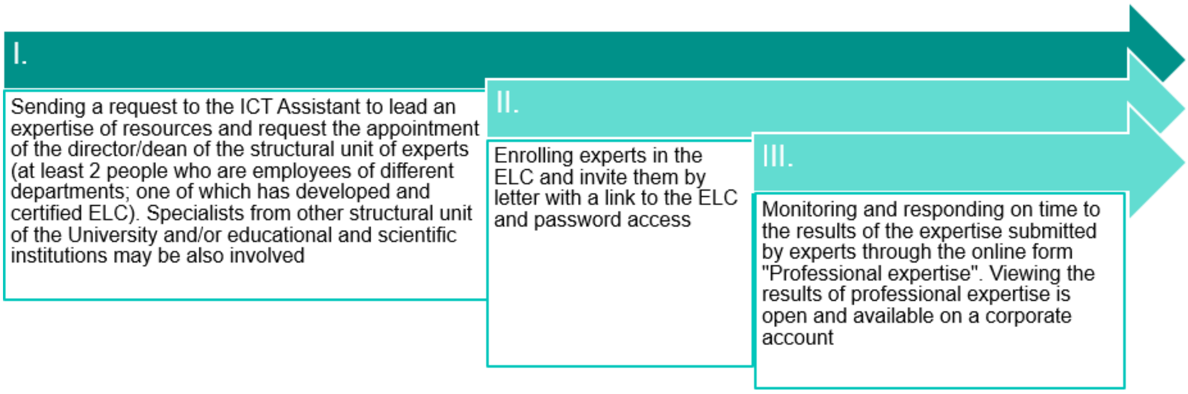

Figure 4: Key-steps of the ELC Internal Certification.

rent month, after which the ICT assistant can acquaint the author/authors with the conclusions of the expertise.

The generalized conclusion of the ELC examination is signed by the director/dean and submitted by the ICT assistant to IT in Education Laboratory.

The technical expertise of the ELC is carried out by the IT in Education Laboratory at the request of structural units with obligatory monitoring in an online document, which is set up open access for viewing to all participants in the educational process. Technical expertise provides an analysis of the implementation of system-wide requirements: the correct operation of the Journal of Assessments; optimal filling of the test bank; correct test setup; availability and settings of blocks “Now on the site”, “Progress of completion”; setting deadlines for tasks.

4.2 Key-steps of the ELC Internal Certification

The ELC certification decision is made by the methodical commission for ELC certification, the composition of which is approved by the order, is adopted collectively based on the generalized conclusion of the head of structural division based on conclusions of expertise.

Authors should initiate ELC certification and take the following steps (figure 4):

I. Send a request to the ICT Assistant to lead an expertise of resources and request the appointment of the director/dean of the structural unit of experts.
II. Enroll experts in the ELC and invite them by letter with a link to the ELC and password access.
III. Monitor and respond on time to the results of the expertise.

The results of each stage of certification are reflected in a free-to-view document, which allows authors to make adjustments to the submitted ELC in accordance with the submitted recommendations.

5 THE IMPACT OF THE ELC INTERNAL CERTIFICATION ON THE QUALITY OF LEARNING RESOURCES FOR BLENDED AND E-LEARNING

In a pandemic, the university's educational process was organized using e-learning, to ensure which the university's e-learning system was used quite actively in combination with online communication and collaboration tools (Buinytska and Vasylenko, 2020).

The number of activities by both teachers and students of higher education has increased many times, which confirms a significant increase in the use of ELC. The number of actions of students in 2020 exceeded 9 million and, compared to 2019, increased more than 3 times, teachers – exceeded 2,5 million, an increase of 4 times, due to the processing of educational material, performance and loading of tasks applicants, checking the downloaded tasks, as well as filling the ELC with educational content and keeping a journal of assessment by teachers.

Ensuring the quality of educational resources with which students work has become an important task for the University teachers.

The number of ELCs created in 2020 has almost doubled compared to 2019, which made it possible to provide ELCs to almost 90% of disciplines, of which 60% of ELC are fully developed and fully used in the study of disciplines, others are gradually filled with educational content and used for keeping a log of assessments.

Analysis of ELC that are actively used in the educational process confirms an increase in active ELC by 1,5 times compared to 2019 (figure 5).

Students rated the ELC on a five-point scale from 0 to 5, according to the proposed criteria: Clarity; Accessibility; Relevant; Creativity; Expediency. The evaluation of the ELC in 2020 compared to 2019 remained almost at the same high level of evaluation.

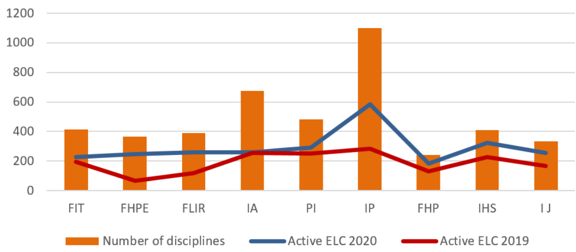

Figure 5: Comparison of the number of Active ELC.

The ELC score in 2021 has significantly increased compared to 2020. The 2020 and 2019 estimates were almost at the same high valuation level. This is a confirmation of the development of the internal certification system of ELC, the effectiveness of conducting systematic trainings for teachers and the implementation of the Corporate Standard of Digital Competence of University teachers (figure 6).

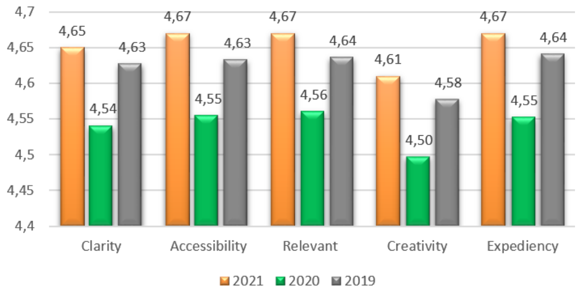

Figure 6: The results of ELC assessment by students.

The observed decrease in the assessment of ELC exhibited by students is caused by the creation and simultaneous use of them during a pandemic, in the mode of full distance learning. Among the reasons are: during the transition to distance learning teachers and students experienced technical difficulties (the need to create activities quickly; insufficient level of digital competence of teachers, psychological barriers to using e-learning, sometimes poor access to the Internet). In 2020, teachers began to use the e-learning system in extreme conditions, not all were fully created ELC, some ELC contained only checkpoints for scoring to form a journal of grades, so students objectively more rigorously assessed ELC in the e-learning system already having a large number of ELC for comparison.

The analysis of the evaluated ELCs confirms the use of ELCs that were filled with content at the same time as the classes, as only 22% of the evaluated ELCs were certified and, accordingly, the level of evaluation of such ELCs averages 4,6 out of 5,0, which remains at levels of 2019.

According to the results of student assessment, certified ELCs are qualitatively developed, the resources presented to them are clear, accessibility; relevant; creativity; expediency and they are sufficient to master the discipline (figure 7). This study was conducted until 2021, and based on its results, it was decided that students will only evaluate certified ELCs.

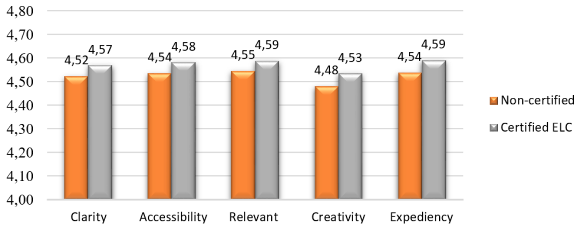

Figure 7: Comparison of assessment of certified and non-certified ELC.

In 2021 and 2020, the percentage of ELC certification remains at a high level of 93%, which is an increase of 20% compared to 2019 (72%) and indicates a positive trend in providing disciplines with certified ELC (figure 8).

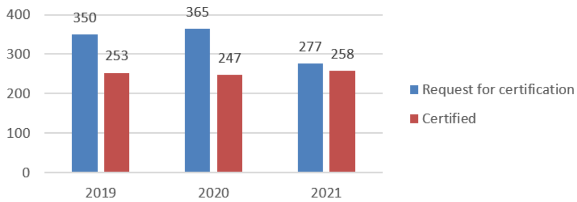

Figure 8: Dynamics of ELC certification.

The positive trend of increasing the number of certified ELCs confirms the need for them by students and teachers. That is why the introduction of the internal certification system justifies an important role in the preparation of quality educational resources and in general in the modernization of the e-learning system of the University now and in the future.

In particular, the opportunity has already been realized for students in a separate ELC not only to have access to educational materials 24/7/365, but also to monitor the progress of personal educational activities. The introduction of the ELC internal certification system has prompted the creation of academic/educational professional programs in the e-learning system, the main advantages of which are the student's ability to see a list of all disciplines to study during semesters and scores in disciplines (figure 9).

The implementation of Academic/Educational Professional Programs in the e-learning system has provided the structuring of the e-learning system, access to educational resources of all disciplines of the curriculum; made it possible to carry out constant monitoring of the provision of academic disciplines with the relevant ELC, the level of their development and certification. It is due to the functioning of the internal certification system that there is an increase in the percentage of quality ELCs that have the status of certified. In the future, it is expected that 100% of all educational programs will be certified by ELC.

Part of the ELC internal certification system is the automated control "Report by the department", which reflects the percentage of certified ELC, provided by the curriculum in graphical form (figure 10).

When deploying such a report, the e-learning system displays a complete list of names of disciplines for which ELC are developed and used and which of them are certified, which encourages teachers to improve the ELC used and initiate their certification. The analysis of the results of the implementation of the ELC internal certification system shows its positive impact on the quality of educational resources and the provision of educational services in general.

6 DEVELOPMENT OF THE ELC INTERNAL CERTIFICATION SYSTEM AND ITS IMPACT ON TEACHERS' USE OF THE E-LEARNING SYSTEM FOR BLENDED AND E-LEARNING

The certification process is a formal procedure and is mandatory for those teachers who wish to extend their employment contract at Grinchenko University. But without a detailed model of the system and the requirements for ELC resources without additional training, it is difficult for teachers to create materials in accordance with the declared quality criteria. Therefore, for the development of ELC Internal Certification System there is a system of increasing digital competence in several schemes. One of them is the involvement of teachers to participate in mastering the Digital Module (figure 11), which aims to increase the level of digital competence of scientific and pedagogical, scientific and pedagogical staff of the university, their ability to effectively use digital technologies in the educational process. The program of the module involves the study of the following topics:

1. Modern educational trends and ways of introduction into the educational process of innovative technologies. 21st century skills and digital skills.
2. Blended and e-learning. E-learning technologies. Resources for creating e-content and criteria for its evaluation.

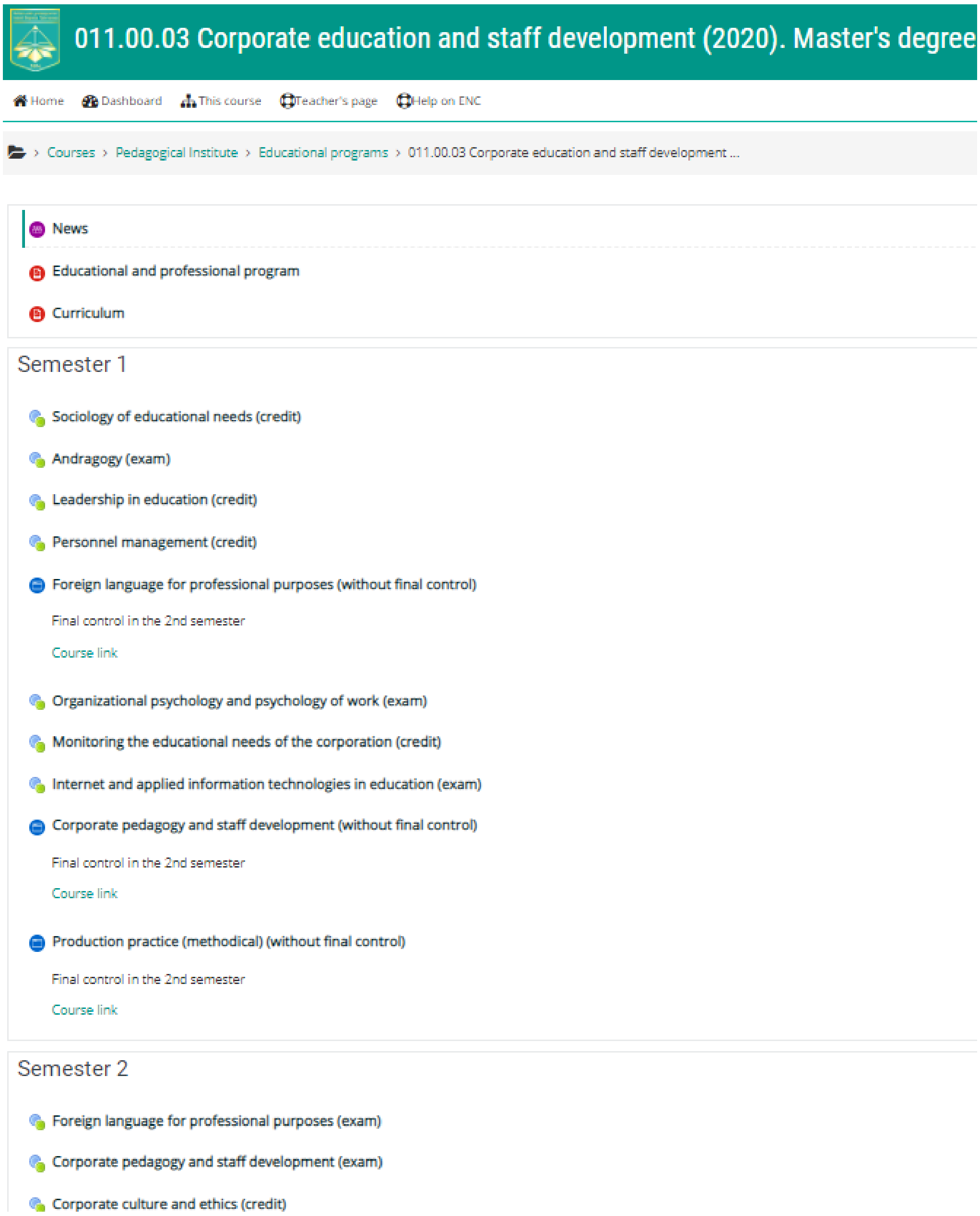

Figure 9: Academic/Educational Professional Programs in the e-learning system.

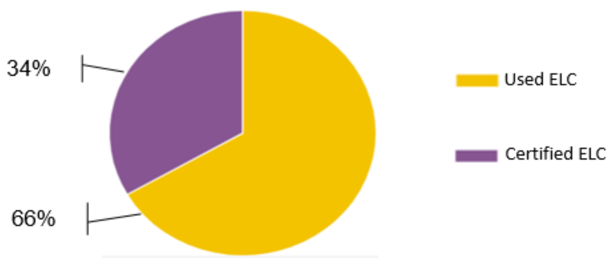

Figure 10: Representation ELC in “Report by the department”.

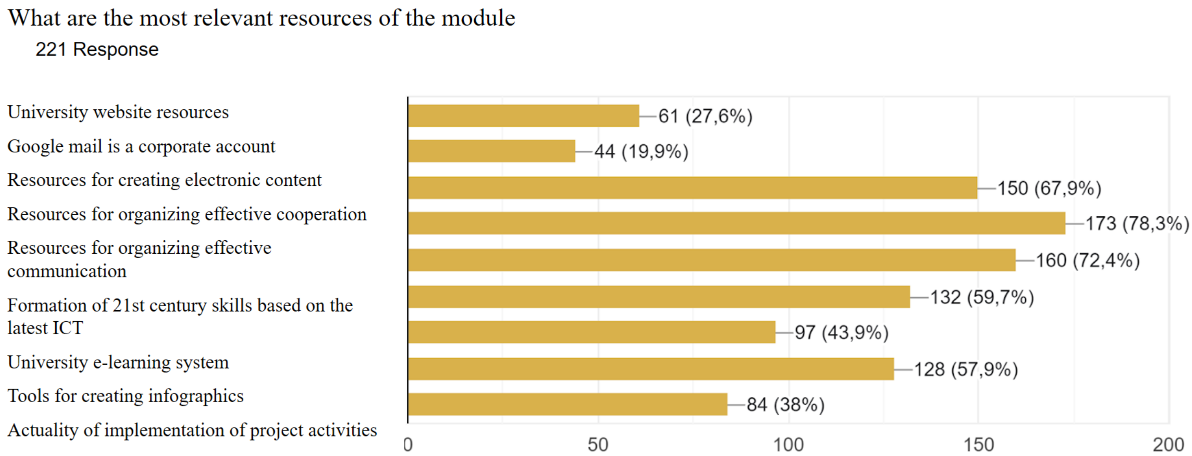

Figure 11: Representation about relevant resources in the Digital Module.

3. Online services and digital technologies of effective communication.
4. Online services and digital technologies of effective collaboration.
5. Online services and digital technologies for formative assessment.

Answering the question about the most relevant resources, the majority chose resources for creating e-content, Resources for organizing effective collaboration, re-sources for organizing effective communication, University e-learning system, Tools for creating infographics.

The developed and approved Corporate Standard of Grinchenko University Teacher Digital Competence (Corporate Standard of Digital Competence, 2021) describes the use of digital skills in the main areas of activity of the teacher, in particular research, educational activities, digital self-management, professional communication and cooperation. The standard defines five levels of digital competence: Research Analyst – A, Integrator – B1, Expert – B2, Leader – C1, Innovator – C2. In accordance with these levels, detailed descriptors were developed, which are the basis of the newly created adaptive system for the development of the teacher's digital competence, access to which is implemented in the personal office of the University teacher.

7 CONCLUSIONS

The development of the system of internal certification of educational resources after the approval of the pilot model of ELC certification confirms the effectiveness of its use and the expediency of further work.

A system of internal certification of educational resources for blended and e-learning can be recommended for implementation in higher education institutions.

The three independent and diverse expertise (professional, resource and technical) that underlie the system of internal certification and evaluation of ELC by students ensure high quality educational resources and, as a result, the quality of educational services. In the future, it is planned to achieve 100% ELC certification for all educational programs that train professionals with a sufficient level of digital and professional competence and are competitive in the labor market.

The development of the internal certification system encourages teachers to increase the level of technical and professional competence, allows you to increase your rating among university teachers; expand the use of digital technologies in the educational process; the creation of modern educational digital resources taking into account the peculiarities of the styles of material perception and the design of criteria for assessing their quality; using digital tools for effective communication and collaboration in blended and e-learning; development of abilities and a sense of the need for constant self-development and self-improvement. On the other hand, teachers, having tools and opportunities for self-development, create high-quality e-content for teaching students.

According to the purpose of the research, we have achieved very important results and have the following advantages:

- quality educational resources,
- expanding access to educational content;
- the individualization,
- improving the quality and efficiency of education through the use of digital and innovative educational technologies;

• monitoring the quality of education.

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The Taxonomies of Educational and Scientific Studies Role in Centralized Informational Web-Oriented Educational Environment

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Keywords: Cloud Technologies, Ontology, Educational Research, Taxonomy, Systematization.

Abstract: The scientific/educational studies may be structured using the formalization of IMRAD approach that provides interoperability of data. The study focusing on the using of the studies' results as part of the centralized informational web-oriented educational environment. The structurization was provided on two studies – "Development of a rational approach for utilizing methane tank waste at LLC Vasylkivska chicken farm" and "Development of a strategy for utilizing methane tank effluent". The specific tools of CIT Polyhedron were used to make specific tools related to processing of studies data. The audit tool provides comparing the newly inputted data to existing data in taxonomies and highlights the cases of full corresponding of some elements of works for existing ones (for example, objects of studies). The approach of integration of studies with educational ontologies (that is part of centralized informational web-oriented educational environment) is described. The formalization of this process is described using mathematical expressions.

1 INTRODUCTION

Now, more than ever, science affects all aspects of human life. The latest scientific developments are often and quickly implemented in the industry. However, the scientific results are usually presented in human-readable form and not in a machine-readable format, so it is hard to process the knowledge using automated informational technologies.

The basic structure of a typical research paper is the sequence of Introduction, Methods, Results, and Discussion (sometimes noted as IMRAD) (Oriokot et al., 2011). Each section addresses a different objective. For example, the Introduction section motivates the research problem that was discovered or the known facts about the problem; the Method section states what authors did to learn and address the issue in a new solution, and what they achieved as results in experiments is written in the Discussion section, and what they had observed is discussed in the Results section.

The most common form of science reporting is a written paper. Depending on the purpose, there are a few different types of papers: Analytical Research Paper, Argumentative (Persuasive) Research Paper, Definition Paper, Compare and Contrast Paper, Cause and Effect Paper, and Interpretative.

The most common research papers types are shown in table 1 (Paperpile, 2019).

Nowadays, most of the papers (but not all of them) are systemized by using scientometric databases. However, educational research reports, which use scientific methods, have not been systemized. Unlike pupils, scientists already know their field of research in detail and can determine their research hypothesis, and they can do further analysis by themselves. Students, instead, can't do this. Automated informational tools can help students in this scientific discovery and analysis tasks.

The STEM (Science, Technology, Engineering and Math) may be interpreted as using of the scientific method in an educational process while providing academic research. This approach is only recently applied in countries such as Ukraine. There are various school competitions for scientific works,

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Table 1: The most common research papers types.

Types of the Research papers	Oriented amount of words required	Specific characteristics
Analytical Research Paper	3000+	Someone poses a question and then collect relevant data from other researchers to analyse their different viewpoints.
Argumentative (Persuasive) Research Paper	3000+	The argumentative paper presents two sides of a controversial question in one paper.
Definition Paper	5000+	The definition paper describes facts or objective arguments without using any personal emotion or opinion of the author.
Compare and Contrast Paper	5000+	Compare and contrast papers are used to analyse the difference between two viewpoints, authors, subjects or stories.
Cause and Effect Paper	3000+	Cause and Effect Paper trace probable or expected results from a specific action and answer the main questions “Why?” and “What?”.
Interpretative Paper	3000+*	An interpretative paper requires to use knowledge that have gained from a particular case study.
Experimental Research Paper	3000+*	This type of research paper describes a particular experiment in detail.
Survey Research Paper	5000+*	This research paper demands the conduction of a survey that includes asking questions to respondents.

* Depends on the purpose of the article and the requirements of the journal, institute, teacher.

such as the competition on scientific articles of the Junior academy of sciences of Ukraine and international competitions (Intel ISEF). Also, the scientific method can be used during the creation of thesis papers (for masters’ degrees, bachelor’s degrees, etc.) and pupil’s research reports. (for events noted before), or in simpler, but more common form of essays. In addition, students can report their results in scientific papers if the quality of their work is satisfactory for the scientific requirements. An overview of the types of educational research reports works is presented in table 2. This paper focuses on the systematization and processing of academic research reports. The problem to be addressed is the lack of a structuring mechanism that complicates the automated processing of such reports.

2 LITERATURE REVIEW

The active dissemination and use of different scientometrics databases continue to increase the convenience and efficiency of scientific data processing, structuring, and systematization of research and scientific results. Specialized databases for structural science information are an integral part of the information-support system for any scientist. Scientometrics is the “quantitative study of science, communication in science, and science policy” (Ramesh Babu and Singh, 1998), commonly referred to as the “science of science”. Scientometrics is essential to help academic disciplines understand various aspects of their research efforts, including (but not limited to) the productivity of their scholars (Ramesh Babu and Singh, 1998; Abramo et al., 2011), the emergence of specializations (Pianta and Archibugi, 1991), collaborative networks (Newman, 2001), patterns of scientific communications (Braun et al., 2001), and quality of research products (Lawani, 1986). Metric studies have been developed as a subsidiary branch of Library and Information Science (LIS) (Khasseh et al., 2017). Often, scientometrics applies bibliometrics, which measures the impact of publications.

To increase the quality and performance of scientometrics the ten principles of the “Leiden Manifesto of Scientometrics” have been stated:

1. Quantitative evaluation should support qualitative expert assessment.
2. Measure performance against the research missions of the institution, group, or researcher.
3. Protect excellence in locally relevant research.
4. Keep data collection and analytical processes open, transparent and simple.
5. Allow those evaluated to verify data and analysis.

Table 2: Types of the educational research reports.

Types of the educational research report	Oriented required amount of the pages	Specific characteristics	The event for which the report was prepared
Esse	In general, up to 10-15 pages	Is simple and very flexible on the content	Classes, completions of school level
Research reports	In general, up to 30-100 pages	Relatively static structure; similar to IMRAD	Competitions of Junior academy of sciences of Ukraine and Intel ISEF
Scientific paper	Declared by the source	Declared by the source	Publication in the journal
Thesis papers	In general, 40-100 pages	Relatively static structure similar to IMRAD	Defence of the qualification works

6. Account for variation by field in publication and citation practices.
7. Assessment of individual research on a qualitative judgment of their portfolio.
8. Avoid misplaced concreteness and false precision.
9. Recognize the systemic effects of assessment and indicators.
10. Scrutinize indicators regularly and update them (Khasseh et al., 2017).

Today, all existing scientometrics databases can be divided into two major groups: international and national (Khasseh et al., 2017; Kostenko et al., 2015; Mulla, 2012; Ravikumar et al., 2015; Pavlovskiy, 2017; Perron et al., 2017; Ramírez and Rodríguez Devesa, 2019). The most well-known international databases are Springer, Scopus, Web of Science, CiteseerX, Microsoft Academic, aminer, refseek, BASE (Bielefeld Academic Search Engine), WorldWideSciense, JURN, Google Scholar, Google Patents, and others. National databases incorporate a variety of bibliographic databases and a variety of library and university repositories. International scientometric databases are characterized by a larger scale and mandatory support for various languages, including English. Also, a characteristic feature of such databases is the availability and work with multiple unique indices that have international recognition, for example, the h-index (Kinouchi et al., 2018).

As scientific publications continue to grow exponentially, the number of academic databases and scientometrics databases increases, which supports gaining insights into the structure and processes of science (Perron et al., 2017). In this case, many scientific publications are devoted to the principle of working scientometrics databases, and their number is growing. Thanks to them, concepts such as "metadata" of scientific articles began to be actively used in scientometrics (Khasseh et al., 2017; Kostenko et al., 2015; Mulla, 2012; Ravikumar et al., 2015; Pavlovskiy, 2017; Perron et al., 2017; Ramírez and Rodríguez Devesa, 2019). Metadata is essential data about data providing information such as titles, authors, abstracts, keywords, cited references, sources, bibliography, and other data. Metadata does not substitute the corresponding article, but it explicitly describes valuable information about the report.

By using scientometrics systems, researchers' contributions in informatics and scientometrics were previously quantified (Mulla, 2012). The principal metadata indicators are:

- The indicators and citation indices of journals.
- The number of authors.
- The number of publications.
- The degree of cooperation is based on affiliation data.

The disadvantage of this research is that it is devoted only to scientific articles. The authors noted that their study could not cover students' and pupils' research reports because there is no single database where they are all located.

The application of the principles of the "Leiden Manifesto of Scientometrics" is stated and substantiated, providing transparent monitoring and support of research and encouraging constructive dialogue between the scientific community and the public. In this work, the bibliometric base, which corresponds to principles of the "Leiden Manifesto of Scientometrics", has been created. The proposed bibliometric center did not address the systematization of students' and pupils' research reports. Still, the authors noted the necessity of involvement of students' and pupils' research reports in their bibliometric center.

The approach of co-word analysis has been introduced, and its application in scientometrics is substantiated in (Ravikumar et al., 2015). The trends and patterns of scientometrics in journals has been revealed by measuring the association strength of selected keywords which represent the produced concept and idea in the field of scientometrics. Also, the authors have developed a web system for extraction of keywords from the title and abstract of the article manually. However, the web system proposed by them cannot work with research reports of students and pupils.

Another concept of analysis is iMetrics, or “information metrics”. Its application in scientometrics is substantiated in (Milojević and Leydesdorff, 2013). iMetrics is devoted to the scientometrics of scientific journals in the field of informatics. The authors note the possibility of applying their approach to the systematization of the scientific works of students and pupils. The research related to scientometrics databases is shown in table 3.

Table 3: Researche related to scientometrics databases.

Subject of study	The general result of the authors study
Citation indices of journals, number of authors of the publication their affiliation	The contributions of researchers in the field of informatics and scientometrics (Mulla, 2012)
Principles of the “Leiden Manifesto of Scientometrics”	Stated and substantiated “Leiden Manifesto of Scientometrics” (Kostenko et al., 2015)
Co-word analysis	The trends and patterns of scientometrics in the journals were revealed (Ravikumar et al., 2015)
iMetrics (“information metrics”)	iMetrics scientometric system has been provided (Milojević and Leydesdorff, 2013)

Previously, ontological graphs were used to systematize scientific articles (Amami et al., 2017; Boughareb et al., 2020; Perraudin, 2017; Parveen, 2018). Systematization and structuring in such graphs are based on different approaches, such as using of scientific article recommendation system (Amami et al., 2017), Scientific Articles Tagging system (Boughareb et al., 2020), machine learning (Perraudin, 2017), and automatic summarization (Parveen, 2018). Also, ontologies can be used to provide interoperability through semantic technologies (Alnemr et al., 2010). However, none of the proposed ontological approaches for systematization and structuring addresses the structuring of research reports of students and pupils.

None of the scientometrics database systems previously proposed (Khasseh et al., 2017; Kostenko et al., 2015; Mulla, 2012; Ravikumar et al., 2015; Pavlovskiy, 2017; Perron et al., 2017; Ramírez and Rodríguez Devesa, 2019) can offer a universal solution for systematization and structured presentation of research and scientific results to pupils and students. Also, the disadvantages of all these systems are the complete lack of many valuable parameters for processing information about scientific works. These parameters are the scientific novelty of the article, the practical value of the study, the hypothesis of the study, subject and object of the research. Also, existing solutions do not allow for comparing the meta data about the research reports between each other.

This work aims to propose and justify using an ontological system, which permits the systematization of scientific articles with all advantages of existing scientometrics systems and without disadvantages of these systems. Which at the same time will not be deprived of the functionality of current scientometrics systems and will meet the Leiden Manifesto for Scientometrics.

As Proof of Concept (PoC) we propose to use the existing cognitive IT platform Polyhedron as the technical basis for solving this problem. The core of the Polyhedron system consists of advanced and improved functions of the TODOS IT platform described in previous works. The polyhedron is a multiagent system that allows for transdisciplinary and acts as an interactive component in educational and scientific research (Stryzhak et al., 2014). Besides, the cognitive IT platform Polyhedron contains a function for comparison with standards which is called auditing (Stryzhak et al., 2014; Globa et al., 2015, 2019). Polyhedron provides: semantic web support, information systematization and ranking (Stryzhak et al., 2021), transdisciplinary support, and internal search (Shapovalov et al., 2019), has all advantages of ontological interface tools (Popova and Stryzhak, 2013), and the construction of all chains of the process of transdisciplinary integrated interaction is ensured (Velychko et al., 2017). Due to active states for hyper-ratio plural partial ordering (Volckmann, 2007; Nicolescu, 2008), the cognitive IT platform Polyhedron is an innovative IT technology for ontological management of knowledge and information resources, regardless of the standards of their creation. The user of the Polyhedron IT system has an opportunity to use an internal search function that has more views than the external one because it provides information created by experts.

Also, the proposed solution for the structuring of educational and research projects can be used together with other modern developments in the academic field, like a virtual educational experiment (Slipukhina et al., 2019), different tools to provide development of ICT (Modlo et al., 2018), the use of mobile Internet devices (Modlo et al., 2019), using the technology of augmented reality education (Bilyk et al., 2022), online courses (Vlasenko et al., 2020; Yahupov et al., 2020), distance learning in vocational education and training institutions (Modlo et al., 2019), educational and scientific environments (Shapovalov et al., 2019).

As was investigated before, the main elements of educational studies are represented by IMRAD nodes and their specific subnodes related to a particular study (Shapovalov et al., 2022). They may be described by a set of formulas. According to the theory of using IMRAD, each examination consists of an Introduction, Methods, Results, and Discussion (that in terms of informational systems, the discussion is charged to processing – P):

$$\{I, M, R, P\} \in S \tag{1}$$

where I – node of ontology that integrates data related to introduction; M – subject of study: node of ontology that integrates data related to methods; R – node of ontology that integrates data related to results; P – results of study's results processing.

Each scientific study contains specific data structured by IMRAD, and it may be represented as a set of tuples (corteges) that describe elements of specific studies. The equations 2 and 3 are used to describe representing two different studies structured by IMRAD:

$$S_I = <I_I, M_I, R_I, P_I> \tag{2}$$

$$S_{II} = <I_{II}, M_{II}, R_{II}, P_{II}> \tag{3}$$

Two different studies integrated into a single ontology will be described as the sum of IMRAD elements. Such representation is shown in equation 4:

$$\langle S_I, S_{II} \rangle = \langle I_I, M_I, R_I, P_I, I_{II}, M_{II}, R_{II}, P_{II} \rangle \tag{4}$$

In such case, some specific elements of studies are overlapping and other are not. For example, the Method section of two different studies represented in form of an ontology using IMRAD will be as follows:

$$M_I = M_a, M_b, M_c, M_d \tag{5}$$

$$M_{II} = M_b, M_d, M_f \tag{6}$$

In such representation M_b and M_d belong to both studies, and it is possible to use them as linking nodes to connect the two studies:

$$M_b \in M_I, M_{II} \tag{7}$$

$$M_d \in M_I, M_{II} \tag{8}$$

It is worth noting that such representation of studies leads to the ontologization of the studies' data. The most specific terms may be used to connect to different types of ontology-based knowledge, for example, educational programs. However, such an approach was not conducted before. This study also aims to provide interoperability between different ontology-based knowledge systems using terms used in conducted studies and other knowledge systems (on the example of educational systems).

3 MATERIALS AND METHODS

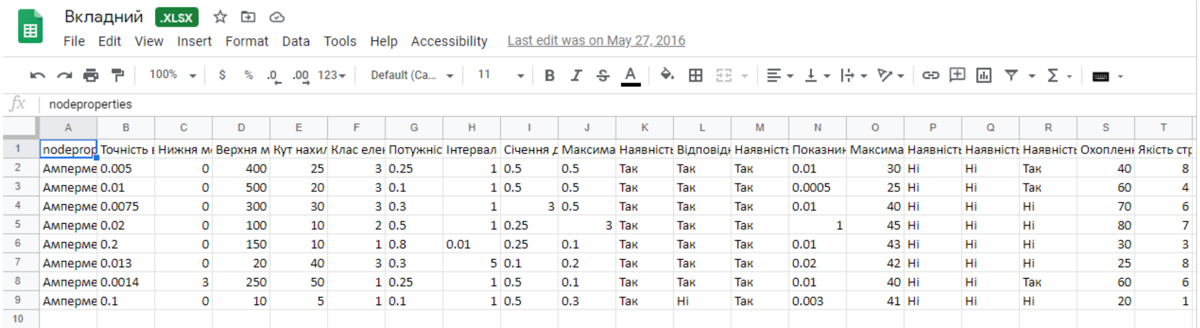
3.1 Ontology Creation Mechanism

To create ontologies in Polyhedron, Google Sheets were used to collect by expert who took the data manually and structuring the information (see example in figure 1). The sheets with research report data (structure file and numeric/semantic data file) have been downloaded and saved in .xls format. The files have been loaded to "editor.stemua.science", part of Polyhedron. After that, the generation of the graph nodes (in .xls) with their characteristics using the data structures in the file has been carried out. The obtained graphs have been saved in .xml format and located in the database. The graphs have been filled with semantic and numeric information for ranking and filtering. Ontological edges (relations) have been formed using predicate equations, as described previously in (Velychko et al., 2017).

3.2 Ranking Tools

Considering that, e.g., proposed reports "A" and "B" are technical, the results of the reported works can be used to analyze the rationality of the implementation proposed in the concrete project. For instance, to offer it, research reports "A" and "B" were also compared with each other using a ranking tool applying the following criteria: "Short-term economic perspective", "Long-term economic prospects". For creating a ranking, the ontologies have used the module "Alternative", described in (Stryzhak et al., 2021). The nodes of a graph have been filled with semantic data to provide this ranking.

The ranking uses a grade scale from one to ten points to underline the relevance coefficient. The projects with a payback period of more than 25 years have been evaluated with 1 point, with 20-25 years of payback period with 2 points, from 15-20 years of payback period with 3 points, from 10-15 years



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	nodeprop	Точність і	Нижня м	Верхня м	Кут нахил	Клас елек	Потужніс	Інтервал	Січення д	Максима	Наявність	Відповідн	Наявність	Показник	Максима	Наявність	Наявність	Наявність	Охоплен	Якість стр
2	Амперме	0.005	0	400	25	3	0.25	1	0.5	0.5	Так	Так	Так	0.01	30	Ні	Ні	Так	40	8
3	Амперме	0.01	0	500	20	3	0.1	1	0.5	0.5	Так	Так	Так	0.0005	25	Ні	Ні	Так	60	4
4	Амперме	0.0075	0	300	30	3	0.3	1	3	0.5	Так	Так	Так	0.01	40	Ні	Ні	Ні	70	6
5	Амперме	0.02	0	100	10	2	0.5	1	0.25	3	Так	Так	Так	1	45	Ні	Ні	Ні	80	7
6	Амперме	0.2	0	150	10	1	0.8	0.01	0.25	0.1	Так	Так	Так	0.01	43	Ні	Ні	Ні	30	3
7	Амперме	0.013	0	20	40	3	0.3	5	0.1	0.2	Так	Так	Так	0.02	42	Ні	Ні	Ні	25	8
8	Амперме	0.0014	3	250	50	1	0.25	1	0.5	0.1	Так	Так	Так	0.01	40	Ні	Ні	Так	60	6
9	Амперме	0.1	0	10	5	1	0.1	1	0.5	0.3	Так	Ні	Так	0.003	41	Ні	Ні	Ні	20	1
10																				

Figure 1: Google sheet with data.

of payback period with 4 points, 6-10 years of payback period with 5 points and with 1-5 years were evaluated as 6-10 points, respectively, by the "Economic attractiveness" criterion. A detailed evaluation for projects with 1-5 years is provided due to its utmost interest for the investor's "payback time", which determines investment expediency.

3.3 Auditing Tools

To provide an audit of the hypothesis of work "A" and "B", the "standard" graph (with which the comparison is done) and the "comparison" graph (which is compared with the "standard") have been created. The "standard" ontology graph contains the data on hypotheses, subjects, objects of research, keywords, and other parameters of the research reports done before. For the "standard" graph, each parameter was presented in a separate node. The content of this ontological graph "standard" is constantly updated and supplemented.

The nodes of the "comparison" graph have been represented as names of the works which need to be audited with the "standard" graph. The parameters of the work used to be audited with the "standard" graph have been located in the metadata of each separate node. The metadata type names were identical to the terms of the nodes of the "standard" graph to enable interaction between graphs.

3.4 Using Centralized Informational Web-Oriented Educational Environment Concept and Ensuring Interdisciplinarity

The developed ontologies were saved in the same environment where elements of the centralized informational web-oriented educational environment were saved. Its features were used to provide interoperability with educational programs, methods, equipment, ontology-based didactical materials, and other ontology tools. As all such ontologies had the same graphs' nodes names, we provided the integration between elements of the centralized informational web-oriented educational environment and proposed structurization of academic studies. We used the same nodes and provided links with each graph that it contains. For example, the term temperature regime that is used in educational programs is connected with all academic programs in physics (part of topic energy, thermal energy), chemistry (amount of topic energy of reaction), and scientific study graph that was conducted by young researcher on biogas production research called temperature regime. Also, we can link this term with a method called ensuring of requested temperature by a thermostat and with equipment dry air thermostat. So, for this, we are using the term temperature regime to provide an interdisciplinarity approach that is related to different fields of science and to varying types of data (educational plans, equipment that is used, specific methods and specific personal studies).

4 RESULTS AND DISCUSSION

The general concept of the proposed ontology-based graph model for Polyhedron research reports has a specific, logically connected structure and can be represented as an ontology. After structuring, it is possible to describe the reports' content in simpler to understand presentation form. Besides, most results can be domain-specific for each industry, and if the current standards are correctly identified, these values will be easy to compare. Also, most research in one field often uses the same equipment, materials, chemicals, standard methods of analysis, literature, etc., which allow comparing these works with each other and correctly structuring them.

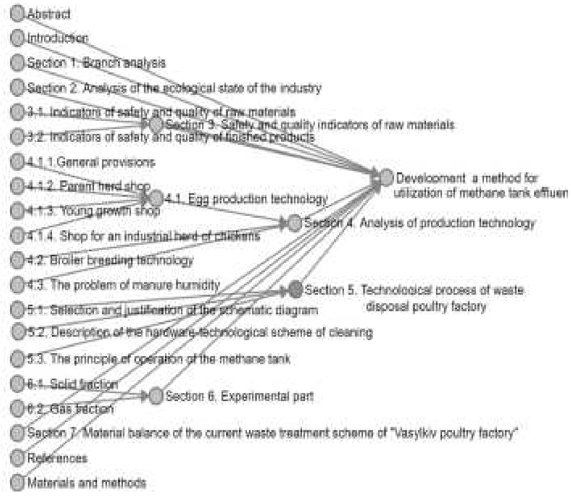
However, the main advantage of the proposed approach (besides structuring the research) is processing results in terms of separated result parameters of the reports. This supports data analysis, further processing using ranking, and semantic data interoperability. The separation of numeric data and its location metadata class is possible due to the addresses of the same field, describing the process using the same (or similar) parameters of the process description and result parameters description. For example, for most reports on anaerobic digestion, the process parameters are temperature, type of substrate, reactor volume, moisture content, initial pH, parameters; the characteristics of efficiency of the process are biogas yield, methane content, average pH during the process, destruction process, etc. (Zhadan et al., 2021).

As all research reports will be simplified, this approach will be especially relevant for pupils and novice researchers with further potential use in the educational process or to streamline the literature review process for the new academic research.

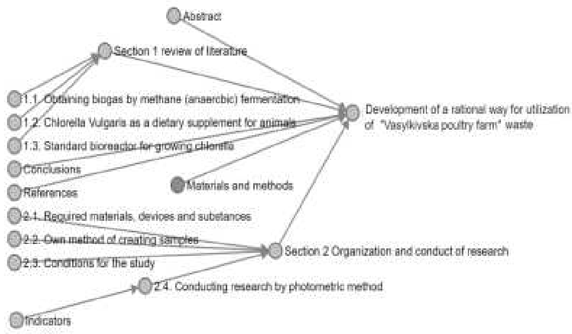
4.1 Description of Scientific Works Used to Provide Structuring

For example, the object of the study of research report "A" is the disposal of anaerobic effluent. The subject of the report's research is the Cultivation of Chlorella Vulgaris microalgae on effluent obtained after methane fermentation. The study aims to develop a method of growing Chlorella Vulgaris in the effluent after methane fermentation. The practical significance of this scientific work is the results, which will contribute to the spread of biogas technologies. Also, the proposed approach makes it possible to increase the economic benefits of utilizing chicken manure by converting the anaerobic digestion effluent into microalgae with a wide range of applications. The scientific novelty of that research report is a method of utilization of anaerobic digestion effluent by using microalgae, also had obtained cultures of Chlorella Vulgaris that had adapted to the anaerobic digestion effluent. The working hypothesis was that the effluent obtained after anaerobic digestion could be used as a nutrient medium for microalgae Chlorella Vulgaris.

The object of the research report "B" study is the disposal of anaerobic digestion effluent. The subject of the research is the processing of anaerobic digestion effluent into humates by the autocatalytic catalysis method. The study aims to establish regularities of processing the solid fraction obtained during the methane fermentation of chicken manure by the autocatalytic catalysis method. The practical significance of this scientific work is that the study indicates the possibility of acquiring salts of humic and fulvic acids by the autocatalytic catalysis method. This approach makes it possible to increase the economic benefits of chicken manure disposal by converting the anaerobic digestion effluent into a more valuable product with a wide range of applications. Its scientific novelty is that potassium humate had firstly obtained from anaerobic digestion effluent. For the first time, the efficiency of receiving humates from the solid fraction of anaerobic digestion was investigated, and the main regularities of the process were determined. The working hypothesis was that the solid fraction of methane fermentation of chicken manure can be recycled by the autocatalytic catalysis method.



(a)



(b)

Figure 2: The general view of the (a) research report "A" (b) research report "B" ontological graph.

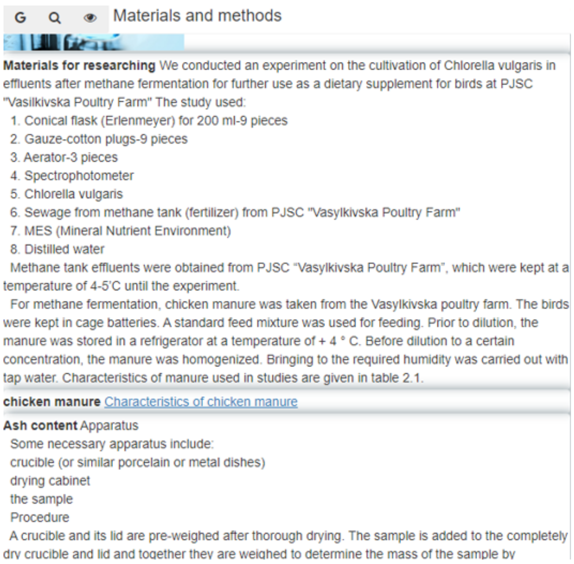
For both research reports, "A" and "B", as a substrate for anaerobic digestion, have used the chicken manure from the same poultry farm. In this case, chicken manure and its effluent, which has been obtained by anaerobic digestion, were analyzed by the same methods and indicators. Such indicators were:

- "Ash and dry content".
- "Determination of volatile fatty acids content" (in

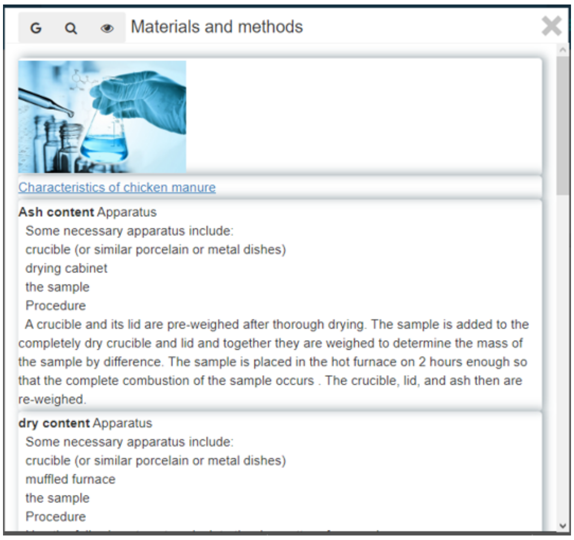
terms of acetic acid).

- “Determination of ammonium nitrogen content with Nessler’s reagent”.

The equipment used to determine these indicators was also the same. Therefore, how these works can be structured and integrated using the cognitive IT platform Polyhedron has been considered. All examples of ontological nodes in the obtained graphs for further potential information processing are presented in table 4.



(a)



(b)

Figure 3: The general view of a) research report “A” b) research report “B” “Materials and methods” node.

4.2 Structuring of the Scientific Works Using Ontologies

To present possibilities and systematization of the research report, we have applied an ontological taxonomy for students’ works “A” and “B”. The general view of the obtained graphs is shown in figure 3 (Velychko et al., 2017).

A separate node called “Abstract” has been created, which contains all the necessary metadata of the work, such as “Object of the study”, “Subject of study”, “The aim of the study”, “Practical value”, “Scientific novelty”, “Keywords” and “Hypothesis of scientific works” in the form of the attributes. All metadata has been used to provide filtering and ranking.

The “Materials and methods” node, which contains all the materials, was used to perform the experiments. Every approach has been divided into the separate attribute of the node. This allows concentrating the reader’s attention, and it helps to process the data with each other. For further researchers, this mechanism will be described in detail. The general view of both works’ “Material and Methods” node is shown in Figure 3 (Velychko et al., 2017).

For each ontological node that duplicates sections of the research report, and that contain specific indicators after analysing, additional separate leaf nodes with these results have been created.

In this leaf node, all the issues are held in the form of semantic and numeric data. These results are automatically available for filtering, auditing and ranking. An example of this leaf node is shown in Figure 4.

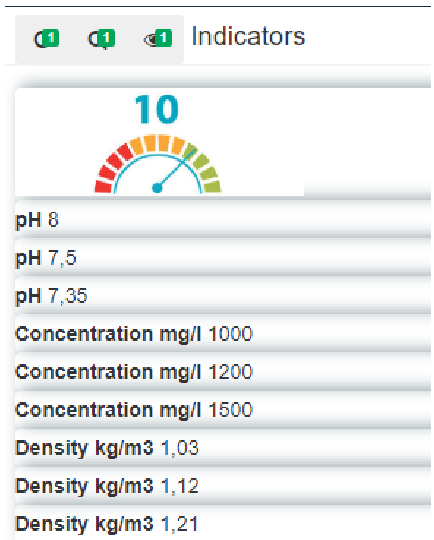


Figure 4: An example of leaf node with indicators after analyzing.

Table 4: Examples of the usage of the educational research element in ontology.

Element of the educational research	Example	The role of the node in the resulting graph	Using of the data
Title	**Node:** "Development a method for utilization of anaerobic digestion effluent"	Parent node	Used only for structuration
Object	**Node:** Abstract **Class:** Object (object is only one per report) **Value:** Anaerobic digestion; **Value:** Microalgae's growth **Value:** Disposal of the waste	Located in Abstract node; each object presented as attribute	Used for the audit; to provide literature review; to link reports for each other with same data; to identify novelty and plagiarism
Subject	**Node:** Abstract **Class:** Subject **Value:** The processing of anaerobic digestion effluent into humates by the autocatalysis method	Located in Abstract node; each object presented as attribute	Same as previous
Hypothesis	**Node:** Abstract **Class:** Hypothesis **Value:** Effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris	Located in Abstract node; each object presented as attribute	Same as previous
Keywords	**Node:** Abstract **Class:** Keywords **Value1:** Biogas; **Value2:** Anaerobic digestion **Value3:** Microalgae	Located in Abstract node; each object presented as attribute	Same as previous
Sections, Abstract, Introduction	**Node:** Introduction; **Class1:** Text; **Value1:** text itself; **Class2:** Biogas production in literature, ml/g of VS; **Value2:** 368; **Class3:** methane content, % ; **Value3:** 59	Each section presented in separated nodes; all text is presented in separate class of metadata, based on type of data	Used for representing of the main text of the educational reports; structuration and navigation
Materials and methods	**Node:** Materials and methods **Class1:** Method1; **Value1:** Desorption1; **Class2:** Method2; **Value2:** Desorption2	Located single node; each method is separated class of metadata	Used to provide links between the reports used same method by indexing and search
Concrete results and parameters of the research	**Node:** Results **Class1:** pH; **Value1:** 7.3; **Class2:** Decomposition, %; **Value2:** 87	Located a in separate node; each parameter is separated class of metadata	Used for the creation of the single ranking tool to systemize results from same field
Economic data	**Node:**Economic data **Class:** Payback period, years; **Value:** 5.3	Located the separate node; payback period presented in metadata	Used to provide comparison of the approaches to assess investment attractiveness
References	**Node:** Li et al. 2018, Chen 2003, Sergienko et al. 2016	Each report (paper) located in separate node	Used to link reports used same reference with each other

5 INFORMATION PROCESSING OF THE RESEARCH REPORT USING POLYHEDRON TOOLS

5.1 Using an Audit Tool to Test a Hypothesis

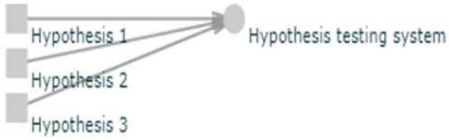
The audit tool (Stryzhak et al., 2014; Globa et al., 2015, 2019) can be used to compare the hypotheses, subjects, objects of research, keywords, and other parameters of the research reports. To demonstrate the capabilities of the audit tool, the focus is on auditing only hypotheses. "A" model version of the "standard" ontology has been created, which contains metadata from the "Abstract" node of the research reports "A" ontological graph. This ontology had a simple structure without branches, with the parent node being named "Abstract". The child nodes duplicate metadata from the "Abstract" node of the research reports "A".

The "comparison" ontology has been created with the child nodes, which contain the following hypothesis: the effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Spirulina Platensis (hypothesis 1), and the effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris (hypothesis 2), the effluent obtained after anaerobic digestion cannot use it as a nutrient medium for microalgae Chlorella Vulgaris (hypothesis 3). The hypothesis 2 node also contains some metadata. This ontology also had a simple structure without branches with the parent node, the "Hypothesis test system". The general view of the obtained ontology of the comparison and the ontology of the standard in taxonomic form is shown in figure 5.

The system has checked whether the hypothesis is true or false by using the audit function. Those indicators which do not correspond to the standard have been colored red. Thus, this solution will allow to test the idea of these scientific works and check other metadata that have already been set by using information from the "Abstract" node (figure 5b).

5.2 Analysing of the Research Reports Result on the Practice Value

Research report "A" and research report "B" have been compared with each other by the following criteria "Short-term economic perspective", "Long-term economic prospects". According to section 2 of the research report "A", the payback period of project "A" is five years, which corresponds to 6 points according



(a)

(b)

Figure 5: General view of in the taxonomic form the ontology of the comparing" (a) and (b) the ontology of the "standard".

to the criterion "Economic attractiveness". This parameter is better for the project described in report "B" with a payback period of four years and three months, which corresponds to 5 points on "Economic attractiveness". The system provides raking of the results. If there is a large amount of data, the instrument will be helpful to quickly and effectively evaluate the projects on "Economic attractiveness". Besides, in further research, the other criteria will be justified and used to provide data management on the educational research, which will make the tool more functional.

5.3 The Role of Taxonomies of Educational Studies in Centralized Informational Web-Oriented Educational Environment

5.3.1 Mathematical Interoperation of Integration of Taxonomies of Educational Studies in Centralized Informational Web-Oriented Educational Environment

As it was shown before, the preleaf nodes (L4) are terms (main ontology elements) that are very promising to use in terms of interoperability with other ontologies of subject areas, for example, with educational programs that in that term will be the additional instrument for Centralized informational web-oriented educational environment.

So, such connection with the centralized informational web-oriented educational environment concept

Hypothesis testing system
(Аудит)

Враховуються властивості

#	Показники	Одиниця вимірю	ДСТУ	Зразки		
				supposition 1	supposition 2	supposition 3
Abstract						
1	Object of study	Object of study	Chlorella vulgaris		Chlorella vulgaris	
2	Subject of study	Subject of study	Cultivation of Chlorella vulgaris microalgae on effluents obtained after methane fermentation.		Cultivation of Chlorella vulgaris microalgae on effluents obtained after methane fermentation.	
3	The aim of the study	The aim of the study	Developing a method of growing Chlorella Vulgaris in effluents after methane fermentation.		Developing a method of growing Chlorella Vulgaris in effluents after methane fermentation.	
4	Practical value	Practical value	The results of this work will contribute to the spread of biogas technologies. This approach makes it possible to increase the economic benefits from the utilization of bird droppings by converting the anaerobic digestion effluents into microalgae that have a wide range of applications.		The results of this work will contribute to the spread of biogas technologies. This approach makes it possible to increase the economic benefits from the utilization of bird droppings by converting the anaerobic digestion effluents into microalgae that have a wide range of applications.	
5	Scientific novelty	Scientific novelty	A method of utilization of methane tank effluent using microalgae is proposed. Cultures of Chlorella Vulgaris were adapted to the methane tank effluent.		A method of utilization of methane tank effluent using microalgae is proposed. Cultures of Chlorella Vulgaris were adapted to the methane tank effluent.	
6	Keywords	Keywords	microalgae		Chlorella Vulgaris	
7	Hypothesis	Hypothesis	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Spirulina Platensis.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can not used it as a nutrient medium for microalgae Chlorella Vulgaris.

Figure 6: General view of the audit results in the "Hypothesis test system" ontology.

Postion	Name	Short ecomonic perspective, points
1	**Development a method for utilization of methane tank effluent** 	8
2	**Development of a rational way for utilization of meta-tank waste at PJSC Vasylkivska poultry farm** 	6

Figure 7: General view of the ranking result.

and ensuring interdisciplinarity is described by formulas. Each ontology is based on the conceptualization of terms. It means that each ontology is described as a tuple (cortege) of terms from the field it contains:

$$O_i = < t_i > \tag{9}$$

So, we can describe ontology of educational program, ontology of equipment that being used, ontology of method and ontology of educational studies as further:

$$O_1 = t_1, t_2, t_3, t_4, t_5 \tag{10}$$

$$O_2 = t_1, t_3, t_5, t_6 \tag{11}$$

$$O_3 = t_3, t_5, t_6, t_7 \tag{12}$$

$$O_4 = t_1, t_3, t_8, t_9, t_{10}, t_{11}, t_{12} \tag{13}$$

As seen for equations, some ontologies have cross-terms that will provide inoperability with CI-WOEE and interdisciplinary. The terms that are cross-terms will be used by the user to transfer from elements (nodes) of one ontology to aspects of another. For this example, leaf or sub-leaf (in the case of educational studies' ontology; such as specific methods, keywords, objects, etc.), t_1, t_3, and t_5 are cross-terms:

$$t_1 \in O_1, O_2, O_4 \tag{14}$$

$$t_3 \in O_1, O_2, O_3, O_4 \tag{15}$$

$$t_5 \in O_1, O_2, O_3 \tag{16}$$

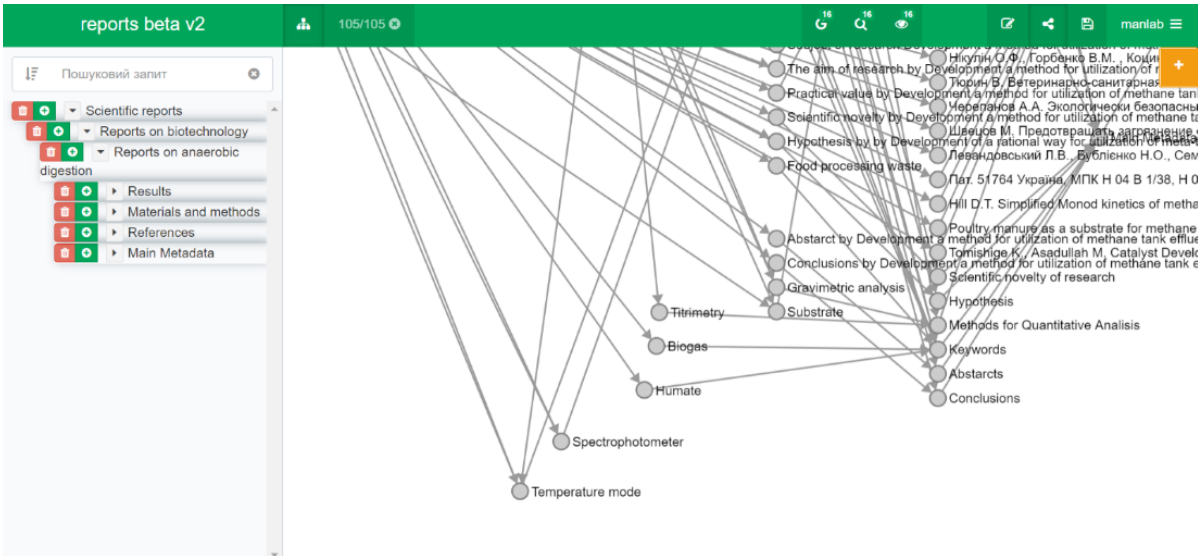


Figure 8: Terms of studies that may be used to link ontology of scientific studies with ontology of educational programs.

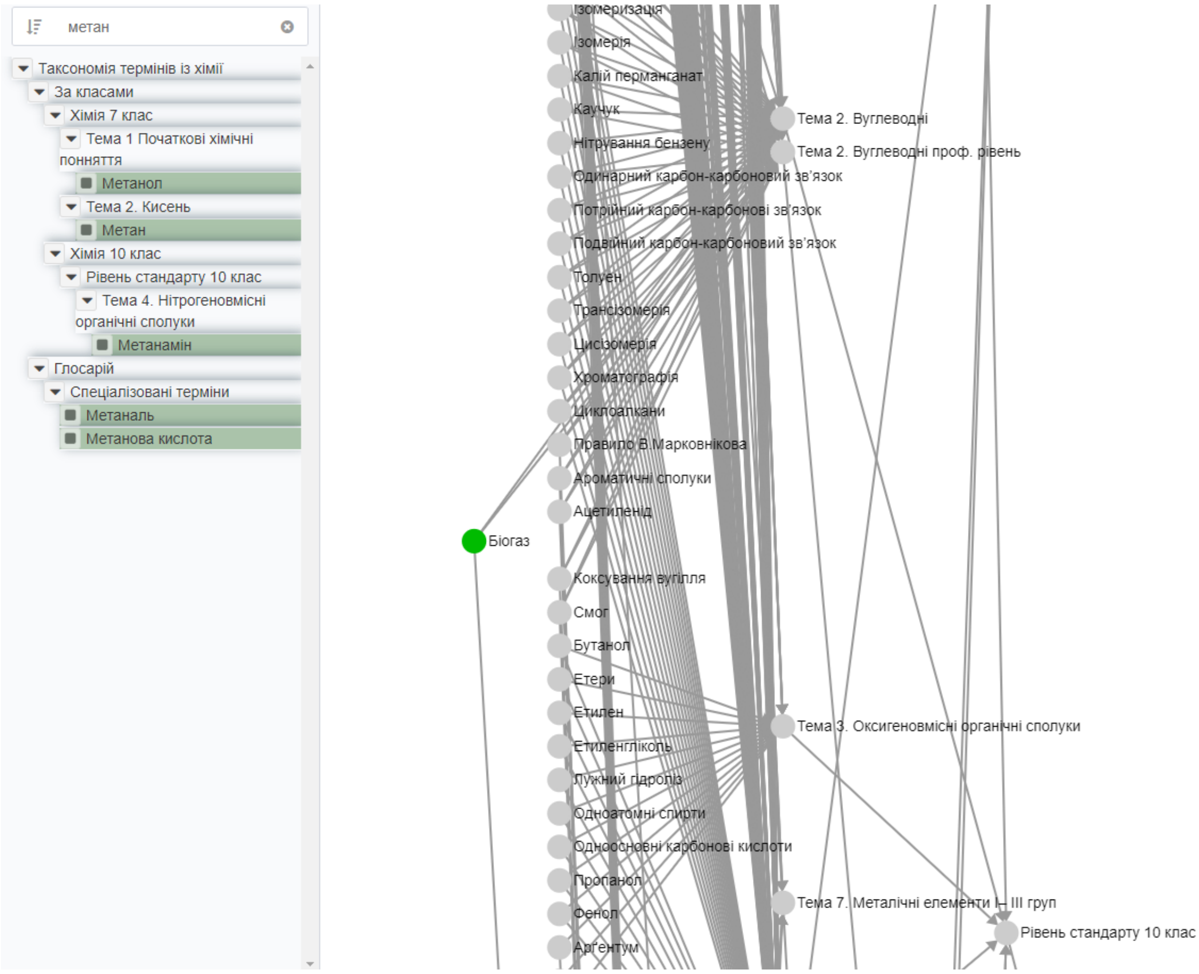


Figure 9: The general view of educational programs' ontology related to chemistry educational programs in Ukraine and terms that may be used to link with ontology of scientific studies.

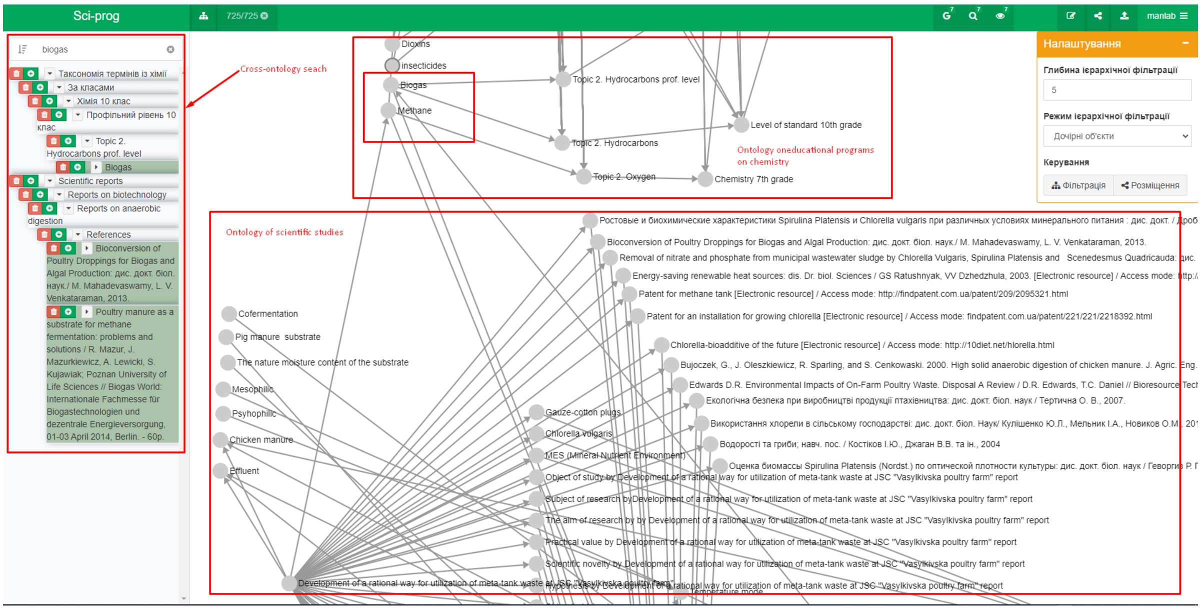


Figure 10: Using of same terms to provide interoperability between educational programs ontology and scientific studies ontologies.

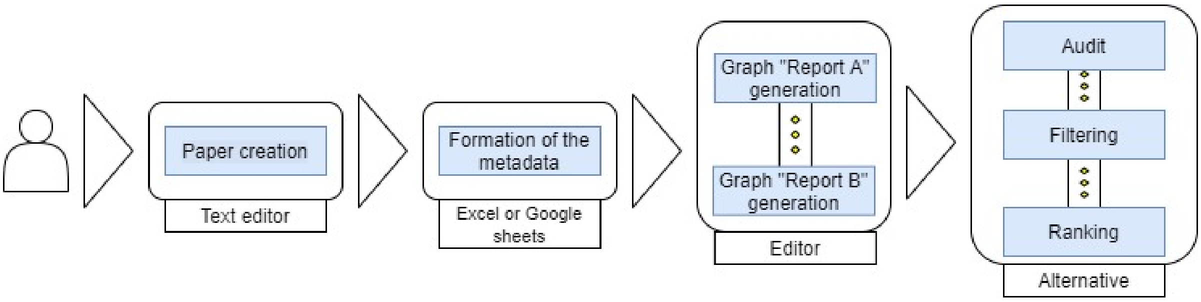


Figure 11: Workflow diagram of the creation of structured ontologies on scientific reports and their processing.

5.3.2 Practical Application of Ontology-Based Integration of Scientific Studies Educational Programs of Centralized Informational Web-Oriented Educational Environment

As shown in equations 10-13, the terms of scientific study ontology, such as specific methods, keywords, objects, etc., are used to provide a link with terms of educational programs. Terms of studies that may be used to link the ontology of scientific studies with the ontology of educational programs are shown in figure 8.

A similar situation is also related to educational programs. There is an ontology that systemizes the data on the knowledge field related to chemistry using schools' educational programs. It also consists of terms that are presented in the form of nodes. The general view of academic programs' ontology related to chemistry educational programs in Ukraine and phrases that may be used to link with the ontology of scientific studies is shown in figure 9.

Therefore, some terms may be related to both educational programs and scientific studies ontologies. In this case, such links allow using subnodes (keywords, methods, etc.) to find scientific studies related to this term. The exact words to provide interoperability between educational programs ontology and scientific studies ontologies are shown in figure 10. As can be seen, the terms "methane" and "biogas" are related to both educational programs and scientific studies and, therefore, they are used to link these ontologies.

6 DISCUSSION

The proposed database follows the "Leiden Manifesto of Scientometrics." In the obtained ontological database, quantitative evaluation can be supported by qualitative expert assessment. Additionally, this ontological database can unite the research missions of the institution, group, or researcher and protect excellence in internally relevant research. The ontological form of research reports can keep data collection and analytical processes open, transparent, and straightforward. Because all metadata is contained in a separate node that can be expanded and supplemented. Thus, the obtained ontological database can also account for variations, e.g., in publication and citation practices. It can provide a base assessment of individual researchers' qualitative judgment of their portfolios. Because all ontological graphs are validated by experts, in this way, it is possible to avoid misplaced concreteness, including false precision, and recognize the systemic effects of all assessments and indicators. In addition, indicators can be scrutinized regularly and updated in the obtained ontological database. Furthermore, the proposed ontology-based research reports can be integrated into a single environment – ontology repositories, as suggested before (Paschke and Schäfermeier, 2018).

The process starts with paper creation. For this stage, we can use various text editors, for example, word or google Docs. Then expert or author of the paper will formulate metadata, which is necessary for the ontology. For this purpose, the author will use Microsoft Excel or Google Sheets. Then, an editor needs to add information to the graph. In our case, the IT Platform Polyhedron is used for this. And last but not least, it is possible to use the "Alternative" system, which includes Audit, Filtering, and Ranking instruments. All proposed tools are illustrated in the workflow diagram below.

It is worth mentioning that this methodology of the centralized information web-oriented educational environment of Ukraine has been developed, and with ontological approach is more systematic now. Educational programs are essential to the world picture that is given to people during education, so they contain all basic terms that may be used to systemize other fields of human activities, including scientific studies. Like researchers, pupils interested in terms can also use such specific term nodes to continue their studying by investigating the studies conducted.

7 CONCLUSIONS

An ontological approach to scientific work systematization has been proposed, assuring compatibility. A system for arranging research reports based on digital taxonomies (ontologies) has been created. It allows users to construct node hierarchies utilizing the natural structure of the reports. Concrete parameters were added to the nodes as metadata (semantic, numeric, images, and links) to enable Polyhedron tools processing. Ranging and filtering were employed to handle semantic and numerical metadata. The obtained results allow for interchange across various study reports (including educational). The "Leiden Manifesto of Scientometrics" is the acknowledged ontological method.

Further study will improve interoperability across research works by developing a single taxonomy that provides hierarchization using the same methodologies, literature, and report findings and its processing using both methods suggested in the research and newly developed ones.

For the first time, it presents the concept of integration of scientific studies ontologies with educational programs that make them more usable for both students and young researchers. The proposed approach aligns with the centralized informational web-oriented educational environment concept.

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The "Operating Systems" Course as a Base of Students' Learning Activity Parameters Investigation

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Keywords: Operating Systems, Students, Learning Activity, Pedagogical Diagnostics, Time Planning, Indicators.

Abstract: The paper is devoted to the study of students' learning activity indicators that concern to the time of learning product submission. There were analysed relations of these indicators with parameters of student model in context of pedagogical diagnostics and prognosis. The research was based on the course "Operating Systems" that were studied in traditional blended learning educational process and in distance mode during COVID-19 pandemic. Empirical work gave possibility to analyse correlation between timeliness of completing the learning tasks by students and their educational achievements as well as to analyse the structure of students' time planning at homework. There was shown that students, who completed their educational tasks in time, have good educational achievement according to test results. But we can not say that all students with high educational achievements submitted results of their independent work in time. There was analysed the distribution of students activity during a day. There was shown that working time of students at distance learning is more natural and correspond to business time of day. Some approaches to improve students' competences in learning activity self-management were discussed. Recommendations to improve the educational process have been suggested.

1 INTRODUCTION

1.1 Statement of the Problem

Nowadays, effective educational process is not possible without active use of information and communication technologies. New educational environment puts forward advanced requirements to management of students' learning activity that become more independent. Such management should be grounded on comprehensive models. Theoretical basis of modelling of the open education organizational systems, theory of designing such systems have been expounded from systemic positions in monograph of Bykov (Bykov, 2008). Kiv et al. (Kiv et al., 2019) underline that Information technologies, especially, cloud technologies transform education, and have analysed according to results of the "Cloud Technology in Education" scientific conference modern approaches to managing students' learning activity in university educational environment. Triakina et al. (Triakina et al., 2018) have described the existing E-learning instruments that was designed by the international organizations for self-education and have suggested the ways of this tools implementation into professional training. Vlasenko et al. (Vlasenko et al., 2019) on the base of survey, conducted for teachers, suggested to develop an educational platform – an online environment for collaboration of the experienced professionals, whose joint activities should help in greatly enhancing their professional skills.

Independent work of students become one of the most significant part of modern educational systems. It is the demand of the curriculums and necessity to provide of the dual learning. Therefore, elements of distance learning are widely used in educational process as a form of education and as a form of management of students' independent work. Students' work is realised in specialised learning management environments without teacher's personal presence, and the teacher has no possibility to use traditional forms of pedagogical observation. The teacher needs in special system for management of students' independent learning activity instead of traditional intuitive man-

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agement of learning process.

Learning management systems, for example Moodle, give us various new highly informative tools for pedagogical diagnostics. Management of students' learning activity in information and communication environment should be based on individual pedagogical prognosis for each student with use of an idealised student's achievements model, a model of student's real state and a model of available variants of learning methods (Kolgatin, 2012). The relationship between parameters of this models and indicators that can be directly measured in a learning management system should be studied experimentally and theoretically. The field of interest in this paper is systematicity of student learning activity as a characteristic of student's leaning style and a parameter of student model in learning management system. Indicators of systematicity and its influence on student learning achievements are in the centre of our attention.

1.2 Analysis of Previous Researches

There are many scientific work devoted to students' independent work, its systematicity. But we want to pay attention to experimental data according to this problem. In focus of our interest are time planning and influence of systematicity of students' learning activity on educational achievements. So, Valynuk and Konovalenko (Valynuk and Konovalenko, 2017) pointed on the basis of survey that only 14 % of students prepare to classes systematically, 8 % – occasionally, but 78 % of students work at home only before practical and seminar classes. Klimenko (Klimenko, 2016) believes that systematic learning work of students promotes accumulation of knowledge, mastering in skills. But large amount of short structured tasks leads to obliviousness of educational material, so special work for systematisation should be suggested to students periodically. Lavrentieva et al. (Lavrentieva et al., 2019) draw attention to the necessity of planning independent work with accounting the complexity of its various types and analysing new methods of organization of students' independent study activities together with the use of ICT and tools.

Particularities of students' independent work distribution in time were experimentally studied by Kolgatin et al. (Kolgatin et al., 2020) with use of learning management system Moodle for measuring and collecting data. These results were obtained in traditional in situ educational process with ICT support of out of classes independent work. The authors concluded that students, who suggested their reports on laboratory works in time were more successful in the assessment at low and sufficient levels.

Very useful investigation of time-related behaviours was carried by Boroujeni et al. (Boroujeni et al., 2016). They have analysed three key dimensions of regularity: intra-course, intra-week and intraday. These authors considered two strategies for participating in MOOCs: regular scheduling of learning activities and adaptive scheduling based on daily work or study schedule.

We can see that researchers consider two aspects of systematicity: according to the educational material structure and according to learning process regularity. The first one correspond to systematicity as knowledge quality, the second – to stability of the learning activity pace. More over, researchers differ systematic and systemic. Systematic work is spread over the days in small portions, which are logically selected and organized by content (Klimenko, 2016). Systematization involves the generalization of knowledge, the establishment of system-forming links to make knowledge to be systemic. There were suggested formulas to process measurements and some criteria were built. There was shown positive correlation between the defined regularity measures and the performance of the student. Students who planed their learning activities in a regular manner had better chances of succeeding in the MOOC.

1.3 Objectives

Despite a number of theoretical and empirical studies in the field of modelling the learning process, there is no integrated model yet. Available models are based on teacher intuition and personal pedagogical observation that complicates using such models for pedagogical prognosis at managing the learning activity in Internet-oriented environments. Great work for specification of models parameters and its indicators, detection of pedagogical criteria influence at efficiency of educational process is very actual. In this way the aim of this paper is to study some indicators of student's time planning in context of their leaning activity systematicity. We try to find correlations between these indicators and at learning results in course "Operating systems". Also we try to look at influence of students independent work management peculiarities on regularity of this work.

2 THEORETICAL FRAMEWORK

In the context of mass education, the teacher cannot pay enough attention to each student to make pedagogical forecast for each student on the basis of own intuition, experience, theoretical and methodological knowledge. It is necessary to equip the student himself as the subject of the educational process with the skills and appropriate pedagogical forecasting tools for an independent choice of the appropriate variant of educational activity. The teacher should manage this pedagogical diagnostics system and provide the student with necessary help. Design of the computer-based pedagogical diagnostic system requires the development of a learning objectives model, a student psychological and pedagogical model (SPPM) and learning technologies model that would form the basis of this system. These models should be specially structured and should contain a limited number of parameters, which can be directly measured in the educational process.

Let fix our attention at one of this three major models in the system of pedagogical diagnostics – the psychological and pedagogical model of the student (SPPM) (Kolgatin, 2012). SPPM is built on the basis of learning objectives model so that the parameters of the student model reflect the forthcoming to the intended learning goal. The SPPM is to allow comparison of successive academic achievements, reflecting the dynamics of learning process. That is, this model should be dynamic. Based on the analysis of pedagogical science data in the field of educational achievement modelling (Pustobaev and Saiapyn, 2005; Bespalko, 2002; Lerner, 1978; Raven, 1991; Babansky, 1989), a system of criteria has been proposed (Kolgatin, 2012) according to such components: motivation and target, educational content mastering, self-management and activity, reflection and prognosis (table 1). Further comprehensive developing of this model needs in a lot of experimental data on correspondence between criteria indicators that can be directly measured in educational process and real results of students' educational work. But we have not enough such data in modern publications as it was shown above.

Estimation of the parameters that characterise the educational content criteria is carried out by means of pedagogical testing based on the concept of the level of educational achievements in accordance with the works of Bespalko (Bespalko, 2002) and Lerner (Lerner, 1978) as well the Ukrainian educational standards. These works are not modern, but classic. The ideas of Bespalko correlate with Bloom's taxonomy (Bloom et al., 1956), but Bespalko's approach is more simple and useful for practical automated pedagogical measurements. Lerner's ideas give us possibility to classify criteria according to indicators than can be measured directly as it was shown in (Kolgatin, 2012).

The parameter of the lasting of knowledge has not included to composition of database for model parameters (Kolgatin, 2012). According to definition, lasting of knowledge is the permanent fixation in the student's memory of the system of essential knowledge and methods of their application or the willingness to derive the necessary knowledge from other based knowledge (Lerner, 1978). A natural measure of lasting of knowledge is the ratio of the appropriate mastering coefficients according to the preliminary and current testing. If the mathematical model used in the automated system of diagnostics considers the parameters of student's academic achievements in dynamics (as a function of time), then a separate parameter "lasting of knowledge" is not needed. It is replaced by the functional dependence of all other parameters on the time that, definitely, carries more information.

The parameters of the student's psychological and pedagogical characteristics are determined by the teacher on the basis of pedagogical observation and analysis of the products of the student's educational activity. The student also takes active part in determining these parameters by introspection.

A high level of reflection on the result of the activity indicate the student's ability to objectively evaluate own results of the learning activity and his desire to complete the task qualitatively, to bring the work to a logical conclusion. The presence of an appropriate parameter in the student psychological and pedagogical model (SPPM) gives a reason to offer students, who have the developed reflection to the result of own activity, educational tasks of a creative nature. Otherwise, such tasks as projects, creative works etc. can be ineffective without student's own reflection, because it is difficult to build an objective and unambiguous algorithm for its checking.

High importance of the result of learning activity for the student is expressed in the desire to master given knowledge and skills as soon as possible, to get the result of the activity in the form of a fully completed task or project, a solved problem, etc. Of great importance is the student's sense of satisfaction from the successful completion of similar tasks in the past (Raven, 1991). The organization of education of such students should provide for certain stop points at which the student can feel the completion of the stage of work. It is advisable to prevent the unexpected additional tasks and complications.

High interest in the process of learning is often native for students with research abilities, who can unlimited improve a computer program or laboratory equipment, collect some data from the Internet and so on. Modern multimedia tools and intelligent learning systems help to increase delight of the learning process itself. But the interest in certain activities in the absence of significance of the learning result leads to a

Table 1: Structure of the student psychological and pedagogical model.

Component	Criteria
Motivation and target	Significance of the result of learning activity for the student
	Student’s interest in the educational process, cognitive interest
	Conscious adherence to the educational discipline
Educational content mastering	Completeness of knowledge
	Promptness of knowledge
	Depth of knowledge
	Flexibility of knowledge
	Systematic of knowledge
	Automation of activity
Self-management and activity	Stability of pace of learning activity
	Ability of the student to mobilize energy, persistence and will
Reflection and prognosis	Student’s reflection on the result of activity
	Student’s reflection on the process of activity

shift in the focus on minor things and reduce the effectiveness of learning. Such students need in regular diagnose of the structure of academic achievement and control the implementation of the curriculum. They need in systematicity of learning activity according to curriculum. Such systematicity can be achieved by direct management of student’s independent work or by training the student in skills of self-management.

Cognitive interest as a separate parameter of the student model provides an opportunity to distinguish features of the student’s motivation for learning activities. An important element of the emotional setting for learning activities is the conscious adherence to the educational discipline (Babansky, 1989), which is expressed in the self-control of the correspondence of the learning activity to the work plan and culture of interaction with other participants of the educational process (timely completion of tasks, conscious fulfilment of requirements, accuracy in visiting classes and appointed consultations).

The strength and stability of the student’s concentration on learning activities in a particular discipline largely depends on the peculiarities of the mental processes and physiological properties of the student and determines the style of educational activity. Therefore, it is important to add to the student model (SPPM) a parameter that characterizes a student’s ability to mobilize persistence and will (Raven, 1991), and a parameter that characterizes the stability of the pace of student’s academic work (Babansky, 1989).

Activity of the student on introspection, observation of student’s educational work, analysis of the style of educational achievements tests passing, analysis of the order of performance and presentation of educational products, analysis of the content of products of educational activity – are the sources of the information for the SPPM. It is advisable to measure parameters of reflection, emotional setting and volitional qualities on a scale of order (low, medium, high). The application of the equal-interval scale is problematic, because these parameters are complex and may include various indicators with significantly non-linear effect. Such measuring becomes a problem in case of lack of personal interconnection between student and teacher.

Summarising the above, it should be pointed that all indicators, which can be measured in some learning management system, are complex and are connected with several criteria of student’s motivation, target of education, educational content mastering, self-management and activity, reflection and prognosis. We need to understand the main binds of each indicator with criteria. There will be studied the time of learning activity products submissions in this paper. We assume that in-time submission of student’s works characterise student’s motivation (criterion: Conscious adherence to the educational discipline), competency in self-managing (criteria: Stability of pace of learning activity; Ability of the student to mobilize energy, persistence and will) and reflection (criterion: Student’s reflection on the process of activity). The time of submission can be directly analysed in Internet-oriented learning management systems, such as Moodle. We can see if the learning activity product was submitted in-time or not. We can also see the time of the submission. We can see if the student worked regular during a week or submitted the work in the last moment.

In this paper the systematicity of student’s activity are understood in context of activity by the plan given by teacher or designed by student in accordance to curriculum. Correlations of systematicity indicators with parameters of student psychological and pedagogical model are analysed both hypothetical and experimental

3 SYSTEMATICITY OF STUDENTS LEARNING ACTIVITY IN BLENDED LEARNING

3.1 Methodology of Empirical Research

Study of features of students learning activity, connection between its systematicity and students' learning achievements was conducted in course "Operating Systems" with use of learning management system Moodle. Methods of learning the course "Operating Systems" are not a matter of this paper, but we should to describe the ground of our empirical work. In 2019 this course combines theoretical and practical issues of operating systems concepts, models of its interconnection with hardware, applied software and users (Tanenbaum and Bos, 2014; Allievi et al., 2022; Bacon and Harris, 2003). The first content module of this course is devoted to history and diversity of operating systems according to peculiarities its application. Students should understand the basic principles of computer hardware building, in particular, von Neumann principles, shared bus architecture, address space, function of the registers, interrupts etc. One of the main fundamental issues of this module is to show the deep connection between the hardware and operating systems architecture. The simple operations in operating systems with use of command interpreter and graphical user interface were also the object of students' educational activity. Second module is devoted to detailed study of main abstractions in the theory of the operating systems: virtual memory, processes and threads. Students used built in and third party software as well as the authors' models to investigate the peculiarities of internal mechanisms of multiprogramming realisation, especially of scheduling CPU time and access to slow devices as well as RAM memory access. The third module covers wide spectrum of practical issues of booting the operating systems and logical organisation of disk drives, file systems, the structure of executable files, mechanism of management of the Windows operating system, security in operating systems.

Practical component of students' educational activity was dominant. Students of second year, future bachelors of computer science and software engineering completed the practical tasks on analysing structure, functionality, principles of design of some operating systems with use of virtual machines. Special software for virtualisation was used for supporting educational activity on installing different operating systems and third party software. Methods of study operating systems with using of virtualisation are enough developed in modern pedagogical works. As an example we can suggest the research of Spirin and Holovnia (Spirin and Holovnia, 2018). The tasks that were suggested for students assumed a part of work to be done in classes and other part was homework. There was traditional educational process in 2019 with some components of student independent work management in Moodle. Personal Learning System in Moodle contained some theoretical materials, reference lists, instructions for the laboratory works. Personal Learning System was used by students to submit their reports on laboratory works completion.

Each student worked according to unique variant of the tasks, but some steps were very similar for all students. Each of these task contained both reproductive and creative steps with problem solving. There were suggested 11 tasks in 2019 year for every student for the semester according to the topics of the curricular:

- Analysing the ReactOS operating system (installing and customising the operating system, doing some work in it);
- Analysing the KolibriOS operating system (installing and customising the operating system, doing some work in it);
- Analysing the Ubuntu operating system (installing and customising the operating system, doing some work in it);
- Analysing active processes and threads in the Windows operating system (operating with processes and threads, obtaining the information about the active processes and threads using built-in and third-party software);
- Analysing CPU and memory managing procedure in the Windows operating system (simulating of the operating system scheduling with use of the special designed model WinMOS);
- Analysing the Windows virtual memory (getting the information and optimising RAM memory with use of built-in and third-party software);
- Analysing the structure of the Windows executable files (getting the information about files and its structure with use of the fields map and third-party software);
- Analysing the Registry in the Windows operating

system (using and changing the registry information for managing the operating system);

- Analysing system services and drivers in the Windows operating system;
- Analysing data security in the Windows operating system (working with accounts, encryption algorithms, digital signature);
- Analysing and optimising the Windows operating system booting.

As the result of this work, students prepared and submitted reports using Assignment activity in the university Personal Learning System based on Moodle. So, we have possibility to monitor the time of completing the task by the student. The grades for reports with late submission were less. The reports that were prepared later than 2 weeks after deadline were not accepted by personal learning system, and students presented such reports to teacher in printed form personally with oral discussion. These reports with very late submissions have not analysed in this paper. In total, 54 students took part in experiment. 274 reports were analysed. The final test in written form has been suggested to students for evaluating their educational achievements. The results of this test were the base for study the connection between systematicity of student’s learning activity and his/her educational achievements.

3.2 Results and Discussion

Specific values of final test results were used for analysing correlation between systematicity of students’ learning activity and their educational achievements (figure 1). This values were calculated as ratio of test result of each student to maximal test result. The indicator of systematicity was evaluated as a part of reports, submitted in time by a student, that is as a ratio of the number of reports, submitted by a student in time, to the number of reports according to plan (11 reports for 11 tasks). We believe that both these variables are measured on an interval scale, so Pearson correlation was used for analysis. The correlation between these two variables is 0.28 and is statistically significant at the significance level 5 % for samples size of 54 that is enough in pedagogical researches.

So, we can conclude that the part of reports, submitted by student in time, positively connected with educational achievements. What is the kind of this correlation? Three variants are possible: 1) systematic work according to the plan, given by the teacher, contributes for increasing educational achievements; 2) students with high initial educational achievements easily execute the tasks and submit their reports in time; 3) students with high competence in self-management of their independent work have high educational achievements at all and, in particular, use their skills to complete the tasks in time for higher grading. Both the first and the third variants correspond the positive influence of systematicity on educational achievements.

Analysing the diagram at figure 1, we can see that the second variant was not realised: students with high test results (above 60 %) had systematicity indicator from 0 to 100 % and there was not any trend. Moreover, there was not any student with very high (above 80 %) systematicity indicator and test results simultaneously. So, we can see that the student with highest educational results did not work according to common plan even losing some grades. They, may be, worked systematically, but according to their own plans, so methodology of our experiment did not give us possibility to measure peculiarities of this work. Otherwise, they may be characterised by low level of importance of the learning activity results and high interest in the process of learning, and high cognitive interest. It should be appropriate to use for such students not the direct management of their independent work, but co-management or self-management.

Analysing the lowest boundary of points allocation at figure 1, we can see that high value of the systematicity indicator (above 60 %) guaranteed sufficient educational results (above 40 %). But students with highest systematicity indicator did not show excellent results in testing. This analysis gives grounds for hypothesis that the kind of management of student’s independent work should be timely turned from direct management through co-management and subsidiary management to self-management according to the level of student’s educational achievements and skills in self-managing for increasing the efficiency of educational process.

Choosing the day for completing the report, students taken into account many tasks in various sides of their life and study. But the fact that the number of reports, submitted in the last day, exceeds in near four times the number of reports, submitted in any other day (see figure 2), show us the lack of students’ competence in time planning and managing own work.

The deadline was set on Sunday at 11:55 PM. There was Saturday, free of classes. In some cases, students had more than a week to prepare their reports. But only 40 % reports were submitted in this period. Only 2 students used this period for stably work with every of their tasks. Our conclusion is to provide students with detailed direct management of their independent work at the initial stages of the course as well as to provide special training for in-

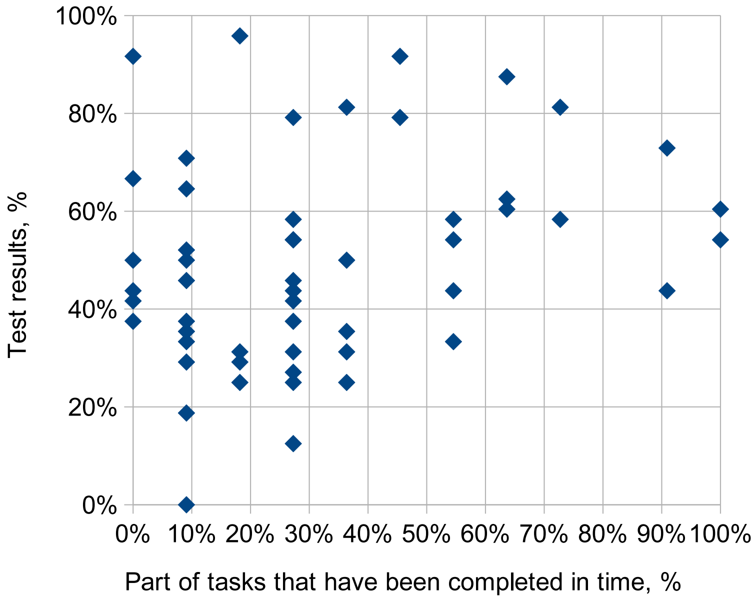

Figure 1: Correlation between systematicity of students' learning activity and their final assessment results at traditional blended learning process.

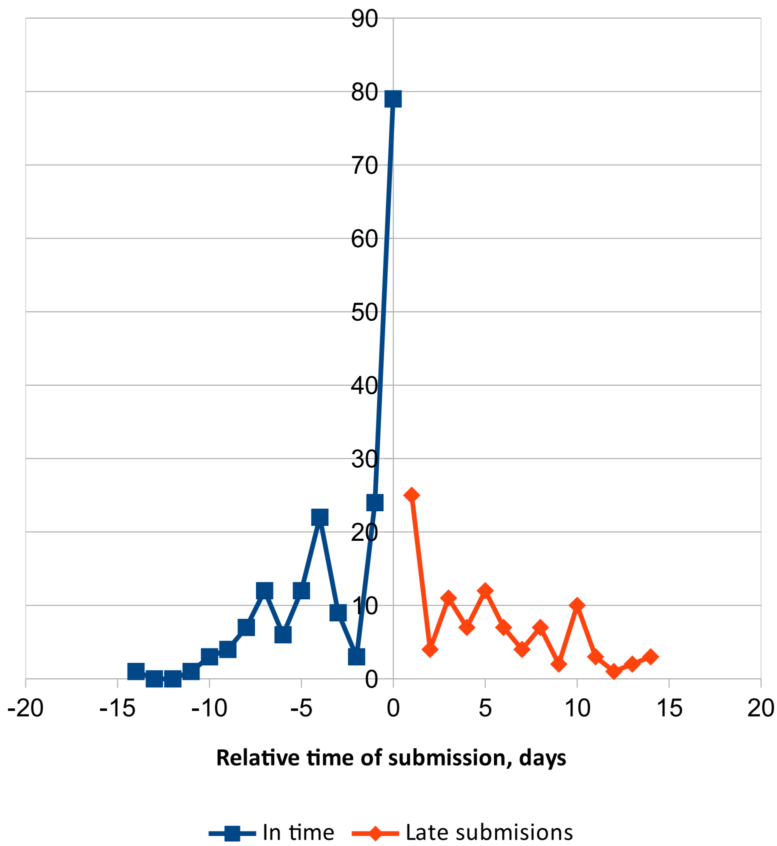

Figure 2: Frequency distribution of students' report submissions by days relatively from the official deadline.

creasing student's competence in time planning and self-management.

Did students work enough hardly in the educational process? Let us analyse diagram at figure 3. We can see that students work at any time of day and night accept of period from 4 AM to 7 AM. In our opinion, such time scheme does not promote the learning of deeper questions of educational material, does not support productive and creative learning activity. This is not a problem of one course or one university, but a complex goal of development the methodology of education in direction to turning from reproductive methods of learning to more efficient students' activity with active use the information and communication technologies in education. We should take into account dual educational process, which is coordinated with professional-oriented practice work.

4 SYSTEMATICITY OF STUDENTS LEARNING ACTIVITY IN DISTANCE LEARNING

4.1 Methodology of Empirical Research

COVID 2019 pandemic changed the educational process to mostly distance form of learning. So we could possibility to compare students behaviour in blended and full distance educational process. We continued to use the course "Operating Systems" and the Personal Learning System in Moodle as the base for our investigations. Participants of this work were future bachelors of software engineering both Ukrainian and foreign citizens. The language of study was English. The educational program was modified a little to shift accent on the student independent work. Theoretical and practical issues of operating systems concepts were studied in two content modules devoted to operating system concepts and administrating processes (table 2). There were suggested 8 laboratory work tasks to students (table 2), which assume solving practical problems on analysing structure, functionality and principles of design of some operating systems. The key attention was paid to Microsoft Windows operating system, because Linux solutions are the matter of additional course according to our educational program. These tasks were devoted to deep understanding fundamentals of operating systems and mastering skills of operating system administrating. Each of these task contained both reproductive and creative steps with problem solving. The tasks were suggested for students assumed all work to be done at home, but with online help of a teacher. The teacher was present online with using Zoom Cloud Meeting environment according to schedule. Each laboratory work was assisted by 2 academic hours of such online consultation and there were additional individual consultation in Zoom Cloud Meeting.

As the result of this work, students prepared and submitted reports using Assignment activity in the university Personal Learning System based on Moodle. The grades for reports with late submission were less. There were not hard deadline for submissions. Students had to presented all their reports to teacher online using Zoom Cloud Meeting environment with oral discussion. In total, 25 students took part in the course during 2020 and 2021 years under COVID-19 conditions. 147 reports were analysed. The final test has been suggested to students for evaluating their educational achievements using Moodle Assessment element. The results of this test were the base for study the correspondence between measured indicators and student educational achievements.

4.2 Results and Discussion

Values of final test results were used for analysing correlation between the part of reports submitted in-time by students and their educational achievements (figure 4). This values were calculated as ratio of test result of each student to maximal test result. The indicator of systematicity was evaluated as a part of reports, submitted in-time by a student, that is as a ratio of the number of reports, submitted by a student in-time, to the number of reports according to plan (8 reports for 8 tasks). Pearson correlation between these two variables is 0.67. This correlation is statistically significant at the significance level 0.1 % for samples size of 25.

We can conclude that the part of reports, submitted by student in time, positively connected with educational achievements.

Analysing the diagram in figure 4, we can see that despite the main tendency some students with high test results had systematicity indicator from 10 %. This results proves our previous hypothesis that some student with highest educational results did not work according to common plan even losing some grades. According to our pedagogical observations some of such students tried to complete the tasks earlier as soon as possible if they wanted to have highest grades. And distance learning process gave them such possibility, because all tasks were uploaded on Personal Learning System in Moodle environment. This situation ones more proves our conception that we need adaptively transform the mode of student independent

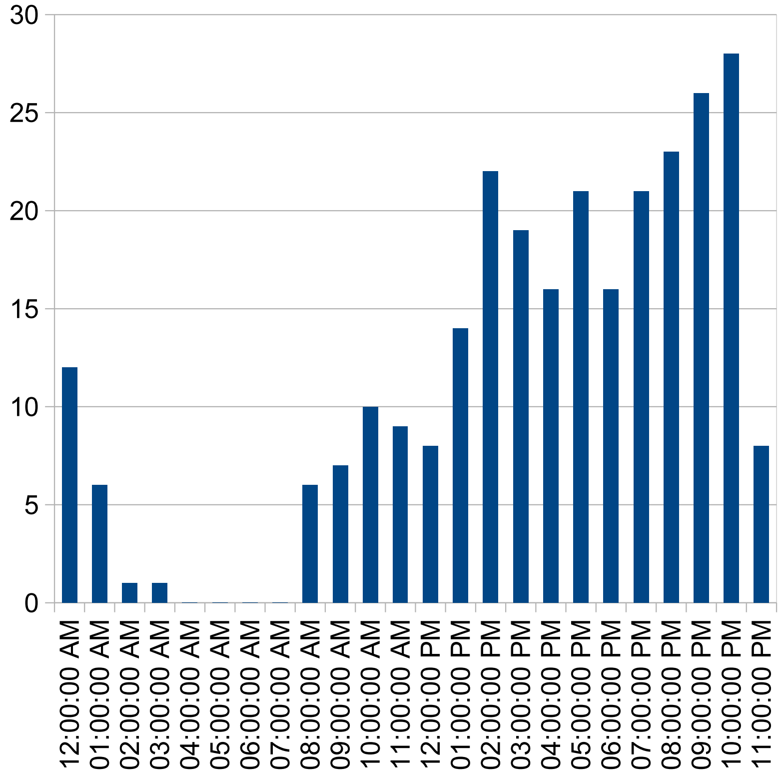

Figure 3: Frequency distribution of students' report submissions by time, summarising all days (Deadline was 11:55 PM).

work management from direct management through co-management and subsidiary management to self-management. We still can see that all students, who completed more than 50 % of the practical tasks in-time, had more than 50 % in test. So systematicity is the base obligatory requirement in educational process.

We see that the day before deadline is the most popular to complete the educational tasks, similar to traditional blended learning process (figure 5). Such behaviour require from student mobilizing energy, persistence and will. From the other side such behaviour can be the result of the lack of students' competence in time planning and managing own work.

The deadline was set at 11:55 PM in different days of a week. All students had more than a week to prepare their reports. But only 44 % reports were submitted in-time. We could not prove the statistical identity of student groups in 2019 and 2021 – 2022 years. There were different proportions of foreign and Ukrainian citizens in these samples, for example. So we can not make statistical comparison of relative time frequency distributions in blended and distance learning process. But analysing the diagram (figure 5) we can see more free students' time planning. There are some local maximums with a week (7 days) period before and after the deadline. The right tail (tasks that was not completed in-time) decreases slow. We believed that obtained new data confirm the conclusion to provide students with detailed direct management of their independent work at the initial stages of the course as well as to provide special training for increasing student's competence in time planning and self-management.

The distribution of students' working time has become more natural in distance learning process (figure 5). The most of reports were submitted in business time unlike the traditional blended learning.

The relative (on deadline) time of student's report submission can be used to build once more indicator – standard deviation of the submission relative time. We calculate the set of differences between the real time of each submission and deadline. After that we calculated the standard deviation for this set of values. Such an indicator take into account not the fact of in time submission, but evaluate stability of earlier and late submissions in comparison with our previous indicator ("Part of tasks that have been completed in time"). May be, some students have the own work schedule. They can submit the report 1 day later each

Table 2: Structure of the “Operating System” course in distance learning format.

Content Module	Theme	Laboratory Work Task
Operating System Concepts	Basic concepts, evolution, types of operating systems	Virtual Machine and Virtual Disks (creating virtual machine, installing and customising the operating system Kolibrios, doing some work in it)
	Architecture and resources of operating systems	Operating System Ubuntu: Basics of Administrating (installing and customising the operating system, doing some work in it, analysing resourses of the operating system using internal tools)
	Multitasking. Scheduling and interaction of processes and threads	Operating System Windows: Basics of Administrating. Task Manager (operating with processes and threads, obtaining the information about the active processes and threads using built-in and third-party software)
	RAM management	RAM and Virtual Memory (getting the information and optimising RAM memory with use of built-in and third-party software)
Operating System Administrating	Operating system booting. File systems	Operating System Booting. File Systems (getting the information about files and file system of different devices using internal Microsoft Windows tools and third party software, analysing and optimising the Windows operating system booting)
	System Registry in OS Windows	System Registry in OS Windows (using and changing the registry information for managing the operating system)
	Executable files. System services and drivers	Executable Files. System Services and Drivers (getting the information about executable files and its structure with use of the fields map and third-party software, analysing internal structure of driver initialisation files, managing system services using internal tools of Microsoft Windows operating system)
	Information security in operating systems	Information Security in Operating Systems (working with accounts, encryption algorithms, digital signature)

time, the stability of learning activity will be high and the value of “Standard deviation of the submission relative time” will be low. May be, some other student always submits the work in time, but does it 1 hour or 1 week randomly earlier. The stability of his learning work will be low, and the “Standard deviation of the submission relative time” indicator will be of high value. The suggested indicator can be useful in cases when the deadline is not hard but is only recommended by a teacher.

We apply this indicator only to students, who complete at least a half of the educational tasks, so the

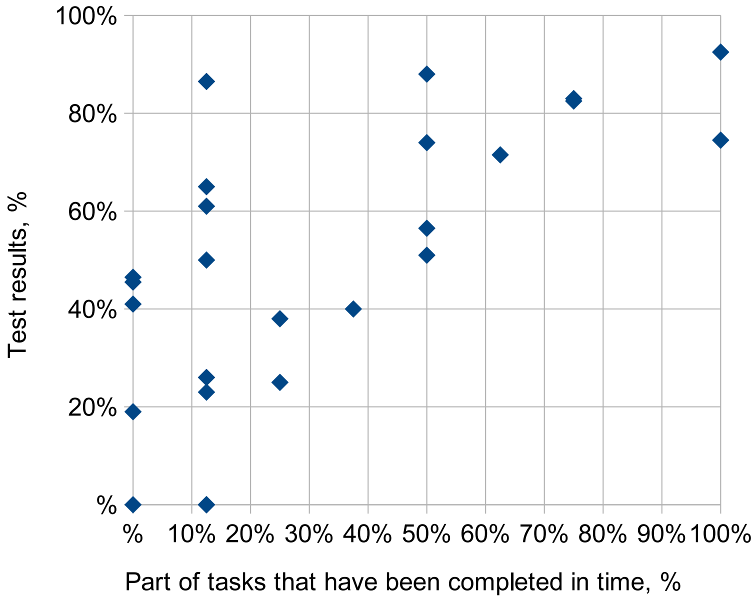

Figure 4: Correlation between systematicity of students' learning activity and their final assessment results at distance learning process under COVID-19 conditions.

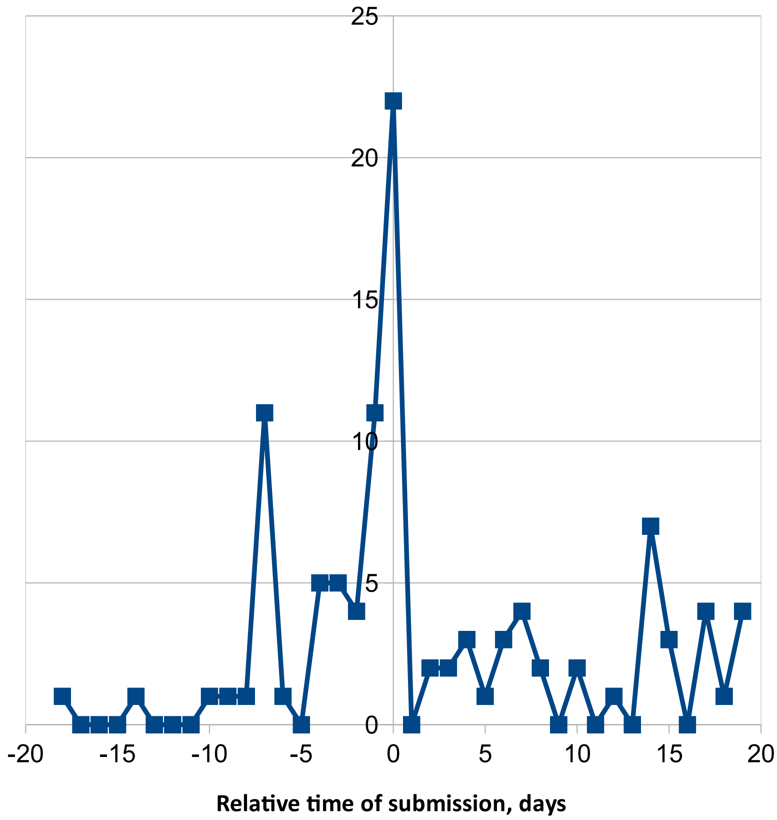

Figure 5: Frequency distribution of students' report submissions by days relatively from the official deadline (distance learning under the COVID-19 conditions).

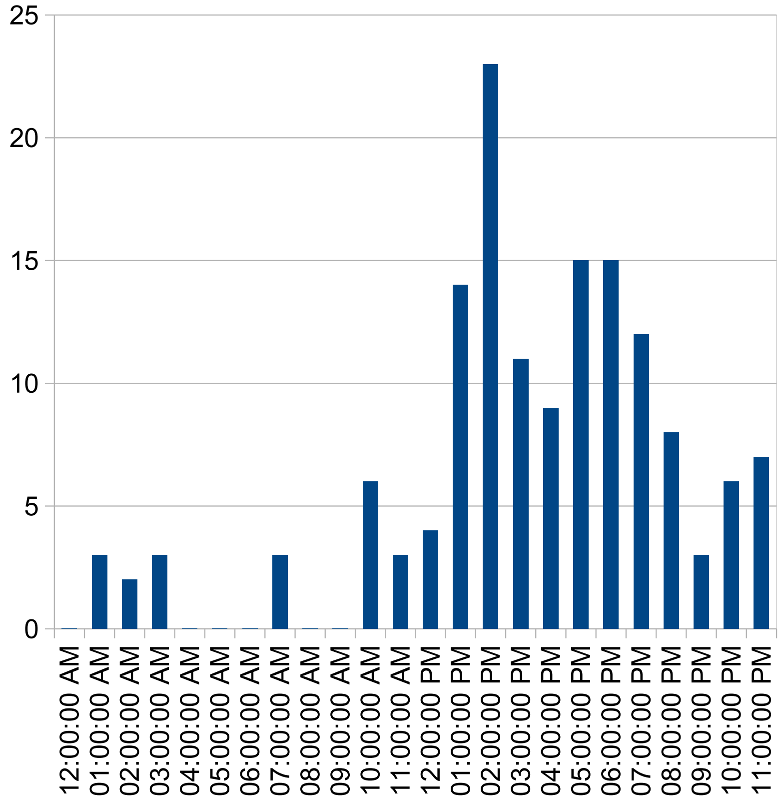

Figure 6: Frequency distribution of students’ report submissions by time, summarising all days at distance learning under COVID-19 pandemic conditions (Deadline was 11:55 PM).

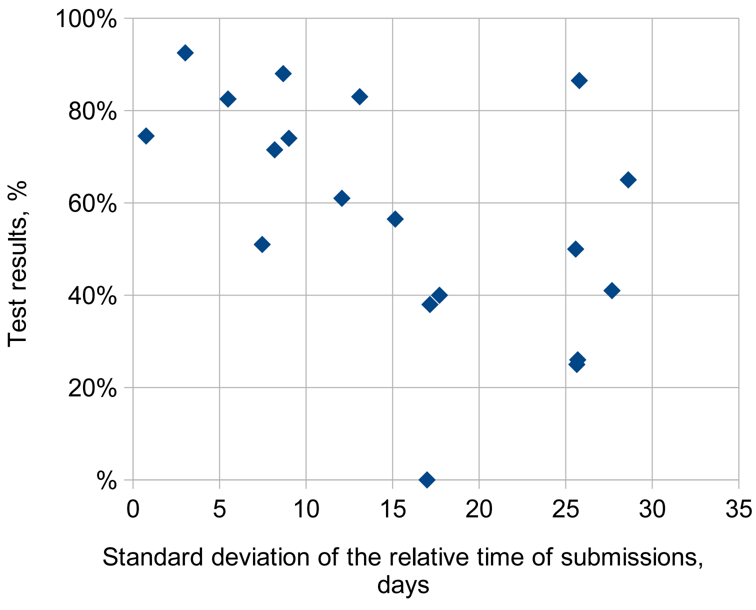

Figure 7: Correlation between standard deviation of the submission relative time and final assessment results of students at distance learning process under COVID-19 conditions.

sample size was 19. We assume that this indicator corresponds to such criteria of the student psychological and pedagogical model: stability of pace of learning activity, student's reflection on the process of activity. We can see negative correlation between this indicator and student's learning achievements (figure 7). The value of Pearson correlation is -0.51 and this correlation is significant at significance level 0.05 for the samples size 19. This result correlates with behaviour of our previous indicator – "Part of tasks that have been completed in time" figure 4. The standard deviation of relative (on deadline) time of student's report submission can be used as a prognosis parameter for student success in education.

5 CONCLUSIONS

Analysis of obtained experimental data in context of our theoretical framework has given the base for such conclusions:

- the ratio of educational tasks number completed in-time to its total number is an indicator that provide combined information about such criteria in student psychological and pedagogical model as 1) stability of pace of learning activity; 2) student's reflection on the process of activity; 3) conscious adherence to the educational discipline; 4) significance of the result of learning activity for the student. This indicator has good prognostic ability on the educational achievements;
- the analysis of relative to deadline time of students' learning product submissions give us information about 1) student's reflection on the process of activity; 2) ability to mobilize energy, persistence and will; 3) stability of learning activity pace;
- new data conform our previous conclusion that students' competency in self-management and time planning should be improved by providing students with detailed direct management of their independent work at the initial stages of the course as well as to provide special training for increasing student's competence in time planning and self-management;
- the mode of student's independent work management should be timely turned from direct management through co-management and subsidiary management to self-management according to the level of student's educational achievements and skills in self-managing for providing the efficiency of educational process at highest level of educational achievements.

This study does not exhaust all the aspects in the field of creating of comprehensive student model for the systems of pedagogical diagnostics and prognosis. The main task in this direction is in obtaining a lot of experimental data about corresponding of some educational process indicators and efficiency of one or another methods of learning. We also need to develop algorithms for estimating given criteria using available indicators.

Concerning further development of the course "Operating Systems" we plan to introduce the management of student's independent work with more or less elements of self-management according to the features and educational achievements of a student.

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Using the Discord Platform in the Educational Process

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Abstract: The paper reveals the results of a study of the feasibility of using the Discord platform in a blended learning environment in higher education institutions. The authors conducted an in-depth analysis of research on the creation and establishment of convenient and productive elements of distance learning (methods of building distance learning courses, special needs of distance learning, requirements for distance learning platforms). The authors believe that modern distance education systems do not fully use the opportunities of blended education, which creates conditions in which the educational process does not use its maximum potential, which leads to a decrease in the level of intensification of education. The main problem, scientists consider the insufficient level of development of distance communication systems and, in order to solve the problem, conduct an experiment on the basis of the Department of Informatics and Cybernetics of Melitopol State Pedagogical University named after Bohdan Khmelnytsky platform Discord as an environment of educational process offline during distance learning, quarantine caused by the global pandemic virus COVID-19.

1 INTRODUCTION

Analyzing the statistics, we can note that 2020 was the year of global informatization of all segments of human activity, the reason for such an increase in the need for IT development, was the global pandemic virus COVID-19. Of course, among the leading problems of mankind, there is the problem of education in full or partial quarantine, which in turn has become a catalyst for research in a particular vector of the educational process in a pandemic. Carrying out a preliminary analysis of research, we can note a significant increase in the number of scientific publications on the educational process in the languages of blended and distance learning, among the leading areas of research are: development of adaptive testing systems for students, use of automated learning systems, process. However, we can note that the educational process, especially in secondary and vocational education requires closer contact when communicating with the teacher and creating conditions for synchronous communication and a preliminary analysis of scientific sources showed insufficient study of this issue, which confirms the relevance of our research analysis and development of recommendations use of distance communication systems in terms of quality learning process on the example of using the Discord platform.

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2 RELATED WORK

Before the analysis of current research in a particular area, we decided to identify the leading vectors of our selection, it was noted:

- scientific developments on determining the specific needs of participants in the learning process in terms of distance and blended learning;
- scientific developments on the peculiarities of the use of the platform identified in the study;
- scientific developments on the coverage of the experience of using the means of distance communication during the educational process in terms of distance and blended learning.

Thus, we expected to get a comprehensive and comprehensive vision of the problem and ways to solve it, to analyze the experience of using remote communication tools by scientists and teachers around the world and to develop recommendations for the use of the platform identified in the study.

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First of all, it is appropriate to note the contribution of scientists who focused their work on determining the fundamentals of the development and conduct of distance or blended learning, among them important in our study were (Bilousova et al., 2021; Kalashnikova et al., 2022; Kukharenko et al., 2022; Martyniuk et al., 2021; Nofandi et al., 2020; Osadcha et al., 2021; Voloshinov et al., 2020).

Methods of using online communication and the problem of creating high-quality blended learning in general quarantine are revealed in (Osadcha et al., 2020; Ovcharuk et al., 2022; Oyegoke et al., 2021; Tkachuk et al., 2022; Trubavina et al., 2021).Important for our study was the work of Jiang et al. (Jiang et al., 2019), who partially revealed the features of the problems of moderation of voice associations, in particular the problem of cyber-bullying, incitement to hatred and other social problems. Based on the preliminary analysis of the sources regarding the actual topic of the study, it is important to note the contribution of Odinokaya et al. (Odinokaya et al., 2021), Arifianto and Izzudin (Arifianto and Izzudin, 2021), Vladoiu and Constantinescu (Vladoiu and Constantinescu, 2020), Lacher and Biehl (Lacher and Biehl, 2018), Ardiyansah et al. (Ardiyansah et al., 2021), Di Marco (Di Marco, 2021), Warni et al. (Warni et al., 2021), Uong et al. (Uong et al., 2022), Wiles and Simmons (Wiles and Simmons, 2022) and Mock (Mock, 2019). These scientists conducted similar experiments on the introduction of the Discord platform in educational institutions and revealed the peculiarities of their experience, which enabled a significant expansion of the research framework and served as a basis for further work.

3 FEATURES OF USING THE DISCORD PLATFORM IN THE LEARNING PROCESS

Starting research on the use of any software to create conditions for quality distance communication during the educational process, it is advisable to analyze the current scientific developments on the fundamental pedagogical principles of implementation and use of distance education to further verify the feasibility of using the Discord platform in education. process. For this purpose it is expedient to refer to the works of Valko and Osadchyi (Valko and Osadchyi, 2020), Voloshinov et al. (Voloshinov et al., 2020), Bykov (Bykov, 2008), Kyslova and Slovak (Kyslova and Slovak, 2015), Kukharenko et al. (Kukharenko et al., 2022), Dushchenko (Dushchenko, 2020). Thus, according to Bykov (Bykov, 2008), we can identify priority properties that are common to all distance learning systems:

- *Flexibility and adaptability*. Students generally do not attend regular classes in the traditional form, but work at a convenient time in a convenient place and at a convenient pace, which provides great benefits for those who can not or do not want to disrupt their usual, active social life.
- *Modularity*. The modular principle is the basis of distance learning programs. Each individual course creates a holistic view of a particular subject area.
- *Economic efficiency*. Due to the use of a more concentrated presentation and unification of the content of educational material, the focus of distance learning technologies on a large number of learners, more efficient use of teaching staff and material and technical base that provide training.
- *New role of the teacher*. The teacher is entrusted with such functions as: coordination of the cognitive process, adjusting the course being taught, advising on the development of an individual curriculum, management of educational projects, checking current tasks, and so on.
- *Specialized quality control of education*. In distance education, both traditional forms of quality control of existing and received education, and distance forms of such work are used.
- *Use of specialized technologies and teaching aids*. Distance learning uses special technologies: case technologies; television technologies; video conferencing technologies; combined technologies. Distance learning technologies combine most of the existing teaching methods and give them a qualitatively new educational and technological level.

The central link in distance learning is the means of telecommunications and their transport base. They are used to provide the educational process: the necessary educational and methodological materials; feedback between the teacher and the learners; exchange of management information within the distance learning system; access to international information networks.

In summary, it can be argued that the tools and methods of distance learning form a unique distributed environment, which provides the main features, benefits and problems of this promising form of education.

Bykov (Bykov, 2008) describe modern means of distance learning that adhere to certain properties, but this range of tasks cannot be fully accepted in the conditions of long-term learning during an emergency situation. This is primarily due to the low level of preparedness of educational institutions for such situations and the low level of preparation of modern students and schoolchildren for conditions of complete isolation and independence in learning. Osadchyi and Varina (Osadchyi and Varina, 2020), Osadchyi (Osadchyi, 2019) and Bykov (Bykov, 2008) claim that the system environment of distance learning is a set of methods and software that ensure the implementation of remote distance learning technology. In our opinion, such an environment can be formed in two ways: 1) using distance learning platforms (systems) (examples may be Moodle, Lotus Learning Space, Blackboard Learning System and others); 2) through a set of services and services of the Internet (blog, e-mail, online board, online video and audio, chats, forums, online testing tools, online presentations, electronic libraries, book publishing services etc). That is, the use of only one online resource at the present stage of development of distance learning does not provide a sufficient number of functions necessary to create conditions for quality distance learning, there is a need to use a set of resources to comprehensively cover distance learning.

Modern distance learning systems allow full interaction with educational content and testing and other forms of control, but communication between teacher and student takes place in chat or video conferences, which are not convenient for the student on a number of issues, the main of which there is insufficient provision of remote settlements with quality material support (high-speed Internet, the latest computer software, etc.). This leads to the impossibility of the student's perception of information in full. Analyzing a similar situation in terms of the educational process in schools, we can say about the low level of readiness of students for self-study and the need for constant interaction between teacher and student in the usual usual format of the lesson.

Analyzing the functionality of modern distance education systems on the example of Moodle, Lotus Learning Space, Blackboard Learning System (Bukreiev, 2020) it was determined that these systems are developed in the vector of asynchronous communication to create greater mobility, but the direction of synchronous communication needed by students quarantine is almost absent. This determines the need to use additional software to create quality conditions for synchronous communication.

As part of the study, we identified the main tasks to be performed by the online communication system. So we were defining general learning objectives as the distribution of tasks for the teacher. They emphasize the need to decide what needs to be done in the classroom, what can be learned, studied and solved at home, which tasks are suitable for individual lessons, and which – for group work on the project. It is important that lessons take the form of project defense, presentation, debate or discussion between students or the teacher with students, which in turn confirms the need for "live" synchronous communication. The electronic unit should contain projects for group work, creative, laboratory and practical tasks, reference materials and links to additional materials on the Internet, intermediate and test tests, as well as tasks of increased complexity for gifted students. Thus, the online communication system must satisfy the possibility of conducting classes in the form of project defense, presentation, debate or discussion between students or teachers with students, ie the system should allow a large number of users to communicate and access visual material on their computer. users. Thus, we can say that the creation of conditions for quality active interaction between teacher and student, especially in the context of distance learning of students, is mandatory. Under quarantine, students can quickly use their motivation, which will reduce the quality of learning, so the use of distance communication should enable students and teachers to conduct quality and productive communication with the addition of multimedia education. Summarizing the general needs and tasks assigned to online communication services, we can determine that the service should meet the following needs: low load on the computer and the Internet; the ability to create conferences in real time; providing the ability to simultaneously display the screens of all participants in the learning process; providing the opportunity to communicate in the mode of individual consultation, or consultations of a small group of users; creating a visual intuitive server interface for users; the ability to administer the server and configure user rights.

Thus, having analyzed and identified the general objectives and needs of the online communication service, we will analyze the features of the Discord platform to verify the feasibility of its use. Discord has support for Windows, macOS, Android, iOS, Linux and runs on all browsers. Determining the system requirements for the computer for the normal operation of the program, we can note the low level of load on the system, for greater visualization, we conducted a comparative description of system requirements between three software tools focused on video conferencing, the most popular nowadays is Skype, Zoom and Google Meet (table 1).

Thus, we can say that Discord requires a lower

Table 1: Comparative characteristics of the minimum system requirements of Skype, Zoom, Google Meet, Discord.

Feature	Skype	Zoom	Google Meet	Discord
Processor	1 GHz	3 GHz	2 GHz	1200 MHz
Hard disk space	200 MB	500 MB	200 MB	256 MB
RAM	512 MB	8 GB	512 MB	256 MB
Bit architecture	x86, x64	x86, x64	x86, x64	x86, x64
Operating System	Windows, Linux, Mac OS X, Android, IOS	Windows, Linux, Mac OS X, Android, IOS	Windows, Linux, Mac OS X, Google Chrome OS	Windows, Linux, Mac OS X, Android, IOS

level of load on the system and works with almost all operating systems. A significant advantage of using Discord is also a simple and fast software launch system, for this you need to download the program from the official website, install it and go through the registration procedure. Then you have the opportunity to send invitations and start communicating. Convenience is confirmed by the fact that for Discord there is no need to install a client, the user can communicate through a browser. To do this, you will need to send him an invitation link. This method of use greatly simplifies the system of interaction between teacher and student in a constant academic mobility, because the system allows mobile connection to the server from any access point and platform. This creates the necessary learning mobility conditions that are required in distance learning during quarantine, but other systems for webinars have not been developed. For such systems, the presence of the installed software and all plug-ins to it is mandatory.

Discord is a completely free platform that does not contain hidden payments or premium subscriptions, which is very important for state and purely educational institutions in the economic situation of the state. Stable operation, good communication quality and simplicity of the interface confirm the expediency of using Discord by users of any skill level. In addition, the platform has features: Push to talk and voice activation, the system allows you to create conditions for simultaneous communication of a large number of user groups, while communication in other software is exclusively synchronous or asynchronous and requires a large number of mutually exclusive connected servers to provide training of one course / flow / school / etc. The platform allows you to add interlocutors to friends and make direct and group calls with text chat support, which creates conditions for working with students with high levels of nervousness and students with low levels of logistics, which causes problems when working with the general flow of students.

The analysis causes an increase in the level of relevance of the use of Discord, but this is not enough to determine the overall feasibility of the selected platform, so it was decided to turn to the works of Striuk (Striuk, 2021, 2022). The authors use the example of training future software engineers to reveal the need for intensive training of future professionals for professional activities and emphasize that it can be effective only if the range of organizational and pedagogical conditions of its operation. In this case we can say that opportunity: creation of high-quality conditions for conducting practice-oriented individualized practical and seminar classes, motivating students to study the subject component through a multimedia worldview during the learning process, motivating students to self-study and self-improvement; establishing synchronous learning in terms of full interaction between teacher and student; involving students in creating a personal information environment.

As we have already mentioned, creating conditions for improving the level of students' motivation for self-study is one of the most important tasks of any distance learning system. Taking into account a certain range of requirements for a modern remote communication system and to further verify the feasibility of using Discord, we will conduct a comparative analysis of software functions when working with them, for comparison we will also use Skype, Zoom and Google Meet (table 2 and table 3).

Based on the results of the analysis, it can be argued that there is a significant advantage in the use of Discord compared to other software tools in the vector of creating quality conditions for synchronous educational process. The problem point of Discord remains the limitation of the number of users on one video channel, but given the need for small groups of up to 30 students, this factor can be considered weightless.

During the study, a detailed review of the possibilities of working with Discord was conducted:

1. *Create an unlimited number of servers*. Creating the conditions for a quality management system of the educational unit is the most important factor in the development of the distance learning system. Thus, the problem arises in the absence of modern

Table 2: Positive characteristics of Skype, Zoom, Google Meet, Discord software functions.

Function	Skype	Zoom	Google Meet	Discord
Individual text messages	+	+	+	+
Conference text messaging	+	+	+	+
Individual calls	+	+	+	+
Conference calls	+	+	+	+
Screencast	+	+	+	+
Ability to control users	+	+	+	+

Table 3: Negative characteristics of Skype, Zoom, Google Meet, Discord software features.

Function	Skype	Zoom	Google Meet	Discord
Multiplayer screen	-	-	-	+
User rights settings	±	±	-	+
Creating parallel channels	-	±	-	+
Connecting bots	-	-	-	+
Restrictions on the number of users	-	-	-	-
Limitations on the number of concurrent video conference participants	25	-	-	50
Set voice priority	-	-	-	+
User Activity Report	-	-	-	+
Server moderation	-	+	+	+
Creating a separate server	-	+	+	+

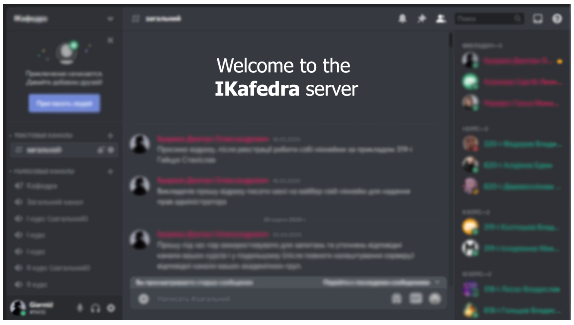

Figure 1: Developed a distance learning server on the Discord platform.

remote communication systems. With the functionality of the Discord platform, a high-quality system for the distribution of training units has been created, which allows for full stratification of user rights and a transparent monitoring system (figure 1 on the left). In terms of the learning process, this feature allows you to create a large number of servers that can conditionally divide the overall structure of distance learning into clearly defined groups (division by faculties or classes). Subject to the development of a quality server system, conditions are created for further reporting and quality control of the educational process by moderating each individual structure of the learning environment.

2. *Configure the interface language and general information about the server.* Analyzing the needs of the learning space, we identified the need to create a high-quality and clear interface of online communication servers to create conditions for high-quality perception of information by students or schoolchildren. To solve this problem, Discord has created: the ability to define the language region of users; setting up an instant notification system; creation of AFK-channel for automatic transfer of currently inactive users to a separate room, which in turn allows you to reduce the load when working with individual channels; creating a unique server logo, for greater separation of each individual server. This feature allowed us to create a high-quality clear interface for all participants in the learning process. Thus, students and teachers already at the initial stage had an intuitive interface that allowed to start work without a long period of training and training of users in the skills of using the platform. What works best during training is important to create conditions for quality learning of foreign languages, so for foreign language classes it is advisable to create a server using the interface of the language, which will qualitatively affect the learning process through full immersion.

3. *Creating an unlimited number of text and voice communication channels.* One of the main problems of the total number of remote communica-

tion systems is the development of asynchronous communication and the need to use a single communication channel. This problem significantly affects the possibility of conducting streaming classes in terms of distance learning in the long term. Modern systems of remote communication, in the long run, need to create a developed system of synchronous communication and the ability to create a large number of parallel channels for different academic groups. The previous analysis showed the need to create a common system that would be able to use the school in full. This need determines the need to create separate communication channels for each group or class, to solve this problem, Discord provides a fairly optimal system (we can see the implementation in figure 1) to create an unlimited number of voice and text channels. Thus, we were able to create a stream of learning and a system of quality synchronous communication of all academic groups of students in the distance learning.

4. *Create invitations of new users by invitation-link, invitation from the list of friends, invitation by creating a widget for the site*. In emergency situations, first of all, there is the problem of creating a single channel of communication, which creates aggressive conditions that do not allow quality dissemination of information and general acquaintance of all users with the future form of work. When using Discord, server administrators have the ability to create user invitations in several different ways, such as creating new user invitations by invitation-link, Discord friend list invitation, and invitation by creating a site widget. This allows full coverage of all communication channels of recipients of training services in order to speed up their connection to the general system. Using a certain range of ways to invite users, in the conditions of our experiment we managed to deploy the server within one week and fill it with users.
5. *Configure user roles*. To create conditions for quality operation of the remote communication server, there is a need for extensive rights of users, in order to prevent offenses by users of the server. Thus, we have developed a system of strict stratification of user rights. This simplified the server management process and the process of monitoring user actions. With the help of a well-developed system of rights, a number of measures were taken to ensure the quality of education (checking couples by the head of the department, mutual visits of couples by teachers of the department).
6. *Setting access rights for different communication channels*. As mentioned above, in order to create conditions for quality operation of the remote communication server, it is necessary to branch out the work areas of each individual user or user group, therefore there is a need to configure access rights of each user group to individual communication channels. channel “Faculty Council”). This creates a clear stratification and user management system, as shown in the figure, creating separate text channels for use by individual courses and channels for use by each individual study group.
7. *Audit journal and moderation*. It is important in the work of distance learning systems and services for their operation is to create a high-quality reporting system, in order to create such a system in Discord created a quality system of moderation and audit, which allows visual and textual display of each user’s actions. opportunity to check the quality of work of teachers and students. Thus, we were able to fully verify all the actions of participants in the learning process and conduct transparent monitoring of the success of user actions. With the help of this system, the administration of the educational institution has the opportunity to take similar measures to check the quality of the educational process and the availability of teachers and students in the classroom.
8. *Pin messages for each of the channels*. During the work of the educational institution an important factor is the early and high-quality dissemination of information among all participants in the educational process. Typically, systems that work in real time have the ability to quickly “clutter” the open text chat, to create the ability to separate and highlight the most important messages, created the ability to pin messages in each text channel. Thus, we have created conditions for the dissemination of information among users without determining the date of their connection to the system. This has greatly facilitated the information process due to the gradual connection of new users to the platform over a period of time.
9. *Live broadcasts*. The most important feature of each system of distance communication in a quality learning process is the ability to conduct online broadcasts by both teachers and students, this is primarily due to the need for quality transmission of information during lectures, and the possibility of feedback (student comments, questions, screen display for verification and clarification, etc.). Discord’s GoLife mode allows you to display a specific application or screen in real

time, and all registered users with a defined access and installed Discord software can connect to this broadcast. Thus, we managed to create conditions for a quality process of conducting classes, which fully allowed to reproduce the usual format of classes. This created a reliable channel of active communication between teachers and students, which helped increase the number of active students and increase the level of activation of students.

10. *Management of user communication tools*. In the conditions of active work of a large number of simultaneous users (especially work with primary and secondary school students) there is a problem with conveying information due to too high a level of noise, usually the causes of noise can be: microphone noise; general household noise of users; presence in the group of energetic and restless students and more. To solve this problem, it is possible for administrators of the system of user communication to have full control. This function includes: reducing the level of "voice" of each individual user; mute the user's microphone, mute the speakers / user headphones. Using certain functions, you can solve problems with the conditions of high-quality information transfer in the shortest possible time.

As part of the study, we conducted an experiment that took place over one year in two stages, in the first stage (March-May 2020), the developers of the Discord platform were ambivalent about the use of the platform in the educational process, as the platform was primarily developed as a tool communications during the gaming process, but under the first quarantine, the number of simultaneous broadcasts was expanded to 25 people in one voice channel, which generally made it possible to use the platform for educational purposes. However, at this stage we noticed a number of significant problems that occurred when using the platform, namely: high noise levels during communication, problems with video connection and broadcasting in some students, problems with low bandwidth of Discord servers and insufficient the level of informativeness of user instructions. In addition, minor problems included the lack of a Ukrainian-language interface and a generally insufficient range of languages for use on the server and encryption of documents when sent in messages, which led to the need to disclose more information before sending. However, all these problems were found to be insufficiently critical to complete the experiment. During the first half of the year, the developers of the platform completed improvements and today we can emphasize the correction of a significant number of significant problems related to the first stage of the experiment, namely: a new noise reduction system for Krisp communication was developed and the system for configuring audio input and output and video information, which in turn solved the problems of most students; The developers carried out high-quality work on debugging and expanding the server part of the platform, which solved the problem of low bandwidth.

At the first stage of the experiment (March-May 2020) a remote communication server was created and implemented on the basis of the Department of Informatics and Cybernetics of Bohdan Khmelnitsky Melitopol State Pedagogical University for students of I-III courses: 122 Computer Science, 014.09 Secondary Education (Informatics), 015 Vocational education. During the first stage of the experiment, a number of measures were taken to check the quality of interaction between students and teachers:

1. *General organizational and educational hour*. During this event, conditions were created for the simultaneous transmission of three parallel simultaneous broadcasts with first- and third-year students. This approach, unlike other remote communication software, creates conditions for uniting students and teachers in improvised groups, which have an active connection with each other, which allowed the general information of a large number of students and receiving feedback from them at the same time. This qualitatively reduces the time required for work and creates the conditions for intensification of the learning process in terms of distance learning.

2. *Mutual visits and verification*. During training it is very important to create an opportunity to check the quality of classes. With the help of the developed server, we created the possibility of fast transition between channels, which enabled the administration departments of the educational institution to conduct a qualitative check of the presence of students in pairs and the quality of their education. A big problem in the conditions of distance learning is the problem of mutual visits of teachers in order to check the quality of education, improve the educational process or gain experience of teaching by young teachers from the faculty. In the conditions of the developed server and the period of the experiment, a number of mutual visitation activities were carried out, where the teachers had the opportunity to join the pairs of their colleagues and follow the course of the lesson. They had the opportunity, if necessary, to ask questions or clarify, join the broadcast and turn on their own.

3. *Conducting classes online*. During the whole period of the experiment, classes were held on the basis of the distance learning site of Bohdan Khmelnitsky Melitopol State Pedagogical University (https://dfn.mdpu.org.ua), but direct communication, lectures and seminars were held on the Discord server. According to a survey of teachers and students, which was attended by 102 students and teachers (table 4), 41.18% answered about the significant negative impact of quarantine measures on learning, but after the introduction of the Discord platform 74.51% of respondents said that significantly increased the quality of perception and transmission of information, students had the opportunity to ask questions during the lecture broadcast, and teachers could adjust their report or explanation of students' questions.
4. *Conducting active seminars*. During the period determined by the experiment, laboratory and seminar classes were conducted strictly in the order determined by the schedule. In the process of pairing, conditions were created under which students simultaneously launched parallel broadcasts on one voice channel and performed tasks, transmitting their work to the teacher, this process significantly accelerated the lesson and all tasks. Focusing on further comments from students, it can be emphasized that it has become much easier for students to complete classes in an environment where the teacher can look around and advise on possible approaches to solving problems. In addition, the opportunity for students to join each other's broadcasts was a qualitative fact, which created conditions for working in groups.
5. *Work in online groups*. Creating conditions for synchronous work and connecting students to broadcast each other, created conditions for group work, so students, divided into groups, developed individual projects under the supervision of the teacher, then on the general channel, were performances and defense projects of each group.

Carrying out of these actions acted in confirmation of expediency of use of the created system and confirmation of expediency of use of the Discord platform as it provides opportunities for carrying out certain actions while the majority of them are impossible in realization on other systems for carrying out webinars.

The survey (table 4) showed a qualitative increase in the level of students' interest in the educational process in quarantine, so 83.33% of students adopted the new system as a quality application to create conditions for synchronous communication with teachers in quarantine, 75.51% of students emphasize that the system greatly simplifies the process of perception of information and 77.45% consider Discord more convenient than the currently available software. However, 82.35% of students emphasize the need to develop distance communication systems, and 80.39% say the need to improve the educational server Discord to expand its pedagogical potential. We consider it appropriate to address the direction of automation of student management processes in pairs, development of bots for the server and training on the use of the platform in general.

We consider it important to determine the factor of psychological isolation of students, so when asked about the use of audio and video, only 79.41% and 38.24% answered positively. This highlighted the need to create quality conditions to reduce the emotional load on students and reduce their stress during training through pedagogical and psychological training, development of automated learning and confidence-building measures during the adaptation of first-year students.

During the first stage of the experiment it was determined that the constant activity of students in interaction with teachers (online lectures, visual seminars, etc.) in the system of distance communication, leads to a qualitative increase in the quality of student interaction. Summing up this stage, we can say about improving the quality of the educational process by activating the desire of students to continue their studies in a familiar and convenient for them, which is as close as possible to real classes. To this end, we considered it appropriate to state that a number of activities are mandatory in the context of long-term distance learning. Creating a remote communication system for these activities is a priority. These measures include:

1. General organizational and educational hour.
2. Mutual visit and check.
3. Conducting couples online.
4. Conducting active seminars.
5. Work in online groups.

To carry out these activities, a system of monitoring the conduct of classes and the opportunity for students and teachers to visit couples who are not part of the spectrum of their personal influence was created. This made it possible for teachers and the administration of the educational institution to check the quality of the educational process, and students had the opportunity to create their own individualized vector of education by visiting additional pairs with the permission of the teacher. Thus, a system was created to fully cover all the needs of educators to create a quality educational environment in terms of long-term

Table 4: Survey of students and teachers on the feasibility of using Discord in the educational process (%).

Question	Yes	No	It is difficult to answer
Have you been negatively affected by the transition to distance learning during quarantine?	41.18	32.35	26.47
Do you use the Discord platform while studying?	83.33	16.67	0
Does the Discord platform make the process of perceiving information in pairs easier for you?	74.51	18.63	6.86
Do you combine the use of a distance learning site with the Discord platform?	76.47	16.67	6.86
Do you find Discord more convenient than other online communication software (Skype, Zoom, Google Meet, etc.)?	77.45	9.80	12.75
Do you use audio communication in your work in pairs?	79.41	20.59	0
Do you use video communication in your work in pairs?	38.24	61.76	0
Has the notification process improved since the launch of the Discord platform?	69.61	8.82	21.57
In your opinion, is it important to further develop the system of remote communication?	82.35	2.94	14.71
Is it necessary to refine the Discord training server to expand its pedagogical potential?	80.39	0.98	18.63
In your opinion, is it appropriate to use Discord in your learning process?	79.41	3.92	16.67

distance learning. This confirmed the assumption that the use of Discord is appropriate in emergencies and in the transition to distance learning qualitatively activates the work of students, facilitating the process of perception and assimilation of the material.

In the second phase of the experiment (September-December 2020), we expanded the functions of the Discord platform to test the asynchronous component of the educational process to determine the possibility of integrated use of the Discord platform as a single platform for distance learning and blended learning.

During the second stage of the experiment, in addition to those already mentioned in the first stage, a number of measures were taken to test the quality of interaction between students and teachers in conditions of complete limitations in the means of conducting classes only Discord platform:

1. *Conducting the total number of classes*. During all classes, conditions were created for the simultaneous transmission of parallel broadcasts with students of I-III courses, by expanding the structure of the educational unit and constant coverage of lectures and practical materials on the appropriate channels of groups and conducting practical classes in constant open communication. The result was the confirmation of the results of the first stage of the experiment, because unlike other remote communication software, with the help of the Discord platform we managed to create conditions for uniting students and teachers in improvised groups, debates between students and presentation of group and individual results. All this significantly reduced the time required for students to perceive the information, which created the conditions for intensification of the learning process in terms of distance learning.

2. *Carrying out settlement practice*. During the study, we had the opportunity to test the feasibility of using the Discord platform not only in the context of general disciplinary classes, but also a more complex process of computational practice in third-year students majoring in 122 Computer Science. Prior to the internship, students were asked about their wishes for the internship platform and according to the results it was determined that 87% of students voted for the internship based on the Discord platform, 11% supported all options and 2% voted for the internship based on the Zoom. This survey once again confirms the high level of motivation and support of students in the vector of using the Discord platform compared to other modern platforms. The result of the work was an excellent increase in the pace of work of students, relative to the results of previous years, all students coped well with the task of practice and managed to defend their work. Regarding the increase in the level of quality of work performed, we can emphasize that there is a decrease in the number of students with a “medium” level of knowledge and a rel-

ative increase in the number of students with a "high level of knowledge" (table 5). We see the reason for this trend in the group work of students in synchronous mode, students were able to support and complement each other, which significantly reduced the level of students with insufficient knowledge and expand the creative abilities of students with sufficient and high levels of knowledge. In addition, communication in a student-friendly mode significantly reduced the level of psychological stress and accelerated the time of work.

3. *Carrying out modular control.* At the first stage of the experiment, all forms of student certification were conducted on the basis of the Zoom platform, but the free form of the Zoom platform is not enough for such an event, so it was decided to conduct an experimental modular control based on the Discord platform. In general, the results fully justified the hypothesis of the expediency of using Discord, all periodic modular tests were conducted in a timely and productive manner, students did not have a high level of psychological load and in a convenient and "already familiar" format for them on the Discord platform passed periodic control and confirmed their assessments. Conducted at the end of the periodic module control stressed that 82% of students "very positively" evaluate the transition of periodic module control to the Discord platform.

4. *Session control.* As part of the experiment, it was decided to conduct a series of exams for third-year students based on the Discord platform. Before the beginning, the hypothesis about the expediency of using Discord during the examination control was determined, but after the examination control, the determined hypothesis was partially refuted. The reason for this refutation was the insufficient development of internal resources of the Discord platform to record the control. Examination in distance learning requires a complete record of the entire process of writing and defending the student's work, its evaluation and possible refinements, but the Discord platform in its free format does not allow recording the process, which required the teacher to find additional screen recording software. The solution to this problem was found in the use of Bandicam Screen Recorder and Faststone Capture software, which are shareware and do not fully solve the problem assigned to them. Therefore, at this stage of platform development, we consider it appropriate to use external platforms (Zoom, Skype and others) for session control, or additional use of screen recording software.

Table 5: The results of the calculation practice of students in 2018-2020 (%).

The level of knowledge of the student	2018	2019	2020
Average	33	28	11
Sufficient	54	66	55
High	13	16	34

Therefore, we can conclude that the experiment allowed us to mark the Discord platform as useful in terms of general educational process, organizational and educational activities, administration of educational process and periodic control, but needs to expand the functionality and additions to reporting on session control, which requires recording the process of passing the exams by the student. The conducted questionnaires and analysis of the results of students' calculation practice emphasize the presence of a high positive evaluation of the platform by users (especially students). The growing level of students motivation to use the platform and the intensification of their educational activities confirms the positive impact of using the Discord platform on the quality of students' knowledge during distance and blended learning. The presence of constant development of the platform by developers, their attitude to the problems of society in quarantine allows us to emphasize the significant constant growth of the platform and make a hypothesis about the possibility of solving the problems of the platform in the future. All this confirmed the assumption that the use of Discord is appropriate in emergencies and in the transition to distance learning qualitatively activates the work of students, facilitating the process of perception and assimilation of the material.

4 CONCLUSIONS AND FUTURE WORK

The purpose of our study was to determine the feasibility and features of using the Discord platform as an environment for creating a quality system of distance communication in distance learning during emergencies. To solve the main task of the study, we analyzed information sources on safety during quarantine activities related to the pandemic of viral diseases and concluded on the needs of users of educational services to provide a quality means of distance learning and communication in long-term emergencies. Having identified the general tasks and needs of the online communication service, a comparative analysis of its Discord platform with Skype, Zoom and Google Meet systems was conducted. The results of the analysis showed that Discord requires much less load on the system and works with almost all operating systems. Further work revealed the features of using Discord functions to establish a quality environment for learning and reflected the results of an experiment conducted in the study, which surveyed students and teachers on the quality of the initial process. For educational activities, a system of monitoring classes and the opportunity for students and teachers to visit couples who are not part of the spectrum of their personal influence was created. This made it possible for teachers and the administration of the educational institution to check the quality of the educational process, and students had the opportunity to create their own individualized vector of education by visiting additional pairs with the permission of the teacher. Thus, a system was created to fully cover all the needs of educators to create a quality educational environment in terms of long-term distance learning. This confirmed the assumption that the use of Discord is appropriate in emergencies and in the transition to distance learning qualitatively activates the work of students, facilitating the process of perception and assimilation of the material. The experiment made it possible to mark the Discord platform as useful in general educational process, organizational and educational activities, educational administration and periodic control, but needs to be expanded and supplemented in terms of reporting on session control, which requires recording the process student exams. The conducted questionnaires and analysis of the results of students' calculation practice emphasize the presence of a high positive evaluation of the platform by users (especially students). The growing level of students 'motivation to use the platform and the intensification of their educational activities confirms the positive impact of using the Discord platform on the quality of students' knowledge during distance and blended learning. Thus, a system was created to fully cover all the needs of educators to create a quality educational environment in terms of long-term distance learning.

In further work, we consider it necessary to expand the existing functionality of the developed platform in the vector of automation of educational processes (class schedule, notification, automatic testing of students after class, creation of automated bots for conducting control tests) and conduct an experiment to identify their impact on the quality of education, in order to increase the quality education under quarantine restrictions or other man-made disasters.

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Author's Refresher Course for Mathematics Teachers on the Use of Open Science Cloud Services

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Abstract: Nowadays teachers need to learn how to use cloud-based technologies and systems to organize distance and blended learning. It is a single cloud-based platform that would ensure the organization of the learning process in the whole without using the third-party tools. The use of the European Open Science Cloud (EOSC) in the process of teachers' training may be useful as a possible platform that brings together more than 200 cloud services. The use of EOSC may help to support the interdisciplinary links. It is the appropriate instrument being helpful for teachers to support the organization of the process of blended and distance learning. The article presents the structure of the author's advanced training course for mathematics teachers "Cloud services of open science in the educational environment of a school". The content of advanced training course, its purpose, and the list of topics are described. It is indicated which competencies are to be improved after successful completion of this course. The given study is the initial stage of the multilevel research. The author's advanced training course for mathematics teachers "Cloud services of open science in the educational environment of a school" is an experimental introduction of the model of the cloud-oriented methodical system for training science and mathematics teachers to work in a scientific lyceum that was introducted and tested in the educational process of Kryvyi Rih State Pedagogical University.

1 INTRODUCTION

1.1 Problem Statement

In view of the approval of the Resolution of the Cabinet of Ministers of Ukraine 21.08.2019 No. 800 "Some issues of professional development of pedagogical and scientific and pedagogical staff" (Cabinet of Ministers of Ukraine, 2019) the teachers' training courses have undergone significant changes. In the speech of Mandzii (Mandzii, 2020) the main opportunities for professional development of teachers were revealed. The main changes in the professional development of teachers include the availability of free choice of seminars, training, workshops, webinars within the in-service training program. There are several areas of teachers' training, but in this study we can single out the use of information and communication technologies and particulary the cloud-based in the educational process.

The content of teachers' training courses is also influenced by the situation connected with the introduction of quarantine measures in Ukraine related to the spread of COVID-19 (2020–2021), as the different forms of distance work, blended and distance learning have become widely used (Abdula et al., 2022; Kovalchuk et al., 2023; Kucher et al., 2022; Tkachuk et al., 2021). To organize distance and blended learning, teachers need to learn how to use the cloud-based training technologies and systems that ensure the organization of the learning process in the whole within the single platform without the use of third-party tools. The option is to use cloud services and cloud-based systems in the process of teachers' training.

On January 16, 2020, the Verkhovna Rada of Ukraine adopted the Law "About Full General Sec-

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ondary Education" (Verkhovna Rada of Ukraine, 2020), according to which the grades 10-12 belong to a profile level, which also requires appropriate specific changes in the retraining of subject teachers. A separate issue is in changing the legal status of the school because the lyceum teachers should meet higher requirements than other ones. Therefore, the content of refresher courses needs to be revised, updated, and filled with modern digital technologies. In particular, the requirements for teachers who will work in lyceums (or scientific lyceums) are increasing, so in-service training courses should gain more academic and scientific components.

The principles of open science will help effectively bridge the gap between researchers and teachers. However, cloud-oriented services of open science have not yet gained widespread use in teaching and professional development of teachers. Underlying the understanding of open science is the concept that research should be reproducible and transparent, and also have long-term value through effective data storage and sharing. Using the principles of open science can be useful for training and professional development of teachers, for the formation of cloud-oriented systems of open science. Effective adoption of open science principles through data management, reproducible research, and stakeholder engagement in multimedia applications may enhance teacher learning. However, there are technical, sociocultural, and institutional challenges to embracing open science, including practical approaches to overcoming these obstacles in teacher training and in-service courses.

The participation of teachers and students in the process of scientific research is an important element in establishing new connections between science and teaching staff. Therefore, it is important to introduce open science, which can contribute to innovations taking into account the needs of teachers, lead to mutual learning and develop a scientific culture in the entire society as a whole. In particular, the introduction of cloud-oriented systems of open science into the process of teaching and professional development of teachers will lead to an increase in the level of distance and mixed learning organization in general secondary education institutions.

1.2 Literature Review

Kaplun (Kaplun, 2021) analyzes the meaning of the concept of "blended learning" and describes possible scenarios for its implementation for teachers' training (for this, the scientist provides a classification of models of blended learning). At the Department of Science Education of the Kharkiv Academy of Continuous Education, the content of advanced training courses for teachers of natural and mathematical disciplines includes the study of the specifics of blended learning and its features.

Yevtushenko (Yevtushenko, 2020) described the system of professional development of science and mathematics teachers in postgraduate education in Ukraine at the structural (national, regional (regional level), local (city/district/united territorial community level) levels. The author highlights the most promising trends in the development of in-service teachers' training: a balanced combination of traditional and distance technologies and methodological systems of training, improving accessibility of resourses and personal orientation.

The study by Bozkurt (Bozkurt, 2021) is devoted to the analysis of the social science teacher training program in terms of skills development in the 21st century. The study showed that the program needs to be improved because teachers had a low level of competence of interaction in the digital environment.

Arslan et al. (Arslan et al., 2020) implemented and evaluated the author's program of advanced training of English teachers in non-formal educational institutions. The two-week online curriculum was designed to meet the professional needs of teachers and and also contained tests. The results of the study showed that the program had a significant impact on the knowledge and behavior of teachers. Although most were positive about the program, some teachers suggested conducting a full-time program and extending the duration of the training.

Kimav and Aydın (Kimav and Aydın, 2020) describes the project of a contextual program of teacher training for the use of Web 2.0 tools in EFL lessons. The participants were 122 English teachers who worked at the School of Foreign Languages of Anadolu University. Eight consecutive stages were followed in the curriculum. This project, according to researchers, can be proposed and developed for such institutions that want to increase the competence of their teachers to integrate technology into the educational process.

According to Vicente-Saez et al. (Vicente-Saez et al., 2020), open science approach has great potential for organizing training and creating new knowledge, accelerating the process of research and innovation to find solutions to societal challenges and it will help to increase the level of specialists' training in certain fields.

Scientists note that the practices of the "old school" – a lot of outdated scientific norms sometimes impair the reliability of research. Therefore, certain norms and practices of "open science" have been developed for different scientific fields to solve these problems. This question was explored in (Gehlbach and Robinson, 2021) namely to what extent and how these norms should be adopted and adapted to pedagogical psychology and education in a broader sense.

In November 2018, the European Commission launched the European Open Science Cloud (EOSC) in Vienna. EOSC envisages the creation of a European data transmission infrastructure, the integration of high-capacity cloud solutions, and ultimately expanding the scope of these services to include the public sector and industry. The European Open Science Cloud (EOSC) initiative aims to support more than 1.7 million researchers and promote interdisciplinary research in Europe. To consider the research community needs, the EOSC Secretariat organizes seminars, interviews and consultations (Chambers et al., 2021). The purpose of such activities is not only to identify the real needs for research infrastructure services and policies in social sciences and humanities, but also the visions and future needs.

Understanding the structure of EOSC is the first step in recognizing the opportunities offered by the recently launched EOSC services. The study (Budroni et al., 2019) offers ideas for a better understanding of EOSC implementation at the present stage.

Higher education is an environment where open science and open education can be linked within a general concept of openness. Open-source research tools are easy and accessible to use for teaching and learning and to access research data and resources by students (Heck et al., 2020).

The purpose of the study is to describe and sustantiate the results of development and implementation of the author's course for advanced training of mathematics teachers "Cloud services of open science in the educational environment of a school".

2 RESULTS

Due to the transition to new standards, there is a need to retrain mathematics teachers. In the coming years, several problems related to mathematics education will have to be solved, among them there are such as:

1) the modification of the content and change of some methodical features of teaching mathematics in secondary and specialized school in particular:
    - the preparation for the implementation of educational standards of the new generation during the teaching of mathematics;
    - the formation and development of mathematics educational competencies;
    - the introduction of modern educational technologies in teaching mathematics;
    - the strengthening of applied and practical orientation in teaching mathematics;
    - the analysis and adaptation of the logical and general cultural components of mathematical training of teachers to modern requirements;
    - the improving the system of working with learners who show interest and ability to study mathematics;
2) the use of modern information and communication technologies (ICT) in teaching mathematics at school:
    - the methodological aspects of using interactive whiteboards in teaching mathematics;
    - the use of Internet resources in education;
    - the analysis of ICT capabilities in distance learning of mathematics;
    - the mathematical packages and training programs in mathematics;
    - the development of media resources and experience of their application in teaching mathematics;
3) the formation of quality assurance system of science education due to the new standards:
    - the modern means of assessing the results of teaching mathematics;
    - the monitoring, measuring, and analyzing the quality of mathematical training of learners;
    - the information technologies in quality assurance systems of science education.

The formulated topical problems of mathematics education in a modern school served as a basis for compiling the program of the author's course of professional development of mathematics teachers based on Kryvyi Rih State Pedagogical University (6 hours).

In 2019, the experiment "Designing a cloud-oriented methodological system for training teachers of science and mathematics to work in a scientific lyceum" was launched. Research work is carried out based on 6 institutions of higher education, among them there is the Kryvyi Rih State Pedagogical University. The author's advanced training course for mathematics teachers "Cloud services of open science in the educational environment of a school" is an experimental introduction of the model of the cloud-oriented methodical system of training science and mathematics teachers and mathematics to work in a scientific lyceum in the educational process of Kryvyi Rih State Pedagogical University.

The main purpose of the refresher course implementation is to form the theoretical foundations and practical techniques necessary for teachers professional activity due to the new standards.

The goal is achieved by mastering the concept of open science, the principles of open science and its significance for a teacher of mathematics; the practical mastering of skills of work with an open science platform, the application of its tools (the separate components) by mathematics teachers; the creation of own project and its filling it cloud services of open science.

The objectives of the refresher course application. The task of the refresher course introduction for teachers of mathematics is to master the theoretical foundations of open science, awareness of the need to use cloud-based systems and cloud services of open science in education; the formation of knowledge about the forms, methods, and approaches to the use of the open science platform and its components for the organization and maintenance of educational activities; gaining practical skills in using the open science platform, in particular the services of the European Open Science Cloud by teachers of mathematics.

The direction of study: the use of information and communication (digital) technologies in the educational process, including e-learning, information and cyber security.

The scope: 0.2 ECTS credits, 6 hours.

The distribution of hours: classroom work, 6 hours.

Persons carrying out the program: mathematics teachers of general secondary education institutions of any qualification category.

A certificate about advanced training of the appropriate standard is issued based on the results of successful training under the program.

The teaching methods are: the practical; the problem-based teaching; the research; the partial search; the problem-searching; the explanatory-illustrative.

The forms of study are: the practical; the problem-based teaching; the research; the partial search; the problem searching; the explanatory-illustrative.

The teaching tools are: European Open Science Cloud (EOSC) tools (separate cloud services) and a platform (or system) for organizing and conducting distance learning courses (e.g. Moodle or Google Classroom).

The requirements for hardware and software on the user's computer are: up to 1000 learners can simultaneously work with the tools (separate cloud services) of the European cloud of open science, which are available through a browser; the workplace must be equipped with a computer (laptop, netbook, tablet), possibly using a smartphone.

The prerequisite: an Internet connectivity (wired, mobile, or Wi-Fi).

While mastering the advanced training course the mathematics teachers learn to use modern digital technologies, with the focus on the introduction of cloud services to the organization of the educational process, the implementation of individual and group projects, the organization of distance and blended learning.

Here is the content of the author's refresher course (table 1). In the process of teaching mathematics, teachers develop spatial imagination, develop the ability to think logically, operate with abstract objects and correctly use mathematical concepts and laws to build a mathematical model of a situation, to understand the beauty of mathematical reasoning, to cultivate determination, perseverance.

However, today not only mathematical but also ICT competencies of teachers related to teaching mathematics play an important role. The world is becoming more dependent on information technology, and both learners and teachers must have a fairly high level of relevant competence. The program of the refresher course includes lectures and laboratory work of learners on ICT. There are some topics examples.

Topic 1. The concept of open science and its significance for the teacher of mathematics (the lecture).

Topic 2. Open science platform and its components (the workshop).

When working according to the new standards, the problem of identifying, supporting and developing talented young people, their specific training and education aimed at training future highly qualified specialists remains relevant. During the course, the issues related to the olympiads of students of different levels were analyzed; the goals, objectives of the olympiads; the methods of training students were analyzed.

Here are the main issues of the methodological section of the course program.

Topic 1. The concept of open science and its significance for the teacher of mathematics (the lecture).

The basic concepts. The fundamentals of open science. The concept of open science. The principles of open science. The fundamentals of academic integrity for teachers and students. The importance of open science for mathematics teachers in the learning process at the profile level.

Table 1: The structure of the author's refresher course.

No.	Topic	The form of the training session	The duration of the lesson
1.	The concept of open science and its significance for the teacher of mathematics	lecture	2
2.	Open science platform and its components	workshop	4
Total:			6

Topic 2. The open science platform and its components (the workshop).

The pequliarities of using the European Open Science Cloud (EOSC). The main features of the open science platform and the difference from EOSC. The stages of registration and project creation in EOSC. The main classification and categories of cloud services of open science. The selection of open science cloud services for use in the educational process. A brief overview of specialized cloud services of open science. There is an exchange of experience in the use of ICT in mathematics lessons between learners. The list of competencies to be improved is the next:

1. The ability to monitor pedagogical activities and identify individual professional needs.
2. The ability to determine the conditions and resources of professional development throughout life.
3. The ability to search for scientific and methodological materials in open journal systems.
4. The ability to select and use open source cloud services to achieve this goal.
5. The ability to organize and implement the learning process using the European Open Science Cloud and to effectively use open science cloud services.
6. The ability to establish cooperation within the open science platform.

The expected learning outcomes:

1. Knowledge and understanding of the role of cloud services of open science in the educational environment of the school.
2. The ability to use cloud services of open science in the educational environment of higher education.
3. The ability to analyze and select a cloud service of open science to achieve educational goals.
4. The knowledge and understanding of the basic concepts of open science, the principles of open science.

The teaching methods

1. The methods of organization and implementation of educational and cognitive activities:
   (a) According to the source of information:
   - Verbal: lecture (traditional or problematic), explanation.
   - Visual: observation, illustration, demonstration.
   - Practical: exercises.

   (b) According to the degree of management of educational activities:
   - under the guidance of a teacher;
   - performance of practical tasks.
2. The methods of stimulating interest in learning and motivating educational and cognitive activities:
   - educational discussions,
   - situations of cognitive novelty.

The control methods

1. The methods of oral control:
   - frontal survey,
   - interview.
2. The methods of self-control:
   - self-analysis.

The methodical support

- lecture outline;
- supporting presentations;
- methodical and training manuals;
- methodical recommendations;
- digital resources;
- professional development program.

The presented author's course is one of the components in the model of the cloud-oriented methodical system of preparation of teachers of natural and mathematical subjects for work in the scientific lyceum (Marienko, 2021). It can be offered as part of the implementation of this methodical system. The block of the methodical system unites three levels of implementation, each of which is a separate technique. The block of the methodical system of preparation of teachers of natural and mathematical subjects for work in a scientific lyceum is the key one. However, its components include three main blocks, the introduction of a methodological system of training teachers of science and mathematics to work in the scientific lyceum at: the basic, the intermediate, and the advanced levels. The described author's refresher course is the intermediate level. This level involves not only a survey of existing cloud services but at least their groups, simultaneously used for different activities (Marienko, 2021).

Formalized interviews with learners (math teachers) were conducted at the beginning and at the end of the course. The interview showed which active and interactive methods were used by teachers in the learning process and for what purpose they were used:

1. What active and interactive methods do you use?
2. How often do you use them?
3. Explain and justify the technology of use.

During a survey conducted in a form of the formalized conversation and interview at the beginning of the training, it was found that:

1. The use of some elements of the strategy of the open science introduction and the teaching techniques of its realization in the learning process: 52% – yes, 48% – no; including pair and group works: 62% – yes, 38% – no;
2. The comprehensive use of the strategy and techniques in the classroom in the presentation of educational material: 48% – yes, 52% – no;
3. The independent work on educational material, to use the strategy and techniques in the classroom: 33% – yes, 67% – no.

Also, at the beginning of the refresher course, a group of mathematics teachers (17 respondents) was interviewed to develop learners' research skills (figure 1). Learners of the refresher course believe that one of the best ways is to use a selection of creative tasks (14 respondents answered). Only 9 teachers out of 17 surveyed work with learners in electives and consider this path not very effective. For some reason, only 4 teachers believe that more complex tasks will help develop students' research skills.

Some questions concerned previous knowledge on the subject of the refresher course (figure 2). The total number of respondents in this survey was 19 learners of the refresher course. It turned out that before taking the refresher course, most respondents (16 teachers out of 19 respondents) were not familiar with the concept of open science, its principles and did not know what European Open Science Cloud (EOSC) was. At the same time, all respondents answered that they use

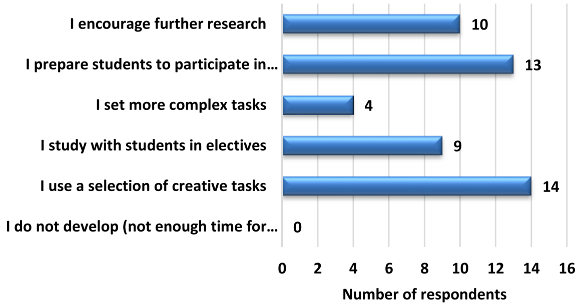

Figure 1: Ways to develop students' research skills.

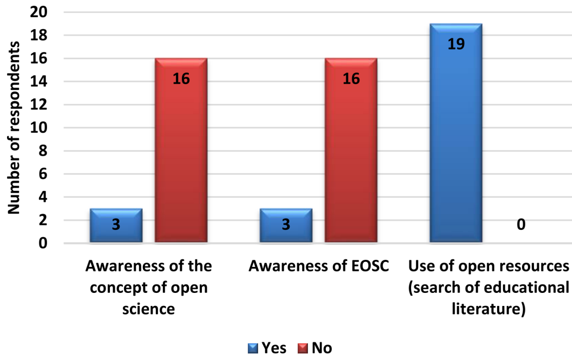

Figure 2: Preliminary awareness of learners on the subject of open science.

only open electronic resources to search for educational literature (figure 2).

A survey conducted at the end of the training in a form of the formalized conversation and interview showed the results presented in table 2.

Questionnaires of learners (mathematics teachers) showed their great interest in using interactive learning technology in advanced training courses. It turned out that learners:

1) approve the assistance and recommendations proposed for teachers of mathematics within the advanced training courses – 68%, difficult to answer – 20%, do not approve – 12%;
2) the level of use of the learning course electronic manuals contained in the LMS of Kryvyi Rih State Pedagogical University in the process of conducting the advanced training courses in mathematics is – 75%, can not use -12%, do not want to use – 13%;
3) the level of the use of the technologies described in the manual in LMS of Kryvyi Rih State Pedagogical University for their developments in mathematics are – 41%, can not use – 44%, do not want to use – 15%;
4) the ability to work independently on the material on the subject – 37%, can not work independently – 42%, do not want to work independently – 21%;

Table 2: Conducting a formalized interview and interview at the end of the course.

	Yes	No
used some elements and techniques in the classroom in the presentation of educational material	65%	35%
including pair and group works	77%	23%
comprehensive use of techniques in the classroom when teaching educational material	58%	42%
used independent work on educational material, to use strategy and techniques in the classroom	38%	62%

5) the ability to use of the cloud technologies of open science in preparation for presentations – 45%, can not use – 34%; do not use – 21%;

6) the desire to master the technologies described in the course manual in LMS of Kryvyi Rih State Pedagogical University for further professional activity – 90%, difficult to answer – 8%, do not want – 2%;

7) the ability to use the technologies described in the course manual in mathematics lessons in secondary education institutions – 80%, do not have a hard time answering – 12%, do not want – 8%.

Two months later after the course, a selective survey of students that have been taught by teachers was conducted. Students highly appresiated the advantages of open science technology in teaching mathematics used by mathematics teachers (that they acquired after passing the refresher course): 65% say that the favorable atmosphere for investigative learning and research has increased, 20% say that in such an atmosphere will be able to learn and investigate independently and only 15% are not sure efficiency. Students' interest in learning mathematics is more than 55%. Students claim that active and interactive technologies of open science help them to study mathematics (52%), to find the right direction in teaching mathematics (29%). And only 19% of students say that it does not affect their learning. More than 65% of students believe that math teachers make little use of active and interactive technologies of open science in the learning process (figure 3).

The last stage of the course was a round table for learners and teachers. During the round table the most successful aspects of the retraining course were highlighted, the learners expressed their wishes to improve the program of future courses. In particular, it was proposed to increase the time for the analysis of the peculiarities of the development of Internet pages and sites of mathematics teachers, to consider the practical implementation of the technology of system-activity approach in mathematics lessons. In general, both teachers and learners of the course conducted the work was considered successful and useful for the practical activities of a mathematics teacher.

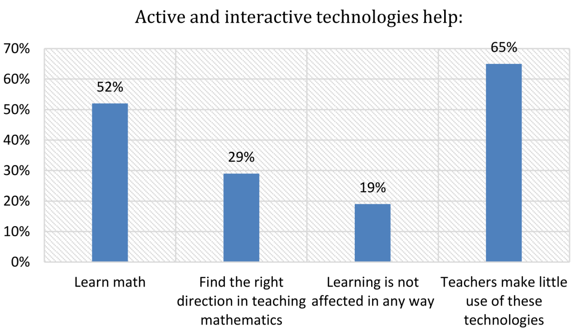

Figure 3: Feedback from students on the use of interactive technology to technologies mathematics.

3 CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The author's course of advanced training of mathematics teachers "Cloud services of open science in the educational environment of a school" is an experimental introduction of the model of the cloud-oriented methodical system of preparation of teachers of natural and mathematical subjects to work in scientific lyceum in Kryvyi Rih State Pedagogical University. The competencies of open science for learners of the advanced training course of Kryvyi Rih State Pedagogical University are constantly monitored. Due to the determined level, timely adjustment of methodical work and further planning for raising the professional competency of course learners is carried out. All participants in the experiment are provided with access to a cloud-oriented methodological system of training science teachers and mathematics to work in a scientific lyceum.

The introduction of the author's advanced training course for mathematics teachers "Cloud services of open science in the educational environment of a school" will lead to a partial solution to the problems associated with mathematics education. First of all, it concerns the modification of the content and changes in some methodological features of teaching mathematics in secondary and specialized schools. The main issues of the methodological section of the course program, aimed at individual competencies to be improved are the next:

1. The ability to monitor pedagogical activities and identify individual professional needs.
2. The ability to determine the conditions and resources of professional development throughout life.
3. The ability to search for scientific and methodological materials in open journal systems.
4. The ability to select and use open source cloud services to achieve this goal.
5. The ability to organize and implement the learning process using the European Open Science Cloud and to effectively use open science cloud services.
6. The ability to establish cooperation within the open science platform.

Questionnaires of learners (teachers of mathematics) showed their great interest in the use of interactive learning technology in advanced training courses. Two months later, a survey of students taught by teachers after the course was conducted. The students highly appreciated the use of interactive technology in teaching mathematics by mathematics teachers after taking a refresher course.

The study involved a small sample of respondents. Further research will be expanded and the sample of respondents will be increased. Subsequent research will deepen the study of the problem of teachers using open science services. As further researches discussion of problems of effective use of a cloud-oriented methodical system of preparation of teachers of natural and mathematical subjects for work in a scientific lyceum, including electronic educational resources, cloud services, etc.

As part of the author's refresher course, teachers only got acquainted with some EOSC services. The number of hours allocated for the workshop is not enough to study each individual EOSC tool in detail. Prospects for further research will expand the content of the author's course and focus on the use of individual services.

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Methodology for Assessing the Quality of an Educational Program and Educational Activities of a Higher Education Institution Using a Neural Network

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Keywords: Evaluation Criteria, Educational Program, Educational Activities, Prognostication, Rating, ANFIS, Artificial Neural Networks.

Abstract: The article discusses a methodology for assessing the quality of educational programs and activities in higher education institutions using artificial intelligence tools such as the adaptive system of neuro-fuzzy inference (ANFIS) and an L-layer neural network. The purpose of the study was to address the problem of objectivity in self-assessment and identify potential problems and shortcomings in educational activities before the start of an accreditation examination. The study used student ratings on a four-level assessment scale as input data for the L-layer neural network, and the criteria for assessing the quality of the educational program as input variables for the ANFIS system. The hypothesis was that students with higher ratings of educational achievement would provide more objective assessments of the quality criteria of the educational program and activities. The results showed that the L-layer neural network made more accurate predictions than the ANFIS model. The article suggests that this approach can provide higher education managers with qualitative forecasts to determine the quality of educational services and identify potential problems before the start of an accreditation examination. However, the study acknowledges the need for further research on larger data volumes to improve the predictive capabilities of the models.

1 INTRODUCTION

In assessing the quality of education, as well as in conducting pedagogical research, we are faced with information that has non-numerical characteristics that are difficult to formalize. For example, the number of computers, the number of students, the area of educational premises in a higher education institution are measurable, but the evaluation of the educational program and educational activities according to the educational program is carried out according to non-numerical criteria. The institution in the process of self-assessment, and subsequently the experts in the process of accreditation examination, must assess according to the assessment scale, which covers four levels of compliance with the criteria: A, B, E, F.

As a result, there is a need to build methods for quantitative description of processes and subjects related to assessing the quality of the educational program and educational activities. Of particular importance is the quality of education, which means some total indicator that reflects the results of the educational institution, as well as compliance with the needs and expectations of society (different social groups) in the formation of individual competen-

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cies. The methods of quantitative evaluation of the educational program and educational activities under this program will allow the higher education institution to identify existing shortcomings and potential problems, as well as provide an opportunity to address them before the accreditation examination.

Assessing the quality of educational programs and educational activities is complicated by the fact that the value of this indicator depends on many factors, possibly with an unknown nature of influence. Also in this case there is a specificity of the "product" of education – a graduate of an educational institution, which should be considered as a complex system. There are various methods and algorithms for assessing the quality of educational activities. In this study, we propose a method of assessing the quality of educational programs and educational activities based on the neuro-fuzzy approach, due to the active development of analytical systems, based on the technology of artificial intelligence. The most popular and proven of these technologies are neural networks, which successfully solve a variety of "fuzzy" tasks – prediction, classification, recognition of handwritten text, language, images (Markova et al., 2018; Tarasenko et al., 2019; Kirichek et al., 2019; Porokhnya and Ostapenko, 2019; Horal et al., 2020; Valko and Osadchyi, 2020). In such problems, where traditional technologies are powerless, neural networks often act as the only effective solution. In this work, artificial neural networks are used to solve the problem of assessing the quality of educational programs and educational activities.

Mandatory conditions for accreditation are compliance with the educational program and educational activities of the higher education institution under this educational program with the criteria established by law. In particular, the forms and methods of teaching should contribute to the achievement of the stated goals of the educational program and program learning outcomes.

Since the educational program and educational activities must meet the requirements of a student-centered approach and the principles of academic freedom, the hypothesis of the study is that based on a sample of students and graduates of higher education, the quality of educational programs and educational activities, which will be able to adequately perform a comprehensive assessment of the quality of the educational program and educational activities.

Intelligent data processing using a neural network allows forming forecast probabilities of values of future results of accreditation examination in a higher education institution, which can contribute to the improvement of measures to improve the educational program. The results of forecasting can be used by the management of faculties and graduating departments as informative and recommendatory. In addition, guarantors of educational programs based on forecasts can plan activities and individual work with teachers to positively change the forecast. Thanks to the analysis of the received data it is possible to reveal weak points of the educational process that will give the chance to modernize it.

With this in mind, the article aims to substantiate, develop and implement a mathematical model of a comprehensive assessment of the quality of educational programs and educational activities based on the methods of the neuro-fuzzy approach.

1.1 Theoretical Background

Assessing the quality of educational activities according to clearly defined criteria and methodologies is an important task in the process of accreditation of educational programs, which are used to train applicants for higher education in Ukraine. In the process of preparing for accreditation and preparation of materials for self-assessment of the educational program, there are problems in determining the objectivity of self-assessment and finding potential problems and shortcomings of educational activities. Due to this problem, the urgent task is to find mathematical tools that could be used by managers of higher education institutions in their approaches to determining the quality of educational services offered.

The paradigm shift in educational philosophy and practice has led to focusing primarily on student learning outcomes. The educational process should be results-oriented – what exactly students know and can actually do. Accordingly, student-centered learning is an approach in which students influence the content, activities, materials, and pace of their learning. This model of learning puts the student at the center of the learning process (Black et al., 2015).

EU initiatives call for increased efficiency, international attractiveness, and competitiveness of higher education institutions. Wächter et al. (Wächter et al., 2015) considers different approaches to quality, quality assurance, and ratings, analyzes recent research, critically analyzes these approaches in a comparative perspective, provides recommendations and policy options for parliament.

The problem of determining a set of effective indicators that are easy to determine and can be applied to both large public universities and small regional private colleges, from university programs to alternative programs is also relevant for the United States (Hammerness and Klette, 2015).

Cherniak et al. (Cherniak et al., 2020) investigated the possibility of assessing the quality of qualimetry objects by graph analytical method, ie to apply the principle of determining the area and volume under curved surfaces both in the plane and in space, which are created by combining estimates of individual quality indicators on a dimensionless scale. It is shown that, as a rule, mathematical dependences are nonlinear and their research is reduced to the development of universal methods that could be applied to objects of qualimetry, regardless of their nature, complexity, importance, and more. Having unit quality indicators in a single (dimensionless) rating scale, it is proposed to determine a single comprehensive quality indicator of the object of qualimetry using the method of integration, which takes into account the evaluation of unit quality indicators.

Parvu and Ipate (Parvu and Ipate, 2007) propose a mathematical model based on a set of indicators that are adapted to the classification structure of intellectual capital, which is unanimously recognized worldwide, namely to the external and internal structure and competence of employees. The Rompedet method, an original product of the Romanian school of management (Isac et al., 2010), was used as a mathematical calculation tool.

When assessing the quality of education, we are faced with a huge number of different criteria, each of which may consist of many sub-criteria, therefore, the task of assessing the quality of education in its mathematical formulation is multi-criteria. Problem situations that are modeled and described by linear models and depend on many factors play an important role, so solving a multicriteria decision-making problem is often accompanied by solving multicriteria linear programming problems, or in other words, vector optimization problems.

Given these problems, mathematical models of integrated quality assessment using methods that are based on the convolution of criteria were also of interest for our study. Models and methods of multicriteria optimization are considered in (Kondruk and Maliar, 2019), in particular, the method of additive convolution of criteria and the method of multiplicative and minimax convolution of criteria. The method of multiplicative convolution of partial criteria to a single generalized indicator, which provides as a normalized divisor to use the maximum (minimum) values of partial criteria, obtaining which does not cause significant difficulties, ie is carried out on many available design solutions is considered in (Grytsyuk and Grytsiuk, 2014). Chervak (Chervak, 2010) uses one of the methods of solving the Paretian multicriteria optimization problem as a mathematical tool of the decision-making process. To organize the selection problems on the same admissible set of alternatives, the concept of the super criterion of any criterion is introduced; if the criterion is a super criterion of this criterion on this set, then the last criterion is a subcriteria of the first. It is shown that the solution of the problem of multicriteria selection by the Paretian convolution is reduced to the solution of the problems of scalar or lexicographic optimization.

The theory of artificial neural networks and models of deep learning is considered in the fundamental works (Goodfellow et al., 2016; Müller et al., 1995; Sivanandam et al., 2006), system design based on a neuro-fuzzy approach (Shtovba, 2007; Shtovba and Pankevych, 2018).

The use of neural networks to classify the status of a graduate of a higher education institution based on selected academic, demographic, and other indicators is considered by Lesinski et al. (Lesinski et al., 2016). A multilayer neural network with feedback is used as a model. The model was taught based on more than 5,000 records of entrance exams and university databases. Nine input variables consisted of categorical and numerical data that contained information about high school education, test results, assessment of high school teachers, parental assessment, and others. Based on these inputs, the multilayer neural network predicted the success of university entrants. With the help of the neural network, it was possible to predict the success of graduates and achieve the best performance with an accuracy of classification exceeding 95%. Black et al. (Black et al., 2015) examining the relationship between quality and success of high school students in college found no convincing evidence that exposure characteristics of high school diminish over time teaching students.

To address the issue of determining the quality of educational training, Mahapatra and Khan (Mahapatra and Khan, 2007) developed the EduQUAL methodology and proposed an integrative approach using neural networks to assess the quality of education. Four neural network models based on a feedback algorithm are used to predict the quality of education for different stakeholders. This study showed that the P-E Gap model is the best model for all stakeholders.

The need to introduce neural network technology in educational courses of educational institutions indicates by Semerikov et al. (Semerikov et al., 2022). Educational neural networks are often used for forecasting. For example, students must choose courses that interest them for the next semester. Due to limitations, including lack of sufficient resources and the overhead of several courses, some universities may not be able to teach all courses of the student's choice. Universities need to know each student's requirements for each course each semester for optimal course planning. Kardan et al. (Kardan et al., 2013) used a neural network to model student choice behavior and apply the resulting function to predict the final enrollment of students for each course. The results showed high prediction accuracy based on experimental data. Arsad et al. (Arsad et al., 2013), Osadchyi et al. (Osadchyi et al., 2018), Okubo et al. (Okubo et al., 2017b) prove that the use of neural networks in predicting educational processes will allow obtaining results with a much higher level of accuracy and less time. According to Abu Naser et al. (Abu Naser et al., 2015), an artificial neural network can correctly predict the success of more than 80% of future students.

Chaban and Kukhtiak (Chaban and Kukhtiak, 2020) analyze the problem of the social system, which consists of many students and teachers of higher education to create effective learning pairs "teacher-student". Elements of the theory of artificial intelligence based on artificial neural networks were used to form the mentioned learning pairs. Okubo et al. (Okubo et al., 2017a) propose to use a recurrent neural network (RNN) to predict students' final grades using journal data stored in educational systems.

Liu et al. (Liu et al., 2022) propose a method for assessing the quality of preparation for graduate school, which is based on the algorithm of neural network backpropagation and stress testing. This method creates a publicly available list of indicators consisting of 19 criteria in 4 groups of criteria, such as attitudes towards teaching, teaching content, approach to teaching, and the main characteristics of teachers. After the neural network algorithm is used to determine the optimal parameters of the evaluation model, a sensitivity test is used to identify indicators that have a significant impact on the quality of education. Also, scenario analysis is used to study the impact of the quality of education in pre-defined situations, providing theoretical and empirical support for assessing the quality of postgraduate teaching, improving the quality of education, and professional growth of teachers.

Educational institutions are constantly striving to improve the services they offer, their goal is to have the best teaching staff, improve the quality of teaching and academic success of students. Knowledge of the factors influencing student learning can help universities and learning centers adapt their curricula and teaching methods to students' needs. One of the first measures taken by educational institutions in the context of the COVID-19 pandemic was the creation of virtual learning environments (Pererva et al., 2020). To understand the factors influencing the university learning process in virtual learning environments, Rivas et al. (Rivas et al., 2021) applied several automatic learning methods to publicly available data sets, including tree-like models and various types of artificial neural networks.

The availability of educational data supported by learning platforms provides opportunities to study student behavior and solve problems in higher education, optimize the educational environment and ensure decision-making using an artificial neural network (Waheed et al., 2020).

Cader (Cader, 2020) uses a deep neural network to assess students' acquisition of knowledge and skills. It is noted that the obstacle to the application of the method in teaching is the relatively small amount of data in the form of available estimates required for neural network training. A new method of data augmentation is proposed – asynchronous data augmentation through pre-categorization, which solves this problem. Using the proposed method, it is possible to carry out neural network training even for small amounts of data.

Do and Chen (Do and Chen, 2013) present a neuro-fuzzy classifier that used the results of previous exams and other related factors as input variables and classified students based on their expected learning outcomes. The results showed that the proposed approach achieved high accuracy compared to the results obtained based on other known approaches to classification, in particular, Naive Bayes, neural networks, and others.

Fazlollahtabar and Mahdavi (Fazlollahtabar and Mahdavi, 2009) proposed a neuro-fuzzy approach based on evolutionary techniques to obtain the optimal learning pathway for both teacher and student. The neuro-fuzzy approach allows providing recommendations to the teacher for making pedagogical decisions based on the student's learning style. On the other hand, the neural network approach is used for the student to create a personalized curriculum profile based on the individual needs of the student in a fuzzy environment.

Taylan and Karagözoğlu (Taylan and Karagözoğlu, 2009) use a systematic approach to designing a fuzzy inference system based on a class of neural networks to assess student achievement. The developed method uses a fuzzy system, supplemented by neural networks, to enhance some of its characteristics, such as flexibility, speed, and adaptability, called the adaptive neuro-fuzzy inference system (ANFIS). The results of the ANFIS model are as reliable as statistical methods, but they encourage a more natural way of interpreting student learning outcomes.

In comparison with these works, this study fills a gap in the methods of a comprehensive assessment of the quality of educational programs and educational activities based on a neuro-fuzzy approach.

1.2 Methods

In this study, methods of mathematical modeling and computational experiment based on statistical processing of data assessments of the quality of educational programs and educational activities were used. The essence of the methodology of mathematical modeling is to replace the original object with its mathematical model and study it with the help of computer technology. Processing, analysis, and interpretation of calculation results were carried out by constant comparison with the results of statistical processing of expert estimates. In the course of the research, refinements were made and the mathematical model was revised and the cycle of the computational experiment was repeated.

The methodology for assessing the quality of the curriculum and educational activities is built using methods and tools of artificial intelligence, implemented in the package Fuzzy Logic Toolbox system MATLAB in the form of adaptive neuro-fuzzy output ANFIS.

A fuzzy inference system can be represented as a neuro-fuzzy network – a neural network of direct signal propagation of a special type, or ANFIS-model. The architecture of a neuro-fuzzy network is isomorphic to a fuzzy knowledge base. Neuro-fuzzy networks use differentiated implementations of triangular norms (multiplication and probabilistic OR), as well as smooth membership functions. This makes it possible to use fast algorithms for training neural networks based on the backpropagation method to tune neuro-fuzzy networks.

ANFIS implements the Sugeno fuzzy inference system through a five-layer feed-forward neural network. Purpose of network layers:

- first layer – terms of input variables;
- the second layer – antecedents (parcels) of fuzzy rules;
- the third layer is the normalization of the degree of implementation of the rules;
- the fourth layer is the conclusion of the rules;
- fifth layer – aggregation of the result obtained according to different rules.

The network inputs are not allocated to a separate layer. Figure 1 shows an ANFIS network with two input variables (x_1 and x_2) and four fuzzy rules. Three terms are used for the linguistic evaluation of the input variable, and two terms for the variable.

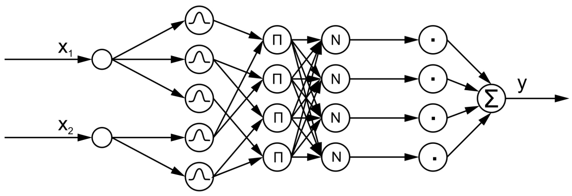

Figure 1: An example of an ANFIS network.

We will use the following notation:

- $x_1, x_2, ..., x_n$ – network inputs;
- y – network output;
- R_r : if $x_1 = a_{1,r}, ..., x_n = a_{n,r}$ it $y = b_{0,r} + b_{1,r}x_1 + ... + b_{n,r}x_n$ is a fuzzy rule with a serial number r;
- m – number of rules $\overline{r = 1,m}$,
- $a_{i,r}$ – fuzzy term with a membership function $\mu_r(x_i)$ used for linguistic evaluation of a variable x_i in the r-th rule $(r = \overline{1,m}, i = \overline{1,n})$;
- $b_{q,r}$ are the conclusion coefficients of the r-th rule $(r = \overline{1,m}, q = \overline{0,n})$.

ANFIS-network works as follows.

Layer 1. Each node of the first layer represents one term with a bell membership function. The inputs of the network are connected only to their terms. The number of nodes in the first layer is equal to the sum of the cardinalities of the term set of input variables. The degree of belonging of the value of the input variable to the corresponding fuzzy term is fed to the output of the node:

$$\mu_r(x_i) = \frac{1}{1 + \left|\frac{x_i - c}{a}\right|^{2b}}, \tag{1}$$

where a, b and c are membership function parameters that can be tuned.

Layer 2. The number of nodes in the second layer is m. Each node of this layer corresponds to one fuzzy rule. The node of the second layer is connected to the nodes of the first layer, which form the antecedents of the corresponding rule. Therefore, each node of the second layer can receive from 1 to n signals. The output of the node is the degree of execution of the rule, calculated as the product of the input signals. Let us denote the outputs of the nodes of this layer as $\tau_r, r = \overline{1,m}$.

Layer 3. The number of nodes in the third layer is also m. Each node of this layer calculates the relative level of execution of the fuzzy rule according to the formula:

$$\tau_r^* = \frac{\tau_r}{\sum_{j=1}^{m} \tau_j}. \tag{2}$$

Layer 4. The number of nodes in the fourth layer is also m. Each node is connected to one node of the third layer, as well as to all inputs of the network (figure 1 connections to the inputs are not shown). The node of the fourth layer calculates the contribution of one fuzzy rule to the network output by the formula:

$$y_r = \tau_r^*(b_{0,r} + b_{1,r}x_1 + ... + b_{n,r}x_n). \quad (3)$$

Layer 5. A single node of this layer sums up the contributions of all rules:

$$y = y_1 + ... + y_r + ... + y_m. \quad (4)$$

Typical neural network training procedures can be applied to tune an ANFIS network, as it uses only differentiated features. It is common to use a combination of gradient descent as a backpropagation algorithm and the least-squares method. The error backpropagation algorithm regulates the parameters of rule antecedents, that is, membership functions. The least-squares method evaluates the rule inference coefficients since they are linearly related to the network output.

Each iteration of the tuning procedure is performed in two steps.

In the first stage, a training sample is fed to the inputs, and, based on the discrepancy between the desired and actual behavior of the network, the optimal parameters of the nodes of the fourth layer are determined using the least-squares method.

In the second stage, the residual mismatch is transmitted from the network output to the inputs, and the parameters of the nodes of the first layer are modified by the backpropagation of the error. At the same time, the rule inference coefficients found at the previous stage do not change. The iterative tuning procedure continues as long as the mismatch exceeds a predetermined value. To tune the membership functions, in addition to the error backpropagation method, other optimization algorithms can be used, for example, the Levenberg-Marquardt method.

The ANFIS editor in Matlab allows you to automatically synthesize a neuro-fuzzy network from experimental data. In this case, the accessories of the synthesized systems are tuned (trained) in such a way as to minimize the deviations between the results of fuzzy modeling and experimental data. The ANFIS editor is loaded using the anfisedit command.

The ANFIS editor contains 3 top menus – File, Edit and View, visualization area, ANFIS properties area, data loading area, source fuzzy inference system generation area, training area, testing area, current information output area, as well as Help and Close buttons, which allows you to call the help window and close the ANFIS editor, respectively.

Participants in the experiment – full-time master's students (22 people) and graduates of higher education institutions of the previous term of study are the same specialties (32 people) – a total of 54 people. This number of respondents is due to the number of indicators of quality criteria because the data format of the artificial network in MATLAB supports square matrices, in this case, 54x54. Before the accreditation examination, students were offered questionnaires with a proposal to assess the quality of the educational program and educational activities of the specialty on an assessment scale covering four levels: F, E, B, A. Student assessments were used to form the vector of artificial neural network inputs. After the accreditation examination, the expert assessments were used to check the quality of the prediction of the artificial neural network.

The experience of European countries demonstrates the expediency of involving students in accreditation examination. For example, the Polish Accreditation Commission consists of 80 – 90 members appointed by the Minister of Science and Higher Education among the candidates nominated by the Senates of higher education institutions, the conferences of rectors of scientific schools and universities in Poland, the Parliament of Students of Poland (the President of the Student Parliament is a member of the Polish Accreditation Commission). In Slovakia, Academic Ranking and Rating Agency is a civic association founded in 2004 on the initiative of former student leaders and academics. The Slovenian Quality Assurance Agency for Higher Education SQAA-NAKVIS (Slovenian Quality Assurance Agency for Higher Education) appoints at least three members of each expert group, of which at least one foreign expert, an expert in the field of quality assessment of higher education and one representative from among students) and others (Tryhub, 2016).

To ensure the representativeness of the sample, the study of its design was carried out based on randomization. The decision on the statistical deviation of the null hypothesis regarding the differences between the averages, thus, was also associated with the procedure of random sampling.

The rating scale covers four levels of compliance by the requirements of the legislation (F, E, B, A) (Verkhovna Rada of Ukraine, 2019). Also, the legislation establishes 10 criteria for assessing the quality of the educational program (Verkhovna Rada of Ukraine, 2019):

1) design and objectives of the educational program (4);
2) structure and content of the educational program (9);

3) access to the educational program and recognition of learning outcomes (4);
4) teaching and learning according to the educational program (5);
5) control measures, evaluation of applicants for higher education and academic integrity (4);
6) human resources (6);
7) educational environment and material resources (6);
8) internal quality assurance of the educational program (7);
9) transparency and publicity (3);
10) learning through research (6).

In turn, each of these criteria has from 3 to 9 indicators (the number is indicated in parentheses). Together, all 10 criteria contain 54 indicators.

2 RESULTS

At the first stage of the study, the collection and statistical processing of data on the results of the assessment of students and graduates of higher education educational programs and educational activities on the educational program for each criterion.

In the second stage, a computational experiment was performed. The cycle of the computational experiment was carried out in several stages:

1) the choice of approximation and mathematical formulation of the problem (construction of a mathematical model of the phenomenon under study);
2) development of a computational algorithm for solving the problem;
3) implementation of the algorithm in the form of a program for the PC;
4) settlements on the PC;
5) processing, analysis and interpretation of calculation results, comparison with the results of statistical processing of expert estimates and, if necessary, refinement or revision of the mathematical model, i.e. return to the first stage and repeat the cycle of the computational experiment.

Assessing the quality of the curriculum and learning activities is complicated by the fact that each of the 10 criteria, in turn, consists of several indicators (3-9) and is due to many factors, possibly with an unknown nature of influence, which is also non-numerical. To assess the quality of the curriculum and training activities, it is proposed to use a two-tier system based on the ANFIS package and artificial neural networks to predict assessment scores.

The ANFIS hybrid system is a combination of the Sugeno neuro-fuzzy inference method with the ability to train a five-layer artificial neural network (ANN) of direct propagation with a single output and multiple inputs, which are fuzzy linguistic variables. As input variables of the ANFIS system, we use the criteria for evaluating the quality of the educational program of 10 groups of factors $V_i (i = 1, ..., 10)$.

The output variable of the ANFIS system is a numerical assessment of the quality of the curriculum and training activities and is defined as a function $y = f(V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_10)$.

Layer 1 of the ANFIS system for the linguistic evaluation of input parameters uses the term set of all possible values of the linguistic variable. $A_{Vi} = \{``F", ``E", ``B", ``A"\}$. In symbolic form we write: $A_{Vi} = \{F < i >, E < i >, B < i >, A < i >\}$. The term set of the original linguistic variable y is the set of values of quality assessments of the curriculum and educational activities: $T_y = \{F, E, B, A\}$. The outputs of the nodes of layer 1 are the values of the membership functions at specific values of the input variables.

Layer 2 is non-adaptive and defines the preconditions of fuzzy production rules. Production rules – a form of representation of human knowledge in the form of a sentence type – if (condition), then (action). The rules provide a formal way to present recommendations, guidance, or strategies. They are ideal in cases where the knowledge of the subject area arises from the empirical associations accumulated during the work on solving problems in a particular field.

Each node of this layer is connected to those nodes of layer 1, which form the prerequisites of the corresponding rule. To solve this problem, four fuzzy production rules are formulated: $P = \{p_1, p_2, p_3, p_4\}$, because according to the features of the ANFIS network, the number of network rules must correspond to the dimension of the term set of the source variable y.

Nodes perform a fuzzy logical operation "I" (min). The outputs of the nodes of this layer are the degree of truth (fulfillment) of the preconditions of each of the four fuzzy production rules, which are calculated by the formulas:

$$\begin{cases} w_1 = \min(\mu_{F1}(V_1), \mu_{F2}(V_2), \mu_{F3}(V_3), \mu_{F4}(V_4)) \\ w_2 = \min(\mu_{E1}(V_1), \mu_{E2}(V_2), \mu_{E3}(V_3), \mu_{E4}(V_4)) \\ w_3 = \min(\mu_{B1}(V_1), \mu_{B2}(V_2), \mu_{B3}(V_3), \mu_{B4}(V_4)) \\ w_4 = \min(\mu_{A1}(V_1), \mu_{A2}(V_2), \mu_{A3}(V_3), \mu_{A4}(V_4)) \end{cases} . \quad (5)$$

Layer 3 normalizes the degree of implementation of each of the fuzzy production rules (calculation of the relative degree of implementation of the rules) as follows:

$$\overline{w}_h = \frac{w_h}{\sum_{i=1}^{h} w_i}, \tag{6}$$

where $h = 1, ..., 4$ is production rule number. Layer 4 calculates the contribution of each fuzzy production rule to the output of the network according to the formula.

$$\begin{aligned} y_h(v, V) = \overline{w}_h(v_h^{(0)} + v_h^{(1)}V_1 + v_h^{(2)}V_2 + v_h^{(3)}V_3 + \\ + v_h^{(4)}V_4 + v_h^{(5)}V_5), \end{aligned} \tag{7}$$

where $v_h^{(0)}$ – coefficients of the initial function ($i = 0, ..., 5$).

Layer 5 summarizes the contributions of all the rules:

$$y = \sum_{i=1}^{4} y_i. \tag{8}$$

Training of the ANFIS network was carried out for 24 epochs by a hybrid method. During training, the type of membership functions, the type of initial function, and their coefficients are selected. As a result of training a fuzzy network for four rules, Gaussian functions were adopted as membership functions, and a linear function was adopted as the initial function. As a result of training, membership functions and their coefficients were also obtained.

To assess each of the 10 groups of factors that affect the quality of the curriculum and educational activities by the evaluation criteria, 10 modules are used, which are implemented using artificial neural networks. Thus, it is necessary to design neural networks, a mathematical model of a comprehensive assessment of the quality of the educational program and educational activities based on the methods of the neuro-fuzzy approach. For this purpose, the Neural Network Toolbox was used. To form neural networks, it is necessary to determine their topology, learning mechanism, and testing procedure. Also, the training of an artificial neural network requires input data – a sample of answers of students and graduates with reliable quality indicators, determined based on these criteria.

A standard L-layer feedforward neural network consists of a layer of input nodes (we will stick to the position that it is not contained in the network as an independent layer), $(L-1)$ hidden layers, and an output layer that is connected in series in the forward direction and does not contain a connection between elements within a layer and feedback between layers. The most popular class of multilayer feed-forward networks is formed by multilayer perceptrons, where each computational element uses a limit or sigmoidal activation function. A multilayer perceptron can form arbitrarily complex decision limits and implement arbitrary Boolean functions. The development of a backpropagation algorithm for determining weights in a multilayer perceptron has made these networks the most popular among researchers and users of neural networks. The vast majority of programs involve the use of such multilayer perceptrons. Networks consisting of successive layers of neurons are more commonly used. Although any network without feedback can be represented as successive layers, the presence of many neurons in each layer can significantly speed up calculations using matrix accelerators.

The popularity of perceptrons is due to a wide range of available tasks that can be solved with their help. In the general case, they solve the problem of approximating multidimensional functions, that is, constructing a multidimensional mapping $F : x \Rightarrow y$ that generalizes a given set of parameters $\{x^\alpha \Rightarrow y^\alpha\}$.

Depending on the type of output variables (the type of input variables is not critical), the approximation of functions can take the form of classification (discrete set of initial values), or regression (continuous initial values).

Many practical problems of pattern recognition, noise filtering, time series prediction, etc. come down to basic settings. The reason for the popularity of perceptrons is that, for their range of tasks, they are, firstly, universal, and secondly, they are efficient in terms of the computational complexity of devices.

As a result of the development of neurocomputing, a large number of efficient models of neural networks have been created, focused on solving various problems. Due to this, artificial neural networks are successfully used to solve a wide class of practical problems. Therefore, when solving a specific problem, it is necessary to solve the issue of choosing the most appropriate neural network model, its parameters, and the training method.

Typically, a network consists of many sensor elements (input nodes or source nodes) that form an input layer; one or more hidden layers of computational neurons, and one output layer of neurons. The input signal propagates through the network in a forward direction from layer to layer. Such networks are usually called multilayer perceptrons. They are a generalization of a single layer perceptron.

Multilayer perceptrons are successfully used to solve various problems. At the same time, supervised learning is performed using such a popular algorithm as the error back-propagation algorithm. This method consists of error correction (error-correction learning rule). It can be thought of as a generalization of the equally popular adaptive filtering algorithm, the mean squared error minimization (LMS) algorithm.

Multilayer perceptrons have three characteristic features.

1. Each neuron of the network has a non-linear activation function. It should be noted that this non-linear function is smooth (that is, differentiated everywhere), in contrast to the hard threshold function used in the Rosenblatt perceptron. The most popular form of a function that satisfies this requirement is the sigmoidal nonlinearity, defined by the logistic function
$$y_i = \frac{1}{1 + exp(-v_j)}, \tag{9}$$
where v_j is the induced local field (i.e., the weighted sum of all synaptic inputs plus the limit value) of neuron j; y_j is the output of the neuron. The presence of non-linearity plays a very important role, since otherwise the "input-output" mapping of the network can be reduced to a conventional single-layer perceptron. Moreover, the use of the logistic function is biologically motivated, since it takes into account the recovery phase of a real neuron.
2. The network contains one or more layers of hidden neurons that are not part of the input or output of the network. These neurons allow the network to learn how to solve complex problems by sequentially extracting the most important features of the input image (vector).

The network has a high degree of connectivity (connectivity), implemented using synaptic connections. Changing the level of network connectivity requires changing the plurality of synaptic connections or their weights.

The combination of all these properties, along with learning-by-doing, provides the computational power of a multilayer perceptron. However, these same qualities are the reason for the incompleteness of modern knowledge about the behavior of such networks. First, the distributed form of nonlinearity and the high connectivity of the network significantly complicate the theoretical analysis of a multilayer perceptron. Second, the presence of hidden neurons makes the learning process more difficult to visualize. It is in the learning process that it is necessary to determine which signs of the input signal should be given by hidden neurons. Then the learning process becomes even more difficult, since the search must be performed in a wide range of possible functions, and the choice must be made among alternative representations of the input images.

The emergence of the backpropagation algorithm was a landmark event in the development of neural networks, since it implements a computationally efficient method for training a multilayer perceptron. The backpropagation algorithm does not offer a truly optimal solution to all potential problems, but it is most effective in learning multilayer machines.

An artificial neural network for the analysis of indicators of the quality of the educational program and educational activities will have the number of input neurons (according to the number of indicators for all criteria) 54; output neurons – 54. Input signals were determined based on students' assessments of each indicator of this quality criterion, while the scale F, E, B, A were translated into numerical 1; 2; 3; 4 respectively. Part of the data is given in table 1.

Table 1: Input signals (T) based on students' assessments of quality criteria.

Indicators of quality criteria	Student grades								
	1	2	3	4	5	6	7	...	54
1	3	4	3	3	4	3	4	...	4
2	4	3	3	3	4	3	3	...	4
3	3	3	4	3	4	4	3	...	4
...	...	...	...	...	...	...	...	...	...
54	4	3	3	3	4	3	3	...	4

It is important that the neural network can predict expert assessments if student and graduate assessments are to be ranked in ascending order based on the determination of the grade point average. According to the hypothesis, we assume that students with higher academic performance are better acquainted with the goals, structure, and content of the educational program, the process and characteristics of teaching and learning according to the educational program, control measures, assessment system, and all other aspects of educational activities. assessments of the quality of the educational program and educational activities will be more objective.

The Neural Network Toolbox application package Matlab Mathematical Modeling Environment (version R2014a) was used in the work. After starting the Matlab system, enter the nntool command on the command line, which opens the window for entering data and creating a neural network (Neural Network / Data Manager) (figure 2).

After starting the MATLAB system, you need to enter the tool command on the command line, which will open the window for entering data and creating a neural network (Neural Network / Data Manager). Clicking the New button opens the Create Network or Data window. After selecting the Data tab in the Name field you must enter a new name of the input data "P", and in the Value field the values of the input data, in which the numbers 1-54 are indicators of

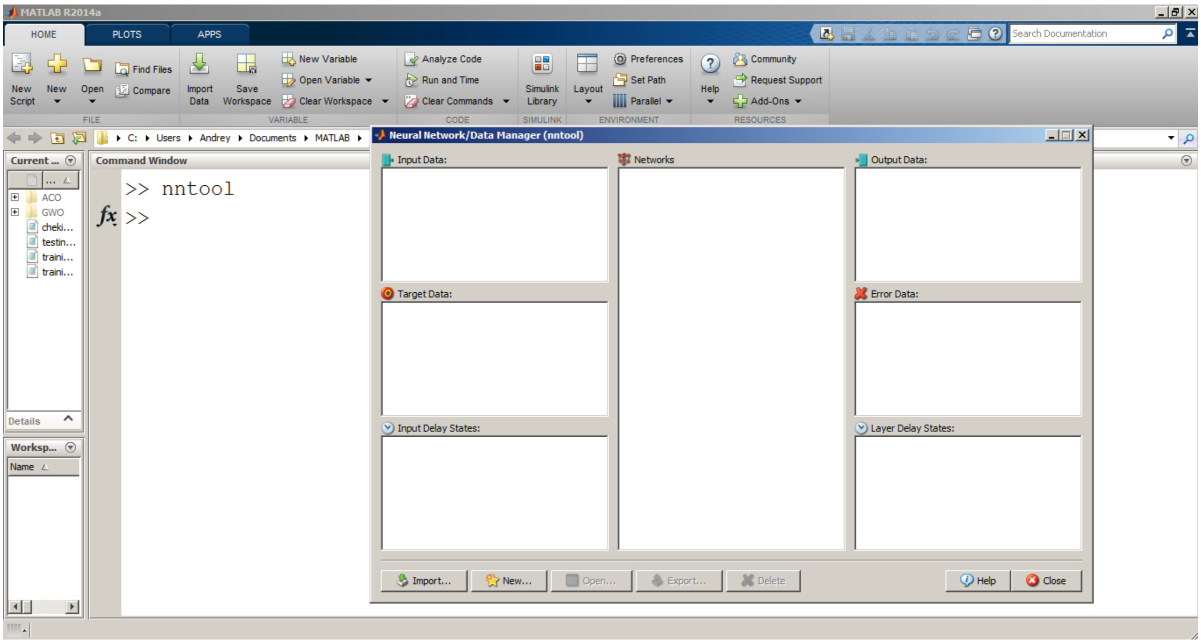

Figure 2: Data entry and neural network creation windows.

quality criteria, and 55-108 – students' and graduates' indicators quality criteria.

To create a new network, we chose New, to view the data you need to select Import. The data is contained in the P.mat file. This file is a matrix of two lines, in which the numbers 1-54 are indicators of quality criteria, and 55-108 – are the evaluation of students and graduates on the indicators of quality criteria. Its contents are stored in the P.txt file.

The next step is to import the data (figure 3).

The next step was to create data ("T") – goals, which are an array of size 54x54, which contains information about the grades given by the participants of the experiment – full-time master's students (22 people) and graduates of higher education institutions there are specialties (32 people) – a total of 54 people. This number of respondents is due to the number of indicators of quality criteria because the data format of the artificial network in Matlab supports square matrices, in this case, 54x54. The data is stored in a T.mat file. Its contents can be viewed using a text editor.

We import data in the same way as for the array P.

In the next step, a neural network was created (figure 4). An artificial neural network for the analysis of indicators of the quality of the educational program and educational activities will have the number of input neurons (according to the number of indicators for all criteria) 54; output neurons – 54. Input signals were determined based on students' assessments for each indicator of this quality criterion, while the scales F, E, B, A were converted to numerical 1; 2; 3; 4 respectively.

The configuration of the neural network of direct propagation is chosen based on a heuristic rule: the number of neurons of the hidden layer is equal to half of the total number of input and output neurons. The artificial neural network for the analysis of quality indicators of the educational program and educational activity will have the number of input neurons 2 (according to the dimensionality of the data – indicators of quality criteria and student evaluation); source neurons 54, therefore, the number of hidden neurons is 28. The View button allows you to view the network structure (figure 5).

In our case, 2 is the number of input neurons, which is known to be selected based on the dimension of the input data (1 – indicators of quality criteria; 2 – student assessments). Output neurons – 54. The configuration of the neural network of direct propagation (feed-forward backdrop) is chosen based on the heuristic rule: the number of neurons in the hidden layer is equal to half the total number of input and output neurons, so the hidden layer has 28 neurons.

The next stage is network training and coaching. Double-clicking with the left mouse button on the created neural network network1 in the window of the Neural Network / Data Manager opens a window with the network.

The View tab presents the neural network itself. Go to the Reinitialize Weights tab, where the Input Ranges column selects the P input from the Get from

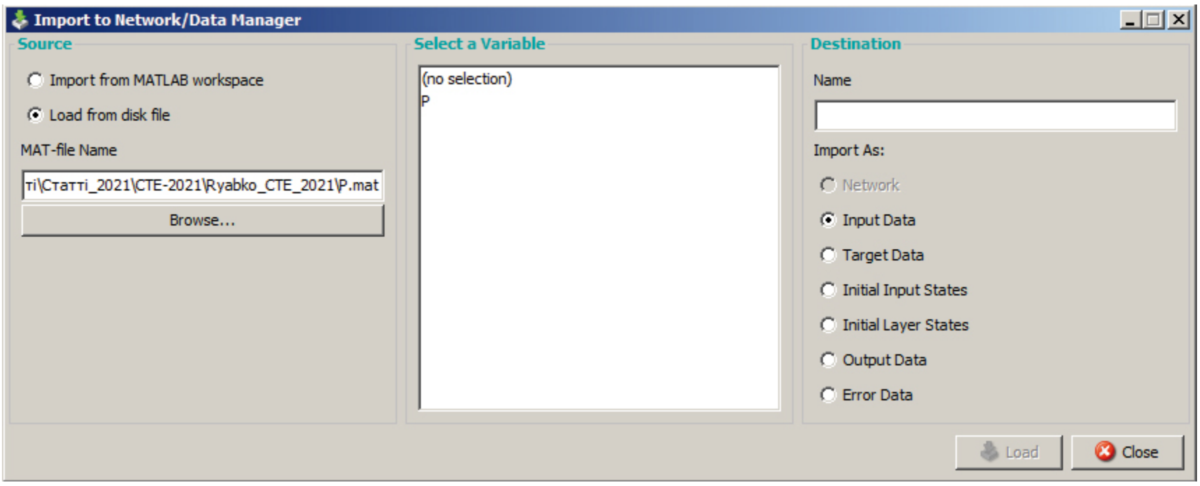

Figure 3: Importing data.

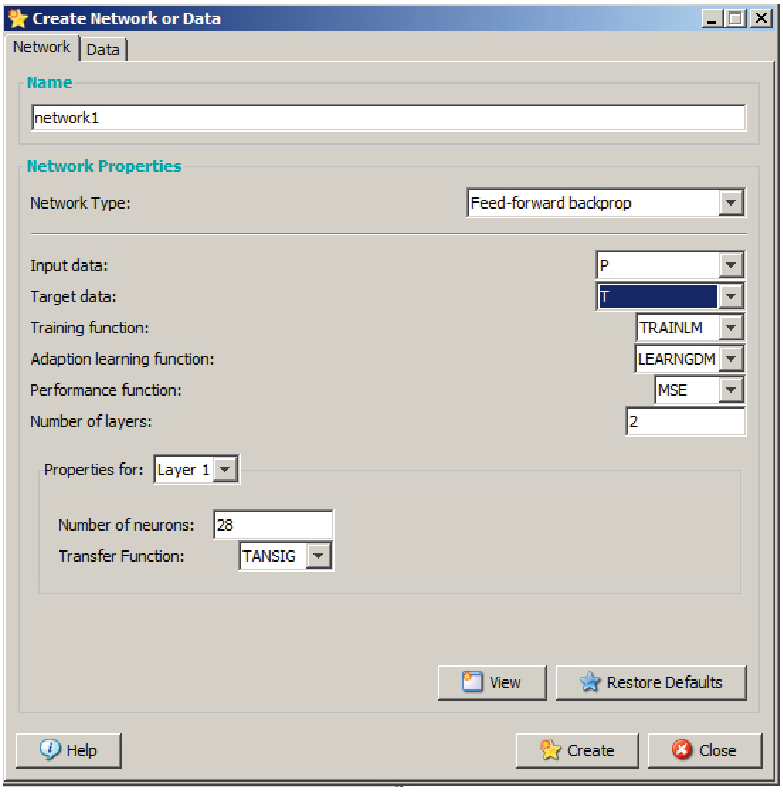

Figure 4: Creating a neural network.

the input list. Then press the Set Input Ranges and Initialize Weights buttons in succession allowing us to initialize the scales needed to initialize the entire network.

The next step is network learning.

Learning the backpropagation method involves two passes through all layers of the network: forward and backward. In a forward pass, the image (incoming vector) is fed to the sensor nodes of the network, after which it propagates through the network from layer to layer. As a result, a set of output signals is generated, which is the actual response of the network to a given input image. In forward traversal, all synaptic weights of the network are fixed. In a backward pass, all synaptic weights are adjusted according to the error correction rule, namely: the actual output of the network is subtracted from the desired (target) response, resulting in an error signal. This

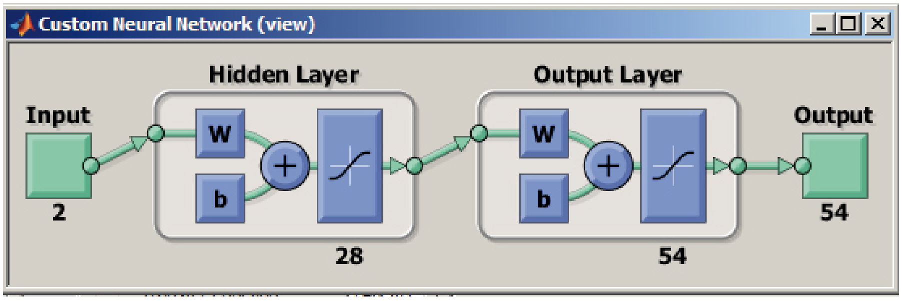

Figure 5: The structure of the neural network.

signal subsequently propagates through the network in the opposite direction of the synaptic connections. Hence the name – backpropagation algorithm. The synaptic weights are tuned to bring the network output as close as possible to the desired statistical meaning. The back-propagation algorithm is sometimes referred to as the simplified back-propagation algorithm. The learning process using this algorithm is called back-propagation learning.

Going to the Train tab opens a learning window in which P and T are selected instead of input data and targets, respectively (figure 6). On the right of the Training Results column, you need to change the name of the Outputs and Errors to O and E, respectively. Then pressing the Train Network button will start network training, the process of which can be observed in the Neural Network Training window. You can close the window after graduation.

After the training was completed, two types of data appeared in the Neural Network / Data Manager window: Output Data (O) and Error Data (E). Double-clicking on data O opens a window with data output. By clicking the Export button in the manager window, and then clicking Export again in the window that opens, you can transfer the data to the Matlab workspace, where it will be presented in the most presentable form. You can view the results in the O.mat and E.mat files.

You can calculate that the average network error is 0.0321, which indicates the efficiency of the system.

After learning the network, you can proceed to data forecasting. Returning to the Neural Network / Data Manager window, you need to create additional input by clicking the New button. Going to the Data tab, the name of the data changes, for example, to P1, and the values are set as follows: values 1-54 still indicate the numbers of indicators of quality criteria of educational programs and educational activities, and 56-109 assessments of students and graduates quality, and the last column – projected expert assessments.

Next, you need to return to the Network window. In the Simulate tab of the input values house, the P1

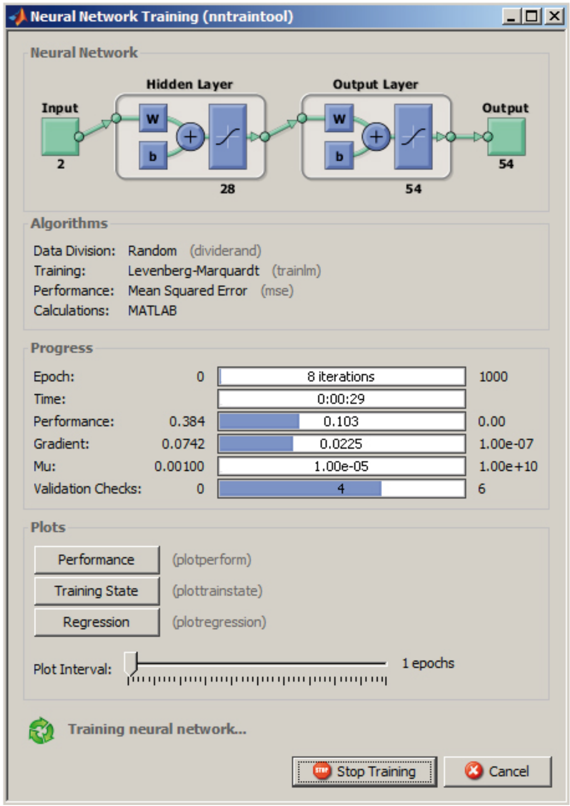

Figure 6: Neural network learning.

array is selected, and the Outputs output value is renamed to forecast (figure 7).

After clicking the Simulate Network button, you can return to the Neural Network / Data Manager window and, by clicking the Export button, copy the source forecast array to the Matlab workspace. After receiving the table in the workspace, pay attention to the last column, which is responsible for forecasting (figure 8).

The data obtained in the study can be viewed in the forecast.mat file.

Comparing the data issued by the system and the real data, we can see that the neural network does make predictions that are quite close to reality. Com-

Table 2: Output signals (O).

Indicators of quality criteria	Student grades								
	1	2	3	4	5	6	7	...	54
1	3.1985	3.252	3.3058	3.3541	3.3933	3.4235	3.4475	...	3.9704
2	3.4521	3.3478	3.2644	3.2035	3.1633	3.1404	3.1319	...	3.9997
3	3.1516	3.1812	3.219	3.2627	3.3062	3.3417	3.3638	...	3.9992
...	...	...	...	...	...	...	...	...	...
54	4	3.4192	3.3522	3.3128	3.291	3.2798	3.2756	...	3.9716

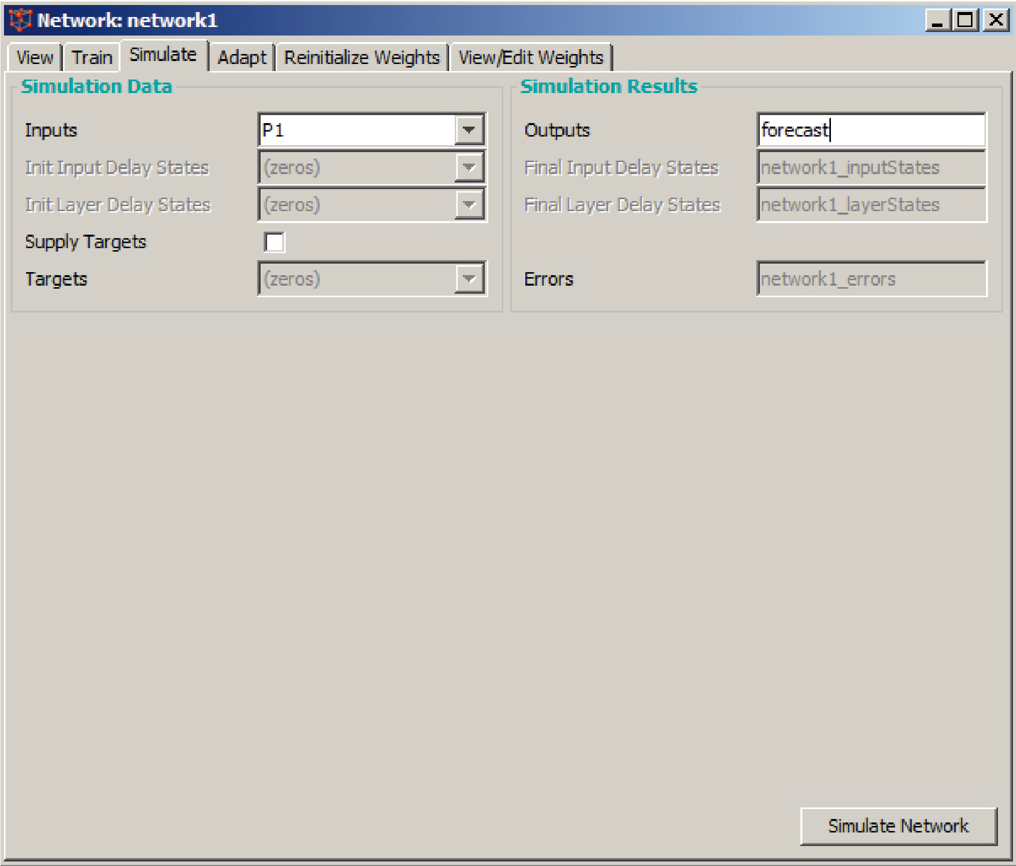

Figure 7: Simulate.

pared with expert estimates, the average absolute error is 0.0321, the relative error is 7.08%.

In the second part of the experiment, forecasting was carried out using a different type of neural network – a neuro-fuzzy network, or ANFIS-model.

Expert estimates are used as validation data. Create data files: training.dat, testing.dat, checking.dat. It should be noted that attempts to consider large data volumes lead to a reduction in the number of observations in the training sample and its simultaneous unjustified growth, which can negatively affect the network's ability to learn. So, first you need to turn the available information into a form that is understandable and meaningful for the neuro-fuzzy network. Consider the average value of the assessment of each of the 10 criteria for assessing the quality of the educational program. For training, we use the average scores of all students for each of the 10 criteria. For testing, the marks of students numbered from 12 to 30 are used, for verification – the marks that were put by 31 students.

We preliminarily transpose the data, so the numbers of students will be in the rows, and the grades according to the quality criteria will be in the columns. The data in the files contains 10 columns – 9 grades (incoming) and 1 grade (source). The first file contains 54 lines and 10 columns. The second has 18 rows and 10 columns. The third has one row and 10

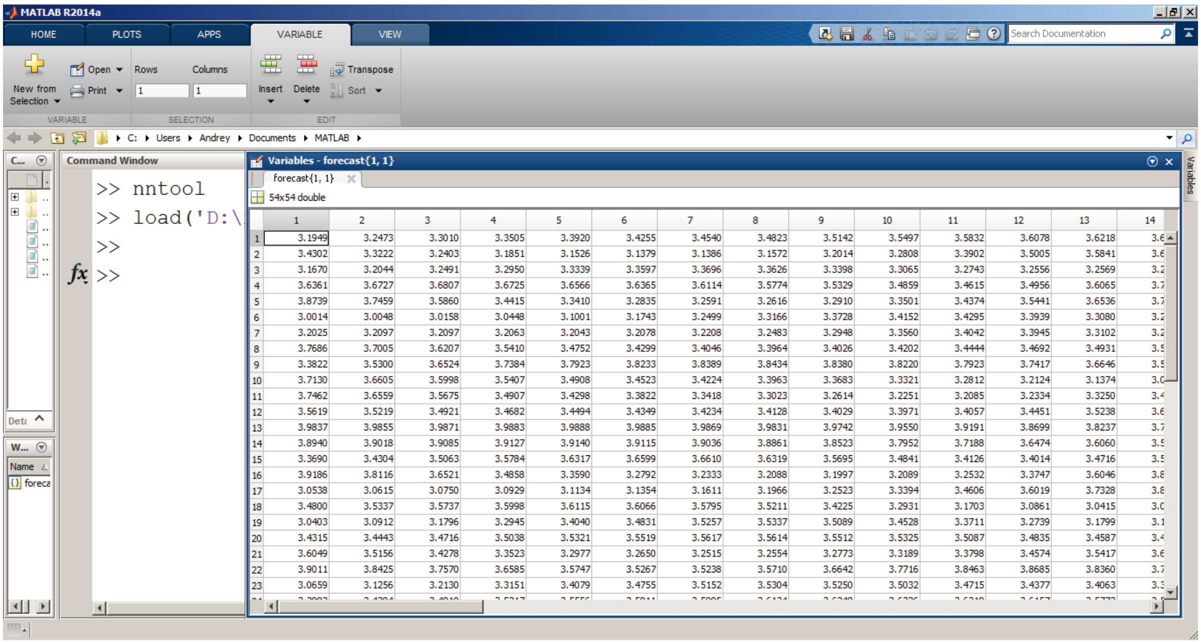

Figure 8: Getting a table with forecasting in the work area.

Table 3: Errors (E).

Indicators of quality criteria	Student grades								
	1	2	3	4	5	6	7	...	54
1	-0.199	0.748	-0.306	-0.354	0.607	-0.424	0.552	...	0.0000237
2	0.548	-0.348	-0.264	-0.203	0.837	-0.140	-0.132	...	0.029607
3	-0.152	-0.181	0.781	-0.263	0.694	0.658	-0.364	...	0.00027
...	...	...	...	...	...	...	...	...	...
54	0.58076	-0.3522	-0.3128	-0.2909	0.7202	-0.2755	-0.2769	...	0.028442

Table 4: Neural network forecast and expert evaluation.

Indicators of quality criteria	Forecast	Estimates
1	3.999977	4
2	3.974844	4
3	3.999750	4
4	3.999379	3
5	3.956661	4
6	3.991731	4
7	3.985698	4
...	...	...
54	3.970182	4

columns.

Anfis Editor is used to building MATLAB fuzzy neural networks. Run the editor with the anfisedit command. In the Load data menu, select Training, and From disk, click the load data button. In the window that opens, select the previously created training.dat file. In the Load data menu, select Testing and From disk, click the load data button. In the window that opens, select the previously created testing.dat. In the Load data menu, select Checking and From disk, and click the load data button. In the window that opens, select the previously created checking.dat. The visualization area contains two types of information: when training the system, the learning curve in the form of a graph of the dependence of the learning error on the iteration ordinal number; when loading data and testing the system – experimental data and simulation results.

Experimental data and simulation results are displayed as a set of points in two-dimensional space. In this case, the serial number of the data line in the sample (training, test, or control) is plotted along the abscissa axis, and the value of the initial variable of this sample line is plotted along the ordinate axis. The following markers are used: blue dot (.) – test set; blue circle (o) – training sample; blue plus (+) – control sample; a red asterisk (*) – simulation results.

Then, having set the Generate FIS menu switch to the Grid partition position, you should press the Generate FIS button. In this case, the model has 10 input variables, each of which corresponds to 9 terms

Training.dat file (first three lines):
3.5000 3.3333 3.5000 3.4000 3.5000 3.3333 3.3333 3.5714 3.3333 3.1667
4.0000 3.4444 3.2500 3.8000 3.7500 3.5000 3.6667 3.4286 3.6667 4.0000
3.2500 3.6667 3.2500 3.4000 3.5000 3.6667 3.0000 3.5714 4.0000 3.8333

Testing.dat file (first four lines):
3.2500 3.4444 3.7500 3.6000 3.2500 3.8333 3.5000 3.4286 3.6667 3.5000
3.7500 3.6667 4.0000 3.2000 3.5000 3.3333 3.1667 3.8571 3.6667 3.6667
4.0000 3.5556 3.5000 3.6000 3.5000 3.8333 3.5000 3.2857 3.3333 3.8333
3.5000 3.5556 3.2500 3.4000 3.5000 3.6667 3.6667 3.5714 4.0000 3.5000

Checking.dat file:
3.5000 3.3333 3.2500 3.4000 4.0000 3.3333 3.8333 3.2857 3.0000 3.8333

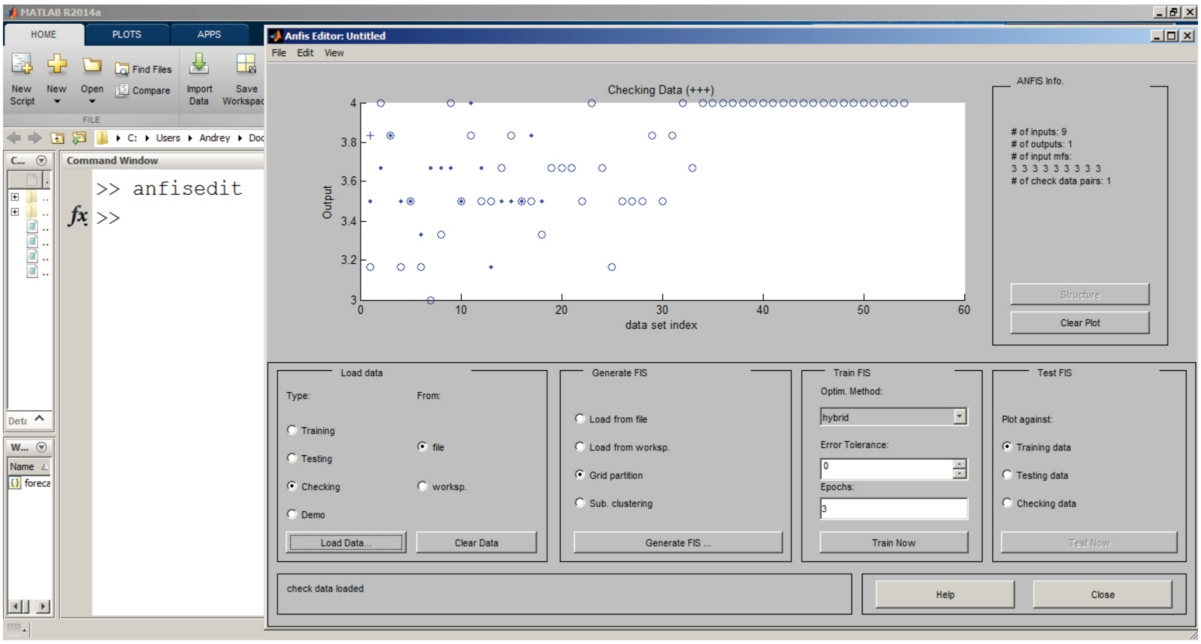

Figure 9: Data for network training and validation.

of the gaussmf type. The original variable is determined by a linear function. Let's generate a Sugeno-type fuzzy inference system by pressing the Generate FIS button. In the window that opens, set 3 membership functions of the gaussmf type for each input variable. The choice of the property function here is because we assume a normal distribution for a random variable, defined by a Gaussian function according to probability theory. For the output variable, we set the membership function const.

To train the hybrid network, we will choose the backdrop method (error backpropagation) with an error level of 0 and a number of cycles of 10. Let's start training the hybrid network (figure 10).

As can be seen from figure 10, according to the training results, the average error is approximately 0.007.

We test the fuzzy inference system first on the training set.

Now let's test the resulting fuzzy inference system on the known values of expert estimates. Now we download this sample in testing mode in the Anfis editor. The results are shown in Figure 12. The mean score of the experts is 3.99; network prediction of the neural fuzzy network is 3.51. The relative forecast error is 12.57%.

Comparing the prediction errors of the neuro-fuzzy network (12.57%) and the L-layer feed-forward neural network (7.08%), we can see that the latter makes a more accurate prediction. It should be noted that the ANFIS model requires significantly more computing resources from the computer, which forced us to reduce the number of input variables to 10, which corresponded to the number of program

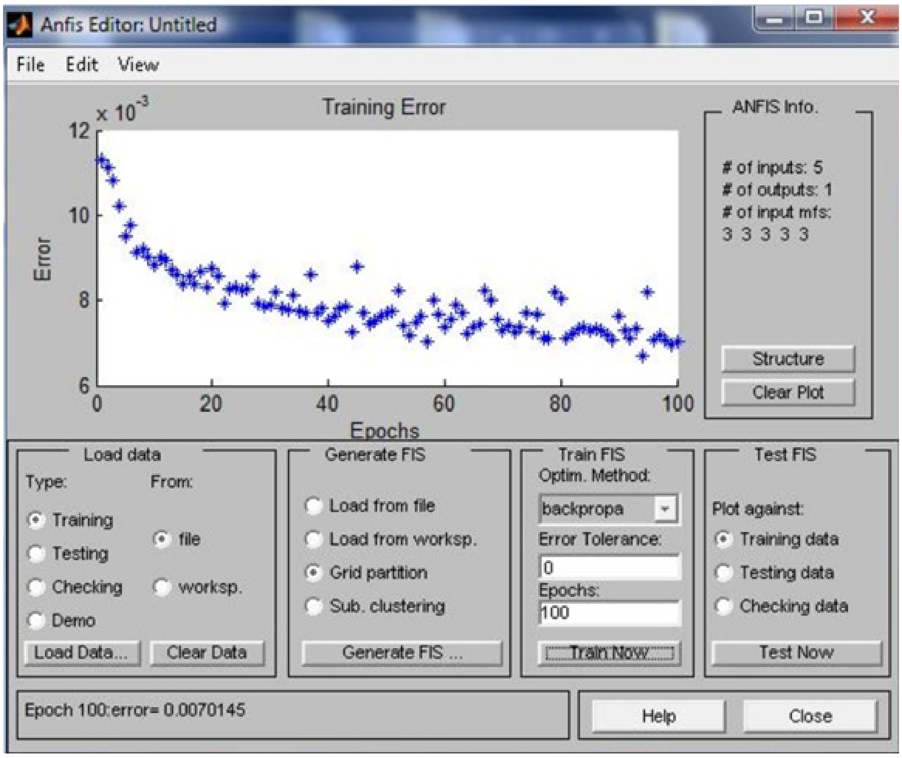

Figure 10: Network training error.

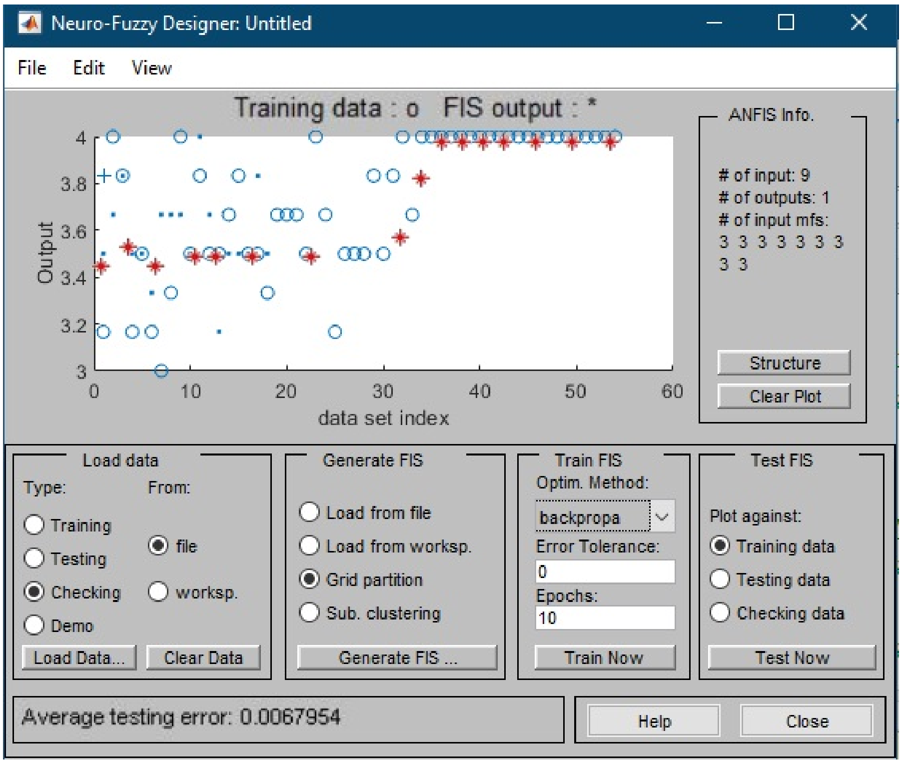

Figure 11: Network training results.

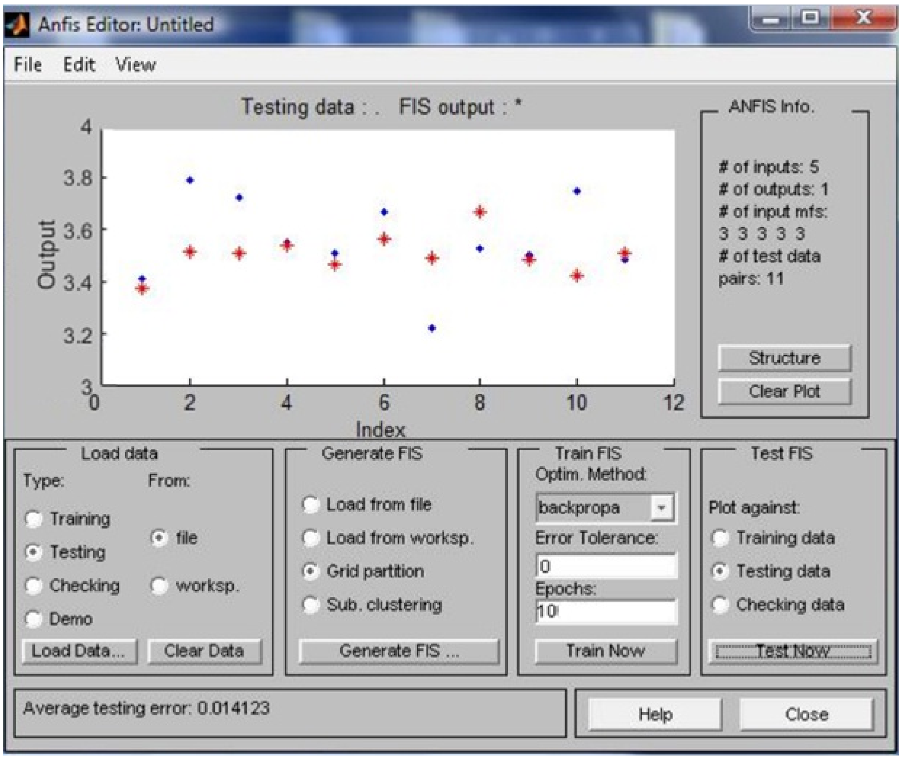

Figure 12: The results of network testing on known values of expert estimates.

evaluation criteria, and use the average values of quality indicators for each of the criteria. Of course, the problem requires further study of large data volumes of other accreditation examinations, but in general, this approach has demonstrated very good predictive capabilities.

Table 4 also shows that the quality of the program and educational activities is at a fairly high level, which reflects the average score of the peer review.

3 DISCUSSION

The study aimed to demonstrate the possibility of predicting the assessment of the quality of educational programs and educational activities can be adequately addressed through an artificial neural network and obtain a comprehensive assessment of the quality of educational programs and educational activities based on a possible neuro-fuzzy approach. The mathematical model involves the use of neural networks and is based on the technology of analytical processing of statistical data. Standard methods of mathematical statistics are used to analyze the estimates received from respondents.

Debatable are proposals for using students as experts in the educational program and educational activities; it is more appropriate to use teachers from other educational institutions, but in the process of preparing for introspection, this approach can be considered quite appropriate.

The results of the neural network should be considered not as final, but as a test. As noted, for more detailed conclusions, it is necessary to train the network on a larger amount of experimental data.

The network structure has room for further improvement and customization in future studies.

The assumption that based on a sample of students and graduates of higher education the quality of the educational program and educational activities can prepare a sample for setting up and teaching artificial neural networks is confirmed by ordering the quality of the curriculum of students and graduates. teaching. In practice, this allows you to predict the results and identify existing shortcomings and eliminate them before the accreditation examination. However, the difficulty of this method is to choose the architecture of the neural network and prepare a training sample to configure the neural network. In particular, in the future, it is planned to increase the volume of the input vector of the artificial neural network, and the form is based on estimates of teachers, stakeholders, and experts.

4 CONCLUSIONS

As a result of a mathematical model of a comprehensive evaluation of the quality of educational programs and educational activities based on the methods of neuro-fuzzy approach, first managed to work out a mechanism for obtaining a quantitative evaluation of educational programs and educational activities in this program that will allow the institution of higher education detect shortcomings and potential problems and solve them before the accreditation examination. Secondly, based on a sample of students and graduates of higher education to evaluate the quality of educational programs and educational activities, you can prepare a training sample for setting up and learning an artificial neural network that can adequately perform a comprehensive assessment of educational programs and educational activities. This can be done by arranging the assessments of the quality of the curriculum and the educational activities of students and graduates in ascending order based on the determination of the average grade point average. It is emphasized that these methods are effective provided they meet the requirements of a student-centered approach and the principles of academic freedom.

Based on a sample of students and graduates of higher education, the quality of the educational program and educational activities was prepared to prepare a training sample for setting up and teaching artificial neural network, which was able to adequately perform a comprehensive assessment of the quality of educational programs and educational activities. A comparison of the results of the operation of an artificial neural network of direct propagation with one output and several inputs with real data shows that the neural network does make predictions close to reality. Compared with expert estimates, the average absolute error was 0.0321; the relative error was 7.08%.

The results of the study can be used in the practice of higher education institutions to predict the results and identify existing shortcomings and eliminate them before the accreditation examination.

We see prospects for further research in the application of software products based on the theory of neural networks to automate the processes of the organization, control, and analysis of the educational process; introduction of neural network software for direct training of students in certain disciplines.

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Complex Systems and Complex Thinking Within the Framework of Education 4.0

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Abstract: The presented paper raises the question of how the principles of Education 4.0 and the theory of self-organization (synergetics) can help in the reformation of the higher education system, and how interdisciplinary research can be useful for both teachers and students. In this paper, we give a brief review of different studies devoted to Education 4.0 and synergetics concepts. Next, we demonstrate the most important characteristics of complex systems and conceptually simplest methods for complex systems modelling. As part of the complex systems modeling course, which will first be presented to students of physics and mathematics, and then, possibly, to students of other specialties, we present signals of seismic activity, gravitational waves, magnetic activity, and stress-strain signal for a typical metal in the process of destruction. Our study demonstrates that complex systems theory and its toolkit can help to study phenomena of various nature and indentify (forecast) their catastrophic states. This kind of analysis can serve as a good basis for the formation of professional skills and universal competencies.

1 INTRODUCTION

In 2021, Syukuro Manabe, Klaus Hasselmann, and Giorgio Parisi were awarded the Nobel Prize in Physics "*for groundbreaking contributions to our understanding of complex physical systems*" (Nobel Foundation, 2021). That is a sign that the study of complex systems is of paramount importance. Nevertheless, we need to deal with the problems of their implementation in the educational process.

The education system in the world today is in a state of crisis. This is evidenced by the following trends: a further increase in the number of illiterate people in the world; the widespread decline in the quality of education; the growing gap between education and culture, education and science; alienation of the student from the educational process.

This situation in the world at the present stage makes the problem of finding a new paradigm of education urgent, since the possibility of sustainable development of society, successful overcoming of global problems, regional and national conflicts characteristic of the present time of the development of civilization is closely related to the achieved level of education of all members of society (Karlov, 1998). But the education system is always based on a certain scientific understanding of the world and man, which determines the goals and objectives of education, its content, principles and methods.

Education 4.0 is such paradigm of education in which complex thinking, reasoning, teaching methods, and techniques become central to support educational processes for the formation of citizens committed to society and its complexity (Ramírez-Montoya et al., 2022). Modern generation of students meet business tasks which nowadays demand a wide range of knowledge, skills, and abilities: integrative, critical, systemic, scientific, innovative thinking; enabling

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analysis, synthesis, continues learning, problem solving. Without an extensive range of different fields of science, it is problematic to be an active transformer of the society. The complexity paradigm proposes new point of view in which contradictory parts of a system compose into interrelated. For soling complex task, the encounter and the exchange between all researchers and academicians in disjunctive domains are necessary.

Figure 1 represents core components that enable to design innovative pedagogical environments in terms of Education 4.0 with correct technologies and infrastructures which will carry out best practices.

Modern technological environment embraces advances of humanity that provide high capacities and performance capabilities in many systems and platforms. Such technologies provide high level of digitalization, virtualization, and datafication. Due to corresponding spectrum of possibilities and student-central environment, we are able to seek, prepare, and graduate new highly competitive professionals capable to propose innovative solutions for current world. Searching for real-world challenges and combining educational experience with ICTs, students are able to transfer from theory to practice very quickly.

Open education, innovations, science, and technologies are the cornerstones of Education 4.0. It relies on personalized learning pathways, innovative digital and management tools complemented with such trending computer science topics as artificial intelligence (AI), blockchain, robotics, virtual reality, etc. Especially should be emphasized AI which provides a framework for understanding complex systems behavior: how multi-agent, interconnected, and intelligent environments interact with each other, mostly producing non-linear and non-predictable dynamics.

The heyday of education in the XVII-XVIII centuries, which happened through the development and spread of classical mechanics of the New Time, led to the determination of the picture of the world, where the studied elements are unchangeable, and the laws of classical mechanics are universal and apply to all types of motion of matter.

Such real-world systems as a pandemic, storm, transport systems, the world-wide web, stock and crypto indices are presented to be complex, irreversible, and sensitive to initial perturbations (Hipkins, 2021). Following deterministic paradigm, where each phenomenon has a cause and at the same time there is a cause of other phenomena, i.e., all the processes taking place in the world are predetermined and predictable, we would encounter that real-world systems neither precisely random nor deterministic. Complex systems tend to display ordered features and unpredictable dynamics simultaneously (Ovens et al., 2013).

Therefore, such ideological and methodological principles as rationalism, determinism, mechanismism and reductionism began to dominate in scientific knowledge, which also had a decisive influence on the education system: on the forms of knowledge acquisition, presentation of material, organizational principles of education.

The discovery by synergetics of the processes of self-organization in inanimate nature clearly shows that the transition from disorder to order, accompanied by the emergence of self-organization and stable structures, the replacement of old structures with new ones occurs according to specific internal laws inherent in certain forms of the movement of matter. Ultimately, it is the qualitative and quantitative criteria of self-organization that characterize the level of complexity and perfection of the corresponding forms of movement (Haken, 1977, 1982). Based on these ideas, it is possible to develop a classification of types, forms, properties of matter according to their degree of complexity, perfection of organization, and thereby the degree of development. In this regard, development itself appears as a very complex, self-organizing process of movement from simple to complex, from less organized and perfect to more organized and perfect. In other words, development, in contrast to the movement that characterizes any changes in general, acts as a directed change associated with the emergence of a new one.

The post-non-classical stage of the development of science shows that rigid determinism and reductionism, which serve as the basis of the mechanistic view of the world, cannot be considered as universal principles of scientific knowledge, since an extensive class of phenomena and processes does not fit into the framework of linear, equilibrium and reversible schemes. In the world around us, a very real irreversibility plays an essential role, which is the basis of the majority of self-organization processes. Reversibility and rigid determinism in the world are applicable only in simple limiting cases, and irreversibility and randomness should be considered not as an exception, but as a general rule.

To integrate the synergetics approach into the educational process, it is important to instill in students ways of setting and solving problems of being and developing complex systems in various spheres: economic, social, natural, etc. It is equally important, at the beginning of studying the methods of studying complex systems, to instill in students at first or repeat with them the concepts of self-organization,

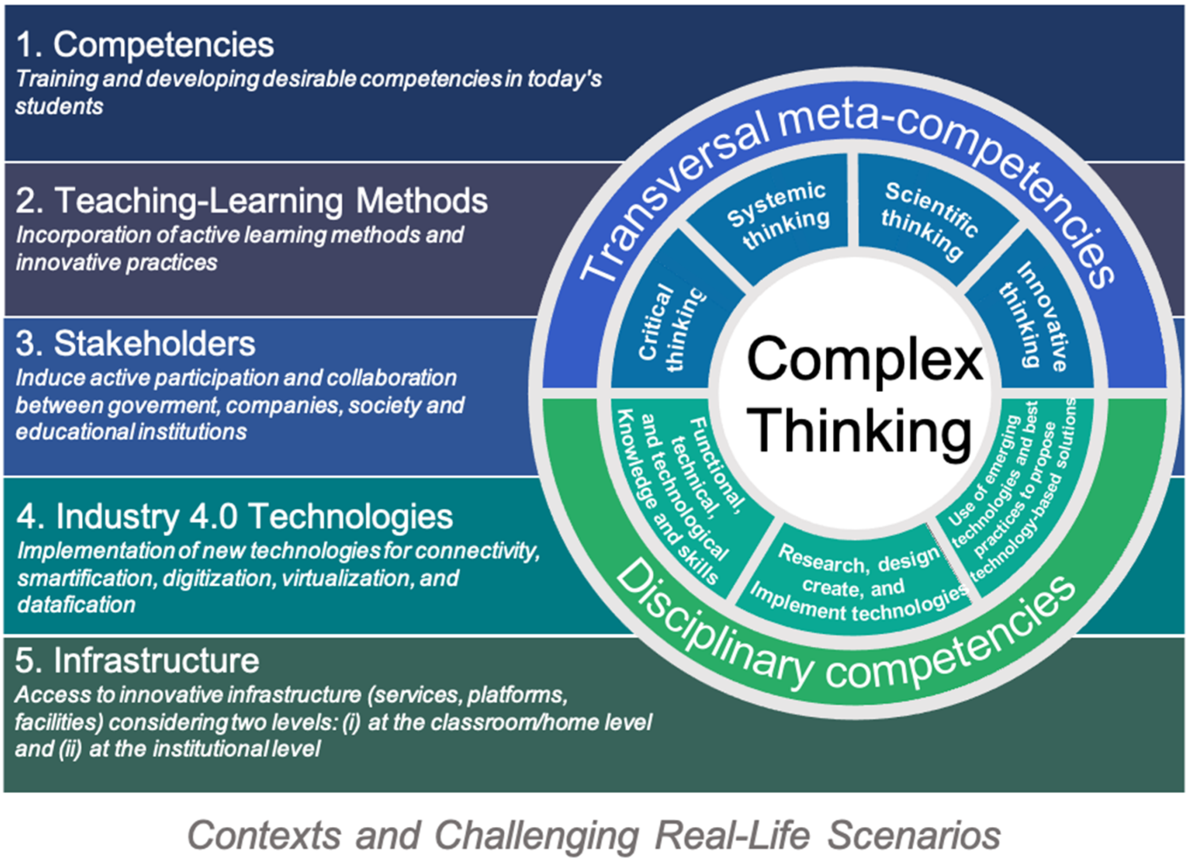


Figure 1: Core components for effective learning in Education 4.0 (Ramírez-Montoya et al., 2022).

chaos, destructive phenomena, to voice the difference between complex and complicated systems, etc.

Complex systems are a field of research that is now acquiring the characteristic features of a well-formed area of science with its own object, conceptual apparatus, and methods of analysis (Thurner, 2017). The concept of a complex system is gradually becoming one of the fundamental concepts of modern science, or, more broadly, it is increasingly appearing in a general cultural context. The expansion of the scope of application of this concept, as well as the identification and awareness of an increasing number of phenomena where it is applicable, causes difficulties in its exact definition. Although the science of complex systems covers a broad interdisciplinary field of research, the methods and concepts of physics (dynamical systems theory, quantum mechanics, statistical physics) are central to it.

So, the processes of self-organization in non-equilibrium conditions correspond to the dialectical interaction between chance and necessity, fluctuations and deterministic laws. Near bifurcations, the main role is played by chaos, randomness, while deterministic connections dominate in the intervals between bifurcations. The ways of development of self-organizing systems are not predetermined. Probability appears not as a product of our ignorance, but as an inevitable expression of chaos at the points of bifurcations. This means the end of the classical ideal of omniscience and creates the need to revise the principle of mechanical rationalism as the dominant scientific explanation of reality. The traditional education system, based on the principles of classical science, cannot effectively fulfill the role of a means of mastering the world by a person.

Hence, there is a need to provide new principles and ideas of the complex systems paradigm in the sphere of Education 4.0.

2 ANALYSIS OF PREVIOUS STUDIES

For building a new way of learning and education, we must be aware that linear thinking and methods are very dangerous in non-linear world (Jörg et al., 2007). Consequently, we should tend to a new way of thinking beyond dualism, reductionism, and the idea of controllable and perfectly predictable events.

Analysis of scientific sources and publications shows that today there is an opinion that synergetics could provide significant assistance in the search for a new paradigm of education. A synergistic approach to understanding patterns operating in nature is associated with the names of Haken (Haken, 1977, 1982, 1984, 2004; Haken and Schiepek, 2006), Prigogine (Prigogine, 1989, 1980; Prigogine and Stengers, 1984, 1997; Nicolis and Prigogine, 1989). Some scientists believe that synergetics, as a theory of self-organization of complex systems, describes the general (common) that is in their development, education is a complex system, and therefore synergetics, which today is developed by various branches of scientific knowledge, necessarily becomes its new philosophy. However, despite the existence of a sufficient number of works devoted to the application of synergetics in various spheres of human activity, the methodological and practical context of synergetics in the philosophy of education remains insufficiently developed. This is especially true for applying a synergistic approach to understanding the higher education system.

In contrast to the traditional interdisciplinary approach in education, the goal is not only to provide knowledge, but also to teach to hear and understand colleagues working in different specialties, to develop skills of dialogue between specialists in different branches of scientific knowledge. Thus, complexity theory is *trans*disciplinary rather than *inter*disciplinary: members of research team from different fields of science such as physics and economics are able to work together if they are sufficiently informed about one anothers's perspectives and motives (Benthem, 2002). The need for such a dialogue is becoming more and more palpable. Since the theoretical physicist Haken (Haken, 2004) introduced this concept into scientific use, the world has been accumulating some experience in the use of synergetics and in the study of social and educational systems.

Research conducted in schools and universities shows that interactive chaotic environments are very productive for developing creative thinking. The results of work in this area were presented by Davis-Seaver et al. (Davis-Seaver et al., 2000), who analyzed the learning process at three levels – from a single point of balance, statement of fact, statement of a single point of view to learning on the verge of chaos, when there are many points of view, when reasoning develops in different directions, when students listen to the opinions of others and on this basis develop their own judgments. The role of the teacher is not to spread knowledge and evaluate the correctness of judgments, but to monitor the progress of reasoning and transfer the learning process from one level to another. As a result, the understanding becomes deeper, more versatile, and the incentives for learning are largely created by the energy of the group, and not by the diligence of the teacher. In the context of revealing a person's creative abilities, a synergistic approach to education seeks not to eradicate chaos, but to find the relationship between order and disorder that would be most fruitful (Kremen, 2013).

The above-mentioned concept of chaos from the point of view of synergetics loses its negative connotation. As Prigogine and Stengers (Prigogine and Stengers, 1997) notes, instability can be a condition for stable and dynamic development. Only systems that are far from equilibrium are able to organize and evolve spontaneously. Thus, there is no development without instability. And if the system is strict against the implementation of new units, new units ('innovators') die". In higher education, self-organizing systems are the Student, Teacher, their interrelation, etc. (Taranenko, 2014).

Jacobson and Wilensky (Jacobson and Wilensky, 2006; Wilensky and Jacobson, 2014) emphasize different research issues that need to be explored. They present such principles in studying complex phenomena as

- experiencing complex systems phenomena;
- making the complex systems conceptual framework explicit (Council, 2000);
- encouraging collaboration, discussion, and reflection; the design of environments for learning about complex systems needs to take advantage of lessons learned from the extensive research on pedagogy that foster collaboration, discussion, and reflection (National Research Council, 2000);
- constructing theories, models, and experiments;
- learning trajectories for deep understandings and explorations.

With a given appropriate conceptual and representational scaffolding in the learning environment, students should be able to tap into their everyday experiences and channel and enhance these experiences to construct understandings of complex systems that are cognitively robust. Nowadays, students should have more possibilities to explore world through computational modeling which progressive scientists use almost everyday.

Jackson (Jackson, 1995) and other, such as Pagels (Pagels, 1988), have observed how the use of computational tools in science allows dramatically enhanced capabilities to investigate complex and dynamical systems that otherwise could not be systematically investigated by scientists. These computational modeling approaches include cellular automata, network and agent-based modeling, neural networks, genetic algorithms, Monte Carlo simulations, and so on that are generally used in conjunction with scientific visualization techniques. Examples of complex systems that have been investigated with advanced computational modeling techniques include climate change (West and Dowlatabadi, 1998), urban transportation models (Balmer et al., 2004; Helbing and Nagel, 2004; Noth et al., 2003), and economics (Anderson et al., 1988; Arthur et al., 1997; Axelrod, 1997; Epstein and Axtell, 1996b). New communities of scientific practice have also emerged in which computational modeling techniques, in particular agent-based models and genetic algorithms, are being used to create synthetic worlds such as artificial life (Langton, 1989, 1995) and societies (Epstein and Axtell, 1996a) that allow tremendous flexibility to explore theoretical and research questions in the physical, biological, and social sciences that would be difficult or impossible in "real" or nonsynthetic settings.

Jörg et al. (Jörg et al., 2007) addressed their study to the theory of complexity, arguing that the present paradigms in the field of education neglect the inherent complexity of educational reality and therefore are not able to give an adequate understanding of reality. They discussed the importance of studying complex systems paradigm and its integration into educational process. In their opinion, complexity paradigm should help to uncover some of the myths we live by, but it is not necessary an unlimited source of truth. It is rather a better alternative for our rapidly evolving world in which we already encounter 'deprivation of our culture' (Midgley, 2001) and 'perversion in system of education' (Baistrocchi, 2018)

Costan et al. (Costan et al., 2021) investigated the existing barriers to Education 4.0 implementation. They collected a systematic review of the 30 journal articles on Engineering, Social Sciences, Computer Science, Business, Management, and Accounting generated from the initial search on Scopus, which were in turn related to Education 4.0. Their analysis provided 12 existing barriers for Education 4.0 implementation: cybersecurity threat, costly, skills gap of human capital, apprehensive stakeholders, lack of training resources, lack of collaboration, knowledge gap for the customization of curriculum design, insufficient available technologies, health issues, time constraint for material preparation, complexity of learning platforms, and insufficient foundation of basic education. Furthermore, a theoretical predictive model was constructed to present the causal relationships in modeling the problems associated with implementing Education 4.0.

Sigahi and Sznelwar (Sigahi and Sznelwar, 2022) studied following questions: (1) how complexity thinking could be applied to engineering education; (2) how that could contribute to current engineering challenges; (3) what were different complexity approaches in engineering and how to integrate them. They conducted a review from fifty eight journal articles and five book chapters. They discussed: engineering axiology; epistemological and ontological perspectives; complex thinking and competences; systematic transformations of engineering education, etc. Were identified main gaps of such education and discussed different thoughts on topic complexity.

Complexity captures even physical education (Bielinskyi et al., 2022). Swedish National Agency for Education presented new curriculum which included such term as *complex movement*. Researchers (Janemalm et al., 2019) provided insights into the meanings of *complex movements* in the context of physical education in Sweden. Using a discourse analytic methodology, six policy texts were examined. The study suggests that there is needed greater consensus as complex movement can have a wide range of meaning, have a context-depended meaning, and for different audiences will be understood in individual ways.

New paradigm of thinking and teaching concerns even sustainable development. It aims to equip learners with necessary knowledge about complex sustainability problems and develop in students creative thinking to acquire innovative sustainable solutions. Green et al. (Green et al., 2022) formed a randomized controlled trial to understand whether an innovative sustainability learning tools help to increase the understanding of a specific sustainability problem. Their learning toolkit incorporates two factors – system thinking and system dynamic simulation. They also tested whether those factors help to transfer knowledge to a second problem with a similar system structure. They used different statistical techniques to analyse the effect of the factors on sustainability understanding. Their research presented that the effectiveness of education for sustainable development increased significantly. Participants gave qualitative feedback on usefulness of systems thinking and simulation.

Network science (graph theory) is the key data analysis instrument for solving problems through their *graph representations*. For Education 4.0 it is one of the main fields of science which must be included into learning process. Many real-world complex systems exhibit common organizing principles, non-trivial patterns that were derived with graph theory. Therefore, network science can be considered as highly interdisciplinary research field (Börner et al., 2008). Weber et al. (Weber et al., 2021) addressed their study to sustainability problems through the tool of network science and presented schematically how complex, real-world sustainability problems can be considered through the prism of graph theory (figure 2).

As the environmental, economic, and political problems of humanity have become global, complex and nonlinear, traditional ideas about individual responsibility are becoming questionable. We need to study and teach new models of collective behavior that take into account the different degrees of our individual abilities and understanding of what is happening.

We believe that the study of the apparatus of physics, graph theory, and computer science is now of paramount importance for the further development of both our society and the entire universe.

In further we need to understand how to grow an interest of students in constructing and revising computational models with multi-agent or qualitative modeling software, and how model building activities may enhance student conduct of real world experiments related to the phenomena under consideration (Abrahamson and Wilensky, 2005a,b; Jackson et al., 2000).

3 THE MOST IMPORTANT PROPERTIES OF COMPLEX SYSTEMS TO BE STUDIED

Based on the previously described characteristics and the direction in which we should move, it becomes clear that synergetics (the theory of complex systems) is the foundation of almost any system. Including pedagogical. Although the initial direction of research within this paradigm was physical systems, the latest objects of research on various manifestations of complexity also appear in the context of business organization and economics. For example, Wheatley (Wheatley, 2006) suggests that we view organizations as being more like living organisms than machines. As such, we need to modify traditional views on controlling organizations. Wheatley (Wheatley, 2006) argues that organizations are dynamic, nonlinear networks of relationships and cannot be separated into parts while maintaining their essential identity.

Complexity thinkers have been seeking for common characteristics in a tremendous range of simple and complex systems: dependence on initial perturbations, long-term correlations, multi-layered and multi-scale, mutual and reciprocal, etc.

In general, they are

- dynamic;
- non-equilibrium and have the potential to change suddenly and may take one path out of an infinite number of others (bifurcate);
- open systems, that is interchange energy (and information) with their surroundings;
- depended. What happens next depends on what happened previously;
- systems where the whole is more than the sum of its parts;
- causal and yet indeterminate;
- irreversible, since the interaction of parts together is transforming;
- multi-agent. They composed of a diversity of agents that interact with each other, mutually affect each other, and in so doing generate novel, emergent behavior for the system as a whole. The system is constantly adapting to the conditions around it and over time it evolves;
- co-evolving and move spontaneously towards the edge of chaos.

3.1 Time Series Data

In order to maintain students' interest in studying complex systems and their corresponding data analysis tools, programming languages, etc. (Shumway and Stoffer, 2016; Fulcher et al., 2013), it is important to select truly interesting and complex systems (series). It is equally important that the studied systems are within the framework of the specialty that students are guided by. However, since we strive for an interdisciplinary approach, the study, for example, by biologists of the corresponding nonlinear methods on the example of the same socio-economic series or physical ones can also be beneficial for general development.

Complexity theory is subdivided into hard and soft complexity. Hard complexity theory stands for analytical analysis that concern with the nature of reality, while soft complexity aims to describe social and living systems. Davis and Sumara (Davis and Sumara, 2006) proposes such term as “complexity thinking” which lies somewhere in between hard and soft skills. We support such idea and would like to promote it among ordinary citizens who are not specialists and, particularly, among universities and their student. Focusing on interdisciplinarity, both hard and soft skills,

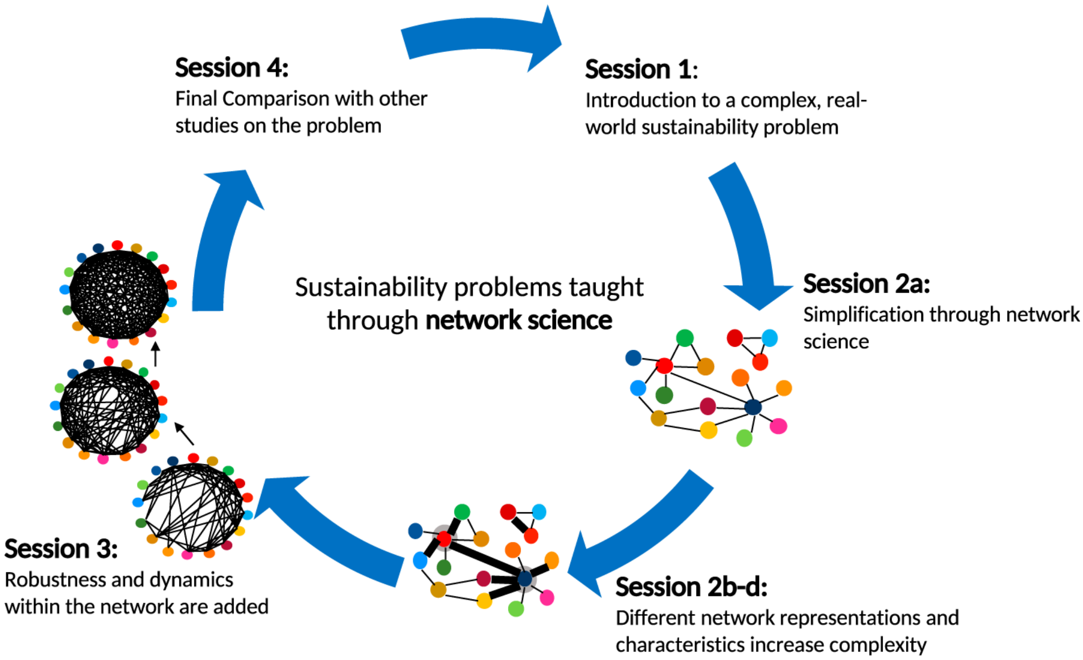


Figure 2: Sustainability problems that are solved through network science.

teachers and students will be more creative and productive in their further research. Knowing about interconnections across different disciplines, there are much more possibilities for collaborative research between different faculties and there is larger probability that people will be able to find common topics for communication and will be engaged to cooperate.

The goal of this work is to present the basic characteristics of complex systems, which should be introduced to students during the course of studying complex systems, and the basic sets of methods that allow analyzing the varying randomness (complexity) of the system during the development of the studied signals.

In this paper, we present some of the most fundamental, applied, robust, and powerful methods on the example of four physical signals: seismic (SEI), gravitational wave (GW), the distribution storm time (Dst) index, and stress-strain ($\sigma(\varepsilon)$) signal for a typical metal in the process of destruction.

SEI dataset constructed by Bladford (Bladford, 1993). Each event has 2048 points fixed at a seismic recording station in Scandinavia.

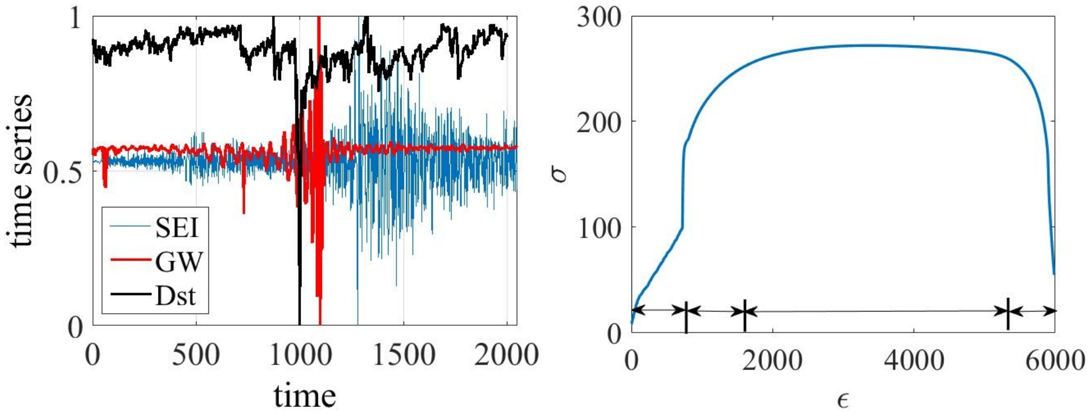
We used GW data GW150914 from Events of LIGO Open Science Center and select strain data (H1 and L1) after noise subtraction (The LIGO Scientific Collaboration and the Virgo Collaboration, 2016) (https://www.ligo.org/detections/GW150914.php).

The Dst index is an index of magnetic activity derived from a network of nearequatorial geomagnetic observatories that measures the intensity of the globally symmetrical equatorial electrojet (“ring current”). Dst is maintained at National Centers for Environmental Information (National Centers for environmental information, 2021) from 1957 to the present. Dst equivalent equatorial magnetic disturbance indices are derived from hourly scalings of low-latitude horizontal magnetic variation. They show the effect of the globally symmetrical westward flowing high altitude equatorial ring current, which causes the “main phase” depression worldwide in the H-component field during large magnetic storms. In this paper, the time series of hourly values of the storm on March 13, 1989 is investigated. It is the strongest storm in the space age in several ways; the power system of the province of Quebec was out of order. The peak of the storm falls in the middle of the time series (point 1000).

The stress-strain signal $\sigma(\varepsilon)$ contains integrated information about the structural transformations of the spectrum of defects in the material under study (point, dislocations, pores, cracks) depending on the applied stress.

In order to study changes of complexity dynamically, i.e., to get not only one value that will characterize the whole system, but an array of values, where each value will reflect the complexity of a signal in a specific period, we use sliding window approach (Soloviev and Belinskyi, 2018a; Bielinskyi et al., 2021b,c).

In figures 3a and 3b is presented the dynamics of all physical signals that could be studied during physics classes. However, students of other faculties



(a) (b)

Figure 3: The signals of SEI, GW, and Dst in normalized scale (a). Stress-strain curve in absolute scale (b).

can also be interested.

Figure 3b shows a typical dependence $\sigma(\varepsilon)$ with 4 highlighted characteristic areas. In the first of them, elastic (reversible), point defects dominate. In the second region of plastic flow and hardening, dislocations multiply and move. It is the most informative. The third region is characterized by a quasi-stationary process of accumulation of pores and microcracks, as well as the nucleation of a neck. Finally, the last region is the phase of the formation of a global crack, ending with the destruction (rupture) of the material.

3.2 Fat-Tailed Distribution

When studying complex systems, we inevitably encounter power distributions characterized by thick tails. A classic example is the power-law of dividing words by their frequency of use in a text, known as Zipf's law (Zipf, 1950).

In economics, this is the law of wealth distribution among individuals (Pareto, 1896); in demography, the distribution of cities by their size (Auerbach, 1913); in biology, the distribution of the size of forest patches (Saravia et al., 2018); in scientometry, the distribution of citations (Brzeziński, 2014). In general, a wide class of phenomena is described in the framework of distributions with a degree dependence, but the researcher (student) will have to find out the nature of such a dependence, which can be caused by many factors: critical phenomena, processes with preference, self-organized criticality, multiplicative processes with connections, optimization and path-dependent nonergodic processes, the phase space of which decreases with evolution (Domp, 1996; Sornette, 2006; Bak et al., 1987; Mandelbrot, 1953; Corominas-Murtra et al., 2015).

First of all, it will be important to build an empirical distribution for our data (figure 4). Having visualized the series we study in this paper, we can already be convinced of the non-Gaussian dynamics of the presented systems.

In the course of our research, we have determined that the Lévy α-stable distribution most successfully covers the key statistical characteristics of both the economic (Bielinskyi et al., 2019, 2021a,c) and those systems that are presented in this paper. Figures 5a to 5d show the window dynamics of the α index derived from the Lévy distribution that characterizes the "heaviness" of tails.

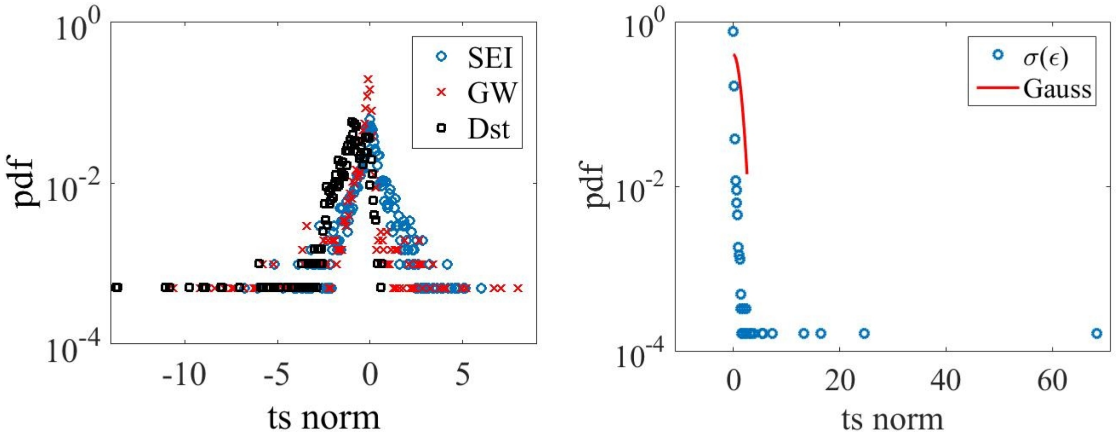
From the figures above we can observe that the dynamics of all signals is beyond normal. Index of stability α decreases during regions of instability, indicating an increase in the tails of the distribution.

3.3 Multifractality

When studying various types of systems, we often encounter both fractal (self-similar) structures and sets of different fractal dimensions (Stanley and Meakin, 1988). In such problems, it is necessary to take into account the entire range of critical indicators that characterize different moments in the distribution of observed quantities. Such properties usually relate to the term "multifractality" (Sreenivasan and Meneveau, 1986).

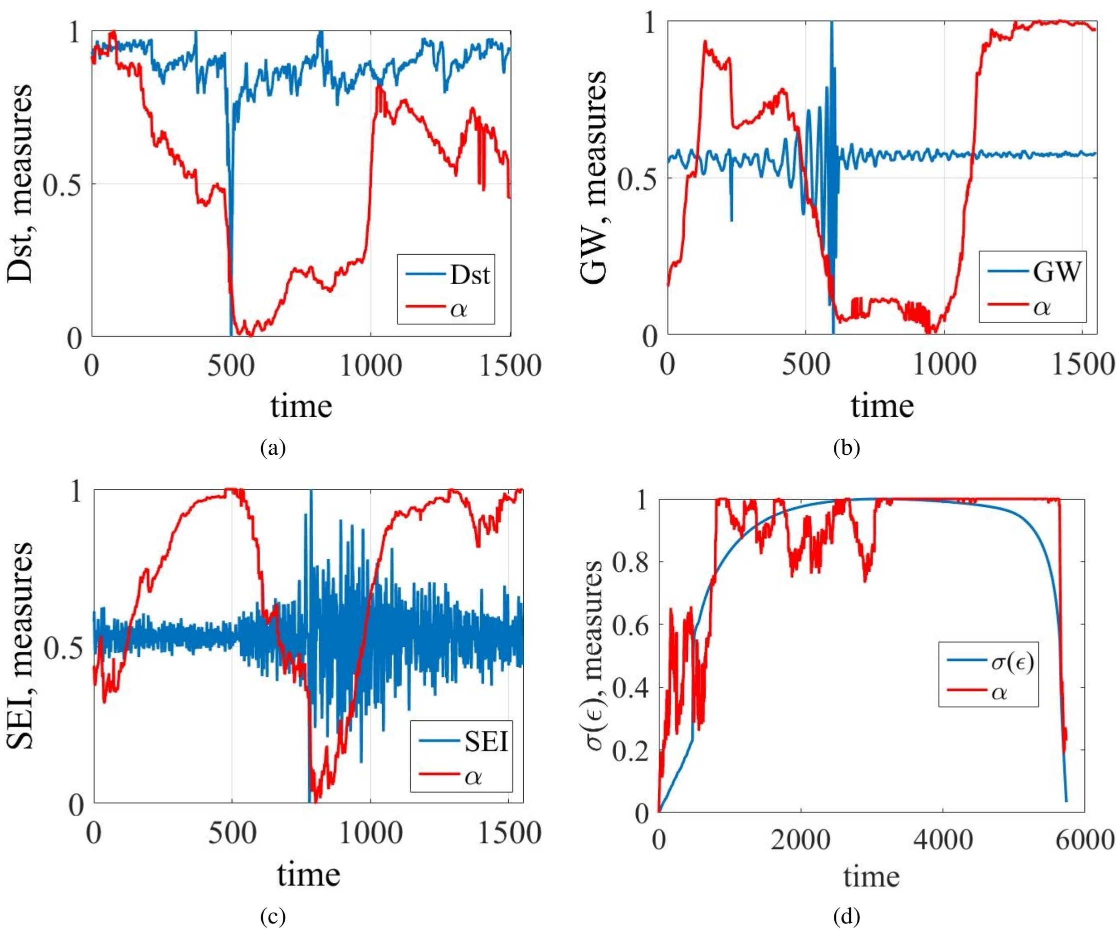
There are several different algorithms that allow the obtention of multifractal spectra from time series. The most famous is the MF-DFA (Kantelhardt et al., 2002; de Freitas et al., 2019; Eghdami et al., 2018).

Based on the MF-DFA procedure, we select the maximum value of such a quantitative characteristic of multifractality as the singularity strength (Ashkenazy et al., 2003), although in the corresponding section of fractal (multifractal) analysis, it would be necessary to characterize and demonstrate the dynamics of all multifractality indicators. The following figure



(a) (b)

Figure 4: Probability density functions (PDF's) of Dst, Sei, and GW (normalized time series – ts norm) (a). PDF of $\sigma(\varepsilon)$ signal comparing to along with the Gaussian curve (b).



(a) (b) (c) (d)

Figure 5: The dynamics of four signals and their α index of stability.

shows the window dynamics of the maximum value of the singularity strength.

Figure 6 demonstrates the increase of multifractality during period of collapse. For Dst, SEI, and $\sigma(\varepsilon)$ critical periods become more multifractal, whereas for GW we have the opposite relation.

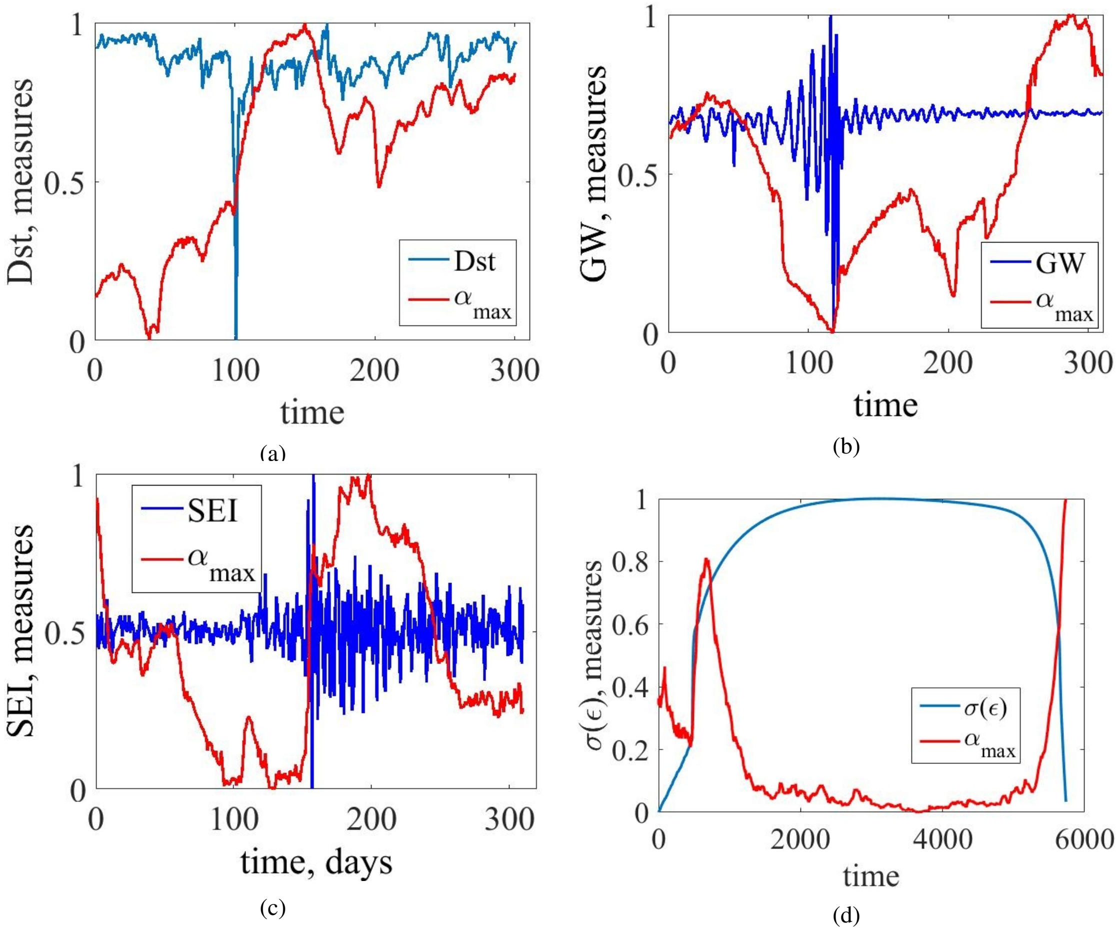


Figure 6: The dynamics of four signals and their α_{max} index of multifractality.

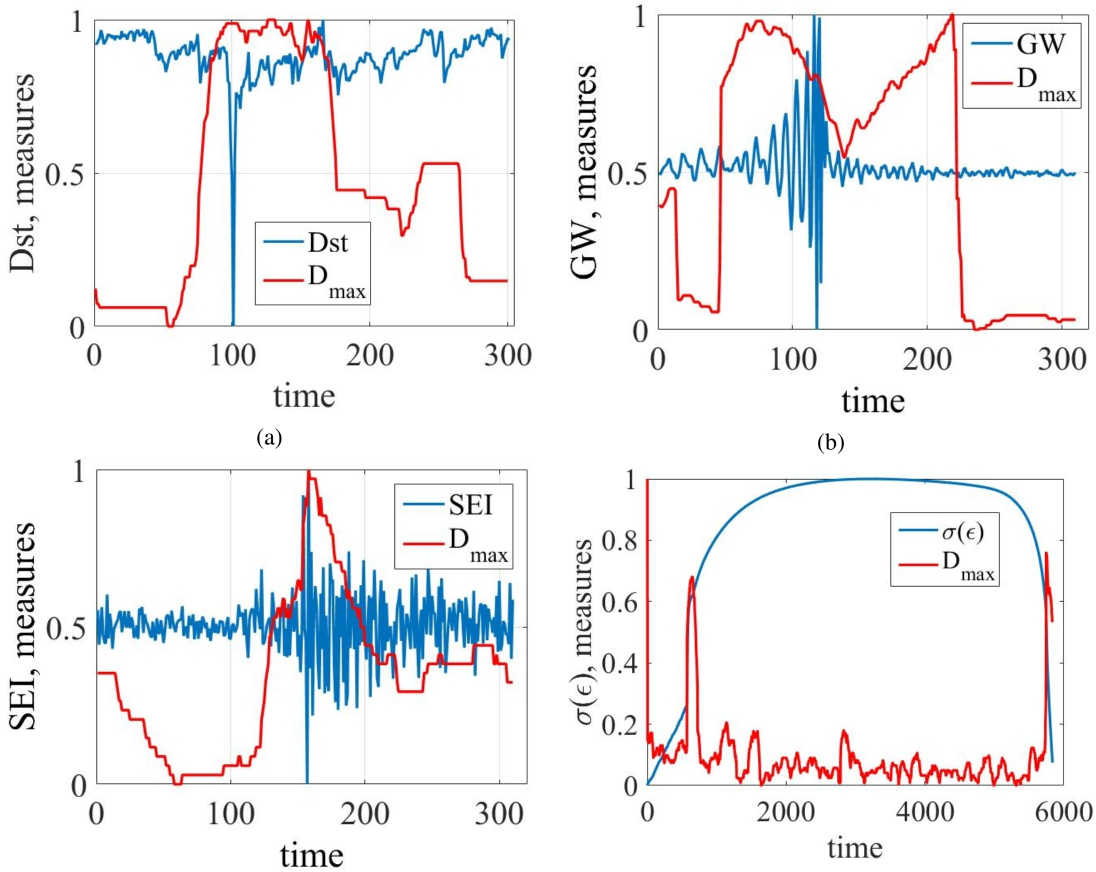
3.4 Network Analysis

Equally important is the network analysis of complex systems. Today, networks play a central role in modeling complex systems, as they offer a way to describe different types of relationships between agents that act as endpoints in the network. Complex networks can characterize information, social, economic, biological, neural, and other systems (Newman, 2003; Boccaletti et al., 2014, 2006; Baiesi and Paczuski, 2004). For example, a society can be represented as a network, where each individual (university, wealth, city) can be represented as nodes of a graph, and the connection between them through edges. For cities, edges can represent a road, where the possibilities of movement can vary, and therefore a different weight can be determined for each edge.

In general, the computer network model is a random graph, the law of mutual arrangement of edges and vertices for which is defined by the probability distribution.

The simplest of networked objects, so-called Erdös-Rényi, or random graphs (Erdös and Rényi, 1959). Such graphs can be characterized within the framework of the Poisson distribution, but most complex systems, as already noted, are characterized within the framework of distributions with heavy tails. One of the most interesting characteristics of networks is the vertex degree. The vertex degree distribution for many real-world networks shows a power-law dependence. Such networks are called scale-independent. Scale-free networks are often characterized by very short average distances between randomly chosen pairs of nodes that may have a strong impact on the whole dynamics.

In addition to the topology of graphs, you can also study their quantitative characteristics. In our case, using the window procedure, we get a variable graph representation of our signal over time. For the presented work, we calculated the maximum vertex degree of the graph (D_{max}), since this measure is one of the conceptually simplest measures, although many other measures can be represented. It is worth noting that there are also various algorithms for con-



(a) (b) (c) (d)

Figure 7: The dynamics of four signals and their D_{max} in accordance with the visibility graph.

verting a time series to a graph. We would like to emphasize the visibility graph algorithms (Bielinskyi et al., 2021c,b; Juan and Guzmán-Vargas, 2013; Kundu et al., 2021; Soloviev and Belinskiy, 2018; Bielinskyi and Soloviev, 2018) (figure 7) and one based on recurrence analysis (Donner et al., 2011) (figure 8).

The index of maximum degree D_{max} start to increase during abnormal phenomena. We can make a conclusion that crisis period is presented to be more concentrated in terms of graph comparing to normal dynamics.

3.5 Recurrence Analysis

Processes in nature are characterized by pronounced recurrent behavior, such as periodicity or irregular cyclicity.

Moreover, the recurrence (repeatability) of states in the sense of passing a further trajectory quite close to the previous one is a fundamental property of dissipative dynamical systems. This property was noted in the 1880s by the French mathematician Poincaré and subsequently formulated in the form of the "recurrence theorem", published in 1890 (Poincaré, 1890).

The essence of this fundamental property is that, despite the fact that even the smallest perturbation in a complex dynamical system can lead the system to an exponential deviation from its state, after a while the system tends to return to a state that is somewhat close to the previous one, and goes through similar stages of evolution.

In 1987, Eckmann et al. (Eckmann et al., 1987) proposed a method for mapping the recurrence of phase space trajectories to $N \times N$ matrix. The appearance of a recurrence diagram allows us to judge the nature of processes occurring in the system, the presence and influence of noise, states of repetition and fading (laminarity), and the implementation of sudden changes (extreme events) during the evolution of the system. If you look at recurrent diagrams in more detail, you can find small-scale structures (textures) consisting of simple points, diagonal, horizontal, and vertical lines, which in turn correspond to chaotic, repetitive, or laminar states.

Using combinations of these states, Zbilut and

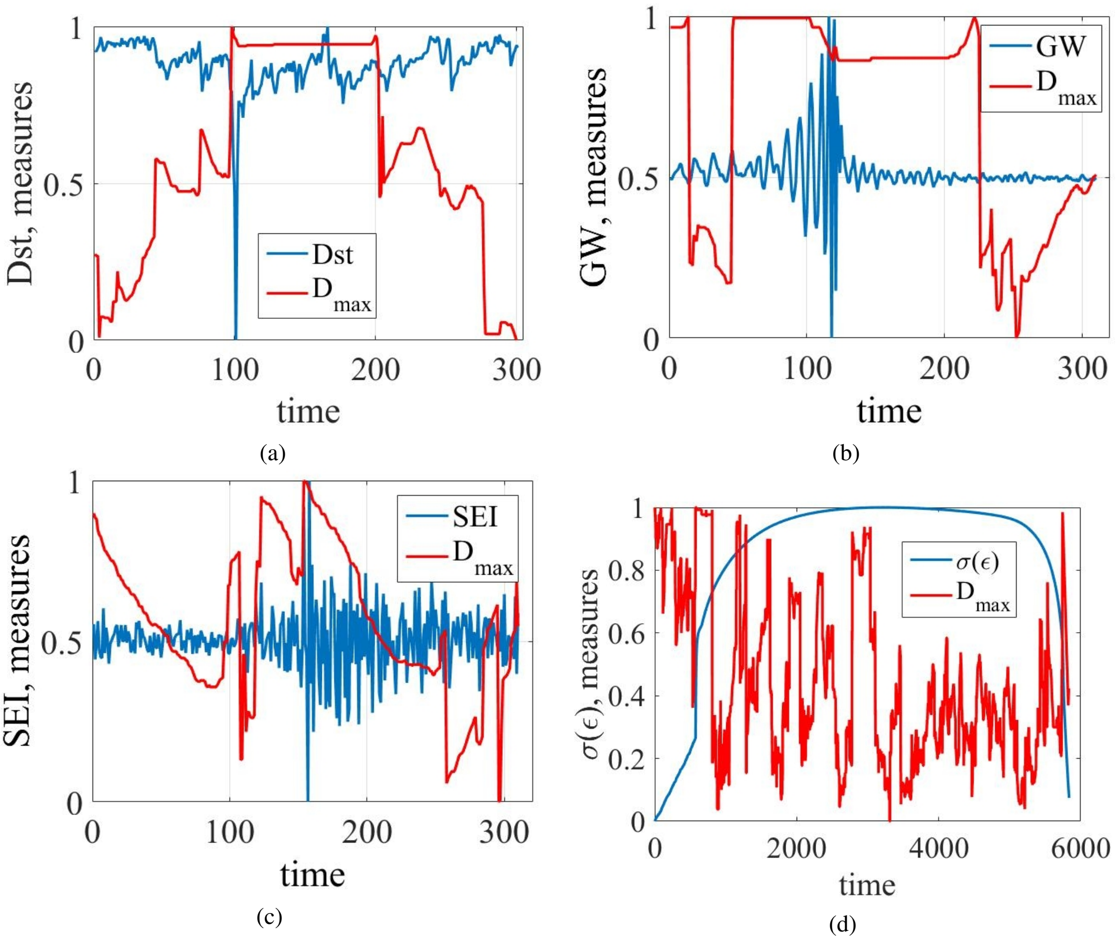


Figure 8: The dynamics of four signals and their D_{max} in accordance with the algorithm based on recurrence analysis.

Webber (Zbilut and Webber, 1992; Webber and Zbilut, 1994) developed a tool for calculating a series of measures based on the distribution of recurrent points on a recurrence matrix. Later, the toolkit for quantitative recurrent analysis was supplemented by Marwan and Kurths (Marwan and Kurths, 2002). The tools of quantitative recurrent analysis include the recurrence rate, determined by the ratio of recurrent points to the total number of points on the recurrence matrix under study. In addition to the recurrence measure, in the course of analyzing complex systems, it would be possible to present such measures as determinism, divergence, entropy, trend, and so on (Soloviev and Belinskiy, 2018; Soloviev and Belinskyi, 2018a; Derbentsev et al., 2020; Fan et al., 2018; Lin et al., 2015; Banerjee et al., 2021).

In this paper, we will focus on the recurrence rate and present it for the already specified series (figure 9).

Figure 9 demonstrates *RR* measure that indicates the probability of finding recurrent (close to each other) points. Our empirical results show that due to abrupt changes that correspond to crisis state, the probability of finding recurrent points become lower. This indicator starts to decrease even before crash, which makes it as indicator-precursor of such events.

3.6 Entropy and Non-Extensive Statistics

The Boltzmann-Gibbs statistical entropy and the classical statistical mechanics associated with it are extremely useful tools for studying a wide range of simple systems that are characterized by a small range of space-time correlations (short memory), the additivity of noise, the presence of intense chaos, the ergodicity of dynamic processes, the Euclidean geometry of phase space, the locality of interaction between elements, the Gaussian probability distributions, etc.

The Boltzmann-Gibbs statistical entropy is a fundamental concept of the school section and the university course of thermodynamics and statistical physics.

In statistical mechanics, entropy denotes the num-

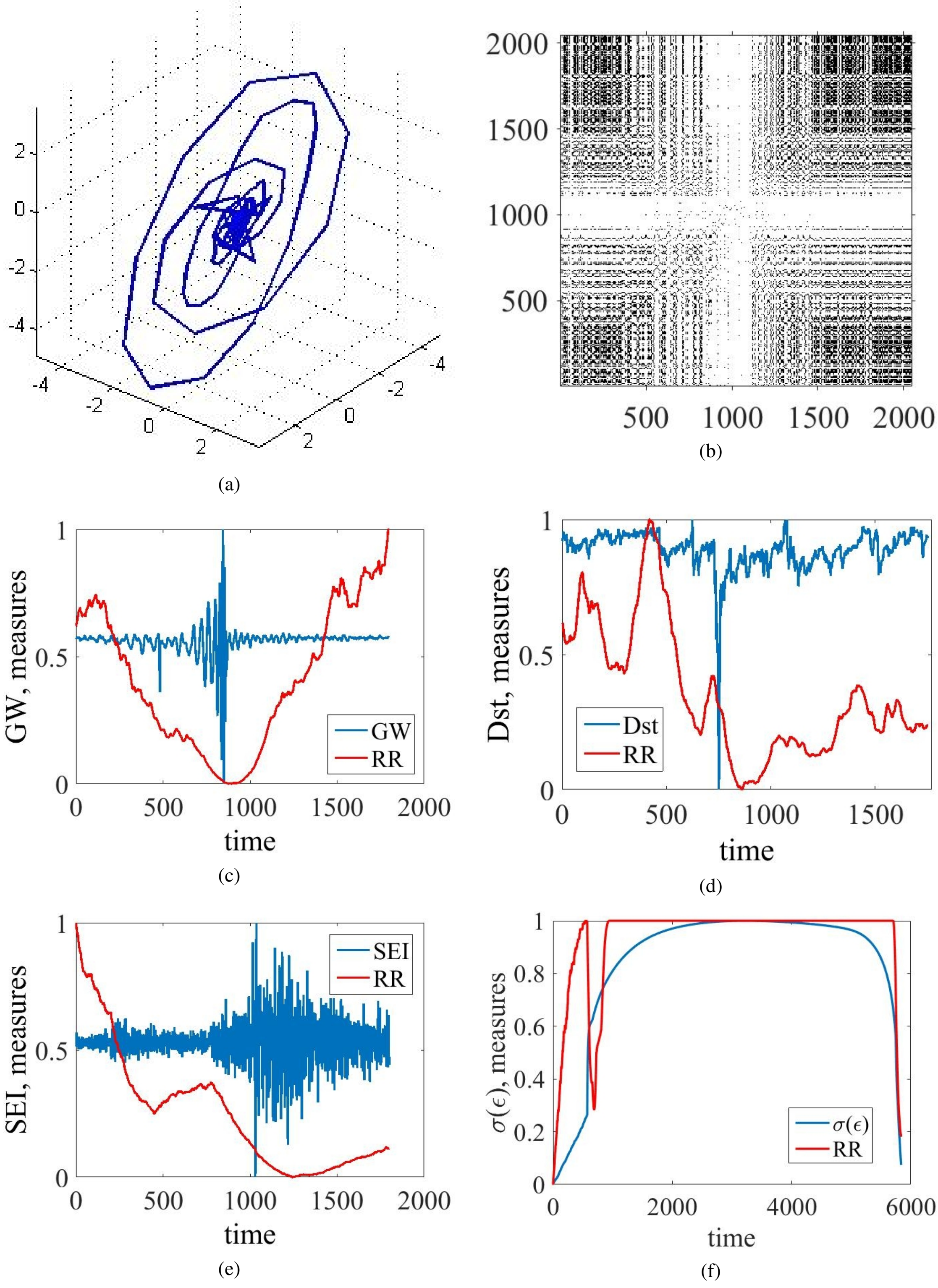
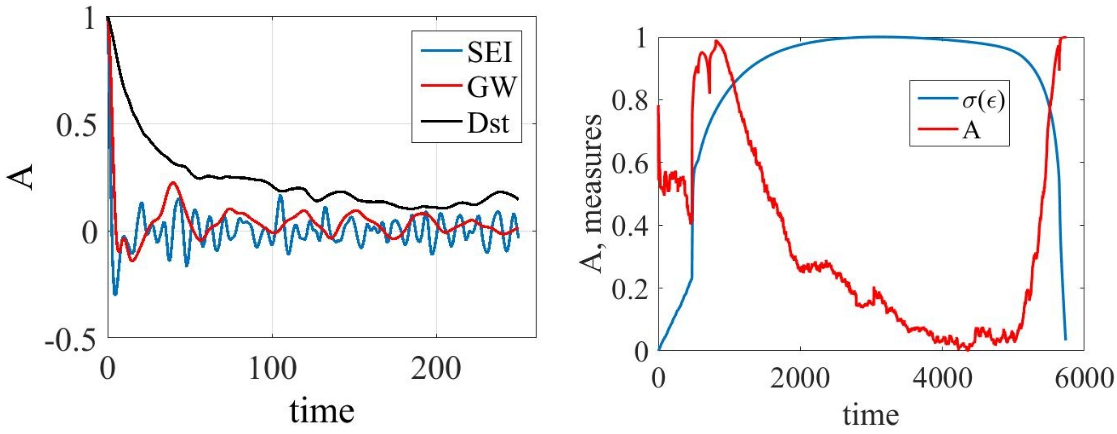
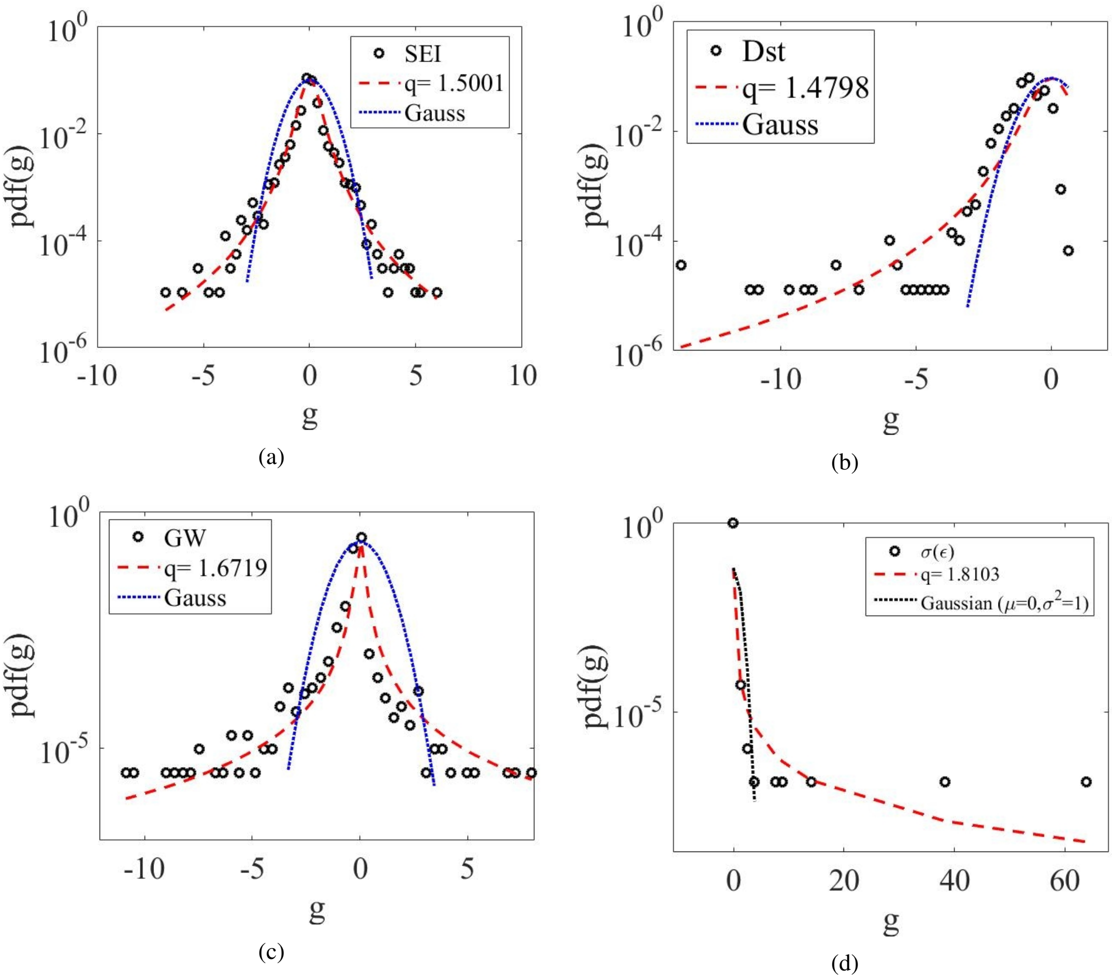


Figure 9: Phase space portrait and recurrence plot of GW (a-b). The dynamics of RR for GW (b), Dst (c), SEI (d), and σ(ε) (f).



(a) (b)

Figure 10: Autocorrelation of SEI, GW and Dst (a), and sliding window autocorrelation for σ(ε) (b).



(a) (b)

(c) (d)

Figure 11: The pdf's of the four signals, Gaussian, and q-Gaussian functions (a-d).

ber of possible configurations of a thermodynamic system. The notion of entropy can be associated with the uncertainty in the system (Clausius, 1870; Boltzmann, 1970). In 1948, Shannon transformed classical statistical entropy to information entropy (Shannon, 1948). Since then, a number of other types of information entropy have been developed (Karakatsanis et al., 2013; Javaherian and Mollaei, 2021; Litvinenko, 2019; Posadas et al., 2021).

In order to study many real-world systems, it is necessary to go beyond the standard course of thermodynamics, statistical physics, and classical Shannon entropy. A whole range of natural, artificial and social systems, which, unlike those mentioned above, are characterized by a long range of spatio-temporal correlations and non-Gaussian processes.

Since the non-Gaussian and multifractal behavior of the studied systems was presented previously, we will depict the autocorrelation function in the figure 10a, as it should demonstrate an indicator decline. This fact will indicate the dependence of the following values on the previous ones.

It is also worth mentioning that such systems are characterized by multiplicative noise, the presence of weak chaos (vanishing maximum Lyapunov exponent), non-ergodicity of dynamic processes, hierarchy (usually multifractality) of the geometry of the phase space, the presence of asymptotically power-law statistical distributions. A fairly wide class of these complex systems (although not all) it is adequately described by non-additive statistics based on the Tsallis parametric entropy.

Figures 11a to 11c show the q-Gaussian distribution from the Tsallis statistics for the considered series in comparison with the classical Gaussian one.

Autocorrelation plot (figure 10a) represents that the highest long-range dependence has the signal of magnetic activity, and autocorrelation with the sliding window approach for $\sigma(\varepsilon)$ signal represents how increases dependence between defects during transition from elastic region to the region of plastic flow and hardening.

Figures 11a to 11d present that signals which dynamics exceeds $\pm 10\sigma$ are described more appropriately in terms of q-Gaussian distribution. Parameter q represented the degree of non-extensivity in each system. With the higher q, we expect more multifractal, chaotic, and dependent dynamics.

3.7 Reversibility and Irreversibility

The last characteristic that we would like to mention is time-reversibility. Temporary irreversibility is a key property of non-equilibrium systems.

Again, such systems are characterized by the presence of memory, while reversibility increases with more noisy and unpredictable signals. Thus, by calculating the irreversibility, we determine the degree of nonlinearity and predictability. It is important to note that the significant time reversibility excludes linear Gaussian processes as a model of generating dynamics. Within the framework of the systems we are considering, we need to think about methods of nonlinear dynamics and non-Gaussian ones (Lawrance, 1991; Stone et al., 1996).

Over the past decade, various methods have been proposed for calculating the degree of irreversibility in systems (Daw et al., 2000; Kennel, 2004; Lacasa et al., 2012; Donges et al., 2013; Flanagan and Lacasa, 2016; Costa et al., 2005; Zanin et al., 2018; Jiang et al., 2016) and we have presented how to use some of them for crises identification (Bielinskyi et al., 2021b). For pedagogical purposes, along with the mentioned concept of multifractality and entropy, we would like to present irreversibility based on the multifractal approach (Jiang et al., 2016) and permutation patterns (Zanin et al., 2018). The last mentioned approach could be taught within the section of entropy approaches if we were teaching students. However, the calculation of irreversibility based on graph theory is also possible (Lacasa et al., 2012; Donges et al., 2013; Flanagan and Lacasa, 2016).

Figures 12a to 12d show the mentioned measures of irreversibility for the studied signals.

In figure 12 we can see that abnormal periods are followed with the increase of irreversibility in signal. In our opinion, permutation-based irreversibility is most stable comparing to the second one. Nevertheless, additional improvements of algorithm for their calculations can be made, and indicators of irreversibility based on graph theory can be studied.

4 CONCLUSION

Nowadays real-world challenges and mass integration of information and communication technologies in every sphere of our life demand an evolution of a pedagogical sector. Consequently, increasing complexity of all social structures require multidisciplinary projects, which can provide valuable experience and competencies not only for colleagues from seemingly independent disciplines, but also for students from the same fields.

The analysis of the adaptive nature of many complex systems led to the creation of methods and the development of concepts that were successfully applied to describe formally similar phenomena in chemical, biological, social and other systems of agents of non-physical nature. It is sometimes argued that if physics is the science of the four fundamental forces that matter interacts with.

It is still relevant to create appropriate open innovation laboratories (Cortes et al., 2020) in which will

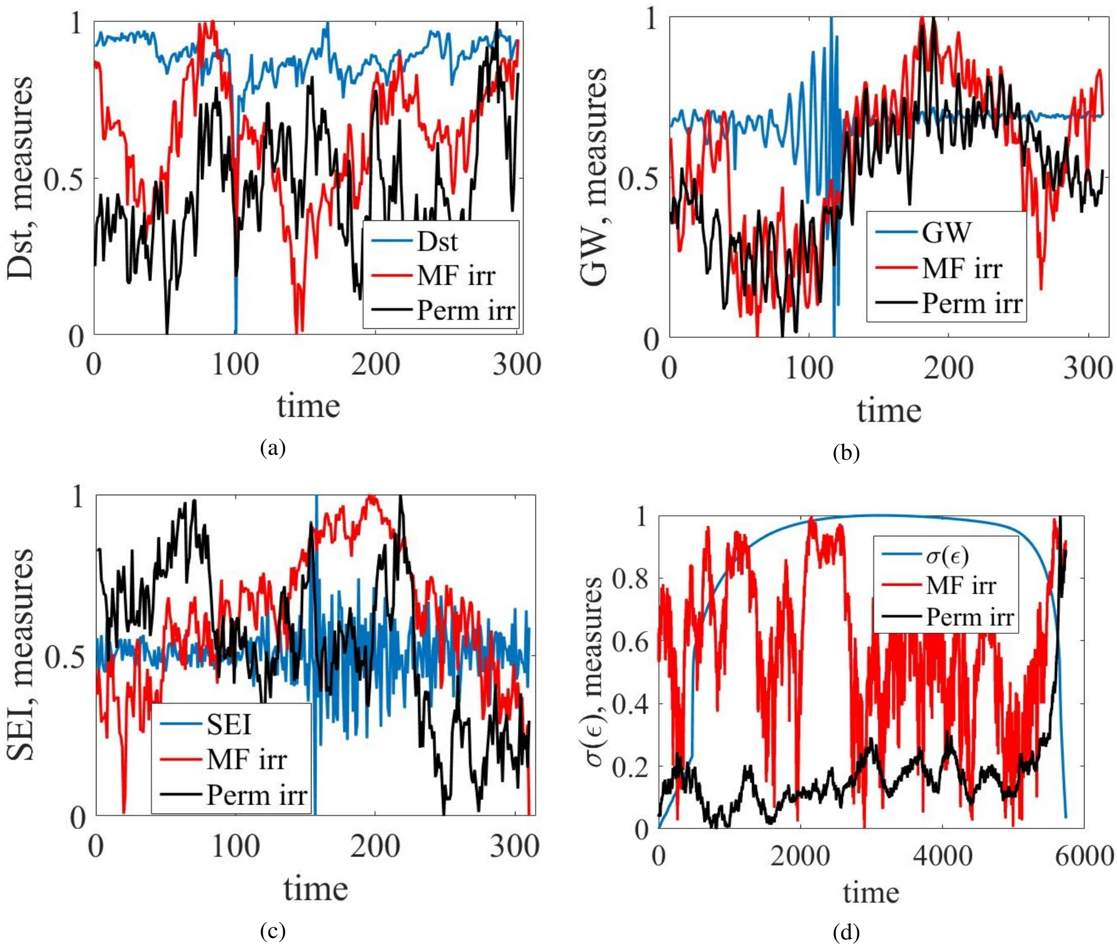


Figure 12: The dynamics of irreversibility measures along with the studied signals.

be possible adaptation of various solutions from the fields of physics, higher mathematics, and computer science to social sciences.

In this paper, we have presented some of the most significant approaches on the example of SEI, GW, Dst, and $\sigma(\varepsilon)$. Empirical results emphasize that we can not only study critical processes (as in the first three cases), but also physical objects in which these (critical) processes alternate with (quasi)-linear and even catastrophic (destruction). Obviously, today's transformations towards Industry 4.0 gave us a wide range of different indicators and signals to study (Chen et al., 2019; Liu et al., 2019), and the task is to get students interested in learning the appropriate complexity theory tools and developing their complexity thinking.

The theory of complex systems is obviously not limited to the methods presented in this paper. Further, we would like to supplement the presented material with entropy (Soloviev and Belinskyi, 2018b; Soloviev et al., 2019, 2020b), chaotic algorithms (Soloviev et al., 2020a), and, for example, the tools of random matrix theory (Soloviev and Belinskiy, 2019; Bielinskyi et al., 2021c).

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Quantum Transformation of School Informatics

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Keywords: Methods of Teaching Informatics, General Secondary Education, Methods of Teaching Lyceums Students, Quantum Technologies, Quantum Informatics, Competencies in the Basics of Quantum Informatics.

Abstract: The study's objective was to theoretically examine, create, and experimentally test various approaches for instructing lyceum students in the fundamentals of quantum informatics. The following was accomplished as a result of the research assignments: 1) The sources on the issue of teaching quantum informatics in Ukraine and abroad were examined; 2) The structure and content of the competences in the basics of quantum informatics for the lyceum students were theoretically grounded and developed (the results of the expert survey and the European competence framework in the field of quantum technologies were taken into consideration); 3) the structural and functional model for forming the competences in the basics of quantum informatics were developed; 4) in the optional course of the same name, it was proposed a methodological framework for teaching the fundamentals of quantum informatics to lyceum students; and 5) it was also experimentally tested to see how well the developed methodology worked in developing the students' competency in the fundamentals of quantum informatics. Further scientific investigations into the quantum transformation of the school's informatics are also described.

1 INTRODUCTION

The changes that took place in the methodology of teaching informatics in schools were caused by the development of information technology and changes in society as a result of their influence (Semerikov et al., 2021). The latter led to the fact that school informatics together with foreign language became available at all levels of school education – from primary school to vocational training at the lyceum. Informatics tools are an integrator for all school subjects, and its methods are the basis for the integration of natural sciences, mathematics and technology. This creates a deep understanding of the service, subordinate and second-row role of informatics in the system of school education. The fundamentalization of teaching content informatics, in particular – through a quantum transformation of basic knowledge about information processes and systems, hardware and software, networks, algorithms and programs will help to get rid of it.

According to the analytical report of the National Institute for Strategic Studies (NISS, 2020), Ukraine is on the sidelines of the development of breakthrough technologies, in particular quantum technologies, which is due, firstly, due to insufficient state budget financing of scientific research on the whole, and secondly, due to the significant inadequacy of professional and qualification workforce to market demands. At the same time, European job search sites have hundreds of job postings for "quantum software engineer" and "quantum programmer".

The analysis of the experience of teaching informatics in Ukraine and the resources on the problems of research allowed us to identify the contradictions:

- between the importance of quantum informatics for increasing competitiveness and successful self-fulfillment of graduates of lyceums in the labor market (in particular, in the field of informa-

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tion technology) and the lack of adequate training materials in Ukrainian language;

- between the importance of practical experience with quantum computers and the difficulty of direct access to them;
- between the need to form competences in the basis of quantum informatics in the lyceums and undevelopment of the appropriate methods.

The need to solve the above-mentioned contradictions led to the definition of the study's aim and formulation of its hypothesis. The aim of the study was to theoretically analyze, develop and experimentally test the methods of teaching the basics of quantum informatics to lyceums students. It has been suggested that the formation of competencies on the basics of quantum informatics to lyceums students at a high level is possible by changing some components of the methodological system of teaching computer science: content and teaching tools.

2 THEORETICAL FOUNDATIONS OF TEACHING THE BASICS OF QUANTUM INFORMATICS TO LYCEUMS STUDENTS

2.1 Quantum Informatics as a Perspective Field of Information Technology Development

In August 2020, consulting company Gartner published yet version of its Hype Cycle of advanced technologies that will have a significant impact on society and business in the next five to ten years. Based on a review of 1,700 advanced technologies, Panetta (Panetta, 2021) identifies 5 new trends in their development:

- Composite architectures;
- Algorithmic trust;
- Beyond silicon;
- Formative artificial intelligence (AI);
- Digital me.

The Beyond silicon description of the direction says that Moore's Law has run out of steam because it is almost impossible to create transistors smaller than 1 nm. There are technical difficulties in manufacturing, so there is a chance to develop non-silicon technologies – carbon-based transistors and quantum hardware, including quantum computers (Panetta, 2021).

At the time when classical computers continue to develop (processors became multicore, co-processors appeared to solve photo processing tasks, video coding, etc.) the pace of quantum technologies development is gaining momentum and quantum computers are becoming a reality. Appearance and development of quantum equipment, in particular quantum computers, has led to a new field of informatics – quantum informatics (Lehka and Shokaliuk, 2018).

One should understand that quantum computers by no means supersede classical ones, but they are indispensable for certain types of tasks – modeling complex chemical reactions to develop drugs and substances with predetermined properties, modeling of physical quantum systems inaccessible for conventional calculations, quantum calculations of complex mathematical tasks, quantum long-distance communication, etc. The solution of these problems is based on already known quantum algorithms – algorithms for function balancing (Deutsch-Jozsa and Bernstein-Vazirani algorithms), algorithm for determining the totality of functions (Simon's algorithm), harmonic analysis algorithms (the quantum Fourier transform algorithm), cryptoanalysis algorithms (Grover's and Shor's algorithms), quantum teleportation algorithm – and new (still experimental) algorithms.

In many countries of the world the development of quantum technologies is supported by legislation and financed by the government.

Thus, in the U.S., artificial intelligence and quantum technologies have been identified as two strategically important fields for the country's economic growth and national security. In 2018, the U.S. government approved legislation for the National Quantum Initiative, which aims to ensure that the U.S. remains a world leader in quantum informatics and its technological applications. Funding for National Quantum Initiative activities for the first five years is \$1.2 billion (NQIA, 2018). Individual commercial research is conducted at the expense of IBM, Microsoft, Google, Intel and others.

In China, in 2016 the government approved the National Science and Technology Innovation Plan until 2030 (NSTI, 2016), and in 2017 the construction of the National Quantum Informatics Laboratory was launched with initial funding of 7 billion yuan (Chen, 2018). The Chinese tech giant Alibaba is making significant investments in its own quantum initiatives, including the launch of a quantum calculator service via a cloud platform (Alibaba, 2018).

Since October 2018, EU countries have launched project program to support fundamental quantum research – "The European Quantum Flagship" (QFlagship), with a minimum duration of 10 years and an expected budget of 1 billion billion euros (EQF, 2021). In addition, to protect against cybersecurity threats, in June 2019, 24 European states participated in the signing of a declaration on the research, development and deployment of quantum communication infrastructures (EDS, 2019).

The demand for specialists in the field of quantum technologies becomes urgent. The lack of quantum-literate specialists hinders the development of the industry. For example, Hilton (Hilton, 2019), vice president of D-Wave, argues that it is necessary to increase the number of quantum-literate workers, invest in the training of teenagers, identify capable young people, develop them in the field of quantum technologies and create a talent pool of promising workers with knowledge in the quantum field.

2.2 Teaching Experience of Quantum Informatics and Popularization of Quantum Technologies in Ukraine and the World

In Ukraine all educational programs on quantum informatics were initiated only in universities within the specialty 104 – Physics and Astronomy (Pinkevych et al., 2018; NUL-bachelor, 2020; NUL-master, 2021), while in the world the training of corresponding specialists is carried out by different specialties (QTEdu, 2022).

The European Competence Framework for Quantum Technologies, launched in 2021, provides for training in quantum informatics, starting from primary school. Such education should be based on conceptual and intuitive understanding of quantum informatics key essences.

Today, both in Ukraine and abroad, mostly programs of non-formal education on individual topics of quantum technologies are offered for students of general secondary education institutions. Its are online schools, master classes, summer camps for children, etc.

Popular science resources about quantum technologies for Ukrainian students are offered by Gnatenko (Gnatenko, 2020a,b). With these electronic materials (after payment) students can get acquainted with fundamental concepts of quantum mechanics – quantum entanglement, quantum beat, quantum parallelism, quantum sensing, quantum entanglement, quantum superposition, tunneling, quantum teleportation, as well as examples of basic tasks of quantum cryptography.

The Richelieu Lyceum, in cooperation with the Odesa I. I. Mechnykov National University, offers a series of lectures "Nanoelectronics: Science and Modernity" (including lectures on quantum effects) (NSM, 2021), and "Quantum Mechanics" (QM, 2021).

Korshunova and Zavadsky (Korshunova and Zavadsky, 2018) in their textbook on informatic for 5th grade (section "Information processes and systems") gives an overview of quantum computers as a technology of the future, pointing out the rapid development of the quantum industry in the next ten years, the use of quantum computers to solve certain types of mathematical problems, emphasizing the use of quantum computers together with conventional computers (Korshunova and Zavadsky, 2018, p. 28-29).

Since August 2020, the White House Office of Science and Technology Policy and the National Science Foundation have launched an innovative project, the Q-12 National Education Partnership, which over the next ten years will bring together industry and science educator leaders for large-scale quantum technology education, ranging from providing classroom tools for hands-on experience, developing educational materials, and supporting students on their way to professional careers in quantum technologies (Q12, 2023). Leading IT companies – IBM, Microsoft, D-Wave, Google and others – offer joint courses with universities, as well as educational resources for informal education, based on the use of a cloud access to quantum simulators and quantum computers, tools for creating and executing quantum circuits and programs, language-independent and language-independent development environments, etc. (QC-IBM, 2021; Google, 2022; QDKit-Microsoft, 2023).

A variety of educational resources on quantum technologies for primary and secondary school students and all those interested are offered on the QT-Edu community portal (QTEduCSA, 2021). The portal is designed to develop an educational ecosystem in support of the QFlagship project aimed at popularizing, informing and educating in the field of quantum technologies. The portal's collection of resources, structured by education level and target audience, includes educational programs, hyperlinks to external resources, quantum games, simulators, video resources, etc., mostly in English, German and Polish (Ukrainian and Russian resources are not available on February, 2023).

Experience of European and world practice of popularization of quantum technologies among high school students is a good evidence of the possibility of mastering the basics of quantum technologies, provided methodical adaptation of educational materials to the specifics of the audience perceiving them.

2.3 The Competencies in the Basics of Quantum Informatics to Lyceums Students

The key idea of the competency-based approach is to provide all interested individuals with a diagnostic tool to measure the level of preparedness of an individual to perform certain activities.

Review of the previous results of the world projects for the selection and determination of the list of competences in quantum technologies – WorldSkills International professional competitions (figure 1 and 2), seminar "Key Concepts for Future Quantum Information Science Learners" (NSF, 2020), Competence Framework for Quantum Technologies (figure 3) – made it possible to identify competencies in the fundamentals of quantum information science of lyceum students as a dynamic combination of knowledge, skills, abilities, ways of thinking, and attitudes, other personal qualities in the field of quantum technologies, which determine the ability of an individual to successfully carry out further professional and/or educational activities using such technologies. Competences in quantum informatics basics of lyceum students include 8 groups of competences:

1) physical basics of quantum technologies (basic concepts of quantum physics, cubic dynamics);
2) mathematical basics of quantum informatics (basics of linear algebra, mathematics of quantum physics basics, basics of quantum measurement statistics);
3) software technology (optical technology, laboratory technology, experimental control);
4) hardware for quantum computers and sensors (spin-based devices, neutral atoms and ions, new types of cubes, equipment for integration, manipulation and counting of cubes, use of hardware platforms for quantum computing);
5) quantum computing and modelling (quantum gates, quantum languages, programming tools and platforms, basic quantum algorithms, quantum error correction, quantum modelling elements);
6) quantum sensors and metrology (atomic gauges, sectors of quantum sensors application);
7) quantum communication (quantum cryptography, quantum networks, quantum communication infrastructure and equipment);
8) practical skills and general competences (basics of classical programming, application of quantum technologies, general skills/competences).

Considering that quantum information technology is an interdisciplinary branch of knowledge, the relevant competencies cannot be defined as part of digital competencies.

3 METHODICAL FOUNDATIONS OF TEACHING THE BASICS OF QUANTUM INFORMATICS TO LYCEUMS STUDENTS

3.1 Special Hardware and Software Tools for Teaching the Basics of Quantum Informatics

For the selection of special hardware and software tools for teaching quantum informatics to lyceums students we analyzed services from Microsoft, QuTech, Amazon and IBM (Lehka and Shokaliuk, 2021; Lehka et al., 2022a,b).

The greatest number of criteria is satisfied with IBM Quantum platform, which was turned into the main instrumental tool for learning the basics of quantum informatics for the course program.

Now IBM provides the greatest opportunities for free use of quantum computers and simulators through two services – IBM Quantum Composer and IBM Quantum Lab.

The first service – IBM Quantum Composer – the simplest tool for working with quantum algorithms in the form of quantum circuits.

The second service – IBM Quantum Lab – provides the possibility to implement quantum algorithms in Python programming language using the Qiskit library.

3.2 Pedagogical Reasonability and Content of Teaching the Basics of Quantum Informatics in Secondary Schools

The model of the educational process (learning) within a single educational unit, which reflects the ordering (elementary in time and space, in accordance with the goals of education and training and taking into account the reverse pedagogy) of the students (those who learn) in terms of the content of training

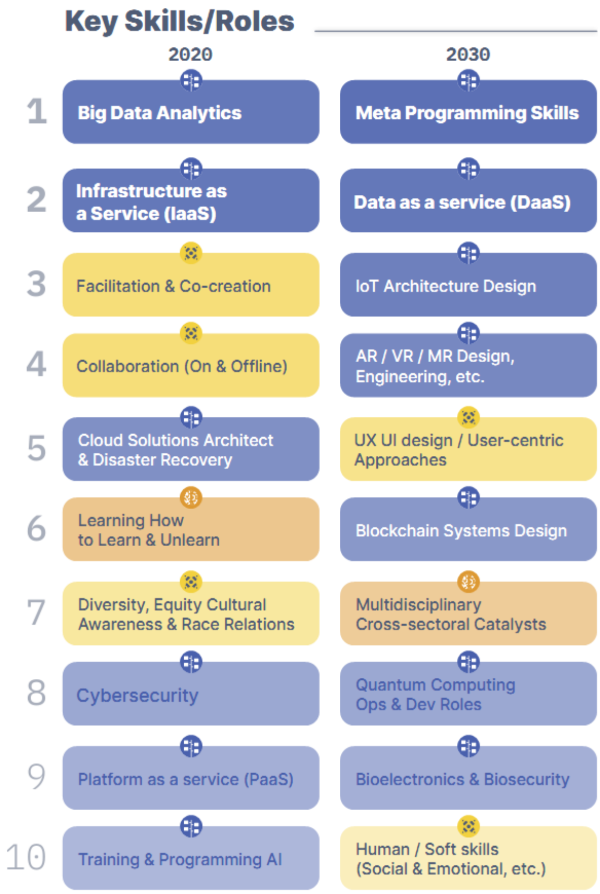

Figure 1: Key skills and roles of the 2020s and 2030s for WorldSkills (WS, 2020, p. 120).

and elements of the learning environment of a particular learning unit, students (those who are taught) regarding the content of the teaching and elements of the learning environment for a particular educational unit is called a normative teaching methods (Bykov, 2008, p. 310).

The real teaching method is based on the normative one and differs from it. The real teaching methods take into account the characteristics of the existing educational environment and mirror the creative aspect of the educational process participants (e.g., specificity of the educational environment of a particular educational institution, mastery of the teacher, additional meaningful elements that he or she uses in the lessons).

The normative teaching method of a certain educational unit (in our case – basics of quantum informatics as a single subject, elective, integrated course, etc.) can be presented in the form of a structural-functional model – a model graphically depicts functional peculiarities of structural elements of a certain process (in our case – formation of competences in quantum informatics basics).

The developed structural-functional model of competence formation in the basics of quantum informatics (Lehka, 2022, p. 82) includes 4 basic (system) blocks – Purpose, Content, Technological and Productive (figure 4) – and 3 additional blocks ensuring the interaction of the model's basic blocks: general didactic principles of teaching quantum informatics, hardware and software tools for teaching quantum informatics and methodological approaches (competence-based, systemic, integrative, personal and activity-based).

Let us consider the aim and content blocks of the model.

The *aim block* of the model includes components (factors) that determine the pedagogical feasibility of the educational unit in the educational process (local or global). Factors of pedagogical feasibility of implementation of quantum informatics basics in the educational process of secondary general education institutions are:

- rapid development of quantum technologies;
- demand of the society for qualified quantum sci-

Figure 2: Forecast of the time of mass demand for skills from quantum technologies for WorldSkills (WS, 2020, p. 121).

entists;

- quantum computerization (availability of quantum computers and other quantum equipment);
- free access to quantum computers;
- world experience in "quantum transformation" of the school informatics;
- pre-professional training in quantum informatics.

To substantiate the feasibility of introducing the basics of quantum informatics into educational programs of secondary general education institutions, To find out the state of awareness of teachers in the field of quantum technologies and readiness to teach an elective course (or a course of their choice) to lyceum students we have studied the opinion (conducted an interview) of teachers of informatics in secondary general education institutions. The survey involved 26 IT teachers who teach chemistry, labor and technology, and mathematics at the same time.

100% of respondents supported the opinion that secondary education should provide up-to-date knowledge and take into account the modern achievements of the industry when studying the disciplines. All survey participants indicated that they use moderate technologies when teaching their subject (65.4% – always, 34.6% – only during distance learning).

96.2% of respondents agree that the educational material (in particular, quantum informatics) should be adapted according to the age of the students.

96.2% of the respondents indicated that they would be pleased with the introduction of new sections and topics to the discipline curriculum, especially if sufficient methodological support is available.

The responses of the respondents indicate that 88.5% would like to take the course "Fundamentals of Quantum Informatics", and 38.5% of them noted that they have encountered a lot of publications on this topic and were interested in it.

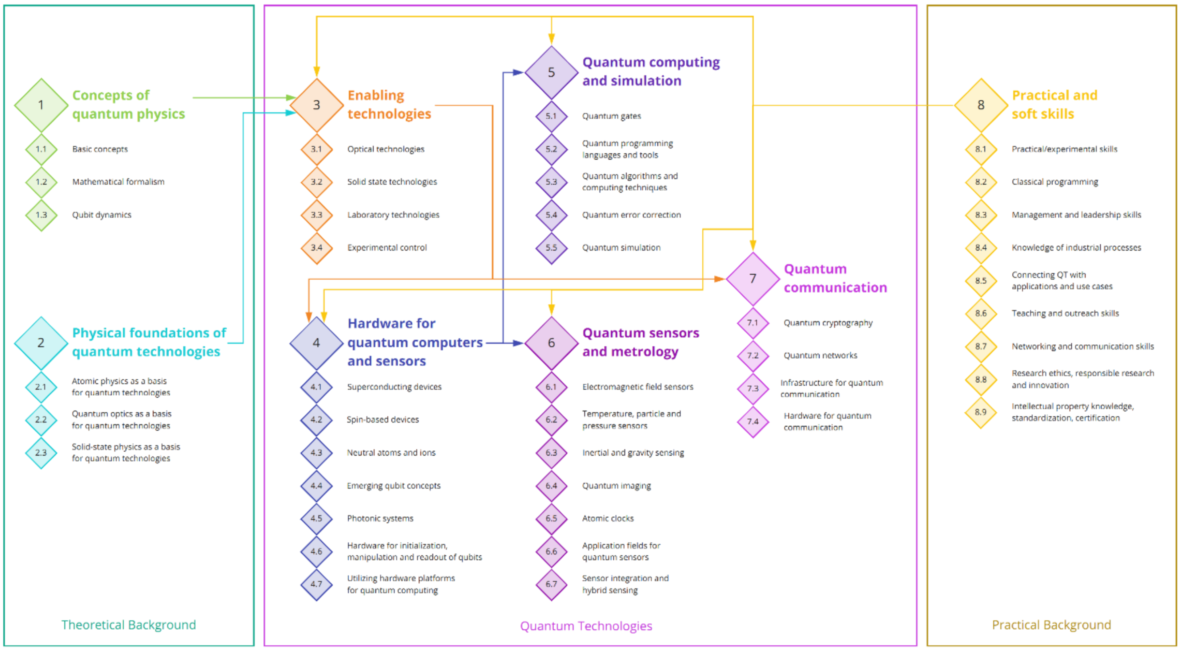

Figure 3: General structure of Competence Framework for Quantum Technologies (Greinert and Müller, 2021).

61.6% of respondents responded positively to the question "Would you offer the course "Fundamentals of Quantum Informatics" for students at your school? 23.1% refused because, in their opinion, this course would not meet the profile of the educational institution where they work. Only 3.8% said no.

The survey indicates that teachers follow new trends in the field and are ready to teach modern and relevant courses in their institutions. As for the implementation of the basics of quantum informatics for lyceum students, the teachers expressed their support for such implementation due to the presence of a corresponding course for teachers and methodological support.

The content block of the model of competence formation in the basics of quantum informatics as a corresponding normative teaching methodology reflects the main content of competence formation in the basics of quantum informatics.

The content block of the model depicts the main content of the competence formation in the fundamentals of quantum informatics:

- European framework of competences for quantum technologies (see section 2.3);
- State educational standards;
- content of informatics curriculum;
- expert selection.

Analysis of the development of methodological systems of teaching informatics (from 1985 and up to now, with the consolidation of four stages) showed that content of teaching school informatics expanded from algorithms and programming through the knowledge of information and information and communication technologies to informatics as a basis for STEM integration.

In order to clarify the content and recommendations for teaching the basics of quantum informatics to lyceums students, to determine the importance of the European framework of competencies for quantum technologies, an interview was conducted among those who are interested in the field of quantum technologies. 36 respondents took part in the survey, some of them combining several positions, such as university teacher and researcher or university teacher and school teacher.

The analysis of the evaluation results (taking into account the competence level of the participant of the expert survey – "have a basic idea" (1), "know with some components" (2), "deeply know with some components" (3), "expert" (4)) has allowed to specify the content of teaching the basics of quantum informatics of the lyceum students and the system of corresponding competences (which included, first of all, those components (knowledge and skills), calculated parameters of which exceeded the specified threshold value).

The first group of competencies "Competencies in the physical foundations of quantum technologies" includes:

- knowledge of the basic understanding of quantum

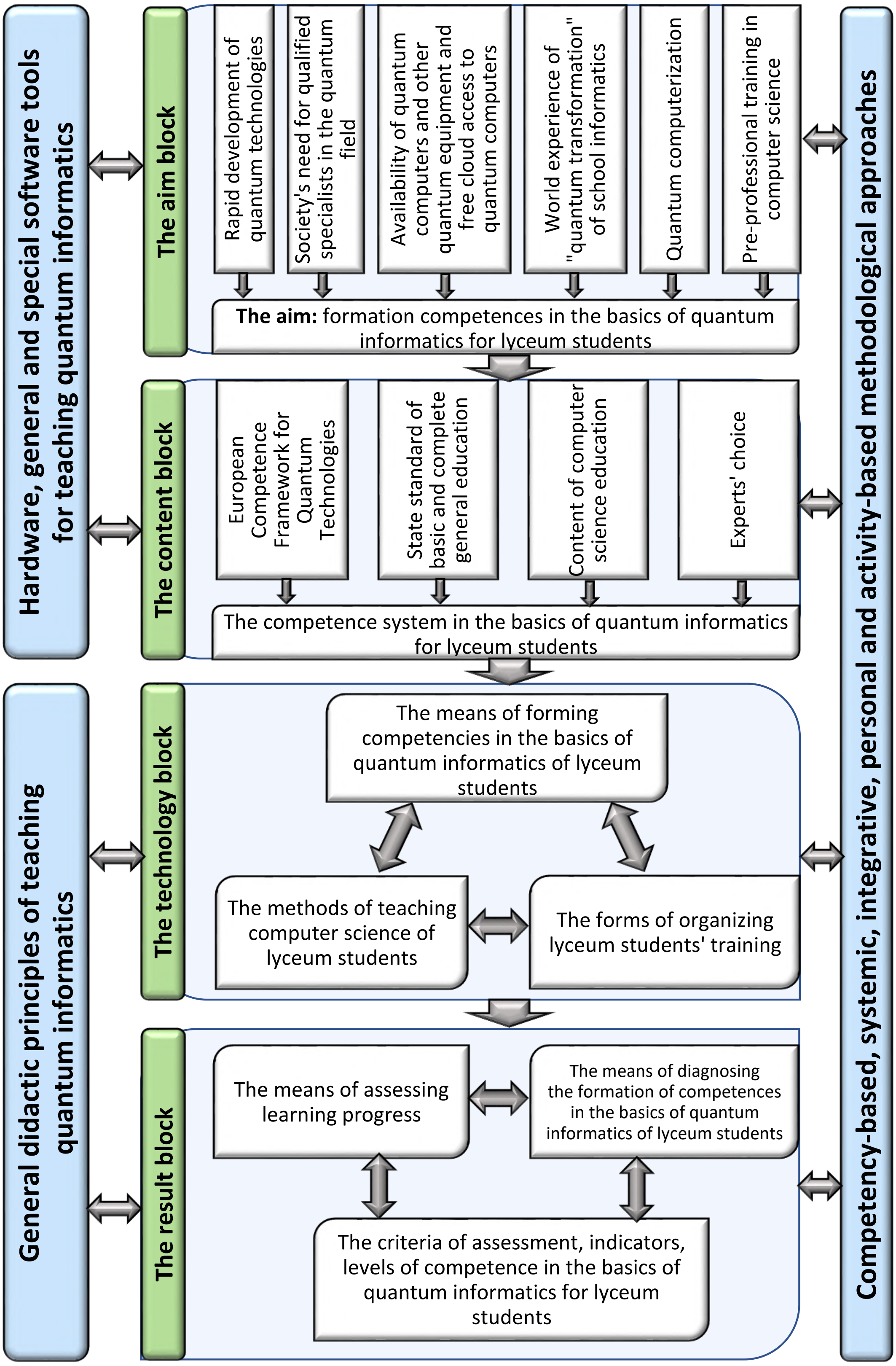

Figure 4: Structural-functional model of competence formation in the basics of quantum informatics.

physics;

- skill to determine whether qubits are in binded states;
- skill to represent qubits on a Bloch sphere.

The second group of competencies "Competencies in mathematical foundations of quantum informatics" includes:

- knowledge of the fundamentals of the theory of complex numbers;
- knowledge of linear algebra fundamentals;
- knowledge of quantum physics mathematical fundamentals;
- knowledge of statistical nature of quantum measurements;
- skill to design vectors (matrix-columns, matrix-rows) of Dirac notation;
- skill to operate with standard bases;
- skill to arrange a vector in a selected basis;
- skill of giving examples of unitary matrices and performing operations with them.

The third group of competencies "Competencies in support technologies" includes:

- knowledge of optical technologies;
- knowledge of laboratory technologies;
- knowledge of experimental control;
- skill to separate photon sources.

The fourth group of competences "Competences in hardware of quantum computers and sensors" includes:

- knowledge of the structure of spin-based devices (in particular, quantum dots);
- knowledge of hardware platforms for quantum computing, methods of their integration with standard equipment;
- skill to describe types of quantum structures of quantum computers and explain their general principles of operation;
- skill to arrange remote access to quantum computers;
- skill to perform quantum programs on quantum computers.

The fifth group of competences "Competences in quantum calculations and modelling" includes:

- knowledge of quantum gates (single-, double- and multi-qubits);
- knowledge of quantum programming languages, tools for development of quantum software and platforms (including graphical ones);
- knowledge of basic quantum algorithms (Shore, Grover, quantum optimization, quantum phase evaluation, quantum linear algebra, etc.);
- skill to record quantum gates by means of unitary matrices;
- skill to separate and use single-cube gates (Pauli transubstantiation, Adamar gate, phase tensions);
- skill to perform operations using multi-qubit gates (CNOT, Toffoli and Fredkin gates);
- skill to use quantum gates for writing quantum algorithms;
- skill to use quantum programming languages and tools;
- skill to implement quantum algorithms (Shore, Grover etc.);
- skill to work with quantum simulators.

The sixth group of competencies "Competencies in quantum sensors and metrology" includes the following:

- knowledge of the quantum sensors applications;
- skill to guide examples of quantum sensors application in various fields.

The seventh group of competencies "Competencies in quantum communication" includes:

- knowledge of quantum cryptography (quantum key distribution, secure authentication, digital signatures, use halls);
- knowledge of quantum networks (quantum internet, sensor and dinode networks);
- knowledge of quantum communications infrastructure and equipment (fiber optic systems, wireless links, satellite systems; quantum random number generators; quantum memory, interfaces, switches; repeaters, terminal nodes);
- skill to describe the operating principles and structure of quantum network equipment;
- skill to give examples of application of quantum cryptography in various fields.

The eighth group of competences "Practical skills and general competences" includes

- knowledge of classical (non-quantum) programming basics: programming languages, algorithms, complexity classes, cryptography;
- knowledge of quantum technologies application;

- skill to implement algorithms of basic complexity classes (in particular, cryptographic algorithms) using programming languages;
- skill to give examples of using quantum algorithms to achieve quantum advantages.

3.3 Teaching Methodology the Basics of Quantum Informatics to Lyceums Students

Experimental realization of the structural-functional model of forming competences on quantum informatics basics is carried out within the optional course "The Basics of Quantum Informatics" for students of 10 (11) grades. The course content is represented by three subject content lines – "Physical and mathematical foundations of quantum informatics", "Quantum computing, algorithms and programming" and "Quantum telecommunication technologies".

Content line "Physical and mathematical foundations of quantum informatics" reveals fundamental physical and mathematical aspects of quantum technique functioning, demonstrates physical realization of microscience phenomena described mathematically.

The conceptual apparatus of the content line "Physical and mathematical foundations of quantum informatics" – quantum physics, quantum, photon, superposition principle, quantum entanglement, tunneling, singularity principle, quantum teleportation, chiral function, interference, diffraction coherence, decoherence, quantum computer, qubit (quantum bit), bracket notation, complex numbers, Bloch sphere.

Here are formulations of concepts, which should be mastered by students in classes on fundamentals of quantum informatics:

- Quantum physics (quantum mechanics) is a science that studies laws of microcosm and describes phenomena at microparticle level (molecules, atoms, electrons, photons, etc.).
- A quantum is an indivisible microparticle, a portion of some quantity (energy, light, etc.).
- Photon (quantum of light) is the elementary particle of which light consists.
- The principle of superposition consists in the ability of a microparticle to be in different states of the same set of characteristics at the same time.
- Quantum entanglement – microcosm phenomenon meaning dependence of microparticles on each other regardless of distance between them.
- Tunneling – ability of microparticles to pass through a barrier. A microparticle can undercut a barrier, "overcome" it or pass through it.
- The singularity principle was formulated by W. Heisenberg and consists in the fact that it is impossible to measure simultaneously coordinates and momentum of a microparticle with a certain accuracy.
- Quantum teleportation is an ultra-fast (on average) transfer of states from one microparticle to another. Quantum teleportation is not transportation or any other physical movement of a microparticle from one place to another.
- Quantum function (state vector) is a quantity, which completely describes a state of a microparticle or quantum system as a whole. Quantum function determines not physical parameters, but approximate law of microparticle state distribution.
- Wave interference is a phenomenon that occurs when two waves arising in the same medium come in contact with each other.
- Diffraction – the ability of waves to ignore imperfections.
- Coherence – coherence of several colival or chiral processes in time, which occurs when they overlap each other.
- Decoherence – incoherence of several colival or chiral processes in time, which is found when they are added to each other.
- Quantum computer – computing device, using quantum superposition and quantum multiplicity phenomena to transmit and process data.
- Qubit (quantum bit) is the most important element for data storage in quantum computers. A qubit is a quantum object with two basic structures, for example: electron spin, photon, neutral atom or ion. Mathematical model of a qubit state is a single two-dimensional vector.

The competence in the basics of linear algebra includes understanding not only the concept of vectors but also matrices, as well as the basic operations over matrices (addition, matrix multiplication by number, usual matrix multiplication, tensor matrix multiplication).

At this stage, students must understand that a vector can be represented algebraically – in the form of a linear (vertical or horizontal) table of numbers or geometrically – in the form of a tensed frame. Vector column, which represents the state of the cube, is a certain table of numbers with one column and two rows. Further, it is worth explaining that there can be several columns and rows of numbers. Such a table of numbers arranged in rows and columns is a matrix. The number of rows and columns determines the matrix size. Vector columns or vector rows are separate (partial) kinds of matrices.

The next step will be to familiarize students with the actions on matrices. We draw students' attention to the fact that matrix multiplication by a number (scalar) is carried out by multiplying each element of the matrix by the required number (scalar). Demonstration of the application of vector multiplication by a number and matrix multiplication by a number.

Explanation of the operation of conventional matrix-to-matrix multiplication begins with matrix-to-vector multiplication, emphasizing that multiplication can be applied only to matrices in which the number of columns of the first matrix and the rows of the second matrix are identical. The result of multiplication is a dimension matrix equal to the number of rows of the first matrix and the number of columns of the second matrix. The elements of the result matrix are the sum of pairwise additions of the elements of the row of the first matrix to the elements of the corresponding column of the second matrix. To multiply a matrix by a vector, each matrix row should be elementally multiplied by the value of the vector.

In the case of a matrix with three (or more) rows and columns, the multiplication technique is analogous.

It is advisable to offer students examples of square matrices and vectors whose elements are exclusively zeros and ones, both for manual (written) execution and using the capabilities of a table processor (and/ or a universal computer mathematics system or programming language) for self-multiplication.

Then students should explain that quantum computing theory uses tensor multiplication of vectors (matrices), which is used to multiply vectors (matrices) of sufficient size. Students must learn that for tensor multiplication two steps are necessary:

1) scalar multiplication of each element of the first matrix by another matrix;
2) to combine the obtained matrices according to the output positions of these elements.

At first, students can find examples of tensor multiplication of vectors. As a practical task, students may be presented with the task of realizing tensor multiplication with the help of a table processor (or/and a universal system of computer mathematics or programming language) for two and three vectors. The following is an application of tensor multiplication of matrices.

Formation of competence in mathematical foundations of quantum informatics is based on knowledge of statistical nature of quantum measurements. Microparticle structures described by the Quantum function have a statistical, i.e., luminescent, nature: the square of the absolute value (module) of the Quantum function indicates the luminescence value of those quantities, on which the Quantum function is dependent.

Before starting to get acquainted with quantum gates (actions that can be performed over cubes), it is necessary to consider the notion of unitary matrix (a special numerical square matrix, elements of which are real or complex numbers, and the result of their multiplication by the Hermite-conjugate matrix is equal to the unity of matrix E), explaining the terms used in the formula. Namely, the square matrix (matrix in which the number of rows is equal to the number of columns), the Hermite-conjugate matrix (the A+ matrix obtained from the A matrix by transposition and replacement of each element with a complex-conjugate one), singular matrix (diagonal matrix, diagonal elements of which are equal to one), diagonal matrix (square matrix, posterior diagonal elements of which are equal to zero). The notion of unitary matrix is suitable to show on two examples – in the first application, we will use matrix with real-integer elements, and in the second – matrix with complex numerical elements.

Methods of teaching the content line "Physical and mathematical foundations of quantum informatics" can be revised, expanded with additional explanations, or shortened, taking into account the training of scientists in mathematics and physics.

Within the framework of the content line "Quantum computing, algorithmization and programming" the competences in hardware of quantum computers and sensors, quantum metrology, competences in quantum computing and modeling are formed and/or developed, first of all, Formation of knowledge and skills to distinguish and use quantum single- and large-cube gates for recording quantum algorithms, use platforms for implementation of quantum algorithms in the form of schemes and programs on quantum simulators and real quantum equipment.

It is advisable to start studying this content line by looking at the structure of a quantum computer and then move to the issue of providing special conditions for their functioning:

- temperature control (close to absolute zero);
- insulation against magnetic, electric and thermal fluctuations, vibrations;
- air dissipation lower than the atmospheric pressure by billions of times.

Further it is advisable to acquaint students with hardware platforms for quantum computing, ways to integrate them with the classical equipment using quantum simulators and computers of IBM, Microsoft, Google, Intel, QuTech and others.

We suggest that competence development in remote access to quantum computers should be based on the IBM Quantum platform, focusing on the specifics of selecting a simulator or quantum computer in graphical (IBM Quantum Composer) and software (IBM Quantum Lab) modes.

The skill to perform quantum programs on quantum computers should be formed starting with simple tasks on using quantum gates to change the state of a quantum system. And then proceed to implementation of quantum algorithms (Bernstein-Vazirani, Deutsch-Jozsa, Grover, Shore).

When introducing the concept of "quantum gates" (basic logical elements/operations for a quantum computer), it is important to pay attention of students, that the understanding of quantum gates is similar to the understanding of gates (logical elements, operations) of a classical computer, and therefore it is necessary to use the previous knowledge about logical operations.

Students must learn that the same logical operations are performed on qubits in order to change their state as on classic bits. It is necessary to consider mathematical representation of each gate (in the form of unitary matrix) and their graphical representation and result of quantum scheme application at the same time.

The interface of the IBM Quantum Composer chromatically oriented service should be considered in a mandatory order, focusing on the instrumental panel of quantum operations, peculiarities of color categorization of gates by type, adding, setting up and disconnecting of quantum gates in the Quantum Scheme Editor area, reviewing changes in the state of qubits.

One should start from one-qubit quantum gates as the simplest, and then go to two- and three-qubit gates. At this stage, students' attention is necessarily focused on the result, which is reflected in the form of the state vector. It is necessary to explain that the received record of the state of qubits in the twofold code is read from right to left. In our application, the result obtained is 01: the zero qubit has a value of 1 and the first one is 0. If there is time, we can ask the students to use a few more cubes on the diagram one after another to observe the display of the results.

After familiarization with basic operations on qubits you can move on to introduction of quantum algorithms, starting with quantum teleportation algorithm. First students are offered a verbal description of the algorithm, then a graphical quantum circuit, and after that a software implementation of the algorithm.

Let us give a verbal description of the quantum teleportation algorithm, which is described graphically using the IBM Quantum Composer service, shown in figure 5:

1) by means of the operation NOT we transfer the zero qubit to state 1, and we leave the first and second qubits in the primary zero state. It should be noted that this operation is mandatory for this example, only to avoid transferring the zero value of the qubit. Indeed, the zero qubit
2) we put the first qubit into superposition by the gate H;
3) we rotate the first and second qubits with the CNOT gates (the first one is control and the second one is purpose. If the control (first) qubit is in state 1, the main (second) qubit is inverted by the CNOT gate);
4) we will similarly loop the zero and first qubits;
5) convert the zero qubit to superposition (using gate H);
6) measurement of the zero and the first qubits (Measurement operation). The measurement results are stored in two classic bits, which are transmitted by the usual (classic, non-quantum) way of communication (channel, protocol);
7) on the side where the zero qubit status is transmitted, there is another qubit to which CX and CZ gates are used (either CX or CZ in turn does not matter which will be the first), as a result we get the value of zero qubit in the other qubit;
8) we measure the value of the other qubit.

After creating the algorithm for quantum teleportation in IBM Quantum Composer, students should be given the task of running this scheme with the help of a simulator or a quantum computer and analyze the results. At this point, it is appropriate to encourage students to focus on automatically generated code in a programming language (e.g., Python). Students should conclude that the resulting code is fully consistent with the structure of the reverse language program. It would be useful to make an analogy between the graphical representation of the gates and their equivalent – the corresponding command (method) in programming language and open this scheme with automatically generated code in IBM Quantum Lab.

After acquiring knowledge about the basic quantum gates, creating a quantum teleportation circuit,

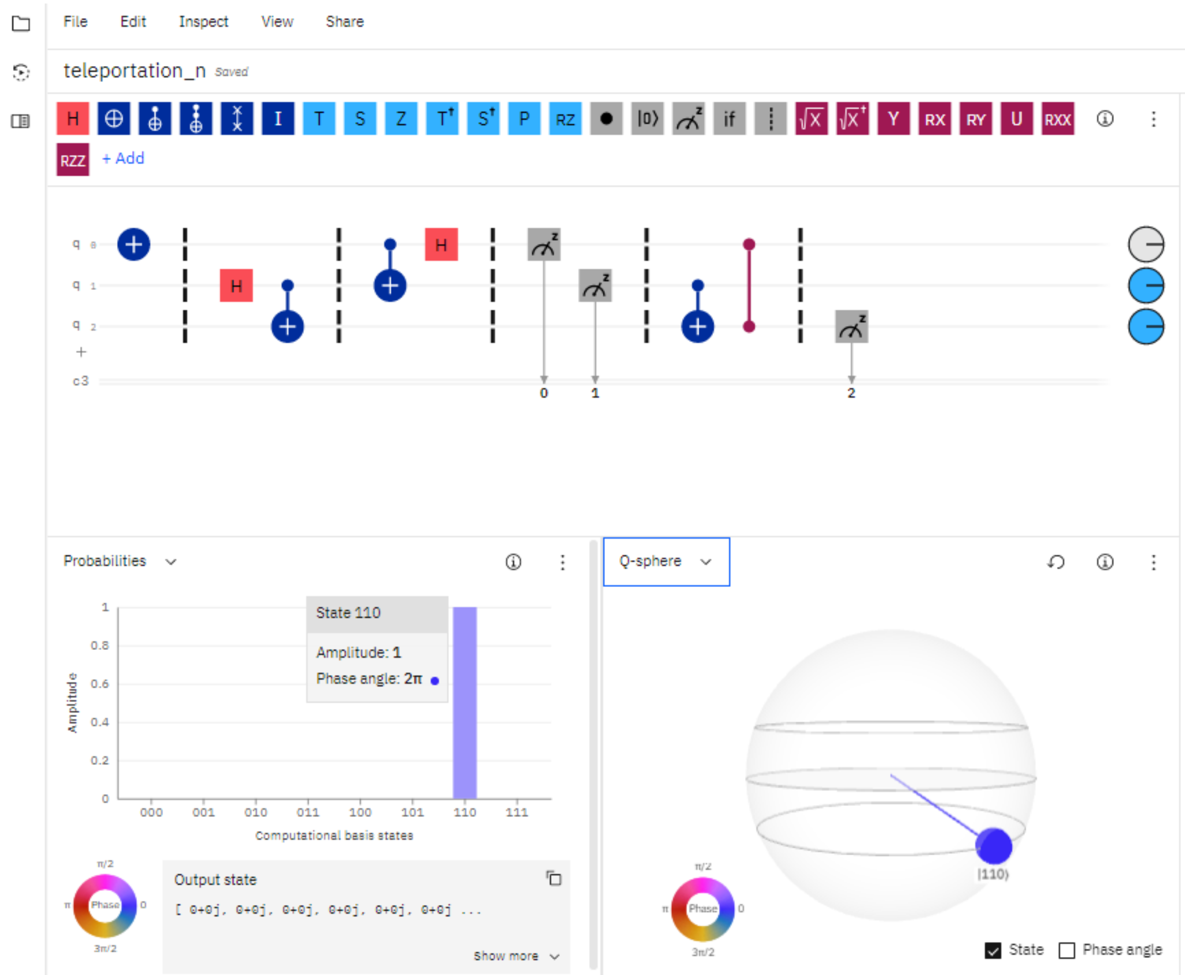

Figure 5: Quantum teleportation algorithm in IBM Quantum Composer

the students are ready to proceed to the next stage of learning the basics of quantum informatics – to implement quantum algorithms in programming language, within the framework of which the formation of knowledge and skills to distinguish and use quantum one-, two- and three-cube gates for the implementation of quantum algorithms in programming language (Python), use online programming services, which support Python work with Qiskit module, for the implementation of quantum algorithms on quantum simulators and real quantum equipment.

The basic foundation for the teaching methodology of this section is the knowledge of the basics of classical (non-quantum) programming and the ability to implement basic classical algorithms in programming language.

This is a dedicated platform for working with quantum algorithms (IBM Quantum) that provides their implementation in Python language. Therefore, it is methodologically appropriate to repeat the basics of structural programming in Python.

Despite the lack of experience of students in the implementation of Python programs with the help of Jupyter Notebook, it is obvious, that before starting to implement quantum algorithms using the IBM Quantum Lab server it is necessary to familiarize students with the peculiarities of their writing and launching, for example, using the online service Google Colab (https://colab.research.google.com/).

After implementing and launching the application programs by means of the online service Google Colab, it is advisable for the students to propose the automatically generated code for the implementation of the quantum teleportation algorithm in IBM Quantum Lab. It is necessary to ask the students: What is similar in the interface of Google Colab and IBM Quantum Lab online services? We make a joint conclusion about the uniqueness of these environments and proceed to consider the features of the connection to the quantum simulators and computers in IBM Quantum

Lab on the requested code fragments.

It should be noted that after completing the content line "Quantum calculations, algorithmization and programming" students will be able not only to learn about the most popular algorithms of quantum programming and try to learn how to implement them on real quantum equipment, but also to improve competence in the basics of programming in Python.

Within the framework of the content line "Quantum telecommunication technologies" the formation of competencies in security technologies (optical technologies, laboratory and experimental control technologies, photon sources) and quantum communication technologies (quantum cryptography, quantum networks, quantum communication infrastructure and equipment).

Formation of competences from the enabling technologies can be carried out in the form of short self-prepared student reports on the topics suggested by the teacher, or in the form of watching short popular science stories that reflect the current state of development of the field.

It is important for students to know about the limitation of quantum communications. The teacher states that the main limitations of quantum cryptography are the speed of key distribution and the distance between the transmitter and the receiver. This problem is trying to be solved by modern physicists who have proposed new protocols, new optical circuits, new methods of quantum-state measurements.

It is also necessary to tell the students that an important task of quantum communication channel quality is to reduce the number of errors (the critical error rate is 11%). Students should know that the greater the distance over which a quantum key is transmitted, the greater the attenuation of the signal in the fiber optic lines, while the noise remains. Because of this, it is not possible to transmit information for hundreds of kilometers in real fiber optic lines.

It will be useful to remember the previously discussed phenomenon of decoherence (disintegration of quantum state due to interaction of quantum system with ambient environment). The teacher can describe that photons after transmission through many kilometers of real fiber optic lines in most cases cease to be quantum entangled (connected) and transform into usual, not interconnected, quanta of light. Therefore, in order to produce efficient fiber optic line it is necessary to ensure preservation of quantum entanglement when the signal is weakened and when it passes through an amplifier. Fibre optic cables laid at the bottom of the oceans contain a number of special amplifiers based on optical warehouse of rare-earth element houses, and these amplifiers make high quality transmission of information possible.

It is worthwhile to find some examples of quantum cryptography application spheres that would motivate further study. It is worthwhile to make an example that today world's bank data centers have encryptors that use symmetric keys. They are additionally complemented by quantum distribution systems for keys, which are changed not monthly (in the classical approach), but every second. On the one hand, this mechanism is not good for the disposable notebook, but on the other hand, it gives tremendous advantage.

You can ask students to use any search engine to find information about the use of quantum technologies in the field of finance, for example, for the last six months. If a sufficient number of students work, the task can be refined by geographical location (on certain continents, in certain countries, etc.).

It will be interesting for students to learn that quantum cryptography can also be used for distributed data storage. It is possible to distribute information in several data centers and constantly move it by means of quantum-secured channels. Thus, even if someone gains access to some of these data centers, he or she does not receive all of the necessary information. This will also work if some of the data centers are disconnected: a light user will be able, by authenticating to the network of data centers, to restore all relevant information.

We also inform the students that quantum keys will be useful for securing authentication tasks, which, in essence, is a check "friend-or-foe". In this case, the combination of hash function technologies and a one-time notepad allows you to check if, for example, the data for the online speech system came from the control center or from someone else. This is very important, because in five or seven years the work of quantum computer is a reality. At the same time on the streets will appear a large number of driverless cars, which are not just a few, but will be millions. And all of them will need to receive control signals and update the firmware in a trusted manner, not interacting with people for thousands of years. This means that they will have to receive quantum keys and use them afterwards in the process of flight.

Prospects of quantum cryptography can be described by the application of China, which has already established a national quantum network that connects Beijing, Shanghai, Hefei and Jinan.

The main technological problem nowadays is whether the humanity will be able to produce a high-quality quantum repeater in the nearest ten years? This question can be discussed by the scientists by dividing them into supporters and opponents of this idea.

4 EXPERIMENTAL TESTING OF METHODS FOR TEACHING THE BASICS OF QUANTUM INFORMATICS TO LYCEUMS STUDENTS

Forty-five students from three schools in the city of Kryvyi Rih (Ukraine) took part in the experiment. In order to evaluate the level of competence in the fundamentals of quantum informatics the entrance examination and post-assessment test were conducted.

Positive dynamics of changes in the level of competence was noted in each group of competencies, which confirmed the study hypothesis.

As a result of the experiment the ways of introduction of quantum informatics basics into the educational process of lyceums were determined:

1. choice module "The Basics of Quantum Informatics" (17 hours);
2. cross-curricular study of quantum informatics basics in physics, mathematics and informatics courses (17 hours);
3. integrated course "The Basics of Quantum Informatics" (35 hours).

Regardless of the choice of experimental model of propaedeutic study of quantum informatics, the main goal of its implementation is to develop the components of computer literacy and information culture through the acquisition of basic theoretical knowledge and practical skills to manage quantum computers as a new generation of computers.

5 CONCLUSIONS

Quantum transformation of school informatics course should be carried out due to the perspective of quantum technologies and the demand for quantum-literate specialists.

The competences of quantum informatics basics of lyceums students is a natural integration of some interdisciplinary physical and mathematical competences and new subject-specific informatics competences.

The normative methods of teaching the basics of quantum informatics to lyceum students is the structural-functional model of forming the corresponding competences.

Teaching the basics of quantum informatics to 10 (11) grades on the IBM Quantum platform can be carried out with the author's optional course materials.

This study does not cover all aspects of the problem of quantum transformation of informatics education. Subsequent scientific searches for its solution are appropriate in the following directions: 1) development of partial methods of competence formation in the field of quantum technologies in accordance with the European framework; 2) integrated teaching of quantum physics and informatics to students of scientific lyceums; 3) use of immersive medium for development of virtual manipulatives of quantum technologies; 4) teaching method development of the basics of quantum technologies to professional schools students.

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Analysis of Research Activities of University Teachers as Part of the Education Quality Assurance System

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Keywords: Publishing Activity, Scientist Profile, Scientometric Databases, Transparency Rating, Rating System, Research Activity, Quality Assurance of Education.

Abstract: The rapid development of digital technologies is changing the role of the university in the digital society. An important aspect of increasing the level of competitiveness of the university in the market of educational services is to ensure the quality of results of all higher education institution activities, especially research, so to analyze the university is important to develop and implement internal university rankings. The article analyzes the international and Ukrainian experience of presenting the results of research activities of university teachers to ensure the quality of education, ways to design systems for analyzing research activities of teachers, tools and components for evaluating the effectiveness of research. The model and stages of designing a rating system for evaluating research activities of teachers are described, which allows for systematic monitoring of openness, transparency, and efficiency of the research component of teachers' professional activities. The key indicators for evaluating the effectiveness of scientific research are identified – citation indicators of the three most important scientometric databases – Scopus, Web of Science, Google Scholar: number of publications, number of bibliographic references, h-index, i10-index. The article presents one of the stages of the model implementation, namely the development of transparency rating by citation indicators in Google Scholar. According to the results of the study, the positive impact of the rating system is identified, the main measures to increase visibility, presence, dissemination of research results are identified, the systematic implementation of which provides effective representation of the scientist in domestic and international rankings.

1 INTRODUCTION

The main priority of each university is to provide quality educational services and increase competitiveness to attract the most promising applicants for education. The rapid development of digital technologies is leading to the transformation of education, changing the role of the university in the digital society. The influence and authority of the university in the European Higher Education Area is significantly influenced by the openness and transparency of all activities. Key areas of educational transformation for global sustainability were discussed at the UNESCO World Higher Education Conference, which include cooperation and diversity, interdisciplinarity, flexible approaches to lifelong learning and knowledge that meet today's societal needs, support for research, etc. (WHEC, 2022). Therefore, an important aspect of increasing the level of competitiveness of the university in the market of educational services is to ensure the quality of results of all types of educational activities of higher education institution, especially scientific.

The defining documents regulating the functioning of the internal quality assurance system of higher education at the university are the requirements of the Laws of Ukraine "On Higher Education", "On Education" and Standards and Recommendations for Quality Assurance in the European Higher Education Area (ESG 2015). According to the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ENQA, 2015), the key aspects of quality assurance in education are: internal and external quality assurance systems of education and quality assurance institutions. The main components of the university's internal quality assurance system include the introduction of internal regulations on the implementation of education quality assurance policy, periodic review and improvement

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of educational programs in accordance with modern labor market needs and state standards, changing paradigms of higher education, including student-centered teaching and learning, monitoring the level of professional competence of teaching staff and creating conditions for continuous professional development and improvement of teachers, availability of educational resources, transparent enrollment procedures, achievements, certification of students based on learning outcomes, introduction of effective information management technologies, transparent coverage of accurate, objective, accessible information in the public domain on various aspects of university, periodic external monitoring of quality assurance. An important component of the internal quality assurance system of education is to increase the openness of university, ensuring transparent evaluation of teachers' professional activities, open access to results, professional and scientific achievements.

One of the tools for measuring the competitiveness of the university is its participation in international and domestic educational rankings. To ensure a complete and objective assessment of the methodology of the most authoritative rankings are based on indicators covering various areas of university activity. Such key indicators are indicators of academic reputation and reputation among employers; teaching quality indicators – the ratio of teachers and students, PhD and academic staff, etc.; indicators of the quality of scientific research – the number of publications and citations in publications included in influential scientometric databases; indicators of international cooperation – the percentage of foreign students and teachers; indicators of visibility and influence of sites, etc. The quality and transparency of research activities of universities is assessed by indicators of publishing activity of teachers. Indicators of the quality of scientific citations according to Google Scholar citations and citations in influential scientific journals are taken into account in international rankings – "Academic Ranking of World Universities" (ARWU), "QS Top University Ranking", webometric ranking of world universities "Webometrics", "Transparent ranking: Top Universities by Google Scholar Citations" and Ukrainian ones – "University rankings according to Scopus indicators", "Top-200 Ukraine", "Consolidated rating of higher education institutions of Ukraine", "Bibliometrics of Ukrainian science" (Buinytska et al., 2018). Comparison of the weight of research indicators in the methodologies of the most authoritative ratings are presented in table 1.

Periodic monitoring of methodologies and key indicators of the most influential ratings is important for the analysis of the effectiveness of the university's performance in the rankings. An effective tool for analyzing university performance is the introduction of internal university rankings. For a comprehensive and complete assessment, it is important that the methodologies of internal university rankings are based on key performance indicators that are taken into account in the methodologies of the most authoritative international and Ukrainian educational rankings. Therefore, to ensure optimal presentation of the research component of the university in the rankings and ensure openness, transparency of the university, it is necessary to develop and implement a rating system for evaluating the research activities of teachers to monitor the effectiveness of research activities and create an appropriate system to increase its openness, transparency international scientific networking communities in order to promote and communicate.

The *purpose* of the study is to develop a rating assessment of research activities of university teachers as part of the internal system of quality assurance of education for openness and transparency of the university.

2 RESEARCH OF THE EXPERIENCE OF THE ANALYSIS OF RESEARCH ACTIVITY OF TEACHERS IN THE EUROPEAN SPACE OF HIGHER EDUCATION

Delgado López-Cózar et al. (Delgado López-Cózar et al., 2019), Martín-Martín et al. (Martín-Martín et al., 2018b), Bykov and Spirin (Bykov and Spirin, 2016), Bykov et al. (Bykov et al., 2020), Semerikov et al. (Semerikov et al., 2018), Kuzminska et al. (Kuzminska et al., 2022), Vakarenko (Vakarenko, 2018) studied the features of the analysis of research results using open scientometric and bibliometric systems.

Theoretical bases of rating estimation of activity of teachers of universities of Ukraine are described in (Dzoba, 2019; Reheilo, 2020; Yaroshenko, 2020). Reheilo (Reheilo, 2020) identified the basic conceptual principles of evaluating the effectiveness of research activities of teachers, identified the principles, structural components and indicators of evaluation of research activities of teachers in the European Higher Education Area. Yaroshenko (Yaroshenko, 2020) emphasized the need to modernize indicators of research activities of teachers, in accordance with the modern realities of university education, summarized the

Table 1: Comparative table of the weight of research indicators in the methodologies of the most authoritative ratings.

Rating name	The weight of research indicators
Academic Ranking of World Universities	60%
QS Top University Ranking	20%
Webometrics	50%
Transparent ranking: Top Universities by Google Scholar Citations	100%
University rankings according to Scopus indicators	100%
Top-200 Ukraine	40%
Consolidated rating of higher education institutions of Ukraine	45%
Bibliometrics of Ukrainian science	100%

main characteristics of rating evaluation of teachers: goals, objectives, functions, principles of ranking.

Kostenko et al. (Kostenko et al., 2019), Shynenko et al. (Shynenko et al., 2021), Gasparyan et al. (Gasparyan et al., 2018) presented features of quality assessment of research results.

Bykov et al. (Bykov et al., 2021), Tkachuk et al. (Tkachuk et al., 2017), Morze et al. (Morze et al., 2022a), Morze and Buinytska (Morze and Buinytska, 2017), Buinytska (Buinytska, 2021) considered the evaluation of the results of research activities of teachers to increase the competitiveness of the university in general and the results of the participation of universities in international and Ukrainian rankings.

The use by scientists their profiles in Google Scholar, ORCID, Mendeley, Academia, ResearchGate increases the visibility of publications in the information space and has a positive effect on increasing citation rates, as noted in (Hohunskyi et al., 2016).

Nazarovets (Nazarovets, 2019) investigated the search engine and database of scientific citations, which contains metadata of all publications that use the Cited-by service from Crossref and support the Initiative for Open Citations – Open Ukrainian Citation Index (OUCI), developed by the State Research Technical Library of Ukraine (OUCI, 2021). The OUCI database contains metadata of scientific publications that receive DOI from Crossref and takes into account citations between scientific publications. OUCI is designed to simplify the search and analysis of research results and expand the presentation of information about Ukrainian scientific publications in international search engines such as Dimensions, Lens.org, 1findr, Scilit, etc. The implemented analytical tool allows to assess the state and dynamics of development of scientific potential of scientific institutions and researchers in terms of fields of knowledge, years, to select appropriate scientific journals for publication.

In (Kostenko et al., 2019) the information-analytical system "Bibliometrics of Ukrainian Science", developed by the Social communication research center, which is a single register of bibliometric profiles of researchers and research teams in the most authoritative scientometric databases Scopus, Web of Science and Google Scholar system. The system allows to analyze the domestic scientific potential, to carry out a comparative analysis of the effectiveness of research activities of Ukrainian scientists in the fields of knowledge, cities, affiliation, agencies, etc. by building rankings on the value of h-index in Scopus, Web of Science or Google Scholar (Bibliometrics, 2022). The presentation of a scientist in the "Bibliometrics of Ukrainian Science" is a passport of a scientist in the educational space, which reflects his authority and influence on the development of a particular scientific field.

3 INTERNATIONAL AND UKRAINIAN EXPERIENCE IN PRESENTING THE RESULTS OF TEACHERS' RESEARCH ACTIVITIES TO ENSURE THE QUALITY OF EDUCATION AT THE UNIVERSITY

During the digitalization of education, traditional tools for managing and organizing the educational process no longer meet the educational needs of different categories of participants – students, teachers, administration, etc., so the quality of information and educational environment of the university acquires special importance (Buinytska, 2021), which will ensure transparency and openness of the organization of the educational process, management, research, internationalization, etc. and will allow participants to access it from anywhere and at a convenient time. One of the components of such an informational and educational environment is the e-portfolio system, which is used to analyze various aspects of teachers' activities: scientific, international, teaching activities and professional development. Therefore, to ensure monitoring of the level of teacher competence, transparency and openness of data, the issue of implementing open systems for research analysis is relevant for the university, which will have a positive impact on the presentation of professional results of university teachers in ranking.

An analysis of the official websites of leading Ukrainian and international universities on the format of presenting the results of research activities of university teachers in open access showed the lack of implemented tools to ensure transparency, openness of key indicators of research activities of teachers.

The National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" has implemented the "Information System Intellect" (Intellect, 2023), which is designed to present the results of the university scientists. The system contains personal pages of scientific and pedagogical, research staff of the university, graduate students, which contains a list of their scientific publications, results of research and development work, reports at scientific conferences, seminars, including international, identifiers of scientometric databases – Scopus Author ID, ORCID, Google Scholar.

At the Taras Shevchenko National University of Kyiv are formed rating tables of publication activity of employees within the university and rating of publication activity of structural subdivisions. Summary ranking tables within the general reports on scientific work in the form of files are published on the official website of the University (Research department of KNU, 2023). The calculation of the rating takes into account the number of monographs, textbooks, scientific articles, citations and the number of articles indexed by the scientometric database Scopus.

At the National Pedagogical Dragomanov University has been introduced a rating system for evaluating the activities of research and teaching staff, but access to it is limited (Rating system of NPDU, 2022).

Lviv Polytechnic National University has introduced an e-portfolio of teachers based on wiki technologies (LPNU, 2023). In addition to personal information, pages of teacher's present areas of study, research interests, a list of selected publications, but there are no links to open access publications and researcher profiles and citation rates in scientometric databases.

The personal pages of teachers of Kryvyi Rih State Pedagogical University contain basic personal information – position, degree, academic title, research interests, etc., as well as links to the teacher's profile in scientometric databases, published scientific papers in the Institutional Repository. The university also formed and published in the form of a file a rating of scientific activities of departments on the main indicators of scientific activity – the number of articles in databases Scopus, Web of Science, Index Copernicus, articles in professional journals, published monographs, defended dissertations, etc (KRSPU, 2023).

The website of the National Aviation University publishes ratings of teachers on the indicators of scientometric databases Scopus, Web of Science, Google Scholar, Russian Science Citation Index (Scientific library of NAU, 2023). The ranking is based on the value of the h-index, as well as the number of publications and citations in the relevant databases. Data for the ranking are obtained from personal pages of teachers, which contain links to the profile of the scientist in scientometric databases with citation rates – number of publications, number of citations, h-index, direction of scientific interests, English transcription of the scientist's name, links to published papers in scientific journals, conference proceedings, publications placed in the institutional repository, etc.

On the official websites of leading foreign universities, employees' pages are published in the form of an e-portfolio with basic contact information and performance indicators. No open ranking rating systems were identified during the study. For example, on the websites of Harvard University, Stanford University, University of Washington, Massachusetts Institute of Technology, published pages of employees contain mostly general contact information, information about education, work experience, research interests, awards, list of selected publications and more (Harvard, 2023; Stanford, 2023; Washington, 2023; MIT, 2022).

The study (Spivakovsky et al., 2019) highlights the experience of designing an information system for the analysis of research activities of university teachers, which is tested on the basis of Kherson State University and Kherson State Maritime Academy. The system implements tools for building ratings of teachers on the main indicators of scientific citation in databases Scopus, Web of Science, Google Scholar, Semantic Scholar, Tutor Network. Ratings are built in terms of structural units, departments, scientific journals on the maximum value of quoting profiles of employees in the unit (Rating of KSU departments, 2023). Data for the ranking are obtained from personal pages of employees, which presents the main citation indicators in scientometric databases – researcher identifiers, citation indicators (number of documents, citations, h-index), list of indexed publications, list of co-authors. The system allows to analyze the publishing activity of university scientists in terms of years in a visualized form, to determine the priority areas of research, to build a network of co-authors.

Borys Grinchenko Kyiv University has implemented an "E-portfolio" system, which reflects a holistic picture of the teacher's activities with certain quantitative and qualitative indicators. The system allows not only to create an e-portfolio of the teacher, but also to form rating tables of indicators of evaluation of the main activities of each teacher and structural units (Morze and Buinytska, 2017). Borys Grinchenko Kyiv University has implemented Corporate Standards for Teachers, in particular the Corporate Standard of Research Activity and the Corporate Standard for Digital Competence of Teachers, which take into account and correlate indicators of teachers' research results and corresponding indicators of digital competence levels of teachers. One of the indicators of compliance of the teacher's research activities with the requirements of the Corporate Standard of Research Activity of Borys Grinchenko Kyiv University (Corporate Standard of Research Activity, 2018) is the indicator of scientific recognition, which is determined by the values of citation indices in Scopus, Web of Science, Google Scholar databases. The key to the optimal presentation of the teacher's research activities in scientometric databases is a sufficient level of digital competence of the scientist (Bykov et al., 2021), which is the ability to effectively use open digital systems in their own research, create, update, supplement articles profiles of scientists in scientometric databases, disseminate research results in scientific web communities and social networks (Corporate Standard of Digital Competence, 2021).

Analysis of official university websites shows that modern universities use a variety of technologies to present the results of research activities of teachers, including Wiki-technologies, published pages on official websites, developed information systems. The main technologies used in the construction of ratings of research activities of teachers are the publication of rating tables in the form of files, the introduction of information systems with tools for rating. The introduction of information systems has a number of advantages, such as rapid data updates, the formation of a single database of employees, automation of ranking, reviewing the details of the indicators, the ability to generate reports, present information in a convenient visualized form.

Analysis of the experience in developing rating systems for evaluating the research activities of teachers determines the most common quantitative indicators of evaluation of research activities: publications included in influential scientometric databases, including Scopus and Web of Science; values of citation indices in scientometric databases – Scopus, Web of Science, Google Scholar, etc. (Morze and Buinytska, 2017).

4 TOOLS FOR DETERMINING THE PUBLICATION ACTIVITY OF TEACHERS

The main indicators of assessing the publishing activity of teachers are the number and quality of published scientific works, namely the number of individual and collective monographs, articles in publications included in scientometric databases Scopus and Web of Science, articles in publications included in other scientometric databases, articles in professional scientific publications included in the approved list of the Ministry of Education and Science of Ukraine, citation indices in scientometric databases, the number of published publications on the results of scientific conferences and seminars, including international, etc.

The most common tools for assessing the publishing activity of teachers are the determination of citation indices in scientometric databases. Scopus and Web of Science databases allow scientometric analysis of a scientist's productivity by analyzing the dynamics of the number of publications in influential international journals, the impact and demand for scientific publications, analyzing the dynamics of bibliographic references and citation indices by year (Smirnova, 2020).

Scopus and Web of Science have powerful analytical tools SciVal and InCites, respectively. The tools allow for a comprehensive analysis of the effectiveness of research on a wide range of indicators: impact, productivity, collaboration, open access, influence of journals, etc. in a visual rendered form; identify promising areas of research, expand the range of scientific collaboration and cooperation.

An alternative to commercial systems is the free Google Scholar system, which indexes full-text scientific publications from many disciplines in various databases. The main advantage of Google Scholar is its freeness and the fact that its index is not limited to a list of journals, unlike commercial scientometric databases like Scopus, Web of Science, but more broadly covers the web space, it indexes publications on electronic journals, repositories, electronic conferences, personal blogs of scientists, etc. For efficient indexing, web resources should be based on platforms with special meta tags (EPrints, DSpace, Open Conference System) (Luparenko, 2020), from which the Google Scholar system receives basic meta data of the publication or publication files designed according to certain formatting requirements of document – design of titles, personal data of the authors, the main content of the article, the list of sources used, etc. (Bykov and Spirin, 2016). The Google Scholar system allows a researcher to create a personal profile and add system-indexed publications to it. The Google Scholar profile has a toolkit for analyzing citation statistics by year, tracking total citations, h-index and i10 index, which are calculated on the basis of the total number of publications and the number of citations by individual indicators for the entire period of scientific work and for the last 5 years in digital form and in the form of a comparative histogram (Smirnova, 2020).

On the basis of scientometric indicators of teachers in scientometric databases the profile of the university is formed, which reflects the main direction of scientific research and the productivity of the research component of the university in general. Figures 1-3 presents the profiles of Borys Grinchenko Kyiv University in open scientific systems and databases: Scopus (figure 1), Open Ukrainian Citation Index (figure 2), Google Scholar (figure 3).

The analysis of indicators confirms that a set of indicators of important scientometric databases should be used for a full comprehensive assessment of the effectiveness of research in various areas.

5 RESEARCH RESULTS

5.1 Model of Rating System of Evaluation of Teachers' Research Activity

In building the model of the rating system for evaluating the research activities of the teacher used indicators of key scientometric databases that demonstrate the effectiveness of research activities of the teacher – Scopus, Web of Science and Google Scholar, quantitative indicators of evaluation and analysis using bibliographic citations. At the same time, it is important for university professors to adhere to the Corporate Standards of Scientific Activity and the Corporate Standard of Digital Competence approved by Grinchenko University, as the level of scientific and digital competence directly affects the quality of research and therefore the university's international and domestic rankings.

The following principles were guided in developing the methodology of the rating system for evaluating research activities of teachers: objectivity, measurability and transparency, so the indicators of citations of scientific publications in open profiles of teachers in Scopus, Web of Science and Google Scholar were chosen as indicators of research performance of teachers easy to get and check – number of bibliographic references, h-index and i10-index.

The main functions to be performed by the rating system of analysis of the research component of the university teachers are presented in table 2.

The implementation of certain functions is possible in the presence of such structural components of the rating system for evaluating research activities as the organizational component, the component of obtaining personal data of teachers, technological component and performance component.

The organizational component provides for the delimitation of access rights to the rating system – administrator, teacher, guest. Administrator rights include starting the formation of the rating, marking incorrectly filled profiles, exporting reports. Rating is available only for viewing and analysis for teachers and unauthorized users.

Component of obtaining personal data of teachers. A personal page in the "E-portfolio" system is automatically generated for each lecturer of the Borys Grinchenko Kyiv University. On the personal page of the e-portfolio the teacher can independently establish the affiliation to the structural unit, department, indicate the degree, academic title, links to the profile of the scientist in Scopus, Web of Science, Google Scholar and ORCID, as well as other personal data and links to pages in social networks Facebook, LinkedIn and on the Wiki-portal of the university. Data from the profile of the e-portfolio of the teacher on the affiliation to the structural unit, department and indicators of scientific citation in Scopus, Web of Science and Google Scholar are obtained during the formation of the rating.

The technological component provides scientometric indicators from Scopus databases, Web of Science, Google Scholar system and personal data of teachers. The structural model of the technological component of the model of the rating system of analysis of research activities of teachers is presented in figure 4. The E-portfolio system of Borys Grinchenko Kyiv University automatically synchronizes the values of bibliographic references, h-index and i10-index for the last 5 years from the bibliographic profile of a scientist in the Google Scholar system, a link to which the teacher can add to his portfolio.

In addition, the "E-portfolio" system automatically synchronizes scientometric indicators from the

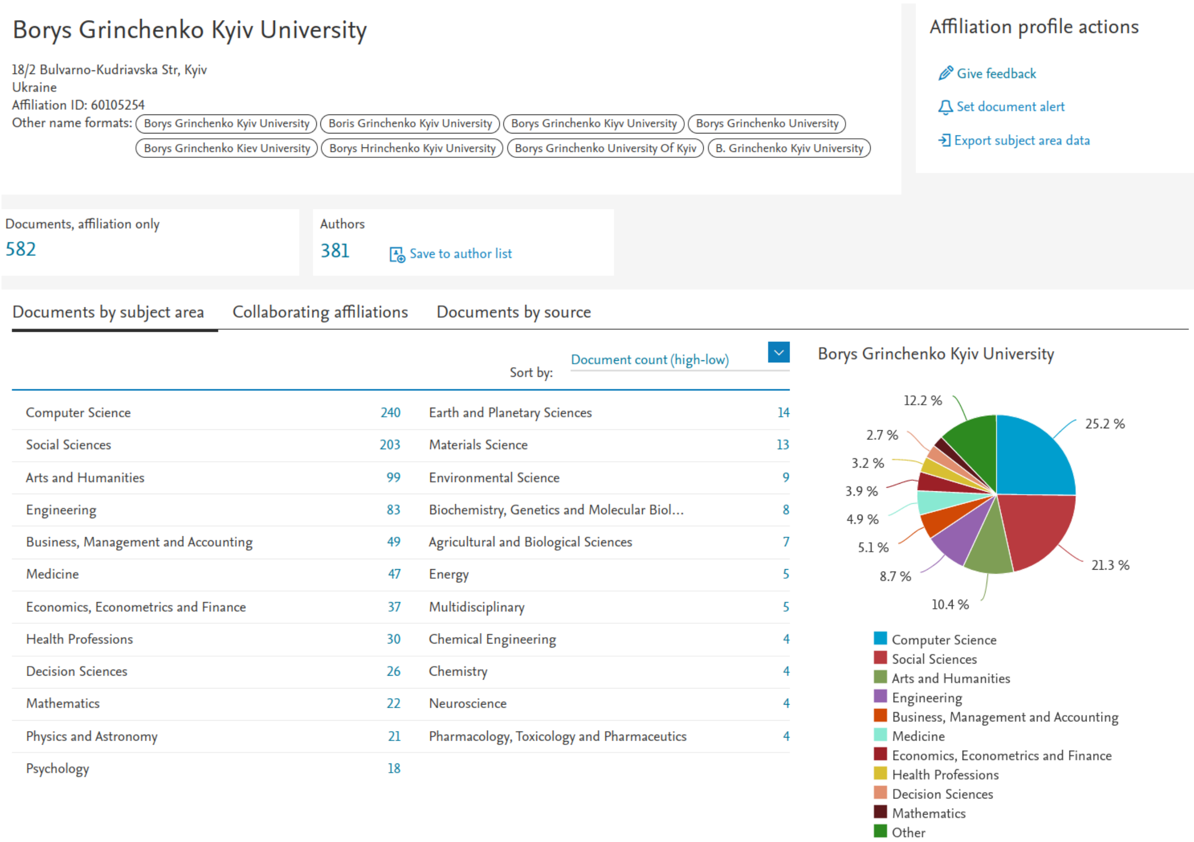

Figure 1: Profile of Borys Grinchenko Kyiv University in the Scopus scientometric database.

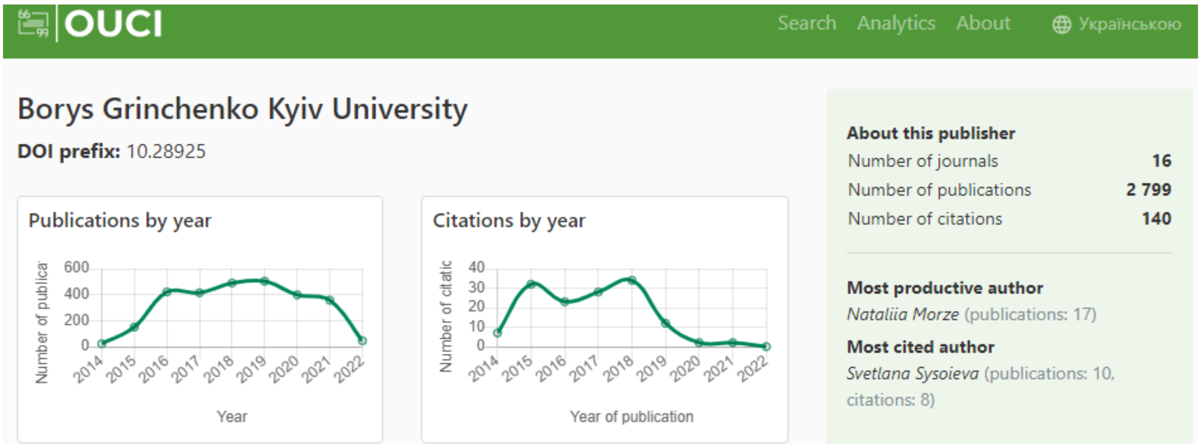

Figure 2: Profile of Borys Grinchenko Kyiv University in the Open Ukrainian Citation Index database.

teacher's profile in Scopus and Web of Science using API-interfaces. The main scientometric indicators are automatically synchronized to the teacher's e-portfolio page – the number of publications indexed by scientometric databases under the university affiliation, the number of citations and the h-index. Data are obtained from the Scopus Author Identifier and the Web of Science ResearcherID, which the teacher can add to their own e-portfolio profile. The profile values of scientometric indicators from Scopus, Web of Science and Google Scholar databases are obtained during the formation of the "Transparency Rating", which is one of the results of the designed model and allows to assess the scientific achievements of a particular teacher and the university in general.

To reflect the importance of the teacher's research

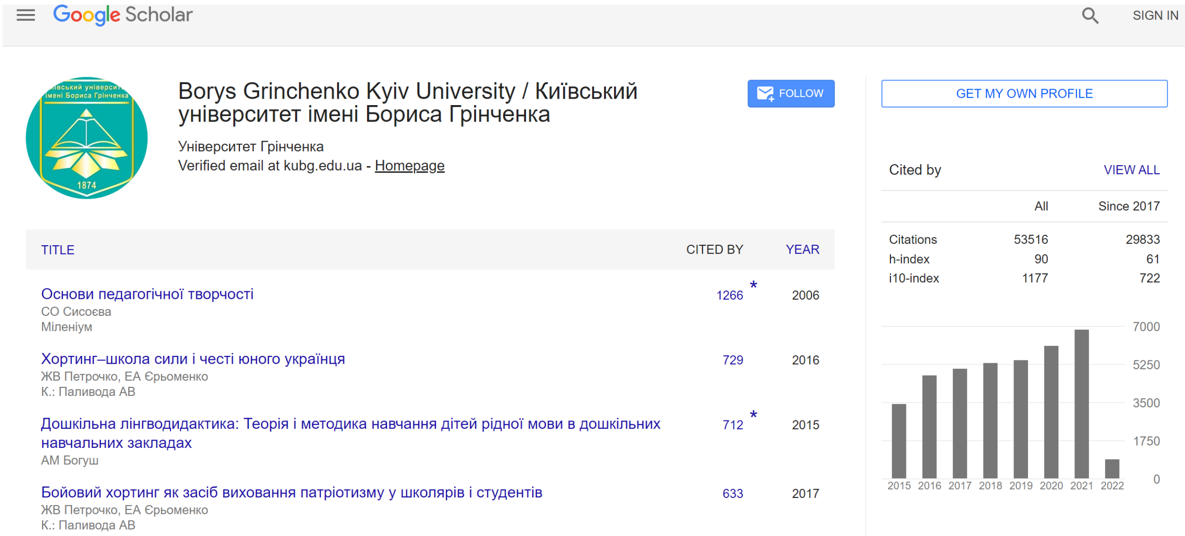

Figure 3: Profile of Borys Grinchenko Kyiv University in the Google Scholar database.

Table 2: Functions of the rating system of analysis of the research component of the university teachers' activity.

Function	Description
Informational	Formation of a single information base of research performance indicators of university teachers for quality assessment
Visualization	Presentation of information in a visualized form to improve perception, reporting
Motivational	Creating an atmosphere of healthy competition, activating the scientific potential of the university
Competence	Encouraging teachers to create, update information in their own profiles in scientometric databases
Analytical	Analysis of the current state of the research component of the activities of departments, chairs and the university in general, identification of factors influencing the effectiveness of research activities of teachers, identification and analysis of relationships
Prognostice	Forecasting of perspective trajectories of university development, development of system measures for increase of indicators of efficiency of research activity of university teachers
Management	Information basis for making management decisions

activity in a certain scientific field, it is planned to expand the technological component of the rating with a new indicator of the Web of Science system – Author Impact Beamplots. The indicator is a normalized indicator of a scientist's citation, reflects the effectiveness of citing the publication and allows to provide a qualitative assessment of the effectiveness of research activities.

Effective component – on the basis of collected data on the affiliation and scientometric indicators of teachers are formed ranking tables of research performance at the university in general and in terms of departments and chairs, based on which the ability to export reports.

Structurally functional model of the rating system for the analysis of research activities of teachers is described in detail in the study (Morze et al., 2022b) and has the following view (figure 5).

5.2 Transparency Rating Methodology and Design

Taking into account the model of the rating system for the analysis of research activities of teachers, a transparency rating has been designed, the indicators of which are system performance indicators.

The rating system model was implemented as a web-based client-server architecture. The PHP programming language was used in the development of the server software. The web interface is implemented using HTML, CSS and JavaScript.

As a result of experimental implementation, a Google Scholar citation rating was developed, which ranks teachers according to their indicators of publishing activity (figure 6).

All teachers of the Borys Grinchenko Kyiv Uni-

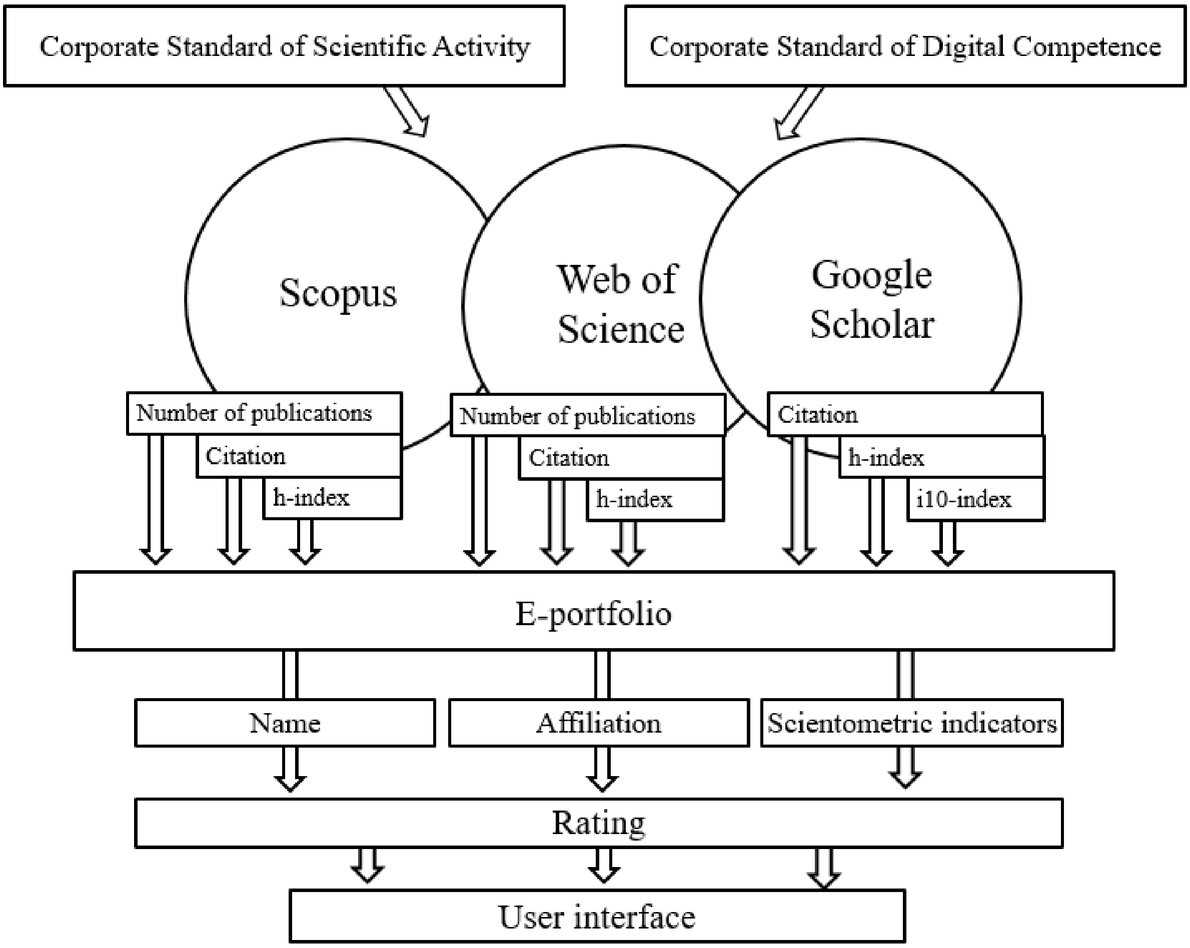

Figure 4: Technological component of the model of the rating system for evaluating the research activities of teachers.

versity take part in the "Transparency Rating of Structural Units". In the ranking, the list of teachers is ranked in descending order of the value of the total number of bibliographic references according to the Google Scholar system. The detailed table of research indicators contains the values of the total number of bibliographic references, h-index, i10-index and links to the teacher's profile in Google Scholar. Also, the page of the rating of teachers reflects the dynamics of citation indicators compared to the previous issue of the rating, which allows teachers to monitor and analyze the effectiveness of their own research activities.

The increase in the total number of citations of both the h-index and the i10-index in the teacher's profile may be due to the indexing by Google Scholar of new publications by other authors that contain direct citations of articles of the teacher; supplementing Google Scholar's teacher profile with previously unstated publications that are already cited in research by other Google Scholar-indexed researchers. On the other hand, a decrease in citation rates may be due to a change in the five-year citation period. When the five-year citation period changes, the publication may no longer be included in the calculation, which negatively affects the total number of citations and the value of the indexes. Another possible reason may be the disappearance from the Google Scholar index or open access to a publication that contains a citation of the relevant article by the teacher.

Creating a database of scientific profiles of teachers in Google Scholar allowed to implement the designation of incorrectly configured profiles in one place.

In addition, the presence of this database of scientific profiles of teachers ensured the implementation of the formation of scientific profiles of structural units with the definition of citations per teacher of the unit (figure 7).

To design the rating of structural units and departments, the average citation rate per 1 teacher was determined as the ratio of the sum of the total number of citations to the number of full-time employees of the structural unit. This approach reflects the con-

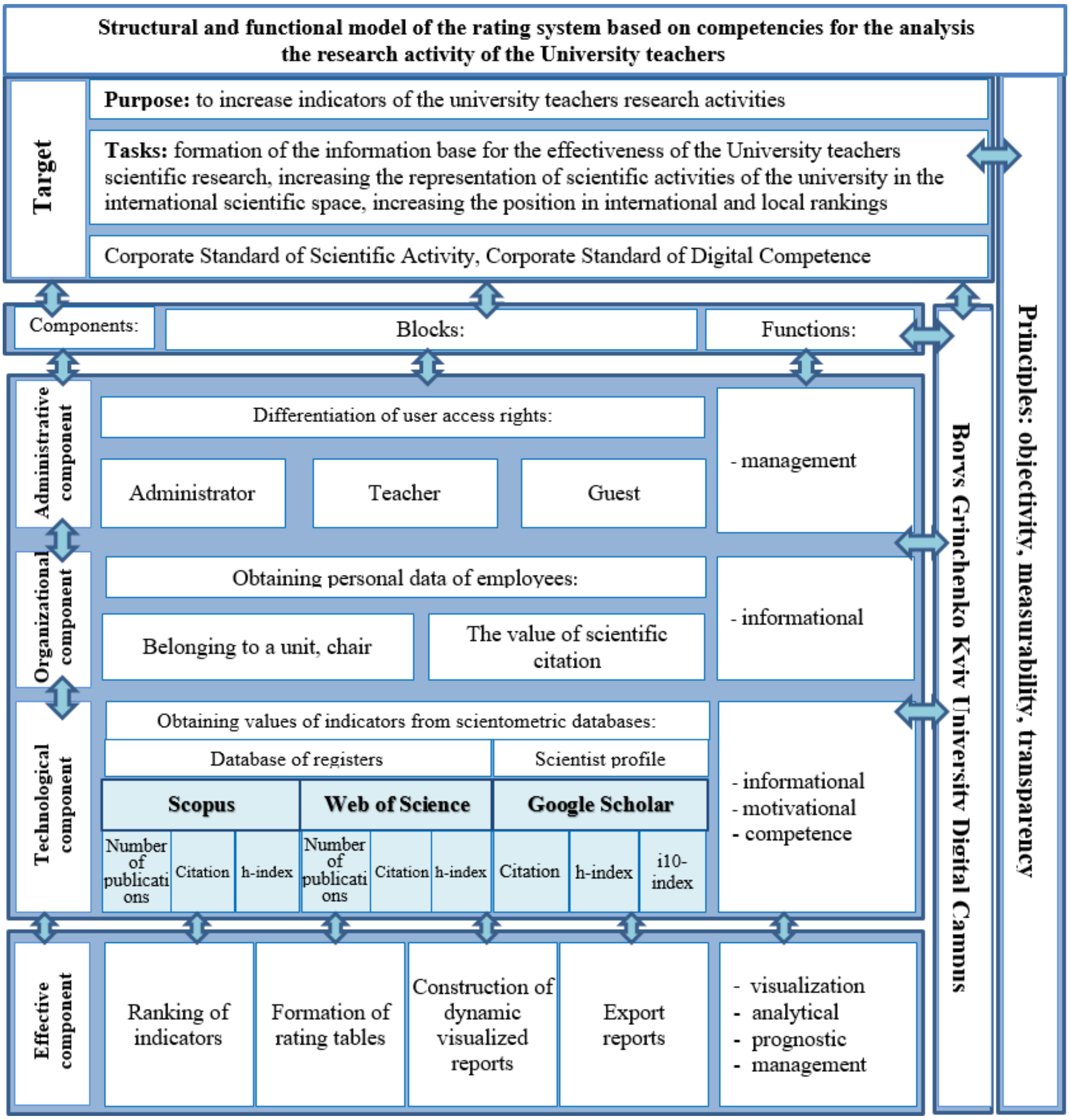

Figure 5: Structurally functional model of the rating system for the analysis of research activities of teachers (Morze et al., 2022b).

tribution of each individual teacher in the scientific achievement of the structural unit and the effectiveness of the research team in general. In the case of the same values, the units in the "Transparency Rating" are ranked by the total number of citations, which is defined as the sum of the number of citations according to Google Scholar for a five-year period of all staff members of the structural unit.

The ranking of structural units and chairs in the "Transparency Rating" is carried out in descending order of the average citation rate per 1 teacher. In the case of the same average citation rates, the structural units are ranked in descending order of the total number of citations of teacher profiles. The choice of the Google Scholar system is due to the fact that, unlike the scientometric databases Scopus and Web of Science, it has a wider coverage and includes publications from these databases and has a high level of correlation in citation values with Scopus, Web of Science, which is confirmed by the results research (Martín-Martín et al., 2018a,b) and provides a greater presence of teachers in the ranking.

№	Name	Structural Unit	Department / Research Laboratory	Number of citations	Dynamics of the number of citations	h-index	Dynamics of the h-index	i10-index	Dynamics of the i10-index	
1	Morze Natalia Viktorivna	FITM	Department of Computer Science and Mathematics	2714	+465	23	↗ 2	84	↗ 21	Google Scholar
2	Petrochko Zhanna Vasylivna	IHS	Department of Social Pedagogy and Social Work	1908	+932	12	↗ 1	14	↗ 3	Google Scholar
3	Kraus Natalia Nikolaevna	FITM	Department of Finance and Economics	1500	+638	19	↗ 6	48	↗ 25	Google Scholar
4	Styshov Alexander Anatolyevich	IP	Department of Ukrainian Language	974	+974	10	↗ 10	10	↗ 10	Google Scholar
5	Oleksyuk Olga Mykolayivna	IA	Department of Musicology and Music Education	923	+152	10		10		Google Scholar
6	Videiko Mykhailo Yuriiovych	FHP	Archeology Research Laboratory	917	-105	16	↘ -1	28	↘ -3	Google Scholar
7	Ilyich Lyudmila Mykolayivna	FITM	Department of Management	819	+129	10		12	↗ 2	Google Scholar
8	Kraus Kateryna Mykolayivna	FITM	Department of Management	787	+349	14	↗ 4	22	↗ 11	Google Scholar
9	Lytvyn Oksana Stepanivna	FITM	Department of Computer Science and Mathematics	777	+88	15	↗ 1	27	↗ 4	Google Scholar
10	Lysenko Olena Mykolayivna	FHPES	Department of Physical Rehabilitation and Biokinesiology	707	+112	13	↗ 1	22	↗ 7	Google Scholar

Figure 6: Ranking of teachers by citation indicators in Google Scholar.

№	Unit	Average citation rate per 1 teacher	Dynamics of average citation rate per 1 teacher	Total number of citations	Dynamics of the total number of citations
1	Faculty of Information Technology and Management	181.1	+43.89	10866	+2908
2	Institute of Human Sciences	133.14	+56.86	6657	+2309
3	Faculty of History and Philosophy	83.2	-0.12	3827	-89
4	Pedagogical Institute	80.43	+18.19	4906	+985

Figure 7: Transparency Rating of Structural Units according to citations in Google Scholar.

To analyze the effectiveness of research activities of the unit on the page of the rating of units and chairs realized the dynamics of citation rates per 1 teacher and the total number of citations compared to the previous issue of the rating. Increasing the value of citations per 1 teacher in the rating of the chair or department can occur both by increasing the number of citations of teachers and by increasing the proportion of highly cited employees in the structural unit.

Visibility and transparency indicators of the university are influenced not only by the activities of teachers, but also by chairs in general, including the dissemination of information on social networks about the main activities, announcements of scientific events, videos, research results and more.

Monitoring of key indicators of research activities of structural subdivisions of the Borys Grinchenko Kyiv University is carried out monthly due to the developed internal rating of structural units, the methodology of which is based on the indicators of the international Webometrics rating. Analyzing the internal rating for research activities, attention is paid to the Quality indicator, namely, the rate of uploading scientific papers to the Institutional Repository, citation rates according to Google Scholar (figure 8).

To monitor the representation of chairs in the Internet space at the Borys Grinchenko Kyiv University, the frequency of updating the official pages of departments in social networks and Google Scholar is periodically analyzed, the results of which are reflected in a specially developed information resource (figure 9). The resource contains a database of official pages of the chairs on social networks Facebook, YouTube and profiles in the Google Scholar system, for which the period of the last update of the profile is marked with special marks, such as week, month, three months, etc.

Periodic monitoring of the period of updating the pages of chairs on the Internet is a motivating factor for updating, filling pages on social networks, disseminating information about current research activities, research results, updating profiles of chairs in Google Scholar, thus increasing visibility, openness and dissemination information about the scientific activity of the departments and the university in general.

To further analyze the ranking positions and indicators of research activities of teachers, build visualized reports on the effectiveness of research activities,

Place in the general rating of subdivisions	Subdivision	Webpage of Subdivision	Visibility (55%)						Quality (25%)				Transparency (20%)					Dynamics of the general rating for a month	Total rating
			Link source domains, 10%	External backlinks, 30%	Facebook, 5%	Visits for the last month, 10%	Visibility rating	Place in Visibility rating	Index of publishing activity, 15%	Institutional repository, 10%	Quality rating	Place in Quality rating	h-index (Google Scholar), 7%	Bibliographic references, 10%	i10-index 3%	Transperancy rating	Place in the Transparency		
1	Institute of Human Sciences	il.kubg.edu.ua	1	1	34	5 420	5,65	4	0,67	34	5,47	1	30	88	100	3,29	3	1,4	14,4
2	Faculty of Information Technology and Management	fitu.kubg.edu.ua	1	1	3	4 225	4,51	7	0,61	33	5,11	2	28	97	150	3,64	2	-0,2	13,3
3	Pedagogical Institute	pi.kubg.edu.ua	1	1	35	6 519	5,82	3	0,36	21	3,08	3	28	112	121	3,82	1	1,1	12,7
4	Institute of Philology	if.kubg.edu.ua	1	1	10	11 586	5,62	5	0,21	35	3,06	4	22	44	86	2,04	4	-0,2	10,7
5	Institute of Journalism	ij.kubg.edu.ua	1	2	6	8 290	8,09	1	0,11	6	0,93	9	15	13	24	0,88	8	1,0	9,9
6	Institute of Arts	im.kubg.edu.ua	1	1	9	3 285	4,59	6	0,27	25	2,83	5	16	18	37	1,08	7	5,0	8,5
7	Faculty of Health, Physical Education and Sports	fzfvs.kubg.edu.ua	1	1	6	2 255	4,37	10	0,14	6	1,07	8	18	48	42	1,79	5	-0,8	7,2
8	Vocational College "Universum"	uk.kubg.edu.ua	1	1	19	14 492	6,26	2	0,02	2	0,22	11	11	11	14	0,66	10	-1,7	7,1
9	Institute of In-Service Training	ippo.kubg.edu.ua	1	0	30	21 080	4,40	9	0,15	8	1,25	7	14	12	21	0,81	9	-0,8	6,5
10	Faculty of Law and International Relations	fpmv.kubg.edu.ua	1	1	3	4 013	4,49	8	0,07	3	0,53	10	7	2	5	0,30	11	-3,6	5,3
11	Faculty of History and Philosophy	iff.kubg.edu.ua	1	0	0	2 381	1,19	11	0,19	8	1,44	6	20	34	64	1,67	6	-1,3	4,3

Figure 8: Internal rating of structural subdivisions of Borys Grinchenko Kyiv University.

Representation of the departments of Grinchenko University in the Internet space

Symbols of the period of the last update of the official page of the department on Facebook and YouTube:

- during the week
- within a month
- 1-3 months
- 3-6 months
- 6-12 months
- over a year
- no records

Published data as of the beginning of 2022.

#	Unit	Chair	Facebook	YouTube	Google Scholar	Number of publications GS (21/22)
1	Institute of Journalism	Department of Journalism and New Media	Facebook	YouTube	Google Scholar	14
2	Institute of Journalism	Department of Advertising and Public Relations	Facebook	YouTube	Google Scholar	9
3	Institute of Journalism	Department of Publishing	Facebook	YouTube	Google Scholar	6

Figure 9: Representation of University Chairs in the Internet space.

it is planned to implement 2 stages of research – expanding the "Transparency Rating" for other indicators presented in the model – the number of publications in databases Scopus and Web of Science with university affiliation, establishing relationships to increase the publishing activity of teachers.

5.3 Influence of Rating Indicators on the Improvement of Research Activities at the University

The research took place in several stages: preparatory, design, experimental (implementation).

At the preparatory level the theoretical bases of rating estimation of research activity of research and pedagogical workers were investigated. At the design stage, a structural-functional model of the rating system for evaluating teachers' research activities was designed, a "Google Scholar Citation Transparency Rating of Structural Units" was developed, and an experimental rating was built. For two months, the administration and faculty of the university had the opportunity to review and analyze the data of the experimental rating, after which the first issue of the rating was built in June 2021. The second issue of the rating was built in January 2022.

The analysis of the experimental, first issue and second issues of the rating, built with an interval of 2 and 6 months, respectively, confirmed the positive dynamics of research performance (figure 10).

There is an increase in the total number of citations and the value of citations per 1 research and teaching staff for all units. The largest increase in citations is the Institute of Philology, which increased the total number of citations by 2648 (+117%) and citations per teacher increased by 15,01 (+109%) and the Institute of Human, whose total citations increased by 2948 (+79%) and citations per 1 teacher increased by 69,19 (+108%), which indicates the active work of teachers in these departments to update and supplement their research profiles in the Google Scholar system.

A negative factor in evaluating the results of research of university teachers is the possible cases

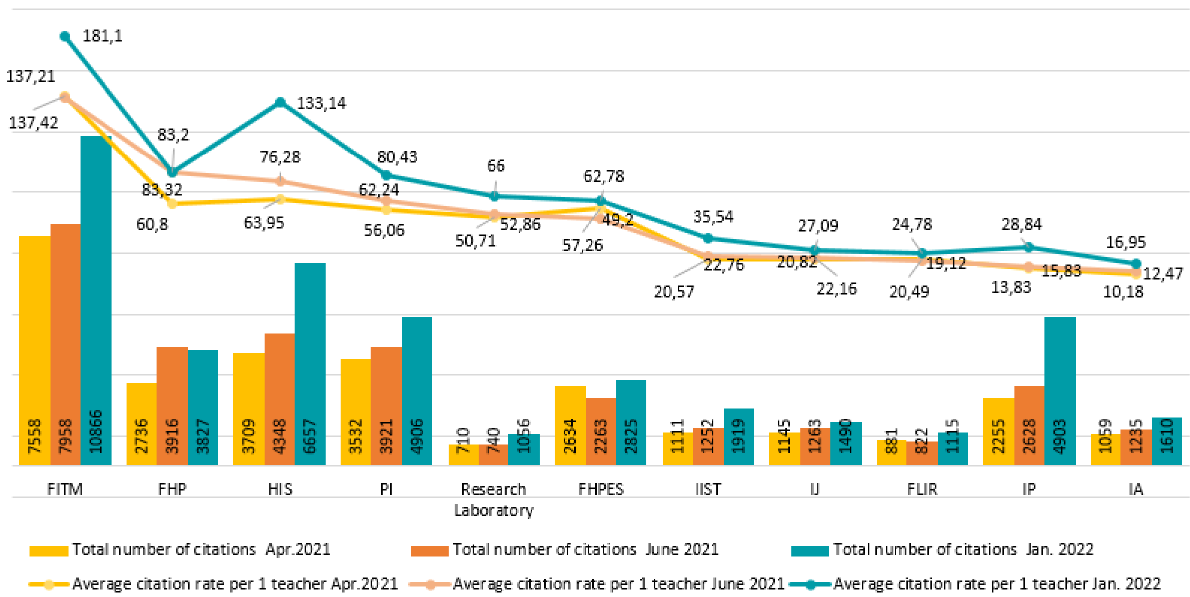

Figure 10: Diagram of citations of the experimental, first issue and second issues of the rating.

of intentional influence on citation rates to increase them, in particular by violating the principles of academic integrity, increasing the percentage of self-citation, etc. (Recommendations NAQA, 2022). In order to reduce the possibility of intentional influence on increasing citation rates, the rating system uses a set of indicators of various scientometric databases, including important international databases Scopus and Web of Science, which make high demands on the quality of scientific publications in the included publications, which reflects the quality and demand for research results on the accumulation of the number and volume of publications and citations.

Having a system and rating is an incentive for teachers to update their e-portfolio profiles, create profiles in scientometric databases, in the absence, update information in profiles, including Google Scholar, supplement indexed publications, disseminate research results, discuss them in the international networked scientific community, thus developing skills in the use of digital technologies in the organization of research and dissemination of research results.

The active work of university teachers on updating their own profiles in the Google Scholar system and the positive impact of the rating system of analysis of research activities of university teachers on visibility, transparency is also confirmed by the dynamics of Grinchenko University in the international ranking "Transparent Ranking: Top Universities by Google Scholar Citations" during 2020-2022 years. The rating methodology is based on the importance of citing profiles of university employees in the Google Scholar system.

Analyzing the indicators of the university in the ranking of 2022, we note that the value of the total number of citations of employee profiles in the Google Scholar system increased by 10921, which is almost 4 times more than the increase in citations from the previous year (+2735). However, the overall position of the university in the ranking of Ukrainian universities decreased by 4 positions, as other universities are also actively working to increase the openness and transparency of research results (figure 11).

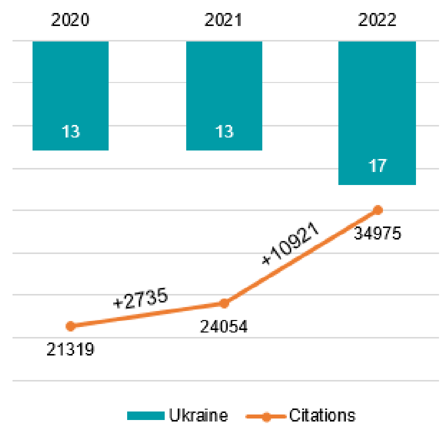

Figure 11: Dynamics of university indicators in the rating "Transparent Ranking: Top Universities by Google Scholar Citations" for the period 2020 – 2022.

According to the results of the study, it was determined that the optimal presentation of the results of research activities of teachers in the ranking contributes to (Smirnova, 2021):

- implementation of measures to ensure open access, transparency, openness of research results;
- use of open journal systems when publishing research results (Open Journal Systems, Open Conference System, DPubS, OpenACS, etc.) (Luparenko, 2020);
- giving preference to publications that give articles a unique DOI that simplifies publication identification and provides a permanent link to the publication, regardless of the change in the publication's web address;
- use of the international identifier of the ORCID scientist to correctly determine the affiliation of the article to the author's profile. ORCID International Scientist Identifier is designed to unambiguously identify the author of an article, which is especially relevant in the case of different spellings of the name of the scientist, scientists with the same names and surnames, etc.;
- placement of publications in open institutional repositories, electronic libraries to increase the visibility of scientific achievements in the network;
- systematic updating of scientist profiles in scientometric databases to increase visibility and update citation indexes such as Google Scholar, ResearchGate, Mendeley, etc.;
- placement of researcher IDs and profile links in scientometric and bibliometric databases on the e-portfolio page (Scopus Author ID, Researcher ID, Google Scholar, ResearchGate, etc.);
- implementation of measures to disseminate research results to increase visibility and presence in the international scientific community.

Currently, work is underway to refine and expand the rating on other indicators Scopus, Web of Science, presented in the model to obtain a full-fledged rating system; systems of analytics and statistics with the formation of dynamic visualization of the effectiveness of the scientific potential of the university.

6 CONCLUSIONS

One of the tools for measuring the competitiveness of universities is participation in international and domestic educational rankings. Full and objective assessment in the most authoritative international and Ukrainian rankings is provided by a set of indicators covering various areas of university activities, including research. To monitor the university's indicators in the rankings, it is important to implement internal university rankings, the methodologies of which are based on key performance indicators that are taken into account in international and Ukrainian educational rankings. One of the key indicators of educational ratings are indicators of research activities of university teachers, so for the implementation of systematic monitoring of openness, transparency of the effectiveness of research activities of teachers is an effective tool to develop and implement a rating system for research analysis. Ensuring transparent evaluation of teachers' professional activities, increasing openness, transparency of university activities, open access to results, professional and scientific achievements of teachers are fundamental components of the internal quality assurance system of education. Also, the placement of open identifiers of scientists in scientometric databases, research results, contact data of the scientist promotes the dissemination of knowledge in the scientific information space and allows to expand the possibilities of scientific cooperation.

The rating system for research analysis is based on the indicators of the three most important scientometric databases – Scopus, Web of Science, Google Scholar and provides the main functions – informational, visualization, motivational, competence, analytical, prognostic and management. The rating system is implemented as a web-oriented client-server architecture. One of the components implemented in the system at the 1st stage of the study is the "Google Scholar Transparent Rating". Based on the results of the research were developed recommendations for improving the quality of teachers' research activities. The formation of the rating confirmed the importance of designing a system of research analysis that improves the quality of research, dissemination of research results in the international educational space, analysis of teachers' own development, monitoring the scientific growth of university faculty and obtaining visualized analytics in real time. Prospects for further research are seen in supplementing the ranking with other indicators of research, implementing real-time rating system updates, integration of modern business intelligence systems to build visualized statistics to analyze the effectiveness of the research component of the university.

Systematic implementation of measures to ensure open access to own research results, increase visibility, transparency and dissemination of research results on the Internet contributes to the optimal representation of the scientist in the rating of the research component of professional activities of university teachers, improving professional competence of teachers and positively influences on the indicators of the quality of research work of higher education institutions in domestic and international rankings.

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Cloud Technologies for the Creation of Open Educational Resources by Future and Practicing Teachers

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Abstract: Practical training plays a significant role in the process of professional training of future teachers. An integral part of the training is the full participation of future teachers in the educational process of secondary education during the internship. The simulation of the professional activity of future teachers in two stages takes place. The first is seminars that provide practical skills in mastering the theory. Educational practice in secondary school is the next step in the practical testing of students' knowledge. During the internship in secondary schools, interns not only implement their own theoretical knowledge, but also increase the level of information competence one. During the period of epidemiological restrictions, the methods and means of e-learning were rapidly used. Electronic educational resources allow us to solve new challenges facing the education system. The change of the quality of e-learning tools and improving the methods of their application realized as soon well. The development of e-educational resources is a difficult task. One of the ways to solve this problem is to involve future teachers in this process during their initial practice. Future teachers have theoretical knowledge of information technology. They know how to use their theoretical knowledge. This is because e-learning in higher education school is actively implemented for many years. By the way, during the initial practice, future teachers have the opportunity to test the developed e-eucational resources. Then, to make some adjustments. Our experiment on the creation of open educational resources by means of cloud technologies during the internship proved the possibility of solving an important practical problem. Analytical analysis of the obtained results allowed making a promising conclusion on the feasibility of developing the practice of developing open educational resources.

1 INTRODUCTION

The basis of informatization of education are information and communication technologies. It is a powerful tool for intensifying the educational process, its organizational processes and activities. The field of accessibility and acquisition of new knowledge, skills and abilities is expanding. The ultimate goal of open education and e-learning cannot be considered informatization and implementation of e-learning tools in the educational process. Modern educational practice needs tools not only for publishing and for storing educational resources. It is necessary to have a developed set of tools for teamwork with different materials (Semerikov et al., 2022). Such materials must meet clearly defined criteria within educational systems. Such systems both inside and outside educational institutions should be used. Not only do users need to have free access to resources. Users need to be able to work collaboratively with learning materials. Users should be able to modify materials, adapt them to the needs of their own educational activities. In fact, the ability to modify e-educational resources their quality will improve. This process provides new knowledge in e-learning. And this is a necessary condition for the creation of open education.

Today, the Open Content Initiative, or Open Educational Resources (OER), dates back to the 2000s, with initiatives from the University of Tübingen in Germany, the Massachusetts Institute of Technology, Hewlet Fondantion. We will use a term that, in our

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opinion, is more successful "Open Educational Resources" or "Open E-Learning Resource". OERs are resources used to teach learning material. These teaching materials or research resources are in the public domain. These materials are free of intellectual property licenses. They are widely available for use or reuse for others.

2 THEORETICAL FOUNDATIONS OF THE STUDY

The development of open electronic resources is a complex and multifaceted problem. Specialists of various specialties are involved in the creation of electronic educational resources. Such specialists are specialists in such fields as learning theory, psychology, ergonomics, information and communication technologies, etc. (Lytvynova, 2018; Day and Erturk, 2017; Vakaliuk et al., 2020; Valko et al., 2020; Shyshkina and Marienko, 2020; Popel and Shyshkina, 2019; Kholoshyn et al., 2020; Nosenko et al., 2019; Nechypurenko et al., 2019; Markova et al., 2019). Wiley et al. (Wiley et al., 2017) formulated a number of questions about the process of creating and using open educational resources, such as:

- Do students assigned to create, revise, or remix artifacts find these assignments more valuable, interesting, motivating, or rewarding than other forms of assessment? Why or why not?
- Do students who make their assignments publicly available demonstrate greater mastery of learning outcomes or show more enthusiasm for their work than students assigned traditional assessments? Why or why not?
- Do students who openly license their work find additional learning benefits? Does openly licensed student work produce additional benefits to the broader community?
- Are there any drawbacks (real or perceived) that are voiced by students or faculty that participate in OER-enabled pedagogy?

Some answers to these questions can be found in (Velychko et al., 2021a,b). In particular, in Velychko et al. (Velychko et al., 2021a) the stages of development of open e-educational resources during the educational activity are offered. We conducted the study of the possibilities of creating open educational resources during the educational practice by means of cloud technologies in the future.

E-learning has made it possible to create and spread such a phenomenon as "Open Education". The advantages of the specifics and basic principles of open education are as follows:

- application of information and communication technologies;
- using of technologies of interaction between participants of educational process in synchronous and asynchronous modes;
- specially designed teaching aids that differ from traditional ones;
- network structures of organization and management of educational content, as well as the learning process;
- specific presentation of educational information, due to lack of control over the concentration of attention on educational material;
- specialized quality control of training, without which there can be no transition to the next stage of training or training material.

Thus, open education is fundamentally different from traditional. It is more in line with the goals, objectives and content of the information society. The main advantages of open education include:

a) popularity and accessibility (open education has almost limitless opportunities for wide coverage of the population and territories, the organization of free access to information and educational resources);
b) adaptability and flexibility (the open education system has a wide range of opportunities to adapt to changing environmental conditions. It is capable of significant transformations of all-important elements of the educational process)
c) internationality and globalization (free functioning of the open education system outside state borders);
d) planetary openness and availability of information and educational resources;
e) modular structure and asynchrony (modular principle of constructing the content and organization of the educational process allows to form individual curricula and programs that best meet the personal needs of students, as well as spread over time various elements of the educational process);
f) economic efficiency (educational results are achieved with less time, money and other resources compared to traditional approaches).

Based on the definition of the General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) during the meeting in

Paris from 12 to 27 November 2019 at its 40th session the following was emphasized.

Open Educational Resources (OER) are learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others (UNESCO, 2019).

Open License is a standard way of granting, restricting the rights to use, transform, reuse, or distribute creative results (sound, text, images, multimedia, etc.). To protect copyright in environments where content (especially digital) can be easily copy and made availabled for public access without the author's permission, Open Licenses have been developed. Open licenses to help guarantee permission to copy and share in a structured legal form are expected. This approach is more flexible than it is today (when all rights automatically granted). Licenses in each case provide certain rights, exempting from the restrictions of traditional copyright. OER is an integral part of this process. OERs provide greater flexibility in the use, reuse, and adaptation of materials to local contexts and learning environments. In this case, the authors receive well-deserved recognition.

Licensing software or electronic educational resources allows you to grant usage rights. They are a mechanism for copyright protection. Licenses must have granted even when authors wish to provide their designs for use free of charge. This mechanism allows you to make no exceptions uses. Moreover, while there are free licenses for software such as the GNU General Public License, the Apache License, the Mozilla Public License, and others, Creative Commons (CC) licenses are typically for content that includes most e-learning resources. The Creative Commons initiative (founded in 2001) is a companion to the Open E-Learning Resource initiative. The main purpose of the organization is to help revive the public domain among creative works, which include electronic educational resources. Creative Commons promotes a collective goal focused on the information society. Creative Commons a web application that helps people grant their creative work open licenses or partially retain copyright has developed. At the same time, it licenses them as free uses, under certain conditions. Unlike the GNU General Public License or others, Creative Commons licenses are not intended for software, but for other types of creative work. Namely, the creation of websites, musical works, movies and videos, photographs, literary works, training courses, etc. The goal is to increase the content on the Internet, as well as open access to educational material free and accessible. To this end, metadata has been developed that can be used by search engines and other online search applications. For example, photos that are free if you mention the original photographer, or songs that can copied, distributed or removed without any restrictions, or electronic educational resources.

Ukraine has a low culture of digital content consumption. An example of this is the significant percentage of unlicensed software use. The Software Alliance estimates that unlicensed software use in Ukraine in 2017 estimated at 80%, equivalent to \$108 million, with an average of 57% across Central and Eastern Europe (BSA, 2018). This culture of consuming digital content also applies to electronic educational resources. How the developed educational resources be protected from illegal use? This question is the most common of many colleagues. Technological tools to limit digital content operations exist, but they are unable to address this issue at a fundamental level. We believe that the introduction of comprehensive licensing of digital content will help address this issue. Compliance with open licenses should help shape the perception of licenses for digital content and the possibility of its use, depending on the license. In fact, the presence of a requirement for a mandatory license for digital content is an indicator of legal relations in the field of electronic educational resources, the civilized process of their creation, distribution and use.

OER-Enabled Pedagogy is based on a student-centered approach to learning. The originality of our learning experience is that in the learning process students are involved as creators of open content development using 5R permissions (retain, reuse, revise, remix, redistribute). In essence, 5R permissions coincide with the four levels of freedom free software and the corresponding practice of its application in educational activities (Velychko et al., 2018). In their study, David Wiley and John Hilton identified the relationship between the types of tasks and the end results of their performance (table 1) (Wiley and Hilton III, 2018). According to these scientists, the results of one-time tasks are important only for students, and therefore, other participants in the educational process can not use the results. Nevertheless, the results of authentic tasks, due to the specifics, can be useful not only to their authors but also to other users. The results of construction tasks, according to the authors of the study, can be made public and reach a wider audience. Ongoing tasks public and licensed openly must made. Renewable tasks provide an opportunity to create open educational resources that meet the requirements of 5R.

Open educational resources should not only have the appropriate licenses, but also the location (link) where they can be downloaded and downloaded, provide an assessment and describe the experience. Most of the open educational resources are stored in appropriate repositories. Examples of open educational resources repositories include Open Discover Space (https://portal.opendiscoveryspace.eu), MERLOT (https://merlot.org) and OER Commons (https://www.oercommons.org).

Unfortunately, there are no repositories in this area in Ukraine. Universities, institutes of postgraduate pedagogical education, city and regional departments of education form their own repositories. Such Repositories are local and do not gain widespread popularity in the educational environment. Despite this, the pedagogical community in Ukraine is uniting. Opportunities for improving and expanding professional competencies on such open educational platforms as EdEra, Vseosvita, “Na urok”, Prometheus, etc. are expanding. Thus, skills in working with open educational resources during the period of study of students in higher education institutions should be acquire. In this context, future teachers have a special advantage. Their responsibility here to society is obvious.

Practical training of future teachers is one of the important stages of the educational process. One of the basic components of practical training of future teachers is, in fact, educational practice in secondary schools – schools, colleges and more. On the one hand, during the internship the future teacher is ready to implement the acquired theoretical skills. On the other hand, they gain practical experience. And this allows you to form the holistic competencies of the future teacher. In the period of sanitary restrictions caused by biological threats, the role of information and communication technologies is growing. This is especially important during the internship. During such challenges, the exchange of experience and learning materials takes place through communication between students, mentors and trainees, between trainees and practice leaders, and directly between trainees. The possibility of collegial activity opens up. Effective results are those that collectively are performs. The result is such electronic educational resources that can be used by the general community. Such practical activity aims to increase the level of formation of information, communication, organizational competencies of students.

What are the opportunities for joint work on the creation of electronic educational resources? First, practical acquaintance with the means of sharing digital content; second, the practical use of cloud technologies; third, conducting a critical analysis of the suitability of certain cloud technology services for the development and creation of electronic educational resources.

Some teachers use open educational resources only as teaching aids. However, another group of teachers involves future teachers in their creation and exchange during training. For example, in the Digital Futures in Teacher Education (DeFT) project, practicing teachers, future teachers and educators participated on an equal footing in the study of digital literacy. They jointly developed open educational resources that were used in the study of digital literacy in high school (Gruszczynska et al., 2013). A similar experience of creating open educational resources in a study by Tur et al. (Tur et al., 2016) was describe. The study involved three groups of future primary school teachers studying at the University of the Balearic Islands. During the course, future teachers had to create open educational resources, which was a testament to their technical skills. The survey showed an overall positive impact on students' perceptions of such developments, the creation and use of open educational resources. However, during the analysis of their answers there were some inconsistencies and nuances.

Kim (Kim, 2018) considered the issue of preparing future teachers for the use of open educational resources and the practice of using open educational resources in educational activities. In particular, the author cited the following principles of training future teachers: 1. It is necessary to involve those teachers who care about the problem of open educational resources, who use different approaches to solving the problem. 2. There is a need to promote the deepening of cognitive processing of educational material by future teachers. 3. Give broad autonomy to future teachers in the process of developing open educational resources. 4. Peer interaction should be encouraged and maintained to improve lesson planning outcomes. 5. Interaction with peers should be encouraged to improve lesson planning outcomes.

The results of a study by Kimmons (Kimmons, 2014) revealed the following points. First, this is what is valuable for improving the literacy of teachers with open education K-12. The need to overcome various misconceptions to support the large-scale development of open education literacy in K-12 has also proven. In addition, proponents of open education must recognize that all teachers, regardless of the time of study: a) are willing to innovate, b) use open resources, c) openly share their achievements. Open pedagogy is becoming increasingly popular as a teaching method to reduce authoritarianism in the classroom while learning. It allows to involve students in pedagogical testing to obtain the initial results of pedagogical work.

To study the impact of open pedagogy on motivation, Werth and Williams (Werth and Williams, 2021) conducted interviews with first-year students of the College of Four-Year Humanities. The survey was conducted after the end of the semester project in the framework of the pedagogical approach described above. The evaluation of students' responses was conducted using the theory of self-determination, in particular on the styles of motivation regulation, which were demonstrated by the research participants. The results showed that students are influenced by various forms of external motivation during a project based on open pedagogy. Incidentally, autonomous forms of regulation were more common than controlled regulation.

Cloud technology services have both advantages and disadvantages. We further highlight those that are critical to the objectives of our study on the application of cloud technologies. The advantages of using cloud technologies include:

- it is not necessary to have your own powerful computers (this is relevant for solving the problem of providing educational institutions with modern computers);
- the problem of using unlicensed software is solved (this is relevant for solving the problem of insufficient funding for the payment of licensed software);
- mobility of resource use (open possibility to work from any suitable point of the network if the necessary communication channel is available);
- the possibility of joint work on documents (which is relevant for solving the problem of organizing collective work on joint projects at a distance).

The disadvantages of using cloud technologies in educational activities are:

- dependence on Internet connection (stability of broadband access is critical for collaboration on documents);
- not every cloud application provides the ability to save the results in a user-friendly form on the desired media (the difference between data formats in cloud applications and desktop software versions sometimes requires data reformatting and loss of original quality);
- there is a risk that the service provider will stop providing cloud services (such problems occur quite often when using free services).

Moreover, if the advantages of using cloud technology services in full must be use, then to overcome the shortcomings must be prepared as follows: a) have an alternative source of Internet connection; b) use open data formats; c) keep backup copies of your own data. The concept and phenomenon of joint activities are actively study by psychology and pedagogy. In the process of studying such a concept as "joint activity", attention should be pay to two aspects: 1) substantive activity; 2) the process of building relationships between people involved in activities and communication. The main "unit" of the analysis of joint activities and its collective subject is the interaction of participants in joint activities.

At the heart of the dynamic concept of joint activities is a conceptual "triangle", which combines three areas:

1) subject-oriented interaction (interaction aimed at changing the subject of joint activities),
2) subject-oriented interaction (interaction aimed at changing the characteristics of the individual subject of joint activities),
3) organizational-oriented interaction (interaction that changes the ways and style of performing activities).

Much attention is paid to the impact of joint activities on intellectual development, the formation of social intelligence and social competence of the subject of education. For all the development of the concept of "joint activities", the organization of such activities in terms of development of technical means that specifically support and strengthen the joint nature of activities is not considered. In this context, the concept of "joint network activity" is a further development of the concept of "joint activity", including special network tools.

Joint networking requires its design based on the following conditions:

- the availability of new pedagogically sound technical means of joint activities on the Internet, which open up opportunities to expand the range of programs, objects, data and communications;
- the availability of new organizational forms and scenarios of educational network activities, focused on the creation of a social network by participants in joint activities.

3 RESEARCH RESULTS

Educational pedagogical practice as a type of practical activity of students aimed at solving various pedagogical problems should be considere. The specificity of this activity is that it identifies with the professional activities of teachers. At the same time, educational pedagogical practice is a form of professional training in a higher education institution, the purpose of which is:

- to deepen and consolidate the theoretical knowledge that the student received at the university, and learn to apply this knowledge in practice in educational work with students;
- to equip students with the ability to observe and analyze the educational work carried out at school with students;
- to prepare students for lessons with the use of methods that enhance the cognitive activity of students;
- to develop and consolidate in students a love for the teaching profession, to encourage the desire to study advanced pedagogical experience and improve their pedagogical skills.

Epidemiological limitations and widespread use of distance learning make adjustments in the process of practical training of future teachers. Until now, it was a good practice to gather from time to time in a higher education institution and discuss with classmates and methodologist's problematic issues of educational practice, share experiences, adjust their theoretical knowledge and more. Today requires communication and common tasks at a distance. To solve this problem, it is necessary to use information and communication technologies and means of joint activities. The best solution to this problem is the widespread use of cloud technology. This is quite effective for the preservation of accumulated data and for communication between participants in educational activities. Using cloud technologies, we get the opportunity to establish communication and joint activities to work in groups.

Based on the above provisions on joint activities, the benefits of using cloud technologies and the need to develop and create open electronic educational resources (Velychko et al., 2022a,b), a program of educational pedagogical practice for future teachers of mathematics, physics and computer science was developing. The peculiarity of the program is that the creation of electronic educational resources to the obligatory results of educational pedagogical practice has been add. The subject of electronic educational resources was limited to the topics of training sessions conducted by trainees. The following two requirements applied to e-learning resources, the first of which is collective resource development. The second requirement was to publish the developed electronic educational resource under an open license, ie the final product must be an open electronic resource.

Tasks offered to students of educational programs 014 Secondary education (mathematics), (physics), (computer science) of the Faculty of Physics and Mathematics of Donbas State Pedagogical University. These students underwent training and production practice in general secondary education institutions of Donetsk, Kharkiv, Luhansk and Dnipropetrovsk regions provided for three areas of activity: the creation of joint electronic educational resources, information visualization, and online organizational platforms. Consider what tools to perform the tasks have been analyzing.

The use of presentations, even in dynamic systems, does not provide an opportunity to engage students in active learning. Quite different opportunities are providing by whiteboards, thanks to which in the online learning format the participant of the educational process takes part in discussing problems, solving problems, etc. We selected and offered 10 cloud services to create training material for the training session (table 1). Before conducting the classes, the trainees had to get acquainted with the proposed list, explore the functions and capabilities of each of these cloud facilities and create training materials for the class. For comparison, the trainees prepared the teaching material in the form of a presentation and demonstrated it to the students, while the students performed the tasks on paper. After the lesson, students were interviewe. It was found out which of the proposed options the students liked the most. The survey of the class showed that 70.0% of the surveyed students out of 374 who took part in the survey preferred the lesson where the "white board" was use.

The systems presented in table 2 were studied to visualize information and create interactive content. Visibility is one of the benefits of electronic educational resources. The development and creation, even of static, e-learning resources is one of the tasks of e-learning. The limited space available for inspection requires the use of scrolling presentation technologies. Accordingly, the method of their application should change, in contrast to the fact that students see a large paper poster. The constant use of the same templates, design styles, etc. in educational activities leads to a loss of visual interest in educational material. Using a variety of design styles, fonts, icons, etc. increases students' visual activity. Each of the proposed systems has its own unique design style. Even having created infographics in different cloud services based on common data, we get fundamentally different digital products.

Practitioners faced the problem of downloading created digital objects to their own device. At the same time, their integration into other objects created

Table 1: Whiteboard cloud services.

Name	Free usage	Localization	Download object	Embedding in systems
Padlet.com	freemium	Yes/Partly	No	Yes
Linoit.com	free	No	No	Yes
Idroo.com	free	No	Yes	Yes
Miro.com	freemium	No	Yes	Yes
Whiteboardfox.com	freemium	No	No	Yes
Jamboard.google.com	free	Yes	Yes	Yes
NoteBookCast.com	free	No	No	Yes
Conceptboard.com	freemium	No	No	Yes
Groupboard.com	freemium	No	No	Yes
Classroomscreen.com	freemium	No	No	Yes

by cloud technology applications took place without hindrance. This problem arose because the cloud technology services we considered, at the beginning of its establishment, most of them offered their resources free. Increasing their popularity, most cloud services have moved to the financial model "Free - Premium" (Freemium), where some services on a free basis and some on a commercial basis are provide. As a rule, on a commercial basis, offer to upload your own data to the user's device. However, for each of the applications, we were able to obtain a digital object created by us on our own computing device by third-party methods.

The created means of visual presentation of data during the training activities of trainees were use. In addition, the interns invited students to create their own posters, charts, graphs, illustrations, etc. in computer science classes and outside classroom. 362 students took part in this study, of which 235 students (about 65%) liked to create digital content of this type. The students included such categories as "beautiful", "visual", and "useful". Students who were dissatisfied with this work used terms such as "not clear", "difficult", "I have no artistic flair". The answers of dissatisfied students have no meaningful basis. It should be noted this fact. Such answers are a weak justification for their unwillingness to use the proposed cloud services. We did not study the reasons for such reluctance on the part of students.

We also asked the students: "What is the main thing in the cloud service to create data visualization in your opinion?". The obtained answers for clarity are presented in figure 1 in the form of a diagram. The largest number of students (32.6%) spoke about "understandable language" used in the cloud service interface. Despite the availability of cloud online translation services, the English-language interface caused difficulties when using the application. In second place (28.2%) is the option that corresponds to the ability to conveniently work with the service on mobile devices, or even as a separate application. Today, the number of users via mobile systems exceeds the number of users via a desktop computer system, so this figure is extremely important. In third position was the design criterion (23.5%). Moreover, although the systems that were proposed were directly relate to graphic design, the ergonomics of these systems still need to be improved. In last place was the criterion of "available examples of work" (15.7%). In our understanding, this criterion indicates a lack of creative thinking and corresponds to the task according to the template. The fact that the smallest number of students are ready to do tasks on the model gives hope, because the capabilities of the systems are sufficient for creativity and creative presentation of information.

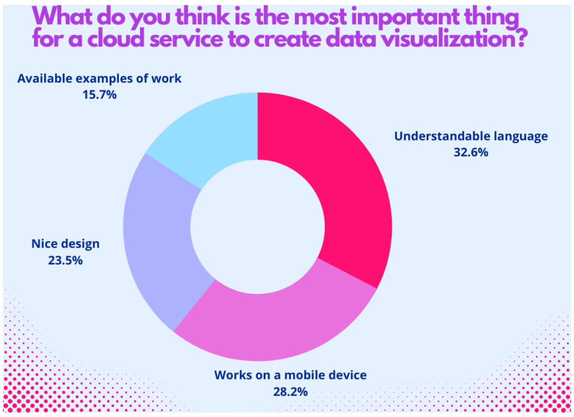

Figure 1: Results of a student survey on the use of cloud services.

The task of creating shared electronic resources was to analyze existing cloud services to create presentations and text documents. For this purpose, it was proposing to use office applications of cloud services, which are presented in table 3. Unlike the previous comparison tables, we analyzed the advantages and disadvantages that were collected according to the subjective judgments of the trainees. It was in these applications that they tried to create electronic educational resources, which then had to be-

Table 2: Whiteboard cloud services.

Name	Free usage	Localization	Download object	Embedding in systems
Easel.ly	Free	No	Yes (wiles)	Yes
Infogram.com	Freemium	No	Yes (wiles)	Yes
Canva.com	Freemium	Yes	Yes	Yes
Crello.com	Free	Yes	Yes	Yes
Genial.ly	Freemium	No	Yes (wiles)	Yes
Chartblocks.com	Free	No	Yes	Yes
Piktochart.com	Freemium	No	Yes (wiles)	Yes
Venngage.com	Freemium	Yes	Yes	Yes
Vizzlo.com	Freemium	No	Yes (wiles)	Yes
Adioma.com	Freemium	No	Yes	Yes

come open educational resources. It should be note that the trainees were already familiar with Google Docs and Office Online. Nevertheless, Zoho Office Suite and ONLYOFFICE turned out to be extremely interesting and useful for students. Interns are interested in both the new built-in design styles and the new functionality provided by cloud services. It was in these office applications that interns tried to create electronic educational resources. Tasks for creating open educational resources were propose for groups of three students and the selected topics were similar in content.

After the end of pedagogical practice, a survey of interns was conduct on the joint creation of open educational resources. They were ask the following questions:

A. Your attitude to open digital content (Positive / Negative)?

B. Do you have previously had experience of using open educational resources during pedagogical practice (Yes / No)?

C. Have you used digital resources before despite not having this action with a license agreement (Yes / No)?

D. Are you ready to create open educational resources (Yes / No)?

E. How do you feel about the joint development of e-learning resources (Positive / Negative)?

F. Is it appropriate to use unlicensed software to develop open educational resources (Yes / No)?

88 students of the Faculty of Physics and Mathematics of Donbas State Pedagogical University took part in the survey. The term of the experiment is two years. The results of the survey are presents in figure 2. Questions A-C were relating to the use of open educational resources, and questions D-F were relating to their development. The question of the research was to find out: are students who use open educational resources ready to develop them? Comparisons of responses between the two groups (A-C) and (D-F) were performed using the Mann-Whitney U test. The results of calculations $U_{emp} = 18$, $U_{0,1} = 3.0$, $U_{0,05} = 7.0$ indicate the absence of significant differences between groups. Therefore, students who are ready to use open educational resources are ready to develop them.

The analysis of the answers shows that there is a not very pleasant aspect, which is highlighted in questions C and F. Students do not pay much attention to the issue of licensing a digital product, and it does not matter whether it is an electronic educational resource or software. It should be note, that the surveys conducted in 2019 on free access to software showed an even worse attitude to the licensing of software.

The following resources were proposed to address the identified issues regarding the licensing purity of digital content, including electronic educational resources, open educational resources, joint development of electronic educational resources, licensing of electronic content, etc:

- open mass online courses “Prometheus: AI101” (https://prometheus.org.ua);
- course of review lectures “Open licenses. Creative Commons Initiative”;
- elective subjects of wide choice for students “Data Visualization” and “Infographics in Education”;
- advanced training courses for research and teaching staff of Donbas State Pedagogical University “Information and communication technologies in education”;
- certificate training courses for teachers “Information and communication technologies in education”;
- modernization of the content of academic disciplines.

The final results of the proposed resources are open and need further study. This is because each of the proposed resources for students of different

Table 3: Cloud office applications.

Name	Advantages	Disadvantages
Google Docs (docs.google.com)	Free and no significant restrictions; Convenient, non-distracting design; Well-thought-out collaboration in the cloud; Integration with Google services regular innovations; Templates gallery	Occasionally there are failures; There is no possibility to personalize the workspace (branding).
Zoho Office Suite (zoho.com)	Extensive list of additional applications; Interesting features in the paid version; Free version available; Convenient work with projects thanks to Workspaces.	Lack of localized documentation and incomplete localization of applications; The mobile version only works in read mode Numerous disadvantages of Zoho Sheet.
Office Online (office.microsoft.com /online/)	Excellent compatibility with MS Office formats; Responsive, stable touch interface and convenient Ribbon tape; Close integration with Office 365 and Microsoft services.	Working with documents needs to be reviewed; A small selection of import and export formats, limited by proprietary licenses; No automatic saving, inconvenient version control; Functional “gaps” in Excel; Fuzzy commenting system.
ONLYOFFICE (onlyoffice.com)	User-friendly interface; Import documents from other services.	No spell check; Quite high rates for individual use of the service; There are no full screen and compact modes; Documentation in English; Weak functionality of Spreadsheet Editor and Presentation Editor.

	Yes / Positive	No / Negative
A	66	22
B	65	23
C	53	35
D	45	43
E	75	13

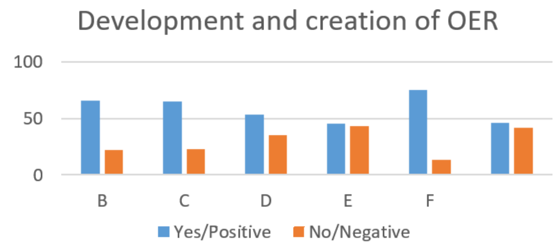

Figure 2: The results of the survey on the joint creation of open educational resources.

courses is designed. By the way, practicing teachers and educators are ready to continue working in this direction in order to create an environment to promote e-learning and create resources for e-learning. The ideas of open education, which are embodies in the process of development and implementation of open educational resources, only when the content of education and information of society will have a common basis, will be spread. Such a process is necessary to create a useful public good.

4 CONCLUSIONS

Open educational resources are a product of the digital world, which has great potential for further achieving UNESCO’s goals in the field of education. They help countries, institutions and teachers to share quality education and materials free of charge. They give teachers a new challenge to integrate digital technology into their courses and programs, and enable students to access quality content offline. They are an incentive for teachers, students and institutions to work together to create original learning material. The creation of open educational resources by future teachers during pedagogical practice provides an opportunity not only to get a great practice of creating e-learning tools. They allow implementing in practice the acquired theoretical knowledge of the theory of learning, methods of teaching specialized subjects, a creative vision of solving urgent problems of learning. The conducted experiment revealed the potential of such a practical activity as the creation of open electronic educational resources. Improving interaction between participants of educational activities by means of information and communication technologies. Launching the process of creating digital educational content of a new type.

Strategic policies need to involve OER in education systems at the state level to be developed, encouraging educational institutions to make full use of these developments to achieve global development goals. Prospective areas of research are the study of the quality of created open electronic educational resources and their classification.

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Methodological Aspects of Utilization of Immersive Technologies in Japanese Language Learning for Future Language Teachers

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Keywords: Immersive Technologies, Augmented Reality, Virtual Reality, Japanese Language Learning, Future Japanese Language Teachers, Blended Learning, Oriental Languages Learning, Distance Learning.

Abstract: The article is dedicated to methodological aspects of utilization of immersive technologies in Japanese language learning for future language teachers. We analyzed the use of virtual and augmented reality for supporting and organizing Japanese language learning for future language teachers and identification of the main approaches to the usage of augmented reality in language learning. It is concluded that immersive technologies provide a new paradigm of teaching materials, which has a positive impact on the formation of basic and professional competencies of future Japanese language teachers; it can be effective when used in blended learning that combines distance, online, traditional and self-directed learning of Oriental languages. Prospect for further research is the creation of guidelines for the use of immersive technologies for teaching Oriental languages at different levels of the training of future language teachers.

1 INTRODUCTION

The development of information and communication technologies and their active use in various fields of human activity require young people to adapt to new ways of working, living, and interacting.

Current technologies, used for various professional activities, are of great importance for implementation in the educational process, in particular general education institutions, and are necessary for the competitiveness of young people in the global labor market.

In this regard, immersive technologies are becoming increasingly popular in education (3, 2020). Immersive Technologies (ITs) are influencing many areas of human life in the 21st century: trade, tourism, the interaction and perception of digital information and media, science and education. Immersive technologies are technologies that extend reality or create a new reality by leveraging the 360° space. Makransky and Petersen (Makransky and Petersen, 2021) note that the use of these technologies can improve real-world visualization through virtual objects, graphics, and object recognition technologies.

ITs include Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), which are now used in many and varied fields – ranging from games and entertainment; theater and live events; museums and cultural heritage; marketing, advertising and tourism; architecture, product development and design; to simulation and health care (Buttussi and Chittaro, 2018).

The ITs are mostly used in education for science classes for covering human anatomy (Anatomy AR-VR, AR Human Anatomy, The Brain AR App, etc.), the universe (Planets AR, EARTH AR Poster, etc.), chemical reactions (MoleculAR, Chemistry Augmented Reality Education Arloon, etc.) and plant anatomy contents (Froggipeadia, Arloon Plants AR, etc.). However, this paper deals with ITs place in foreign language education, in particular Japanese language learning. Since a very limited number of applications and ITs content are available for language education, we will describe all possible uses ITs (VR and AR) for Japanese language learning and the experience of students.

2 THEORETICAL BACKGROUNDS

The multifunctionality of ITs and unfamiliarity of "virtual reality" became the impetus for the actualiza-

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tion of the concept of "virtual", the rapid expansion of its scope; the impetus for the conceptual design of the idea of virtual reality in various fields of human activity.

AR has great potential in the field of language education (Amelina et al., 2022), as it performs such functions as contextual visualization (that is presentation of virtual information in an extended context) and interactivity of learning (that is the embodiment of interaction with virtual content). VR is a virtual 3D world that allows users to get visual simulations and feel immersed in a time and space-free environment.

The popularization of the phrase "virtual reality" belongs to Jaron Lanier in the late 1980's (Firth, 2013).

At the present stage of information and communication technologies (ICT) development Immersive technologies based on VR can be represented as (figure 1):

- VR with full immersion, which provides realistic simulation of the virtual world with a high degree of detail (for example, the game zone Virtual Shooter);
- Partial immersion VR, consisting of VR and real-world attributes, is performed by embodying computer graphics objects in a reality scene (for example, a flight simulator) (de Oliveira et al., 2020);
- VR without immersion, related to the virtual experience with a computer, when you can control individual characters or their actions in the software, while the environment does not interact directly with the user (for example, World of WarCraft, ReHabgame);
- VR with group work, which represents a three-dimensional virtual world with elements of a social network (for example, Minecraft already has a version of virtual reality, which is supported by Oculus Rift and Gear VR helmets) (Monahan et al., 2008);
- CAVE (Cave Automatic Virtual Environment), which was developed by students of University of Illinois in 1995, and is a three-dimensional stage with wall projections (de Oliveira et al., 2020; Chang et al., 2012).

The term "Augmented Reality" was created by aircraft engineers Caudell and Mizell (Caudell and Mizell, 1992) in 1990. They developed the head-mounted displays as equipment for electricians to be used during assembling complicated wiring harnesses (Arth et al., 2015).

Nelson (Nelson, 2012) singles out augmented reality as important element of "Bring your own device" (BYOD) approach, which stands for usage of mobile devices by teachers and students in classroom for learning purposes.

Calo et al. (Calo et al., 2015) define Augmented Reality as "...a mobile or embedded technology that senses, processes, and outputs data in real-time, recognizes and tracks real-world objects, and provides contextual information by supplementing or replacing human senses".

AR is a technology that incorporates digital information such as images, video, and audio into real-world spaces, giving the possibility to blend virtual environment with reality (Kiv et al., 2019). Users of this technology have a chance to learn in immersive, computer-generated environments through realistic sensory experiences.

The mobile AR applications can be grouped into three categories depending on their purpose, place of use, and usability, such as marker-based, creation-based, and marker-less AR (figure 2).

It should also be noted that some apps in these categories may have both creation-based and marker-less features. However, if an app is a marker-based one, it can't have a marker-less AR feature because it could only work with flashcards.

We can distinguish the following types of mobile AR (Soroko, 2021):

- marker-based, that uses a camera and a special visual marker, such as a QR code (quick response code);
- creation-based, that uses the browser-based platform allows users to upload 3D files and edit them with comments, detailed instructions and animations via a drag-and-drop interface;
- marker-less, that uses Global Positioning System (GPS); the most common uses are to mark destinations, search for the right number, such as a café or office, or in location-oriented apps.

Researchers identify the following positive effects of AR on students' foreign language learning: improving the effectiveness of their language skills in professional translation, increasing motivation to learn, and involving students in cooperation with each other, as well as with native speakers of the foreign language studied (Cheng et al., 2010; Chik, 2014; Kiv et al., 2019; Frazier et al., 2018; Makransky and Petersen, 2021; Geng and Yamada, 2020a,b; Monahan et al., 2008; Nelson, 2012; Popova, 2017). AR has great potential in the field of language education, as it performs such functions as contextual visualization (i.e. presentation of virtual information in an extended context) and interactivity of learning (i.e. the embodiment of interaction with virtual content).

Review of the literature by Viberg and Grönlund

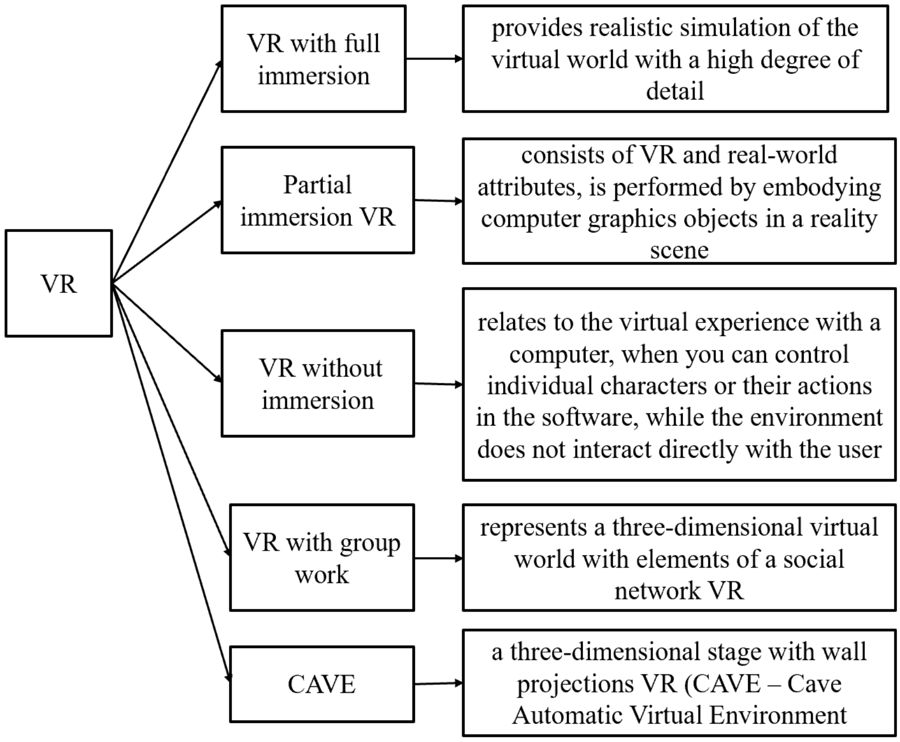

Figure 1: The five categories of VR.

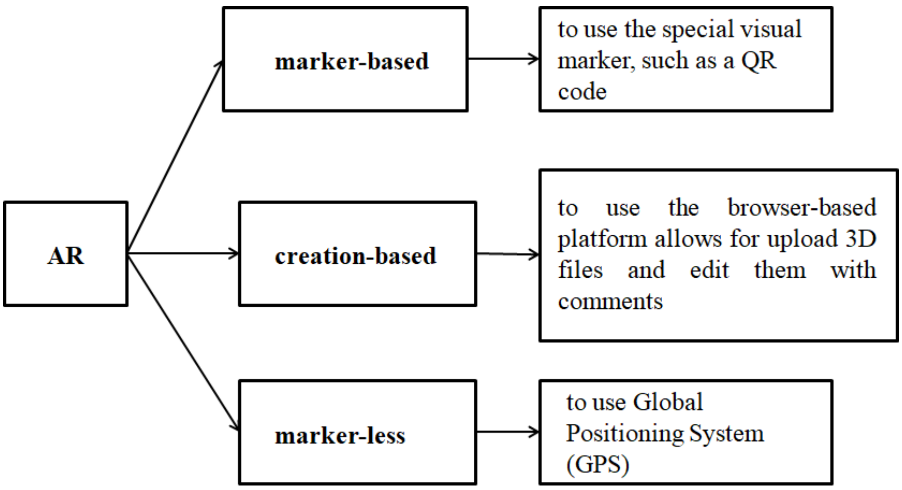

Figure 2: The three categories of mobile AR.

(Viberg and Grönlund, 2013) states that Mobile Assisted Language Learning (MALL), as the mobile technology which can be adapted to support language learning, is applied in a number of ways but generally focuses on vocabulary acquisition, listening and speaking skills and language acquisition while grammar learning, pronunciation and writing skills were underrepresented in the application of MALL.

Hein et al. (Hein et al., 2021) analyzed 2507 sources and selected 54 articles for the period from 2001 to 2020, relating to the immersive technology's role in students' foreign language learning.

They found that most of these studies concerned the comparative analysis of traditional blended learning methods, which included the use of VR and AR. The main characteristics of these technologies, that support the foreign language learning, are to promote the vocabulary learning, to development of speaking skills and intercultural competence, students' motivation to foreign language learning, to overcome anxiety and discomfort when communicating in a foreign language. The advantage of learning with AR over traditional teaching methods is in a fact that the student is given the opportunity to feel, rather than imagine, the subject, situation, scenario, which cannot be demonstrated or described in traditional teaching methods.

The purpose of the article is to analyze the use of immersive technologies for supporting and organizing the Japanese language learning for future language teachers, and identification of the main approaches to the use of immersive technologies in Japanese language learning.

3 RESEARCH METHODS

To achieve the purpose of our study and also to clarify the problem of utilizing the immersive technologies for future Japanese language teachers we used the following methods: systematic and comparative analysis of pedagogical, psychological, philosophical, sociological works, methodological and specialized literature; analysis of the pedagogical experience of usage of immersive technologies at the Institute of Philology of Taras Shevchenko National University of Kyiv at lecturers and seminars of study of “Japanese characters”; synthesis and generalization to formulate the main points of the study; interpretation of the research results by student survey and comparative analysis of exam results in Japanese lexicology of students who will study language using ICT and immersive technologies with exam results of students who will study language using ICT but not using immersive technologies. The research hypothesis is based on the assumption that the training of future Japanese language teachers will be effective if the following pedagogical conditions are implemented: activating the motivation of future foreign language teachers to carry out project activities in the use of immersive technologies as didactic tools for learning Japanese; improving the content of training future foreign language teachers in order to form their knowledge about the use of information and communication technologies and immersive technologies for learning Japanese.

4 RESULTS AND DISCUSSION

Scientists attach special importance to the use of augmented reality in the study of Oriental languages by students, in particular future teachers of Japanese language.

They note that the preparation of future teachers of Oriental languages (including languages with character-based writing, such as Japanese, Chinese) for professional activities is a complex process, as it differs significantly from the study and teaching of any other foreign language (for instance, English, French, German, Italian, Spain, Turkish languages that are also included into educational planning of Institute of Philology of Taras Shevchenko National University of Kyiv).

Researchers recognize the use of ITs as solving the problems of fast, active, correct, and convenient students’ Oriental languages learning (Cheng et al., 2010; Kiv et al., 2019; Frazier et al., 2018; Makransky and Petersen, 2021; Geng and Yamada, 2020a; Nelson, 2012). They note that the use of these technologies can improve real-world visualization with virtual objects, graphics, and object recognition technologies.

Frazier et al. (Frazier et al., 2018) singles out application Google Earth VR and AR for foreign language learning, including Japanese language that allowed users to visit different locations throughout the world; in meanwhile supports their own learning of various studies i.e. history, political studies, international relations, etc.

Google Earth AR includes various numerous instruments, like Mindshow for creation of different new exciting places and using them for role playing (Nelson, 2012). This tool is marker-less, that uses GPS. Scientists focuses their attention on the issue that these instruments are useful for distant language learning, thought should be supervised by teacher.

We should pay attention to the possibility of foreign language learn-ing, in particular Japanese, with the help of this service and others that focus on various fields of science in Japanese.

We want to pay attention to augmented reality services that support the teaching of various disciplines. Special emphasis should be placed on training in the fields of STEM training, which involves integration between the disciplines of natural sciences, technological sciences, engineering and mathematics (Soroko, 2021; Lukychova et al., 2022; Mintii, 2023). For example, many augmented reality applications offer materials in Japanese (BioDigital Human 3D anatomy, 3D Anatomy Learning – Atlas, GeoGebraAR, Planets AR, etc.). It is clear that the vocabulary of these applications is designed for students who have language skills at the level of B1 and above.

Geng and Yamada (Geng and Yamada, 2020a,b) offer their experience of usage of AR generators to create markers based on Kanji characters as QR codes. They made an AR compound verb learning system to support learning of Japanese verbs. Under this system, students can scan a card with the Kanji characters of a particular verb, and thus watch an animation that displays the corresponding action with the card through the smartphone screen in the application. “In this system, the meanings of verbs, including both single verbs and compound verbs, were represented by 3D animations created using Maya, according to the image schemas of the verbs. Maya is a 3D computer graphics software, and it is used to create interactive 3D animations and visual effects”. The application was developed by scientists using Unity 3D and Vuforia. In addition, the combination function was proposed based on a combination of two cards with the corresponding Kanji characters (V1 + V2) to facilitate the effective study of complex verbs by students. Researchers have proven that approach involving AR in Oriental languages learning is the most effective for students compared to the traditional method.

Platte et al. (Platte et al., 2020) suggests using ARTranslate (https://github.com/benpla/ARTranslate) to foreign language learning using augmented reality. ARTranslate is software that recognizes up to 1,000 objects in a user’s environment using the Convolutional Neural Networks (CNN) method and names them accordingly. Objects are superimposed on 3D information in different languages, using AR. The user can open the surrounding everyday objects in any language by switching languages in the ARTranslate application settings. The software runs on iOS version 12.

We surveyed students (31 students took part in this survey) about their attitudes toward the use of ITs to improve the quality of Japanese language learning. We proposed the following statements, that students should be designated as “Strong disagree”, “Disagree”, “Neither agree”, “Agree”, “Strongly agree”: “I have a clear understanding of what ITs are and how I can it integrated it into my own education process”, “I have heard about ITs in foreign language learning”, “I have discussed with my friends about ITs for foreign language learning”, “I have experience when teachers use approaches with ITs for Japanese language learning”.

According to the questionnaire analysis of the attitudes and understanding of ITs in Japanese language learning process, it was found out that students understand what augmented reality is, but have not used these tools to learn Japanese: “I have a clear understanding of what ITs are and how they can be integrated into my own education process”: Strongly disagree – 8% students; Disagree – 17% students; Neither agree nor disagree – 32% students; Agree – 39% students; Strongly agree – 4 % students; “I have heard about ITs in foreign language learning”: Strongly disagree – 3%; Disagree – 16%; Neither agree nor disagree – 28%; Agree – 49%; Strongly agree – 4%.

We showed students the options for using such IM for different levels of Japanese language learning (Japanese language learning levels are available at https://www.jlpt.jp/) as:

- ITs for not language learning such, as BioDigital Human 3D anatomy, 3D Anatomy Learning – Atlas, GeoGebraAR, Planets AR, Google Earth AR and VR;
- ITs for language learning such, as Easy japanese news, Triplens, ARTranslate;
- Platforms for creating web projects with AR elements such, as BlippAR and Google ARCore, and with VR such, as CoSpaces, that for students to create their own examples of language learning.

This tools were proposed to use by 3rd year students of Bachelor program in study “Japanese Kanji characters”, 4th year students of Bachelor program in study “Linguistic Tradition of Japan”, 4th year students of Bachelor program in study “Japanese Language Etiquette”, 2nd year students of Bachelor program in study “Japanese language: Practical Course for Translators”, 1-2 courses year students of Bachelor program in study “Oriental Language (Japanese language)” of the Department of Languages and Literatures of the Far East and Southeast Asia of the Institute of Philology of Taras Shevchenko National University of Kyiv.

After classes and self-study of students with the help of ITs, a survey was conducted as experts (27 students) on the choice of approaches to the study of Japanese characters. They were asked to use the Likert Scale method to rank approaches to language learning according to their importance – from ineffective (1 point) to very effective (5 points).

Approaches to the study of Japanese Kanji characters were determined according to traditional methods (direct method, grammar-translation method, audiolinguistic method, cognitive method) and considering the use of information and communication technologies, in particular immersive technologies.

Our students were offered the following approaches to Japanese Kanji ( ) learning for the assessment:

- use of electronic dictionaries;
- search and use of Internet resources;
- usage of online educational literature;
- creation and application of their own associations (offline);
- handwriting Kanji characters (offline);
- use of AR and VR applications;

Table 1: The results of students' survey on their understanding of ITs in Japanese language learning process (2020-2021).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have a clear understanding of what ITs are and how they can be integrated into my own education process	8%	17%	32%	39%	4%
I have heard about ITs in foreign language learning	3%	16%	28%	49%	4%
I have discussed with my friends about ITs for foreign language learning	18%	35%	14%	33%	0
I have experience when teachers use approaches with ITs for Japanese language learning	8%	43.6%	35.5%	12.7%	0
Total ($N = 31$)					

- creation of their own educational materials on the basis of ITs.

The results of this questionnaire are presented in table 2 "Results of students' questionnaires on their opinion on the choice of approaches to the Japanese Kanji characters learning".

Thus, the results of students' questionnaires about their opinion on the choice of methods for studying Japanese Kanji characters showed that the most necessary for them was an approach based on the creation of students' own learning materials based on augmented reality (5). According to interviews with students who wished to comment on their answers, this was motivated by the creation of an augmented reality Kanji characters that would be of interest to other students and reflect the most difficult cases in Oriental language translation practice. It is also important to use electronic dictionaries (4.8), in particular, most AR applications are focused on the assimilation of foreign language vocabulary by users (for example, Triplens, ARTranslate, etc.).

To achieve our goal, we created organized and implemented educational content (training course) "Information Support of Philological Research in Japanese Studies" for philologists-bachelors of Oriental languages, based on the use of immersive technologies. It consists of the following modules: Module 1 "Theoretical foundations of the use of ICT in the study of foreign languages", covering topics such as "Basic concepts", "Methods of using ICT in the study of foreign languages", etc .; Module 2 "Electronic educational resources for learning a foreign language (Japanese)", which covers topics such as "Electronic dictionaries and their practical use in translation and teaching", "Online tests in foreign languages: the use of international test systems and the creation of personal tests using web services"; Module 3 "Immersive technologies of learning a foreign language (Japanese)", which covers such topics as "Model of learning a foreign language using virtual reality", "Model of learning a foreign language using augmented reality"; Module 4 "Research activities on the establishment of Electronic Educational Resources for the translation and teaching of Japanese".

Students were divided into groups according to their desire to learn language using ICT, including immersive technologies, which are present in separate modules of the course "Information Support of Philological Research in Japanese Studies", which is part of a series of linguistic disciplines that form the philological basis of the bachelor's program at the Institute of Philology of Taras Shevchenko National University of Kyiv at different lecturers and seminars.

To the question "Do you want to learn a language using immersive technologies?" 21 students answered, 8 students did not take an active part in the survey and training due to extreme conditions (military action in Ukraine). As a result of the survey, two groups were created: 11 students who will study language using ICT and immersive technologies, and 10 students who will study language using ICT but not using immersive technologies. A group of students studying "Japanese language and literature" course using ICT and immersive technologies passed the exam with an average of 95 points, a group of students that studied language using ICT, but did not use immersive technology, passed the exam with an average of 85 points only.

5 CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Thus, ITs provide a new paradigm of presentation of educational materials, which has a positive impact on the formation of basic and professional competencies of the future teachers Japanese language. We can indicate the following benefits of using ITs to train future teachers with the Japanese language:

- the usage of ITs makes the learning process more

Table 2: Results of students' questionnaires on their opinion on the choice of approaches to the Japanese Kanji characters learning.

The approaches to Japanese Kanji ( ) learning	Mean values
use of electronic dictionaries	4.8
search and use of Internet resources	4.4
usage of online educational literature	3.2
creation and application of their own associations (offline)	2.9
handwriting Kanji characters (offline)	4.7
use of AR applications	3.8
use of VR applications	3.7
creation of their own educational materials on the basis of augmented reality	5

visual and mobile;

- the usage of ITs increases the interest and motivation of students to learn the language;
- ITs improve the learning process, which uses innovative forms of work with students;
- ITs use the conditions for the formation and development of creative abilities of students;
- these technologies and approaches contribute to the support of the linguistic and cultural aspect in student learning.

The following approaches to the use of ITs for the study of Japanese by students should be distinguished: 1) the use of specialized applications for language learning; 2) the use of applications for the study of other disciplines (anatomy, biology, computer science, astronomy, etc.), using a foreign language learning by students; 3) creation of personal examples by students for learning a foreign language with the help of special Web platforms.

ITs can be effective if they are used in blended learning that combines distance, online, traditional and self-directed learning of Oriental languages.

Author is planning to continue the longitudinal research, analyzing the statistical data of students' academic performance, expanding the research to several other subjects (taught by Taras Shevchenko National University of Kyiv) during the academic year of 2022-2023.

Prospects for further research are the creation of guidelines and manuals on the use of immersive technologies for the study of prefabricated languages at different levels of training of future teachers of Japanese language.

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Results of Experimental Work to Check the Effectiveness of the Method of Using Geoinformation Technologies

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Abstract: A modern person cannot live without the Internet, namely without digital technologies. The constant growth of information has led to the fact that there are many opportunities for digital transactions in various professions, one of them is a mining engineer. The process of reforming this profession requires more effective use of digital technologies in ecology, providing information management through introduction of innovations, creation of databases, programs, implementation of which will improve the quality of management of innovation processes. One of the promising directions of solving this problem is the use of geoinformation technologies. The article presents the results of the formula stage of the pedagogical experiment on checking the effectiveness of the method of using geoinformation technologies as a means of forming ecological competence of future engineers of the mining profile using the Pearson's χ^2-criterion, the Kolmogorov-Smirnov's λ-criterion and Fischer's ϕ^*-criterion. It is clear that the distribution of students in experimental and control groups by the level of environmental competence is statistically significant, due to the application of the developed methodology. In continuation of scientific search on this problem, it is expedient in the direction of development of methodical system of training of geoinformation technologies in students of specialty 122 "Computer sciences".

1 INTRODUCTION

The use of information and communication technologies in education at the present stage, undoubtedly, can be a catalyst in the solution of important social problems of increasing accessibility and quality of educational resources and services. The constant increase in the amount of information and the speed of transmission of information flows through digital communication networks remains as important as ever. Information technology has reached an unprecedented level of sophistication. Everything has changed with the arrival of the Internet in every home. Modern people of any age can no longer do without the Internet. The information space provides a lot of opportunities to perform all possible operations while staying in the office or an apartment.

Many professions are obliged to their appearance in computer, they would simply not appear without the creation of digital technologies.

If we consider the profession of an engineer – a person who is engaged in engineering activity, i.e., in particular, different researches, designing, development of various documentation and conducting of a huge number of calculations, for very complex calculations, which even when using the computer equip-

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ment's capabilities are hours and days, but without its use or would be decided for many months, or could not be realized at all (Semerikov et al., 2021).

Legal and organizational principles of mining engineering activity are defined by the Mining Law of Ukraine (zak, 2020), according to which the state policy in mining industry is based, in particular, on the principles of improvement of ecological safety of mining enterprises and provision of training of personnel of high qualification for mining industries. The level of ecological state in the country has become dangerous not only for the present, but to a greater extent for future generations. The negative impact of harmful environmental factors on the human body is the deterioration of the health of the nation.

The main environmental requirements in the field of mining work, prevention of harmful effects of mining work and ensuring environmental safety during mining work are not only the subject of consideration of separate articles of the Ukrainian Mining Law, but also the obligatory components of preparation of an environmentally competent engineer of the mining profile.

The problem of forming the environmental competence of the practitioner has been the subject of research at different levels, such as (Orr, 1992; Bofinger, 2006; Harvey, 2002).

Various aspects of professional training of mining engineers were investigated in (Bidiuk, 2000; Medvedovska, 2012; Derevianko, 2013; Morkun et al., 2014; Hryshchenko and Morkun, 2015; Morkun et al., 2017).

The problem of using information and communication technologies in training of mining engineers of the mining profile is especially urgent today. The process of reform requires more efficient use of digital technologies in the environment, providing information management through introduction of innovations, creation of databases and programs, which implementation will help to improve the quality of management of innovation processes. One of the promising directions of solving this problem is the use of geoinformation technologies.

An analysis of the recent studies and publications on the investigated issues reveals that the use of modern geoinformation technologies was investigated by Kulibekova (Kulibekova, 2008), Hryshchenko and Morkun (Hryshchenko and Morkun, 2015), Morkun et al. (Morkun et al., 2014, 2017) and other scientists.

However, the peculiarities of using geoinformation technologies in teaching and conditions of their introduction into the state administration of ecology and mining in scientific literature are not covered enough.

One of the promising ways of solving this task is application of geoinformation technologies that allow considering the location of a mining enterprise's facilities, mineral storages and rock dumps on any required detail level; monitoring discharged water and air purification while introducing advanced mining methods; simulation of a sanitary protection area between a mining enterprise and residential buildings in accordance with the law; ensuring complex steps for preventing subsidence, submergence, salting, salting, draining and pollution of the surface by industrial wastes; preventing unfavourable influence of water removal on the level of ground waters and surface water objects; monitoring the decreased pollutant emissions in the mining industry and introducing accident prevention measures associated with volley and immediate emissions and releases, etc.

The **purpose** of the article is to highlight the results of experimental work on the verification of effectiveness of the method of using geoinformation technologies as a means of forming ecological competence of realization of future engineers of the mining profile using the Pearson's χ^2-criterion, Kolmogorov-Smirnov's λ-criterion and Fischer's ϕ^{**}-criterion.

At the time of scientific and pedagogical workers should be ready to use digital technologies in teaching, which help to define the following approaches of students of engineering specialties formation of motivation, intensification of cognitive activity, professional orientation and creativity in teaching, remote complex application of methods and means, and also assessment of quality and systematization of control.

2 MATERIALS AND METHODS

In order to achieve the set goal, the following research methods were used: theoretical analysis of different views of scientists; statistical, generalization of results.

3 EXPERIMENTS

The purpose-oriented creation of a future mining engineer's environmental competence using geoinformation technologies occurs in the special course, Environmental Geoinformatics. The three-component structure of its method system is the central element that determines the training content and goals which, together with the training technology are made concrete in the special course, Environmental Geoinformatics. The special course goal is to create environmental competence through specific knowledge and skills, thereby, providing students with the opportunity to use geoinformation technologies both in their learning activities and then, later, in their professional lives. The special course goals are determined by the following tasks: introduction of basic models and methods of geoinformatics, mastering the modern means of geoinformation technologies in one's professional activities, and the formation of environmental research skills using geoinformation technologies.

The basic forms of training that use geoinformation technologies include lectures, demonstrations, frontal laboratory works, laboratory and calculation "immersion" practicals, seminars, practical classes, projects, consultations, training excursions, simulation games, and independent work. Among these training methods, the leading ones are demonstrative examples, reasonably chosen tasks, a calculation experiment, and projects.

The choice of training (with regard to geoinformation technologies in particular) is determined by the peculiarities of its creation on different stages. In the first stage geoinformation technologies such as cartographical software (Google Maps, Google Earth) and Internet sources with geographical and environmental data (with regional specific features in the field of professional activity) are used. In addition, in the course, "Informatics", students learn how to deal with electronic tables and databases as means of working with table space and coordinated data; they also use search engines to gather geographical and environmental data and to put this into a system. Computer mathematics systems (MATLAB as the basis of the multifunctional GIS Mapping Toolbox) are also used. Training used in the second stage of creating a future mining engineer's environmental competence are divided into general (course books, Internet sources, means for creating, storing, processing text, table and graphic data, and Moodle) and specific purposes (cartographical software such as Google Maps and MapInfo; multifunctional such as Mapping Toolbox and QGIS; and mining and environmental GIS such as Datamine Studio and Geoblock). At the third stage of creating environmental competence, all of the geoinformation technologies mastered in the previous stages are used; however, special attention is paid to the application of mining and environmental GIS (Datamine Studio, Geoblock, K-MINE, etc.).

The pedagogical experiment results were processed and the efficiency of the developed methods of training mining students was assessed using mathematical statistical methods. As the research aimed to determine differences in feature distribution (the level of maturity of the environmental competence) when comparing two empirical distributions (students in the control and experimental groups) (Sidorenko, 2003, p. 34), either the Pearson's χ^2-criterion, or the Kolmogorov-Smirnov's λ-criterion and ϕ^{**}-criterion (Fischer's angular transformation) can be used.

The Fischer's angular transformation was calculated according to table 1:

1. Before the formation stage of the pedagogical experiment:
   - in the control groups, 66 students (88%) had low and medium maturity levels of environmental competence and 9 students (12%) had sufficient and high levels;
   - in the experimental groups, 64 students (85.33%) had low and medium levels of maturity of environmental competence and 11 students (14.67%) had sufficient and high levels.
2. After the formation stage of the pedagogical experiment:
   - in the control groups (CG), 60 students (88%) had low and medium maturity levels of environmental competence and 15 students (20%) had sufficient and high levels;
   - in the experimental groups (EG), 40 students (53.33%) had low and medium maturity levels of environmental competence and 35 students (46.67%) had sufficient and high levels.

The experimental data completely met the restrictions of the Fischer's angular transformation:

a) any compared fraction is not equal to zero;

b) the number of observations in both selections is more than five, which enables any comparison.

Let us formulate hypotheses (H).

H_0: The fraction of students whose environmental competence is at the sufficient and high levels was not greater in the experimental groups than in the control ones.

H_1: The fraction of students whose environmental competence is at the sufficient and high levels was greater in the experimental groups than in the control ones.

The below formula was applied:

$$\phi^*_{emp} = 2\left|\arcsin\sqrt{P} - \arcsin\sqrt{Q}\right|\sqrt{\frac{n_1 n_2}{n_1+n_2}},$$

where P and Q are the percentage of students whose environmental competence is sufficient or high, $n_1 = n_2 = 75$ is the number of students in the control and experimental groups. Therefore:

1. Before the formation stage of the pedagogical experiment: $\phi^*_{emp} = 0.481$.

Table 1: The comparative distribution of students by the level of environmental competence maturity in the control and experimental groups.

Level	Before the formation stage				After the formation stage			
	CG		EG		CG		EG	
	Number	%	Number	%	Number	%	Number	%
The first component: Understanding and perception of ethical norms of behavior with regard to other people and nature (principles of bioethics)								
low	9	12%	8	10.67%	3	4%	1	1.33%
medium	18	24%	25	33.33%	12	16%	2	2.67%
sufficient	45	60%	36	48%	55	73.33%	50	66.67%
high	3	4%	6	8%	5	6.67%	22	29.33%
The second component: Environmental literacy								
low	28	37.33%	29	38.67%	14	18.67%	11	14.67%
medium	23	30.67%	24	32%	24	32%	22	29.33%
sufficient	20	26.67%	15	20%	32	42.67%	27	36%
high	4	5.33%	7	9.33%	5	6.67%	15	20%
The third component: A basic knowledge of ecology to be applied in one's professional activities								
low	28	37.33%	29	38.67%	14	18.67%	11	14.67%
medium	23	30.67%	24	32%	24	32%	22	29.33%
sufficient	20	26.67%	15	20%	32	42.67%	27	36%
high	4	5.33%	7	9.33%	5	6.67%	15	20%
The fourth component: The ability to apply scientific laws and methods to assess the condition of the environment, take part in environmental operations, perform an environmental analysis of steps in the field of activity, and to work out plans to reduce technogenic pressure on the environment								
low	65	86.67%	66	88%	61	81.33%	24	32%
medium	8	10.67%	6	8%	11	14.67%	31	41.33%
sufficient	2	2.67%	3	4%	3	4%	18	24%
high	0	0%	0	0%	0	0%	2	2.67%
The fifth component: The ability to ensure sustainable activities, and methods for the rational and complex development of georesources								
low	65	86.67%	67	89.33%	67	89.33%	36	48%
medium	7	9.33%	6	8%	6	8%	26	34.67%
sufficient	3	4%	2	2.67%	2	2.67%	10	13.33%
high	0	0%	0	0%	0	0%	3	4%
Environmental competence								
low	35	46.67%	41	54.67%	23	30.67%	13	17.33%
medium	31	41.33%	23	30.67%	37	49.33%	27	36%
sufficient	9	12%	10	13.33%	15	20%	28	37.33%
high	0	0%	1	1.33%	0	0%	7	9.33%

2. After the formation stage of the pedagogical experiment: $\phi^*_{emp} = 3.532$.

The critical value of ϕ^*_{cr} corresponds to the level of statistical significance established in psychological and pedagogical investigations, and is equal to

$$\phi^*_{kr} = \begin{cases} 1.64 \ (p \leq 0.05) \\ 2.31 \ (p \leq 0.01) \end{cases}$$

Then:

1. Before the formation stage of the pedagogical experiment, the inequality $\phi^*_{emp} < \phi^*_{cr}$ is realized and this provides the evidence for accepting the zero hypothesis H_0 and stating that before the formation stage of the pedagogical experiment, the difference in the maturity level of students' environ-

mental competences from the control and experimental groups is statistically insignificant (figure 1): i.e., the control and experimental groups before the formation stage of the pedagogical experiment coincide with the significance level of 0.05.

2. After the formation stage of the pedagogical experiment the inequality $\phi^*_{emp} < \phi^*_{cr}$ is realized thereby providing the evidence to reject the zero hypothesis H_0 and accept the alternative H_1. Considering the fact that $\phi^*_{emp} = 3.532 > 2.31 = \phi^*_{0.01}$, we have obtained the following result: the validity of differences in the experimental and control groups after the formation stage of the pedagogical experiment is 0.99 (figure 2).

4 RESULTS

Therefore, after the formation stage of the pedagogical experiment, students from the control and experimental groups have statistically significant differences with regard to the sufficient and high maturity levels of environmental competence that result from the application of the suggested methods.

To find out the difference in distribution of maturity levels in environmental competence, we applied the Pearson's χ^2-criterion.

In our research, the samples are random and independent. Considering the fact that intervals with zero frequencies are unacceptable and not less than 80% of frequencies should be more than 5, the "sufficient" and "high" levels were united. The measurement scale is the one with $C = 3$ levels (1 is "low", 2 is "medium", 3 is "sufficient and high"). One independent condition was imposed and the number of freedom degrees was $\nu = C–1 = 2$.

The zero hypothesis was H_0 and therefore, the probability of the control group students ($n_1 = 75$) and those of the experimental one ($n_2 = 75$) getting into each of i ($i = 1,2,3$) categories is equal: i.e., H_0: $p_{1i} = p_{2i}$ ($i = 1,2,3$), where p_{1i} is the probability of maturity of the control group's environmental competence on the i level ($i = 1,2,3$) and p_{2i} the probability of formation of the experimental groups' environmental competence on the i level ($i = 1,2,3$).

The alternative hypothesis implies H_1: $p_{1i} \neq p_{2i}$, at least for one of C categories.

The value of χ^2 is calculated by the formula:

$$\chi^2 = \frac{1}{n_1 n_2} \sum_{i=1}^{C} \frac{(n_1 Q_{2i} - n_2 Q_{2i})^2}{Q_{1i} + Q_{2i}}$$

where Q_{1i} is the number of the control group participants with the environmental competence formed at the i level; Q_{2i} is the number of the experimental group participants with the environmental competence formed ar the i level.

Let us denote

$$S_{12i} = \frac{(n_1 Q_{2i} - n_2 Q_{2i})^2}{Q_{1i} + Q_{2i}}$$

Calculation results of the given samples are in table 2.

Table 2 shows that the χ^2 values of the freedom degrees number provides the critical value of the statistics: the significance level of $\alpha = 0.05$, $\chi^2_{0.05} = 5.99$; the significance level of $\alpha = 0.01$, $\chi^2_{0.01} = 9.210$.

As before the formation stage of the pedagogical experiment the value is $\chi^2 < \chi^2_{0.05}$ ($1.859 < 5.991$), it does not occur in the critical zone. The acceptance of the hypothesis, H_0, reveals that before the formation stage of the pedagogical experiment, the control and experimental groups with a significance level of 0.05 are not different in the three formation levels of environmental competence.

The calculation of the χ^2 criterion for the experimental and control samples, after the formation stage of the pedagogical experiment, reveals that $\chi^2 > \chi^2_{0.05}$ ($12.340 > 5.991$) and $\chi^2 > \chi^2_{0.01}$ ($12.340 > 9.210$). It is the reason for rejecting the zero hypothesis H_0. Acceptance of the alternative hypothesis H_1 involves stating that the samples have statistically significant differences with the significance level of 0.01: i.e., the developed methods of applying geoinformation technologies to training future mining engineers enhance the maturity level of their environmental competence.

To find out the level of maximum differences, we checked the samples according to the Kolmogorov-Smirnov's λ-criterion, which is not parametric and applied if:

- samples are random and independent;
- categories are arranged by an increasing or decreasing order.

The given conditions are fulfilled for the obtained samples and the λ-criterion can be applied to assess the deviation of distribution in the experimental groups and the control groups in all four levels.

Let us denote $F(x)$ as the unknown distribution function of probabilities with regard to the maturity level of a future mining engineer's environmental competence in the control groups and $G(x)$ as the unknown distribution function of probabilities in the experimental groups.

The zero hypothesis implies H_0: $F(x) = G(x)$. The alternative hypothesis implies H_1: $F(x) \neq G(x)$. When the hypothesis H_0: $F(x) = G(x)$ is fulfilled, the deviation $D = \sup_x |G(x) - F(x)|$ is small and when the hypothesis is not fulfilled, this deviation is great.

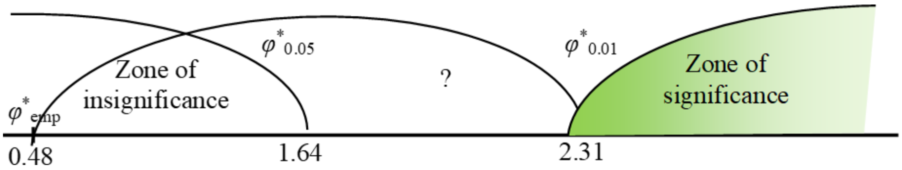

Figure 1: The significance axis for the ϕ^*-criterion before the formation stage of the pedagogical experiment.

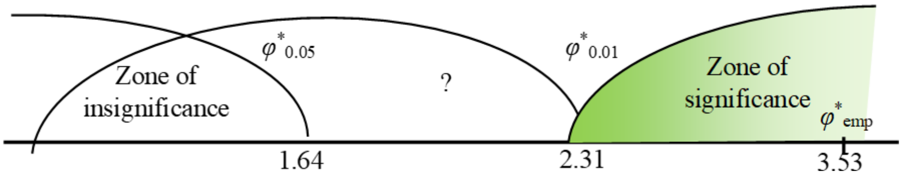

Figure 2: The significance axis for the ϕ^*-criterion after the formation stage of the pedagogical experiment.

Table 2: Calculation of χ^2-criterion.

i	Before the formation stage			After the formation stage		
	Q_{1i}	Q_{2i}	S_{12i}	Q_{1i}	Q_{2i}	S_{12i}
1 – low	35	41	2664.474	23	13	15625
2 – medium	31	23	6666.667	37	27	8789.063
3 – sufficient and high	9	11	1125	15	35	45000
χ^2			**1.859**	χ^2		**12.340**

The value of the criterion λ is calculated by the formula

$$\lambda = D_{max}\sqrt{\frac{n_1 n_2}{n_1+n_2}},$$

where $n_1 = n_2 = 75$ is the number of students in the control group (CG) and in the experimental group (EG). Under $n_{1.2} > 50$, the limit values are $\lambda_{0.01} = 1.63$, $D_{0.01} = 0.2662$; $\lambda_{0.05} = 1.36$, $D_{0.05} = 0.2221$.

The results of processing the experimental data are given in table 3 (before the formation stage of the pedagogical experiment) and in table 4 (after the formation stage of the pedagogical experiment).

The calculation of Kolmogorov-Smirnov's criterion before the formation stage of the pedagogical experiment results in $D_{max} = 0.08 < D_{0.05}$ and $\lambda = 0.4899 < \lambda_{0.05}$, which accepts the zero hypothesis H_0: $F(x) = G(x)$ with a significance level of 0.05.

After the formation stage of the pedagogical experiment, $D_{max} = 0.2667 > D_{0.05}$ ($D_{max} \approx D_{0.01}$) and $\lambda = 1.6330 > \lambda_{0.05}$ ($\lambda \approx \lambda_{0.01}$) allows the rejection of the zero hypothesis H_0 with a significance level of 0.05 and the acceptance of H_1: $F(x) \neq G(x)$.

Considering the fact that in the experimental groups, environmental competence is formed by the developed methods, one can state that this allowed better results. Therefore, we assume that the suggested hypothesis is experimentally confirmed.

The significance of changes in certain components of the environmental competence in the case of applying geoinformation technologies is determined by Fischer angular transformation (table 5) on the basis of table 2.

The statistic hypotheses are formulated as follows:

- H_0^i: the fraction of students with the i-th component of environmental competence ($i = 1,2,3,4,5$) at sufficient and high levels in the experimental groups was not greater than in the control;
- H_1^i: the fraction of students with the i-th component of environmental competence ($i = 1,2,3,4,5$) at sufficient and high levels in the experimental groups was greater than in the control.

Table 5 reveals that statistically significant changes did not occur when forming two components of the environmental competence: the second and the third ones. It is caused by the fact that the experimental work was conducted while teaching the special course, Environmental Geoinformatics, which was preceded by the course "Ecology" according to the model of applying geoinformation technologies when creating a future mining engineer's environmental competence. When studying the latter, statistically significant changes in the formation level of the second and the third components of the environmental competence were observed.

After the completion of the experimental work, the first component of environmental competence is the most developed, which is explained by the general orientation of mining and geological activity in sustainable industrial development. The fourth and the fifth components of environmental competence re-

Table 3: Calculation of the Kolmogorov-Smirnov's criterion before the formation stage of the pedagogical experiment.

Level	Absolute frequency		Accumulated frequency		Relative accumulated frequency		D
	CG	EG	CG	EG	CG	EG	
0 – low	35	41	35	41	0.4667	0.5467	0.08
1 – medium	31	23	66	64	0.88	0.8533	0.0267
2 – sufficient	9	10	75	74	1	0.9867	0.0133
3 – high	0	1	75	75	1	1	0
D_{max}							**0.08**
λ							**0.4899**

Table 4: Calculation of the Kolmogorov-Smirnov's criterion after the formation stage of the pedagogical experiment.

Level	Absolute frequency		Accumulated frequency		Relative accumulated frequency		D
	CG	EG	CG	EG	CG	EG	
0 – low	23	13	23	13	0.3067	0.1733	0.1333
1 – medium	27	27	60	40	0.8	0.5333	0.2667
2 – sufficient	15	28	75	68	1	0.9067	0.0933
3 – high	0	7	75	75	1	1	0
D_{max}							**0.2667**
λ							**1.6330**

Table 5: The ϕ^*-criterion value for each of the environmental competence components after the formation stage of the pedagogical experiment.

Environmental competence component	ϕ^*	Hypothesis (p)
Understanding and perception of ethical norms of behavior with regard to other people and nature (principles of bioethics)	3.212	$H_1^1(0.01)$
Environmental literacy	0.680	$H_0^2(0.05)$
A basic knowledge of ecology to be applied in one's professional activities	0.818	$H_0^3(0.05)$
The ability to apply scientific laws and methods to assess the condition of the environment, take part in environmental operations, perform an environmental analysis of steps in the field of activity, and to work out plans to reduce technogenic pressure on the environment	4.180	$H_1^4(0.01)$
The ability to ensure sustainable activities, and methods for the rational and complex development of georesources	3.250	$H_1^5(0.01)$

mained underdeveloped at a high level. This is due to the fact that the experimental special course had been suggested much earlier than the special professional subjects aimed at applying scientific laws and methods when assessing the condition of the environment, taking part in environmental operations, conducting an environmental analysis, working out plans to reduce the technogenic pressure of the industry on the environment, ensuring sustainable activities, and mastering methods to facilitate the rational and complex development of georesources.

In spite of this, the statistical significance of changes in the formation of the fourth and fifth components of environmental competence indicates that it is the introduction of professionally-oriented geoinformation technologies (mining and environmental GIS) in the process of training future mining engineers that predetermines the efficiency of the experimental work.

We can draw the conclusion that the application of mining and environmental geoinformation technologies is the major factor when forming environmental competence and their methodologically substantiated application is one of the conditions of training an environmentally competent mining engineer. Therefore, the research hypothesis is confirmed.

The analysis of the experimental work results concluded that the introduction of geoinformation technologies when training future mining engineers created the following conditions:

- sharing information in professional training through the systematic application of geoinformation ICT;
- increasing inter-subject connections between fundamental and professionally-oriented subjects through the integrated content when teaching Environmental Geoinformatics;
- using the research-based approach in training and teaching Environmental Geoinformatics; this is forms organization skills and allows individual and collective investigations to be conducted.

5 CONCLUSIONS

Applying geoinformation technologies to create a future mining engineer's environmental competence requires a system of interrelated methods and teaching methods to realize these technologies at all stages of creating competence. the authors have analyzed sources that investigate the problems of environmental competence formation and the of geoinformation technologies in training. this research also improves the system of competences and examines the geoinformation technology used in the education process.

The experimental research program aims to check the efficiency of the methods used to apply geoinformation technologies when forming environmental competence was realized in three stages: analytical-ascertaining, designing-searching, and forming-generalizing.

The formation stage of the pedagogical experiment introduced the application of geoinformation technologies to create environmental competence in the special course, Environmental Geoinformatics. In the laboratory lessons of the control groups, multifunctional geoinformation systems were used, while the experimental groups used multifunctional GIS, mining and environmental GIS, and the software component of the methodological complex, "EcoKryvbas". After completing the experimental training, it was found that 49.33% of students in the control groups achieved a medium level of environmental competence maturity. 20% achieved a sufficient level, while in the experimental, 37.33% achieved a suffucuent level and 36% a medium level.

The pedagogical experiment results were processed and efficiency of the developed methods of training mining students was assessed using mathematical statistics. As the research aimed to determine differences in feature distribution (the level of maturity of the environmental competence) when comparing two empirical distributions (students of the control and the experimental groups) (Sidorenko, 2003, p. 34), the Pearson's χ^2-criterion or the Kolmogorov-Smirnov's λ-criterion and ϕ^*-criterion (Fischer's angular transformation) were used.

When using the ϕ^*-criterion, it was found that after the formation stage of the pedagogical experiment, students in both the control and experimental groups had statistically significant differences with regard to their achievement of sufficient and high levels of environmental competence maturity ($\phi^*_{emp} = 3.532 > 2.31 = \phi^*_{0.01}$). The adequacy of differences in the experimental and control groups was 0.99.

The χ^2-criterion was used to calculate the control and experimental samples after the formation stage of the pedagogical experiment revealed that $\chi^2 = 12.340 > 9.210 = \chi^2_{0.01}$ with the adequacy of differences in the experimental and control groups of 0.99 for the 3-level scale. Considering that intervals with zero frequencies were not acceptable and not less than 80% of frequencies were to be more than 5, the levels "sufficient" and "high" were united.

To find the level, on which the differences were the greatest, the samples of the formation stage of the pedagogical experiment were checked by means of the Kolmogorov-Smirnov's λ-criterion. The criterion value, $\lambda = 1.6330 > 1.36 = \lambda_{0.05}$, resulted in the students' differences in the experimental and control groups of 0.95 and $D_{max} = 0.08$, which corresponded to the maximum changes on the low maturity level of environmental competence.

The significance of the changes in environmental competence when applying geoinformation technologies was determined by means of the Fischer's angular transformation. It was found that statistically significant changes did not occur in the formation of the second ($\phi^*_{emp} = 0.680 < 1.64 = \phi^*_{0.05}$) and the third ($\phi^*_{emp} = 0.818$) ($\phi^*_{emp} = 0.818$) components of environmental competence. This was explained by the fact that the second stage of environmental competence formation (the special course, Environmental Geoinformatics) was preceded by the first stage (the special course, "Ecology"), during which the given components were formed. The changes in the rest of the environmental competence components were statistically significant: the first component $\phi^*_{emp} = 3.212$, the fourth component $\phi^*_{emp} = 4.180$, the fifth component $\phi^*_{emp} = 3.250$. The fourth and the fifth components of environmental competence remained underdeveloped due to this fact, and determined the need to conduct the third stage of environmental competence formation. The statistical significance of changes during the formation of the two components indicated that the introduction of profession-oriented geoinformation technologies (mining and environmental GIS) conditioned the efficiency of the experimental research work and its results confirmed the research hypothesis.

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The Creative Path of Academician Myroslav Ivanovych Zhaldak in the Informatization of Secondary and Higher Pedagogical Education in Ukraine

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Keywords: A Prominent Scientist of Ukraine, Academic M. I. Zhaldak, Prominent Specialist in the Field of Informatics, Scientific School of M. I. Zhaldak, Bibliographic Information About M. I. Zhaldak.

Abstract: The article is about a prominent specialist in the field of informatics and methods of its teaching, the founder of a powerful scientific school and research areas, the author of many textbooks and manuals in mathematics and computer science. The stages of his formation as a scientist. Biographical and bibliographic information about him and his scientific achievements are given. The study highlights “First steps in life”, “Beginning of scientific path and management”, “Scientific works and educational materials”, “Scientific and organizational work and awards”, “Formation of the scientific elite of the state”, “Main activities of scientific school M. I. Zhaldak”. The achievements and main directions of functioning of the scientific school of M. I. Zhaldak are analyzed. The influence of the scientific school on the informatization of secondary and higher pedagogical education of Ukraine is determined.

1 INTRODUCTION

Historical and biographical research occupies a prominent place in the history of science and allows to personify the history of its branches, to assess the contribution of scientists, individuals involved in research and organization of science. In the context of biography, the method of organizing biographical information and research tools are important (Liashko, 2013). Therefore, the figure of a prominent Ukrainian computer scientist – Myroslav Ivanovych Zhaldak – was chosen for this study. The personal scientific achievements of M. I. Zhaldak and his students are an invaluable, socially significant contribution to solving the problems of informatization of the education system in Ukraine, humanization of education and humanization of the educational process, fundamentalization of knowledge and providing them with applied, practical significance.

The creation of scientific schools is a good national tradition, which is a consequence of the peculiarities of the cultural and historical development of Ukraine. Trends in modern science, which gave rise to a number of problems, including problems related to the organization of research: creating optimal conditions for the most effective activities of research teams, ways to form and manage them – made relevant the study of the origin and operation of specific scientific schools. “Scientific School” is a community of scientists of different statuses, competencies and specializations who coordinate their research activities, who have contributed to the implementation and development of the research program and are able to actively represent and defend the goals and results of the program (Honcharenko, 2012). Thus, the scientific school is an informal association of scientists whose research is concentrated in the field of ideas created by scientists of high spiritual and intellectual potential. We emphasize that a necessary condition for the creation of a scientific school is the presence of spiritually and intellectually gifted personality of the scientist – the founder of the school (Leshchenko and Yatsyshyn, 2015). The organizer, leader and first initiator of scientific ideas of the school is its leader, and its students and staff form its staff. Such groups have a common ideology, it can be their own methodology and methodology, their own views and

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beliefs about certain facts and phenomena, their own vision of the main path of science. Important is the product of their activities, publication of results, i.e., school publications, which should be published regularly (periodically): thematic collections, monographs, etc. (Zaruba, 2007). The reasons for recording the existence of such a school are three generations of researchers: the founder of the school – his follower – the students of the follower (Marahovsky and Kozubtsov, 2012).

From the works (Honcharenko, 2012; Leshchenko and Yatsyshyn, 2015; Marahovsky and Kozubtsov, 2012; Zaruba, 2007) it can be concluded that the main tasks of the scientific school are: training of scientific and scientific-pedagogical staff; discussion of the main results of dissertations of graduate students, doctoral students, applicants and staff; opposing doctoral and candidate dissertations, preparing responses to abstracts, reviewing curricula, manuals, textbooks, guidelines, collections, etc.; study, generalization and dissemination of advanced interdisciplinary scientific and pedagogical experience; preparation, organization and holding of scientific and practical events of different levels.

Therefore, it is important to generalize the experience of the scientific school, the leader of which is Academician M. I. Zhaldak, and its role in the informatization of secondary and higher pedagogical education in Ukraine.

2 THEORETICAL BACKGROUND

The study analyzed scientific publications and supporting sources in several areas:

1. Publications devoted to the activities of scientific schools (Kremen and Levovitsky, 2012; Franchuk, 2017; Honcharenko, 2012; Marahovsky and Kozubtsov, 2012) and historical and biographical research (Liashko, 2013).
2. The source base of the study were publications about the personality of M. I. Zhaldak. The collection (Bibliographic Index, 2011) on the life and scientific path of M. I. Zhaldak presents the most comprehensive data, but this information now needs to be updated. The sources present certain biographical data (Nahorody, 2022) and memoirs of colleagues of M. I. Zhaldak (Mykhalin, 2010).
3. The training of scientific and scientific-pedagogical staff of the highest qualification for informatization of education is described in works (Leshchenko and Yatsyshyn, 2015; Spirin and Iatsyshyn, 2013; Spirin and Yatsyshyn, 2014; Spirin et al., 2016) which mention the role of M. I. Zhaldak and representatives of his scientific school in this process.

We believe that the significant scientific heritage of Academician M. I. Zhaldak and his students has not been studied enough, and this study is an attempt to summarize the significant contribution of M. I. Zhaldak in the development of informatization of the educational process of secondary schools and universities of Ukraine.

The purpose of the article is to clarify the features of the scientific school of Academician M. I. Zhaldak and its impact on the informatization of domestic secondary and higher pedagogical education.

To perform this study, a set of methods was used:

- theoretical – biographical analysis and systematization to determine the stages of formation of M. I. Zhaldak as a scientist and manager; analysis and generalization to clarify the prerequisites for the creation of the scientific school of M. I. Zhaldak and determine the main directions of its work; concretization and generalization of the provisions shown in the scientific works of M. I. Zhaldak and his students; systematization of materials about the life and scientific achievements of M. I. Zhaldak; comparative method was used to determine the stages of formation and organizational features of the scientific school of M. I. Zhaldak, as well as to identify the importance of experience in training scientific and scientific-pedagogical staff of the highest qualification in the new scientific specialty "Information and Communication Technologies in Education"; bibliometric method for studying the citation of the works of the leader by his students and followers;
- empirical – conducting interviews with graduate students, doctoral students, applicants who performed dissertations under the guidance of M. I. Zhaldak and his students; supervision of training and certification of scientific and scientific-pedagogical staff in specialized scientific councils, which included M. I. Zhaldak.

3 RESEARCH METHODOLOGY

Liashko (Liashko, 2013) found that for a long time (since the XII century) mankind has created the principles and mechanisms of practical or normative classification of people who worked in the field of science. The basis of such a classification is a person's contribution to the development of a particular branch of science on a formal basis – a degree, academic or academic title, acquired in the normatively defined manner. That is, it is the fixation of certain stages of normative recognition of a person's scientific achievements.

As already mentioned, each time, epoch, period of history is associated with the relevant people who influenced the development of science in a particular field, one of them is M. I. Zhaldak. Throughout his life, he demonstrated to society the potential of a talented scientist, strong leader, progressive educator, and wise mentor. The results of scientific work and his creative work give grounds to claim that he has currently formed a solid scientific school of researchers in the theory and methods of teaching computer science and the use of information and communication technologies in education (Franchuk, 2017).

The formation and development of scientific schools in each country is an extremely important problem of national importance. The development of one or another field of scientific knowledge, and accordingly – education, culture, and economy, largely depends on its support and consistent solution (Kremen and Levovitsky, 2012). According to (Honcharenko, 2012, p. 28), a full-fledged scientific school cannot exist without a teacher, without students, without the substantive content of joint activities, but each school in science necessarily differs in certain unique, unique, properties. The nature of science does not support reduplication, reproduction of standard products, the invention of the invention. Therefore, the function of learning, involvement in the tradition is inextricably linked in the scientific school with the search for new solutions and approaches – both conceptual and methodological. That is why every scientific school is unique.

Thus, scientific schools are the core informal structure of science because they make a significant contribution to its development, and their representatives usually achieve significant scientific results (Leshchenko and Yatsyshyn, 2015). Researchers of scientific schools (Honcharenko, 2012), and (Kremen and Levovitsky, 2012, p. 82), emphasize that the school operates not only through the development of scientific ideas, but also through the organization of scientific work on the basis of scientific principles, tact, respect, responsibility and creating an atmosphere of decency. And the educational influence on the personality of the applicant has the ability of the head of the school to think strategically. Also, the presence of mature intelligence, broad worldview, prudence, wisdom of life, the ability to generate ideas, anticipate the consequences of decisions, commitment, and self-discipline (Kremen and Levovitsky, 2012). In our opinion, M. I. Zhaldak meets all these qualities and therefore, to describe his path as a scientist and the work of his scientific school is an important and honorable task.

Myroslav Ivanovych was a doctor of pedagogical sciences, professor, full member of the National Academy of Educational Sciences of Ukraine, head of the Department of Theoretical Foundations of Informatics of the National Pedagogical Dragomanov University. He is a well-known scientist and organizer of national education and science in Ukraine and abroad. He himself was always at the forefront and involved his students, gained followers, gathered around him like-minded people. It is easy and difficult to study the biography and activities of the scientific school of M. I. Zhaldak, because he is friendly, open, respected by people, has charisma and his scientific achievements are large and diverse, and to thoroughly study this requires special research. M. I. Zhaldak was a prominent figure in modern Ukrainian pedagogical science.

According to the results of generalization and clarification of the system of basic criteria, which determine the scientific and pedagogical school among other scientific associations, the following criteria include (Honcharenko, 2012):

- creation of educational materials of different nature, recognized at the national and regional levels, fully provide the educational process from the block of academic disciplines and constitute the content of the educational process in a particular specialty (group of specialties);
- the use of original or creatively adapted teaching methods with essential elements of developmental learning and the use of modern means of communication in the scientific community;
- conducting teaching activities from the block of academic disciplines that constitute the educational and content core of the program of a particular specialty (specialties) during the period of specialist training;
- the topic of dissertation research of members of the scientific school should be conceptually related to the direction of scientific research of its leader. This indicates a set of qualitative indicators, primarily conceptual, related to the continuation of scientific direction and the development of ideas of a scientific school;
- recruiting new members of the community, including from the student body of the university, until the end of the training of highly qualified specialists;

- conducting scientific-practical and scientific-theoretical events (conferences, seminars, etc.), including a permanent seminar of scientific and methodological nature. During these events, the function of replication of pedagogical innovations is realized;
- simultaneous implementation of two functions: 1) the initiator of fundamental scientific ideas, their dissemination and protection; 2) training of young scientific candidates (Doctor of Philosophy) and Doctor of Sciences (Bykov et al., 2017).

To conduct this study, the analysis of biographical information about the life and scientific achievements of M. I. Zhaldak is paramount. After all, in (Kremen and Levovitsky, 2012) it was determined that it is important to analyze the personality of the founder and head of such a school as the most important factor in its formation. Next, it is worth considering the school's research program – when the leader involves students in their own ideas, creativity, which involves his desire for collective forms of work and the need to relay their views and their discussion. An important condition for entering a scientific school is the identification of the student with the teacher, that is, the perception of his methods, ideas, way of thinking and acting. The identification of the student with the teacher and with the scientific school is a characteristic feature of scientific schools and is extremely important for understanding them as a pedagogical phenomenon. Inheritance and identification ensure the transmission and preservation of the achievements and traditions of the scientific school. However, this should not prevent the formation of the scientist's independence, the discovery of his own professional and personal position.

4 RESULTS

4.1 The First Steps in Life

Myroslav Ivanovych Zhaldak (figure 1) was born into a family of teachers on August 15, 1937 in the village of Lazirky (formerly Lazirkivsky, now Orzhytsky district), Poltava region. He began his studies at the school in 1944 in the village of Tarandyntsi (formerly Lazirkivsky, now Lubensky district) Poltava region, which he graduated in 1954.

The future scientist was educated at the Taras Shevchenko Kyiv State University, where he studied at the Faculty of Mechanics and Mathematics, graduating in 1959. It was also fateful that for the first time

Figure 1: Myroslav Ivanovych Zhaldak.

in 1959 graduates of this faculty were awarded qualifications in Mathematics. mathematics-calculator, which received and M. I. Zhaldak.

While still a student, he met a close person, Valentina Nikolaevna Babakova (1936–1973), whom he married in 1958. He had three sons – Andrew (1958), Igor (1961), Vladimir (1968), and now grandchildren.

After graduating from university, Myroslav Ivanovych was sent to work in Tula (Russia) as an engineer (DKB subscriber box 56). However, in 1960 he returned to Kiev and was enrolled in the position of assistant professor of higher mathematics at the Kyiv Higher engineering radio engineering schools of air defence forces.

4.2 The Beginning of the Scientific Path and Management Activities

Zhaldak's scientific path began in 1960 with admission to part-time graduate school at the Department of Higher Mathematics of the Kyiv State Institute of Food Industry (now the National University of Food Technology), and his supervisor was Doctor of Physical and Mathematical Sciences, professor S. I. Zukhovytsky (1908–1994). And again, the fateful case directed the further future of M. I. Zhaldak, because in 1962 he was transferred to the inpatient graduate school of the same institute, where in the same 1962 (due to a change of place of work of the supervisor), transferred to graduate school at the Department of Mathematical Analysis of the Kyiv State Pedagogical Institute named after O. M. Gorky (now the National Pedagogical Dragomanov University). He graduated from graduate school in 1964 and was enrolled as a junior researcher in the computer laboratory at the Department of Mathematical Analysis of the Kyiv State Pedagogical Institute named after O. M. Gorky, and later was transferred to the position of assistant professor of higher mathematics. In May 1965 M. I. Zhaldak presented his scientific results in the form of a candidate's dissertation and received the degree of candidate of physical and mathematical sciences.

M. I. Zhaldak began to hold leading positions in 1968, working as Deputy Dean of the Faculty of Physics and Mathematics, and later, in 1980 – Head of the Department of Higher Mathematics. During this period, the range of scientific issues studied by the scientist significantly expanded. He was awarded the title of Higher Mathematics in 1970. In connection with the organization of the Department of Fundamentals of Informatics and Computer Science he became an associate professor of this department and was appointed Deputy Head of the Department, and in 1989 was elected Head of the Department.

From the mid-60's to the mid 70's of the twentieth century. in the laboratory of computer technology of Kyiv State Pedagogical Institute named after O. M. Gorky worked a group of young scientists who worked on one electronic computer "Minsk-1". In this group of young researchers stood out M. I. Zhaldak, who not only worked on the computer "Minsk-1", but also excellently taught future teachers. "Personally, I (recalls H. O. Mykhalin (08.01.1945–03.12.2020)) enjoyed the lectures of M. I. Zhaldak on probability theory (Mykhalin, 2010)". M. I. Zhaldak in 1972 was an experienced associate professor of higher mathematics and at the same time conducted research at the Main Computing Center of the Ministry of Education of Ukraine and which already had the most modern computers of the ES series. During the period from 1960 to 1985, young scientists of the Kyiv State Pedagogical Institute named after O. M. Gorky worked on computers of all generations – from the earliest to the most modern and involved their students and graduate students in this activity (Mykhalin, 2010).

As H. O. Mykhalin noted, a team was gradually formed around M. I. Zhaldak, and later a scientific school, which he headed. During the 25 years from 1985 to 2010, this school included hundreds of teachers from all over Ukraine, whose scientific and pedagogical activities are related to the pedagogical software GRAN, created under the leadership of M. I. Zhaldak (Mykhalin, 2010).

In 1989 the attention of the scientific community was drawn to the dissertation of M. I. Zhaldak for the degree of Doctor of Pedagogical Sciences "Teacher training system for the use of information technology in the educational process", which was defended in 1990 at the Research Institute of Content and Methods of Teaching USSR (Moscow). The scientific consultant was Doctor of Physical and Mathematical Sciences, Corresponding Member of the Academy of Educational Sciences of the USSR, later a full member of the National Academy of Educational Sciences of Ukraine, Professor M. I. Shkil (1932–2015). After defending his doctoral dissertation, the leading role of M. I. Zhaldak was fully manifested. If during the period from 1965 to 1990 under his leadership only two dissertations were prepared and defended (Yu. V. Tryus and N. V. Morze), then for the period from 1990 to 2010 the number of defended as PhD and doctoral dissertations, and now his students work in all parts of Ukraine and in leading institutions of higher education (Mykhalin, 2010).

In 1991 M. I. Zhaldak received the title of professor, and in 1992 he was elected a corresponding member, and in 1995 – a full member of the Academy of Educational Sciences of Ukraine.

At the National Pedagogical Dragomanov University of Institute of Informatics was established in 2008, where M. I. Zhaldak was elected its director and head of the Department of Theoretical Foundations of Informatics, which he headed until the end of his life.

Myroslav Ivanovych Zhaldak passed away on February 26, 2021. His heart stopped beating at the age of 84. Myroslav Ivanovych was buried in the town of Rzhyshchiv, Obukhiv district, Kyiv region, Ukraine.

4.3 Scientific Works and Educational Materials

Scientific schools carry out theoretical and methodological, information-analytical, scientific-organizational, experimental-pedagogical, and innovation-research activities. By exchanging experience, ideas, scientists enrich each other's innovative potential, create an environment of productive scientific communication, creative style of teamwork, contribute to the development of new effective methodology and original methods of scientific knowledge of innovation processes (Kremen and Levovitsky, 2012).

It should be noted that in the early 1990's at the National Pedagogical Dragomanov University were created positive prerequisites for the emergence of scientific and pedagogical school on the problem of informatization of secondary and higher pedagogical education. Under the leadership and with the direct participation of M. I. Zhaldak, a number of concepts, standards, educational materials, educational and methodological and program-methodological complexes were developed: content and programs of courses "Numerical Methods", "Mathematical Logic and Theory of Algorithms", "Fundamentals of Informatics", "Informatics", "Computational Practice" for physics and mathematics faculties of pedagogical institutes (1992), in-depth study of mathematics at school (2001), the concept of informatization of education in Ukraine (1994), the concept of the content of end-to-end education of Informatics and Computer Engineering for All Levels of Education (1993), State Standard of General Secondary Education in Ukraine in Informatics (2003), standard program of the candidate exam in specialties 13.00.02 "Theory and methods of teaching computer science" (1999) and 13.00.10 "Information and communication technologies in education" (2008), Industry standards of higher education in the direction of training 0101 Pedagogical education, Specialty 6.010100 Pedagogy and methods of secondary education – Mathematics and Physics (2002) (Bykov et al., 2017).

M. I. Zhaldak, a reviewer of more than 100 scientific and methodological works, is the author and coauthor of more than 300 works, including 50 books and brochures (figure 2), including:

- Zhaldak, M. I., Kuzmina, N. M., and Mykhalin, H. O. (2009) Probability theory and mathematical statistics: a textbook for students of physical and mathematical specialties of pedagogical universities. Poltava. 500 pages.
- Zhaldak, M. I., Kuzmina, N. M., and Mykhalin, H. O. (2009) Collection of problems and exercises in probability theory and mathematical statistics: a textbook for students of physical and mathematical specialties of pedagogical universities. Kyiv. 610 pages

and others (Naukova diyalinist, 2022).

In the works of M. I. Zhaldak introduced modern computer-based methodological systems for teaching mathematics and, in part, physics, focused on a harmonious pedagogically appropriate and balanced combination of traditional methodological systems of teaching and modern information and communication technologies.

The software complex GRAN (figure 3), which is well known today in schools and pedagogical universities of Ukraine, was developed by M. I. Zhaldak and his graduate student A. V. Penkov (1958–2016) as early in 1989. The program and methodological complex GRAN, together with other textbooks and manuals for students at pedagogical universities, teachers and students of secondary schools ("Probability Theory and Mathematical Statistics" (Zhaldak et al., 2020), "Stochastics", "Mathematics with a computer (Zhaldak et al., 2012)") contains more than 20 books, electronic copies of which are available on the website of the Department of Theoretical Foundations of Informatics (https://ktoi.fi.npu.edu.ua/).

You can get acquainted with GRAN software using Open Virtual Desktop (OVD) cloud technologies. The Ulteo OVD system was used to deploy Remote Desktop. For this purpose, the work of two servers (application server and session manager server) was organized, using the web-oriented virtual environment PROXMOX.

One server, namely the session manager server, is configured using the Linux Ubuntu operating system. Using the Windows operating system, an application server was configured on which the GRAN software (Gran1, Gran2D, Gran3D) was installed (Zhaldak and Franchuk, 2020).

You can get to the virtual desktop to the remote server at the link http://gran.npu.edu.ua. As a result, a page with the form (Ulteo Open Virtual Desktop) will open, where in the line "Username" you need to select from the proposed list one of the available names, such as "*gran*", and then in the line "Password" enter the password "*gran*" (Zhaldak et al., 2021).

It should be noted that developed by M. I. Zhaldak and his colleagues approved the textbook "Probability Theory and Mathematical Statistics" in 2008 by the Ministry of Education and Science of Ukraine as a textbook for students of physical and mathematical specialties of higher pedagogical educational institutions (Bibliographic Index, 2011; Zhaldak et al., 2020).

M. I. Zhaldak was a member of organizing committees and regularly participates in many masses' scientific events, both in Ukraine and abroad. Particularly M. I. Zhaldak was the permanent head of the All-Ukrainian scientific-methodical seminar on the problems of informatization of the educational process.

Here are the indexes of citations of publications M. I. Zhaldak according to Google Scholar

Figure 2: The main books of M. I. Zhaldak.

(https://scholar.google.com.ua/citations?user=SDRlaCAAAAAJ) as of February 2023: general citation statistics – 4698, h-index – 34, i10-index – 58 (figure 4).

To convey his work, M. I. Zhaldak successfully used digital technologies. In particular, he created profiles in various citation systems so that everyone could see the real value of his publications. Especially for domestic research, especially in the social sciences and humanities, it is mandatory to publish in publications that are indexed in international databases Web of Science or Scopus. In figure 5 (https://www.scopus.com/authid/detail.uri?authorId=16424101400) we can see the number of publications as well as the years of these publications. It is from this that it can be argued that in this case the scientist was one of the first to place his work in scientometrics databases. However, it should be noted that Myroslav Ivanovych was a supporter of the publication of his works in Ukrainian scientific journals.

4.4 Scientific and Organizational Work and Awards

Scientific and organizational achievements of M. I. Zhaldak is reflected in his character traits: friendliness, perseverance, principledness, great diligence and the ability to bring the case to an end. The scientist can be described as a purposeful leader who had broad scientific interests, because he always supported new developments and improvements in technical means and tried to implement them in the educational process.

M. I. Zhaldak was the scientific editor of many monographs and manuals, was a member of the editorial boards of professional publications in pedagogical sciences of Ukraine, namely: the scientific journal “Computer at school and family”, “Mathematics at school”, newspaper “Informatics”, electronic publication “Information technologies and teaching aids”, editor-in-chief of the collection of scientific works

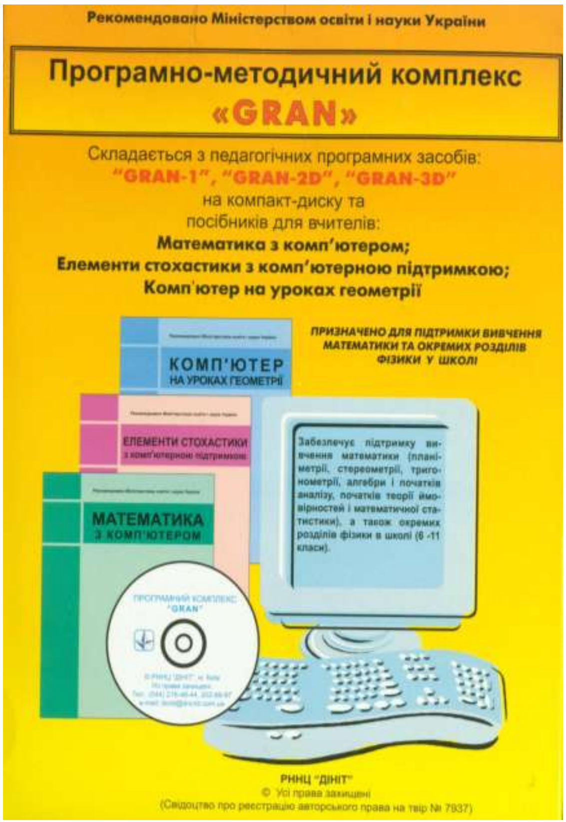

Figure 3: Software and methodological complex GRAN.

"Computer-based learning systems" and others (Nahorody, 2022).

Scientific and organizational activities of M. I. Zhaldak include work in numerous methodological commissions and groups, including: member (later chairman) of the methodological commission on informatics at the Scientific and Methodological Council of the Ministry of Education and Science of Ukraine (1985–2005), member of the Interdepartmental Council for Coordination of Scientific Research in Pedagogical and Psychological Sciences in Ukraine, Chairman of the Informatics Section of the Commission for Higher Pedagogical Education (0101) of the Scientific and Methodological Council of the Ministry of Education and Science of Ukraine (since May 2007), Chairman of the Working Group for Development direction 6.040302 Informatics* training of specialists in higher educational institutions at the educational and qualification level of bachelor (since October 2007). From 1987 to 2002 he was the chairman of the jury of regional and national competitions in computer science, national competitions "Teacher of the Year" in computer science (2002, Kherson) and mathematics (2004, Bila Tserkva), participated. in the work of the Small Academy of Sciences (1998–2000, chairman of the jury), Vice-President of the Kyiv Small Academy of Sciences of Ukraine (Bibliographic Index, 2011).

The selfless scientific and organizational work of M. I. Zhaldak was worthily awarded numerous state and scientific awards. For 59 years of work at the university M. I. Zhaldak received (Bibliographic Index, 2011; Nahorody, 2022):

1. Letter of thanks from the administration of the secondary school number 2 town Ukrainka (1984).
2. Diploma of the Kyiv State Pedagogical Institute named after O. M. Gorky (1985).
3. Excellence in Public Education of the USSR (1987).
4. Diploma of the Kyiv City Committee of Trade Unions (1988).
5. Excellence in Education of the USSR (1989).
6. Veteran of Labor (1997).
7. Diploma of the Academy of Educational Sciences of Ukraine (1997).
8. Diploma of the II degree of the Academy of Educational Sciences of Ukraine (1997).
9. Honored Worker of Science and Technology of Ukraine (2000).
10. Excellence in Education of Ukraine (2004).
11. Diploma of the first degree of National Pedagogical Dragomanov University (2004).
12. Diploma of the Cabinet of Ministers of Ukraine "For significant personal contribution to the development of education, training of highly qualified specialists, many years of hard work" (2005).
13. Gratitude of National Pedagogical Dragomanov University (2007).
14. Sign "K. D. Ushynsky" (2007).
15. Title of Honorary Professor of Chernihiv State T G Shevchenko Pedagogical University (2007).
16. Award of the National Academy of Sciences of Ukraine "For preparation of scientific change" (2009); Medal of M. P. Kravchuk "For scientific achievements" (2010).
17. Diploma of the Verkhovna Rada of Ukraine "For special services to the Ukrainian people" (2010).
18. Title of Honorary Director of the Institute of Informatics of National Pedagogical Dragomanov University (2011).
19. Honored Professor of National Pedagogical Dragomanov University (2011).

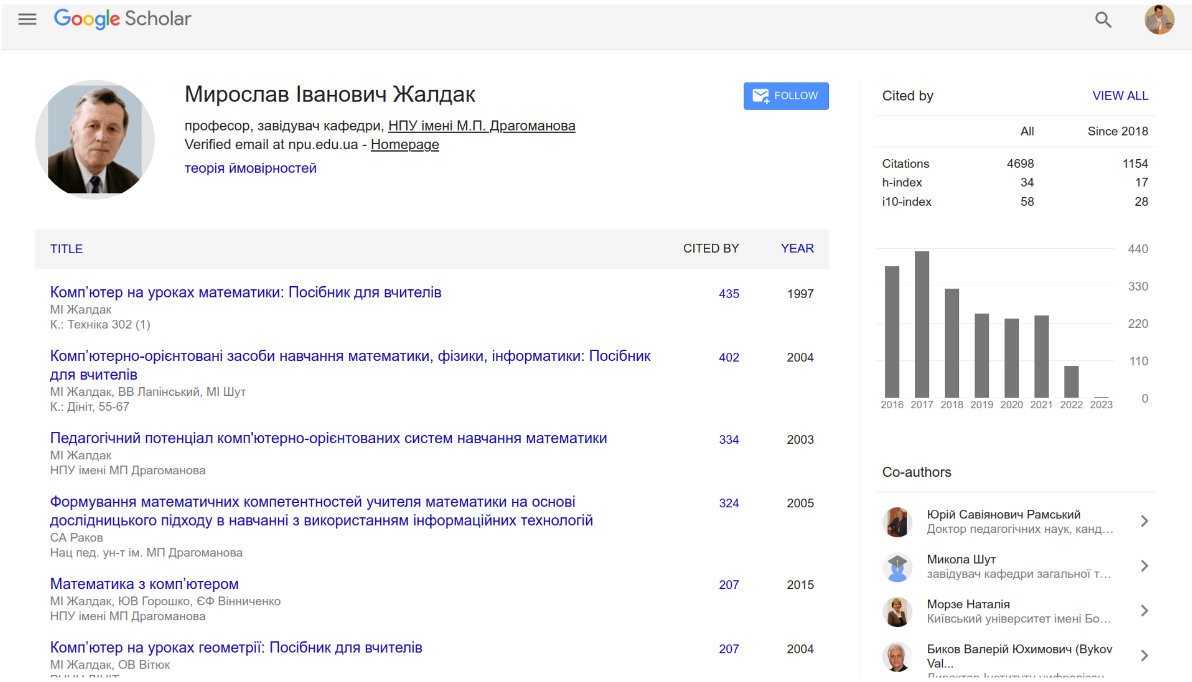

Figure 4: Citation indices of M. I. Zhaldak's publications according to Google Scholar.

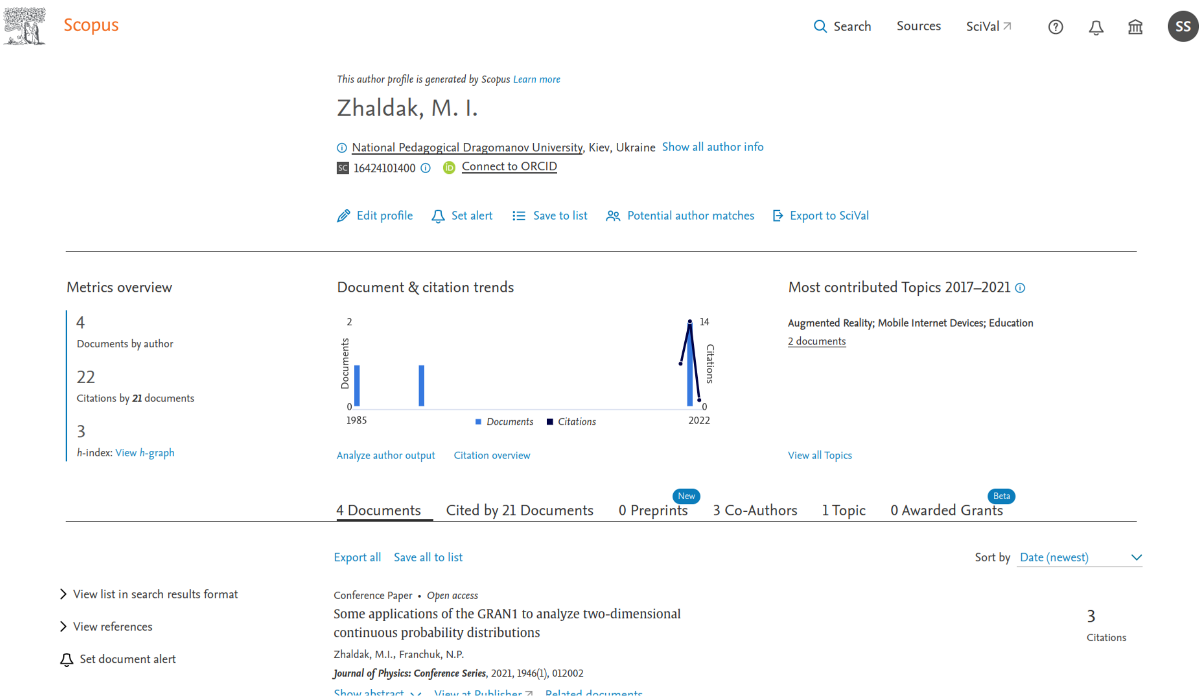

Figure 5: Citation indices of M. I. Zhaldak's publications in Scopus.

20. Medal "Grigory Skovoroda" (2012).
21. Gold Medal "Mykhailo Petrovych Dragomanov 1841-1895" (2012).
22. Diploma of the Institute of Information Technologies and Teaching Aids of the National Academy of Educational Sciences of Ukraine (2012).
23. Medal of M. P. Kravchuk "For scientific achievements" (2012).
24. Diploma of the Kyiv City Organization of the Trade Union of Education and Science Workers

of Ukraine (2017).

25. Diploma of the Verkhovna Rada of Ukraine (2017).
26. Medal “Dragomanov Family” (2018).
27. Medal “People’s Honor to Ukrainian Scientists 1918–2018” (2018).

4.5 Formation of the Scientific Elite

Being an effective form of organization of scientific life of the researcher, the scientific school greatly contributes to the acquisition of scientific experience, the formation of values in the implementation of research. Involvement of a young scientist in scientific research, giving him real powers and rights, the opportunity to choose a personally significant problem, pedagogical support and trust have a positive effect on the overall development of the researcher’s personality and significant results (Kremen and Levovitsky, 2012). Training of scientific personnel in postgraduate and doctoral studies is one of the main sources of constant replenishment and renewal of the intellectual potential of the state, its scientific elite (Biriukova, 2010).

M. I. Zhaldak was a permanent member (and since 2003 chairman) of the specialized Academic Council D 26.053.03 at the National Pedagogical Dragomanov University on the defense of doctoral dissertations in the specialty 13.00.02 – theory and methods of teaching (mathematics, computer science). Note that it is under the leadership of M. I. Zhaldak, this scientific field has reached the highest popularity, because applicants came from all over Ukraine to defend their scientific results in this specialized scientific council.

The most common method of identifying scientific schools is the study of various candidate and doctoral theses of scientists who are part of these informal teams (Marahovsky and Kozubtsov, 2012).

M. I. Zhaldak took great care of young people and actively involved talented students in research, postgraduate studies, and recommended talented colleagues for doctoral studies. According to scientific advice M. I. Zhaldak trained 16 doctors of pedagogical sciences. Under his scientific guidance, the scientific results of 41 candidate dissertations have already been evaluated (Nahorody, 2022).

It is worth noting the historical experience and analysis of the current state of training and certification of domestic scientific and scientific-pedagogical staff of the highest qualification in the field of pedagogical sciences, particularly in the new scientific specialty 13.00.10 – “Information and communication technologies in education”, established in 2009 (Spirin and Yatsyshyn, 2014).

It should be noted that back in 2008 at the initiative of academicians of the National Academy of Educational Sciences of Ukraine V. Yu. Bykov and M. I. Zhaldak at the Institute of Information Technologies and Teaching Tools of the National Academy of Educational Sciences of Ukraine consisting of 11 people created a working group to prepare a draft passport of a new scientific specialty 13.00.10 – “Information and Communication Technologies in Education”, approved by the Higher Attestation Commission of Ukraine in 2009. to the field of pedagogical sciences, which investigates the theoretical and methodological problems of the use of ICT in education, psychological and pedagogical rationale for the development of these technologies to ensure the functioning and development of educational systems (Spirin et al., 2017).

In 2010 M. I. Zhaldak became a member of the specialized doctoral scientific council for the first time created in Ukraine in the Institute of information technologies and learning tools of the National Academy of Educational Sciences of Ukraine (now Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine) in the specialty 13.00.10. This council has a unique composition, as it combines outstanding personalities known not only in Ukraine but also abroad – scientists, managers, practitioners who have degrees in various fields of science and have made a significant contribution to the computerization of general and higher pedagogical educational institutions, informatization of scientific and educational space of Ukraine (Spirin et al., 2016).

4.6 The Main Activities of the Scientific School of M. I. Zhaldak

The scientific school is called the guardian of acquired traditions, scientific worldview, concentrated experience of many generations, a kind of relay transfer of experience, which helps to reveal the creative abilities of young scientists, their education, formation, and transformation into mature researchers. In modern conditions, the scientific school, in order to maintain its progressive character, must be armed with advanced methodology, have professional mobility (Leshchenko and Yatsyshyn, 2015).

Given (Mykhalin, 2010; Bibliographic Index, 2011; Nahorody, 2022) we outline the main directions of the scientific school, headed by Academician M. I. Zhaldak:

- features of teaching computer science in secondary schools and training computer science teachers for this;

- development of electronic educational resources (pedagogical software) focused on the school course of mathematics, easy for students to master, easy to use;
- creation of computer-oriented systems of teaching mathematics in various educational institutions;
- development and improvement of methodical systems of teaching computer science and mathematics to university students;
- introduction of technologies of distance learning of computer science and mathematics disciplines;
- development of information-didactic and educational-methodical materials, in particular creation of new textbooks, task books, textbooks for school, for teachers and students of pedagogical universities;
- introduction of information and communication technologies for training, management, and support of scientific research (Bykov et al., 2017).

According to many leading scientists, the scientific school of Academician M. I. Zhaldak is a source for the creation and development of new scientific schools, which will later be headed by his students.

5 CONCLUSIONS

M. I. Zhaldak was a man of hard work and modesty, versatile talent, deep knowledge, and wisdom of life. High decency, simplicity, modesty, principledness and determination in defending their positions, the ability to work with people became an example of devotion and service to the pedagogical field to which he dedicated himself. His fruitful work is generous with life-giving fruits, respect, and love. And the result is an extremely powerful scientific school.

M. I. Zhaldak managed to prepare and focus highly qualified scientific and scientific-pedagogical staff on priority and promising areas of informatization of the educational process in schools and universities, which determine the innovative development of education and science of Ukraine. The study provides grounds to argue about the significant role of the scientific school of M. I. Zhaldak and its impact on the development, promotion of international prestige and authority of national education and science.

From his own many years of experience working with M. I. Zhaldak, we note that in the educational process, research, and management, he uses effective innovative approaches. M. I. Zhaldak is a great professional, whose potential is realized in all spheres of education and science. His colleagues and students know that it is worth working with him according to his principles and at his own pace. And his principledness in scientific and organizational issues ensured the respect of colleagues and students and contributed to his scientific recognition.

Carrying out research on the biography, scientific achievements of Academician M. I. Zhaldak and his scientific school, it should be noted that he is one of the leaders, scientists, creators of educational innovations: teacher, scientist, organizer of education and science.

In the future it is expedient to study the phenomenon of development of scientific schools of students and followers of Academician M. I. Zhaldak.

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Using the Gran1 Program in Mathematics Lessons

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Keywords: A Software Package Gran, Mathematics, Gran1, Mathematical Problems, Cloud Technology.

Abstract: The article considers the mathematical software package Gran. There are described examples of solving problems by the graphical method using the Gran1 program, which can be used in the process of teaching mathematics at school. The issues under consideration are quite complex, and their solving without software such as Gran1 for graphical analysis of various issues is quite time-consuming. The range of tasks that can be solved using the Gran software package, in particular, the Gran1 program, is quite wide and needs a creative approach. Their analysis and solution can have a positive effect not only on the mental but also on the general cultural development of students. The purpose of the study is to consider examples of the effective use of the GRAN complex in mathematics lessons for solving issues of different levels of complexity.

1 INTRODUCTION

On February 26, 2021, Ukrainian science suffered a heavy loss. A well-known scientist in Ukraine and the world, the founder of a powerful scientific school, Myroslav Ivanovych Zhaldak, Doctor of Pedagogical Sciences, professor, academician of the National Academy of Pedagogical Sciences of Ukraine, passed away. One of the most significant contributions of Myroslav Ivanovich to science and education is the Gran software complex conceived by him and developed under his leadership. The Gran program complex has received an author's certificate, it is recommended by the Ministry of Education and Science of Ukraine for use in secondary and higher education institutions of Ukraine, and is also known abroad, for example in Poland.

Myroslav Ivanovych Zhaldak began active scientific and pedagogical activities at a time when computerized means of searching, collecting, storing, processing, presenting, and transmitting various data began to be introduced into the educational process. He emphasized that this opens broad perspectives for humanitarian education and human learning, contributes to the deepening and expansion of the theoretical foundations of knowledge, gives practical significance to learning results, creates conditions for revealing the creative potential of children, taking into account their age characteristics and experience, individual requests, and abilities. At the same time, the teacher is not forced to use any specific method of presentation, consolidation of knowledge and control, any specific content, methods, forms of organization and teaching tools, to maintain a certain balance between independent preparation of students and group work, etc. (Zhaldak, 1989).

Teacher should determine all these aspects according to his own preferences, with specific conditions of work, with individual features of pupils and of whole class. It's clear that it's impossible and unnecessary to teach all the children equally, to form equal knowledge in various subjects for all the children, to claim reaching equal level of logical and creative thinking development, equal perception of reality. It also relates to teaching mathematics, methods of problems solving, plotting and analysis of mathematical models for various processes and phenomena, results in-

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terpretation, and generalization of results of this analysis. At the same time there arise a lot of difficulties dealing with the content, methods, organization forms and means of study, necessary knowledge levels in various subjects for every pupil (Bobyliev and Vihrova, 2021).

Of particular importance is the teaching of natural sciences and mathematics, during which students must consider and build models of various processes and phenomena, and then explore them, analyzing their various features and characteristics, possibly using different information and communication models to perform calculations or experiments, and based on the results of such analysis, synthesizing the relevant conclusions. This approach to learning allows students to effectively develop logical, critical, creative thinking, scientific worldview, creative approach to solving various problems, their correct vision and ability to explain their nature and essence (Zhaldak et al., 2021).

The specified educational aspects can be effectively implemented using the pedagogical software complex GRAN, created under the creative leadership of Myroslav Ivanovich Zhaldak.

We consider the advantages of the specified software complex to be:

- convenient user interface, in particular, the possibility of using most services without a keyboard;
- availability of English and Polish localizations;
- methodical support developed over several decades, including teaching aids recommended by the Ministry of Education and school textbooks;
- confirmation of the effectiveness of the program by the results of numerous candidate and doctoral dissertations on the methodology of teaching mathematics and computer science.

2 THEORETICAL BACKGROUND

For the study, scientific publications and supporting sources in the following areas were analyzed: theory and practice in mathematics teaching development (Jaworski, 2006), development of mathematical and logical thinking (Astafieva et al., 2019), mathematical speech of students (Semenikhina and Drushlyak, 2015), using the Gran software package in mathematics lessons (Zhaldak et al., 2012, 2020) and other.

Since 2003, the Gran software complex has been used in some educational institutions in Poland (Smirnova-Trybulska, 2003; Smyrnova-Trybulska, 2004).

The widespread introduction of modern ICT tools in the educational process makes it possible to significantly strengthen the links between the content of education and everyday life, to give the results of training practical significance, applicability to solving everyday life problems, satisfying practical needs, which is one of the aspects of the humanization of education.

At the same time, the informatization of the educational process should be based on the creation and widespread introduction into everyday pedagogical practice of new computer-oriented methodological teaching systems for all academic disciplines without exception on the principles of gradual and non-antagonistic, without destructive restructurings and reforms, embedding information and communication technologies into existing didactic systems, a harmonious combination of traditional and computer-oriented learning technologies, not denying and discarding the achievements of pedagogical science of the past, but, on the contrary, their improvement and strengthening, including through the pedagogically balanced and expedient use of achievements in the development of computer technology and communications.

However, it is important to understand that not all tasks require the use of a computer. Scientific analysis of creative, productive thinking shows that the main thing in the process of thinking is not so much operational and technical procedures and programs for solving already set tasks, but rather building a model of a problem situation, putting forward a hypothesis, guessing, formulating a problem, setting a task. The modern development of computer software has reached a level where in many cases the algorithm for achieving the goal can be built automatically. In this case, instructions to the computer can be given in terms of the desired results, and not in descriptions of the processes leading to such results. The main difficulty is to characterize the desired results in a qualified and accurate manner, which puts forward appropriate requirements for the overall rigor and logic of the user's thinking.

3 RESULTS

The latest version of the software Gran1, Gran2D, Gran3D, as well as some training manuals can be obtained on the website: https://ktoi.npu.edu.ua. All materials posted on this site are distributed free of charge (Gran, 2021).

Let's consider some examples of solving some math problems using the cloud version of Gran1.

Note that the names of services, help, tips, messages, etc., depending on the settings provided in the program, can be provided in one of four languages: Ukrainian, Russian, English, Polish.

Suppose it is necessary to solve an equation $f(x) = 0$, i.e., in domain of dependence $y = f(x)$ find all the values of the argument x that their corresponding values $f(x)$ are equal to zero.

When the dependence $y = f(x)$ is represented graphically, to find a solution of the equation $f(x) = 0$ means to find all the points on the graph of dependence $y = f(x)$ that have zero ordinates. In other words, it is necessary to find points that lie both on the graph of dependence $y = f(x)$ and on the axis Ox that is described by the equation $y = 0$. That is, one should find points that lie on the line (straight or curve) that has equation $y = f(x)$ as well as on the line, that has equation $y = 0$.

Plotting graph of the dependence $y = f(x)$ with the help of the command "Graph /Plot" and setting cursor in corresponding points for getting their ordinates makes it easy to determine abscises of all the points on the graph of dependence $y = f(x)$ that also lie on the axis Ox.

Examples

1. Find solutions of the equation $x^2 - 2 = 0$.

Plot a graph of the dependence $y = x^2 - 2$ and set cursor so that the cursor's abscissa coincides with the intersection point of the graph and the axis Ox. The result is as follows $x_1 \approx -1.4$, $x_1 \approx 1.4$ (figure 1).

If it is necessary to precise the roots one can enlarge a part of the graph or change the segment of function determination and plot the graph in quite small areas of the points defined before, with the help of enlarged zoom.

2. Find solutions of the equation

$$|x-1| + |x+1| - 3 = 0.$$

Plot a graph of the dependence

$$y = abs\,(x-1) + abs\,(x+1) - 3$$

and make sure that any point on the axis Ox of the segment $[-1, 1]$ lies on the graph of a considered dependence (figure 2). Thus, for the equation exists unlimited set of solutions and any value $x \in [-1, 1]$ is a solution of the equation.

3. Find solutions of the equation

$$\sin x + 2 - \ln x = 0.$$

Plot a graph of the dependence

$$y = \sin(x) + 2 - \ln(x)$$

on the segment $[-1, 40]$ (figure 3) and make sure (considering properties of functions $\sin x$ and $\ln x$), that out of the segment $[-1, 40]$ there aren't roots of the equation.

While considering the graph of dependence

$$y = \sin(x) + 2 - \ln(x),$$

represented in the figure 3, one can suppose that the equation $\sin(x) + 2 - \ln(x) = 0$ has 6 solutions:

$$x_1 \approx 3.9;\, x_2 \approx 6.1;\, x_3 \approx 9.2;$$

$$x_4 \approx 13.2;\, x_5 \approx 14.9;\, x_6 \approx 20.25.$$

If high accuracy of calculation is not necessary, such conclusion can be accepted.

However, if higher accuracy of results is required one should enlarge the zoom of plotting in quite small areas of the points x_1, x_2, x_3, x_4, x_5, x_6 (figure 4, figure 5) to sure that the equation has 5 solutions:

$$x_1 = 3.851,\, x_2 = 6.088,\, x_3 = 9.203,$$

$$x_4 = 13.184,\, x_5 = 14.928$$

It should be noted that precise analytical solution of the equation cannot be found, while the search of its approximate solutions without graphical plotting requires laborious calculations and careful analysis of the results.

The calculus mathematics investigates special methods of search approximate solutions of equations of the form $f(x) = 0$ on given segment $[a, b]$ (bisection method, chord method, tangent method, iteration method etc.).

Sometimes it is convenient to represent the equation $f(x) = 0$ in the following form:

$$f_1(x) - f_2(x) = 0$$

where $f_1(x) - f_2(x) = f(x)$, or a problem leads to searching solutions of the equation of the form

$$f_1(x) = f_2(x).$$

In this case it is convenient to plot graphs of the dependencies $y = f_1(x)$ and $y = f_2(x)$, then set cursor in intersection points of the graphs and determine coordinates of the points lying on both graphs simultaneously. Abscissas x of the points are solutions of the equation $f_1(x) = f_2(x)$. If the values x are found in a such way, the values $f_1(x)$ and $f_2(x)$ are equal.

4. Find solutions of the equation:

$$\sqrt[3]{x} + \frac{1}{8}\sin(10x) = \log_{\frac{1}{2}}(x + 3.5).$$

Plot graphs of the dependencies

$$y = \sqrt[3]{x} + \frac{1}{8}\sin(10x)$$

and $y = \log_{0.5}(x + 3.5)$ and make sure that the equation has unique solution. Set cursor in the intersection point of the graphs to get $x \approx -1.3$ (figure 6).

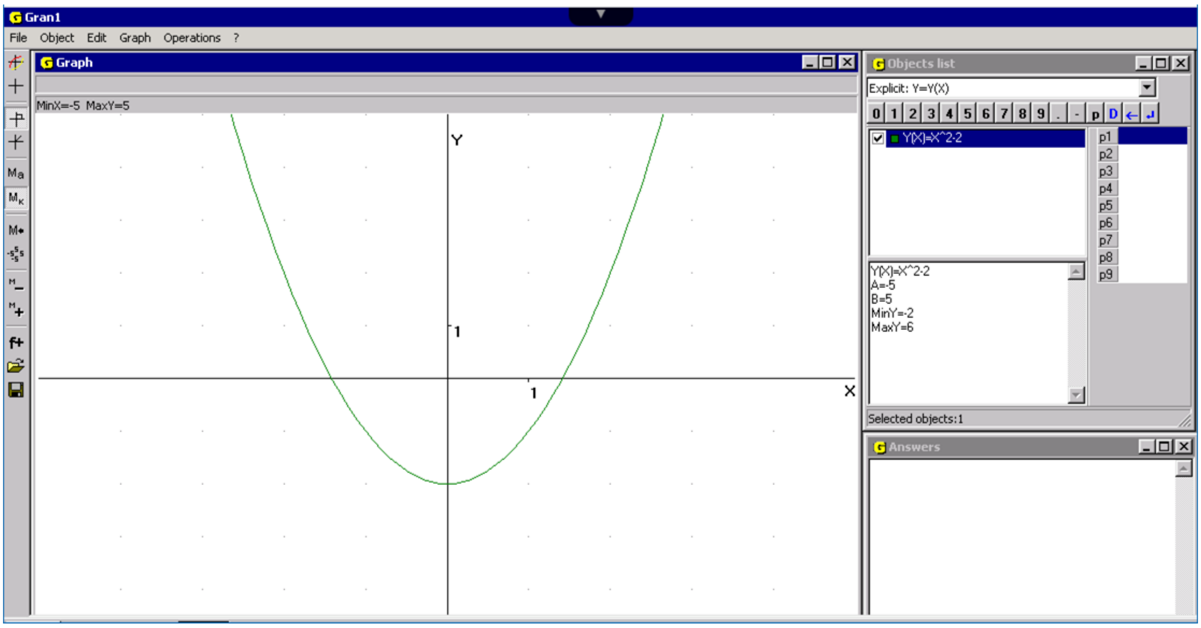

Figure 1: Graph of a given function $y = x^2 - 2$.

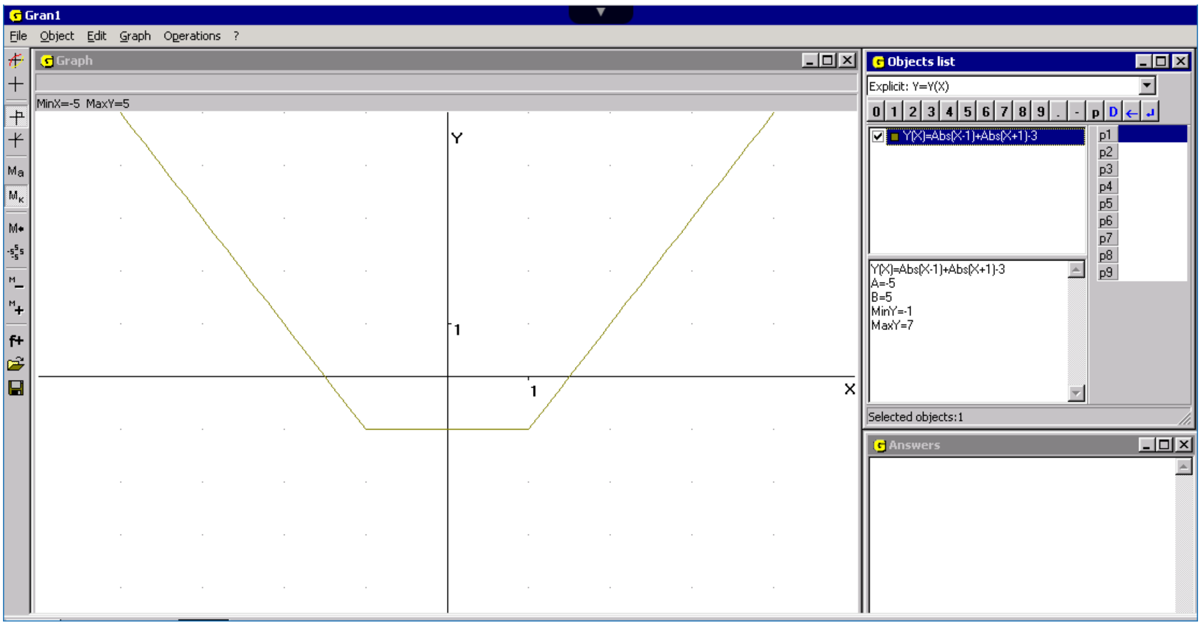

Figure 2: Graph of a given function $|x-1| + |x+1| - 3 = 0$.

Now solve the system of equations of the form

$$\begin{cases} G_1(x,y) = 0, \\ G_2(x,y) = 0, \end{cases}$$

where $G_1(x,y)$ and $G_2(x,y)$ are some expressions of two variables x and y.

Set the type of dependence $G_1(x,y) = 0$ and plot graphs of the dependencies $G_1(x,y) = 0$ and $G_2(x,y) = 0$, then set cursor in intersection points of the graphs and determine coordinates of the points that meet both equations

$$G_1(x,y) = 0 \text{ and } G_2(x,y) = 0$$

i.e. coordinates of intersection points of the lines described by the equations

$$G_1(x,y) = 0 \text{ and } G_2(x,y) = 0.$$

5. Solve the system of equations $\begin{cases} x^2 + y^2 = 16, \\ \lg(xy) = 0.1 \end{cases}$

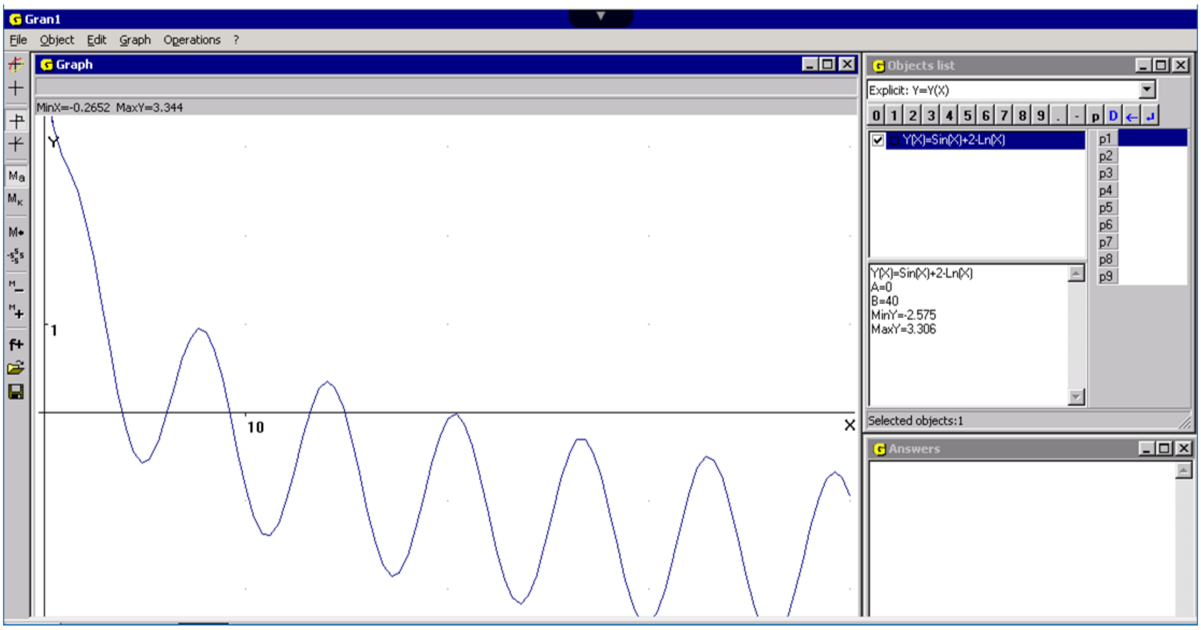

Figure 3: Graph of the dependence $y = sin\,(x) + 2 - ln\,(x)$.

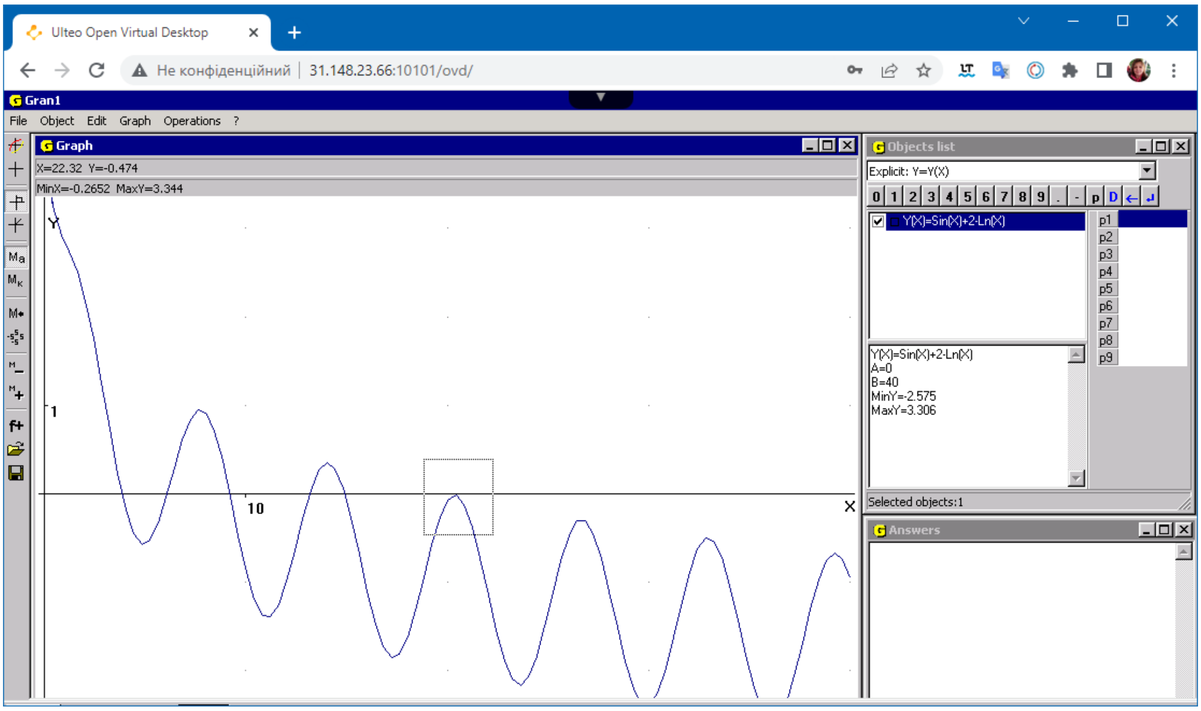

Figure 4: Increasing the scale of graphic constructions in rather small points.

Represent the equations in the following form: $0 = x^2 + y^2 - 16$, $0 = \lg\,(xy) - 0.1$ and plot graphs of the dependencies (figure 7).

Set cursor in each of intersection points of the graphs and obtain:

1. $x \approx -3.99$, $y \approx -0.31$;
2. $x \approx -0.31$, $y \approx 3.99$;
3. $x \approx 0.31$, $y \approx 3.99$;
4. $x \approx 3.99$, $y \approx 0.31$.

For more precise determination of coordinates of the intersection points of graphs one should enlarge the zoom of plotting, i.e., use the command

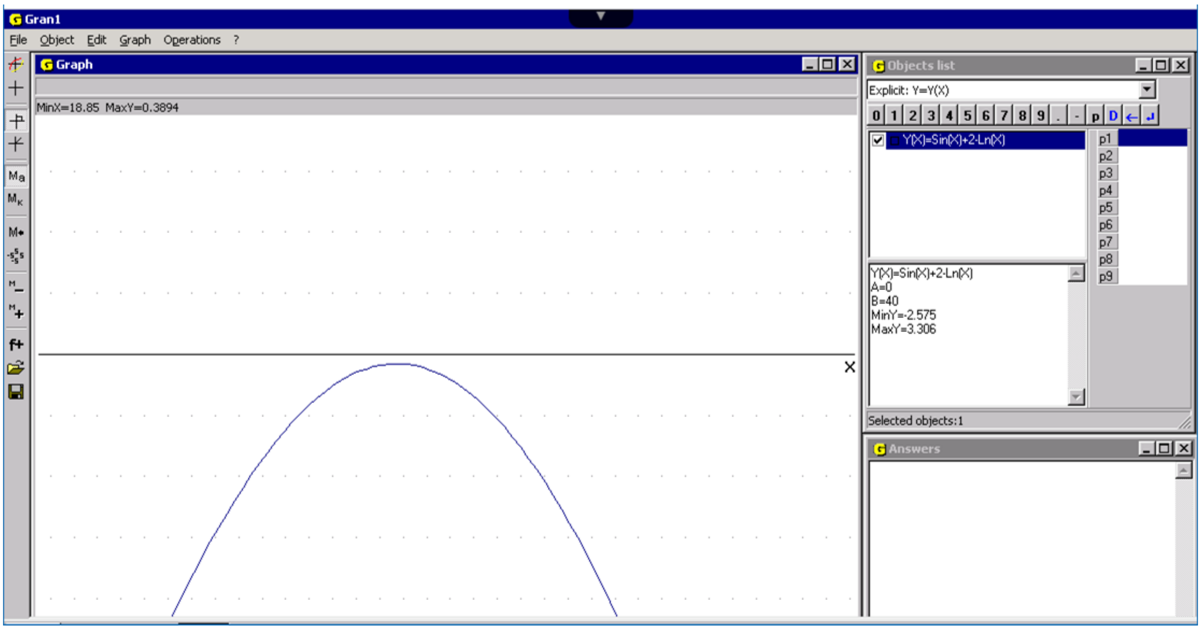

Figure 5: Enlarged scale of graphic construction $y = sin(x) + 2 - ln(x)$.

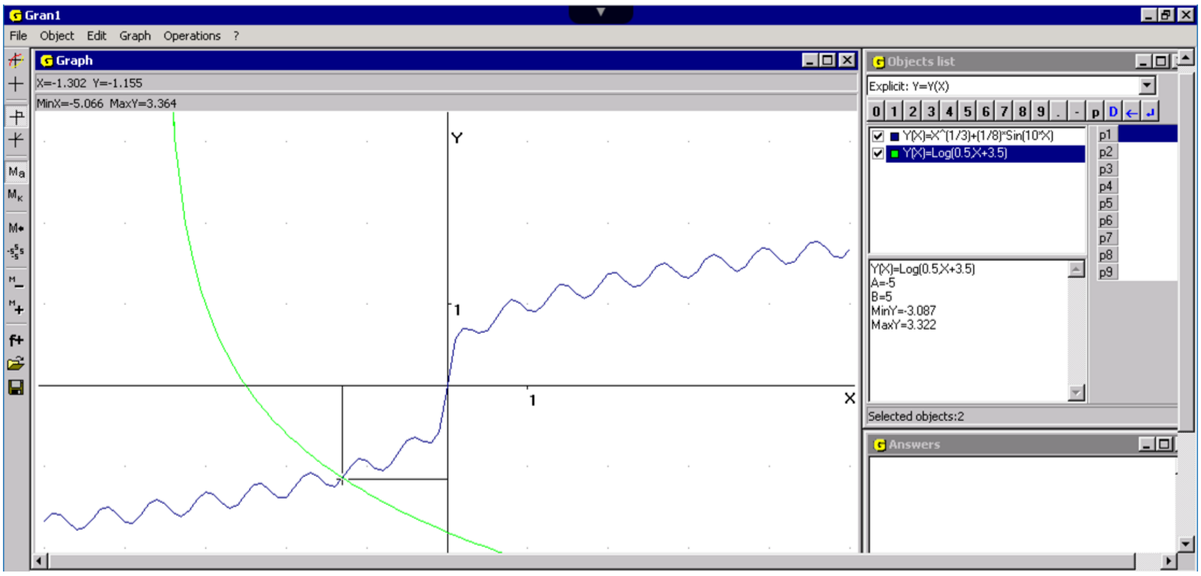

Figure 6: The point of intersection of graphs of functions.

„Zoom in" or change bounds for the variables x and y. For example, if we change the zoom by setting the bounds $MinX = -4.5$, $MaxX = -3.5$, $MinY = -0.5$, $MaxY = 0.1$ and plot the corresponding graphs, we obtain the image represented in the figure 8. Use the coordinate cursor to get $x \approx -3.988$, $y \approx -0.316$, and while cursor is moving, the third digit after the comma is changing (is defined more exactly).

One can put $MinX = -4.0$, $MaxX = -3.98$, $MinY = -0.32$, $MaxY = -0.3$ (using the command "Graph / Zoom / User zoom") to obtain $x \approx -3.9875$, $y \approx -0.3157$, and while the cursor is moving, the fourth digit after comma is changing (is defined more exactly).

It should be noted that the problem of finding solutions of the equation $f(x) = 0$ can be also considered as the problem of solving the system of equations

$$\begin{cases} 0 = y - f(x), \\ 0 = y, \end{cases}$$

and the problem of finding solutions of the equation $f_1(x) = f_2(x)$ as the problem of solving the system of

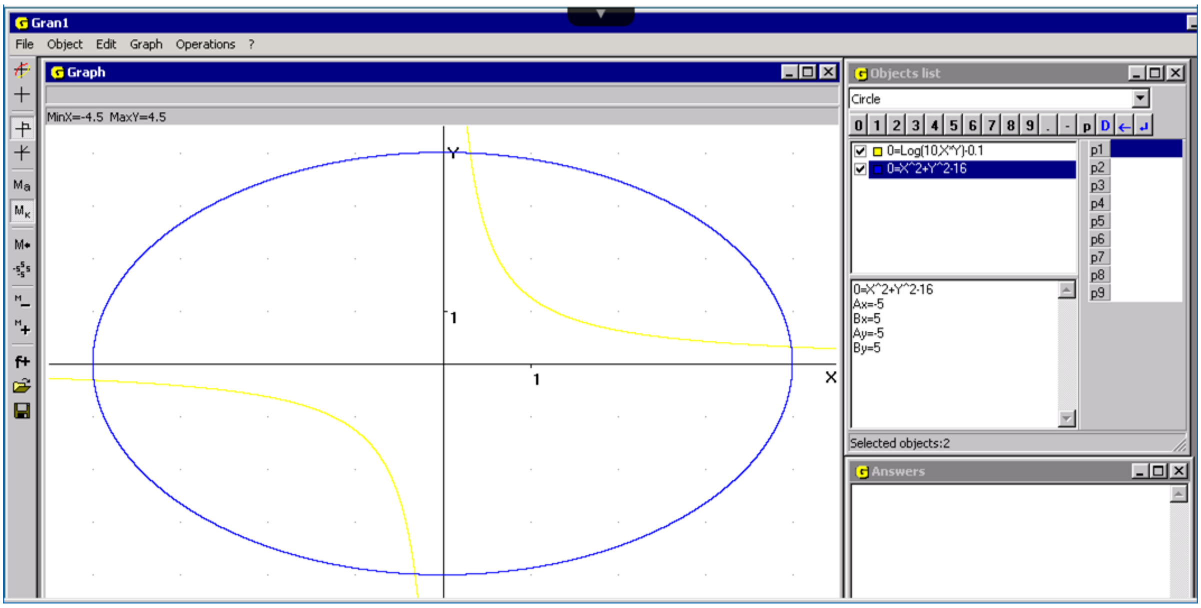

Figure 7: Two equations are graphically represented.

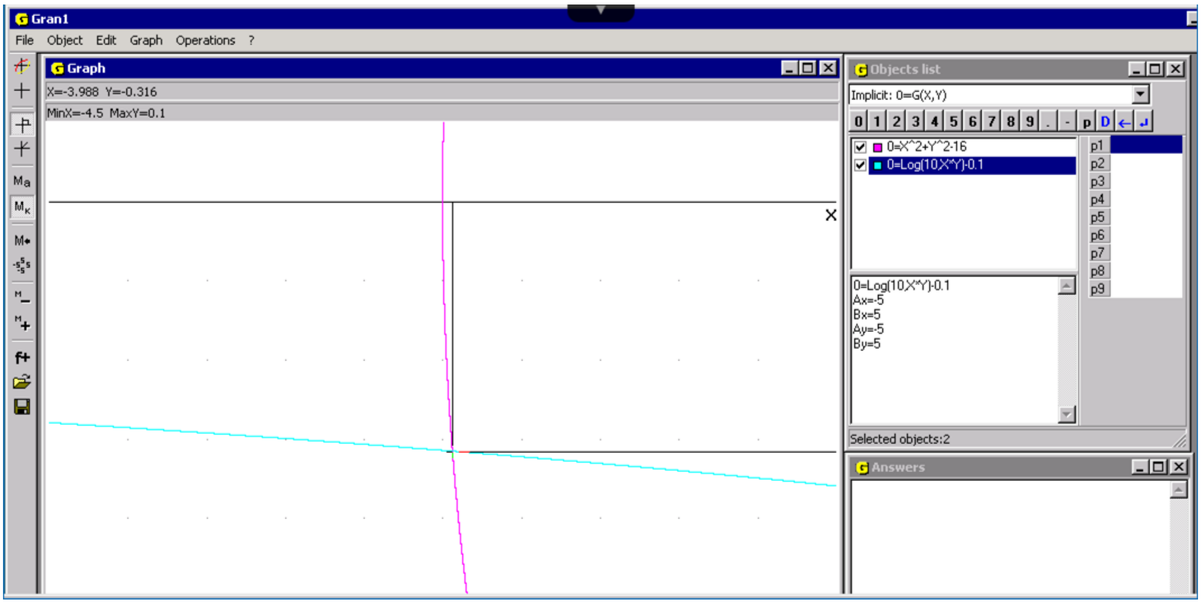

Figure 8: Graphically, two equations are presented on a modified scale.

equations

$$\begin{cases} 0 = y - f_1(x), \\ 0 = -f_2(x). \end{cases}$$

In many cases finding solutions of the system of equations $\{G_1(x,y) = 0,\ \ G_2(x,y) = 0\}$ with the help of plotting is unique suitable method for practical use since the method of variable exclusion or other methods are very difficult or lead to wrong results.

6. Solve the system of equations (figure 9)

$$\begin{cases} 0 = \sin(xy) + \cos(x-y), \\ 0 = \frac{x}{y} - \lg(x+y). \end{cases}$$

In this case it is impossible to exclude one of the variables x or y and it is difficult to offer any practically suitable way of solution besides the graphical method.

It is obvious that plotting can be used for determination of intersection points of lines independently of types of the dependencies. For example, if it is

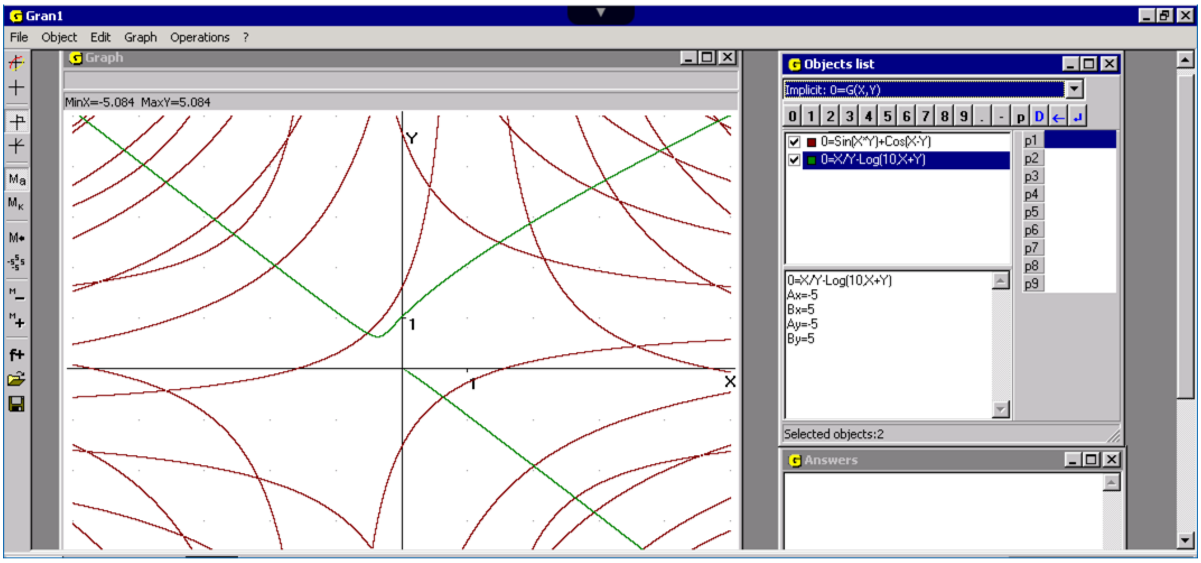

Figure 9: The system of equations $\begin{cases} 0 = \sin(xy) + \cos(x-y), \\ 0 = \frac{x}{y} - \lg(x+y). \end{cases}$ is presented graphically.

required to determine coordinates of points of the circle $x^2 + y^2 = 9$, that lie on the parabola $y = \frac{x^2}{7} - 2$ or on the five-petalled (pentapetalous) rose (5φ) (figure 10), one should plot the graphs and obtain coordinates of the required points (with accuracy up to hundredths) with the help of the coordinate cursor:

1. $x = -2.89, y = -0.81; x = -2.89, y = 0.39;$
2. $x = 2.89, y = -0.81; x = 2.89, y = 0.39;$
3. $x = -2.18, y = -2.06; x = 2.18, y = -2.06;$
4. $x = -2.63, y = 1.44; x = 2.63, y = 1.44;$
5. $x = -1.29, y = -2.71; x = 1.29, y = -2.71;$
6. $x = -0.55, y = 2.95; x = 0.55, y = 2.95.$

In this case it is impossible to exclude one of the variables x or y and it is difficult to offer any practically suitable way of solution besides the graphical method.

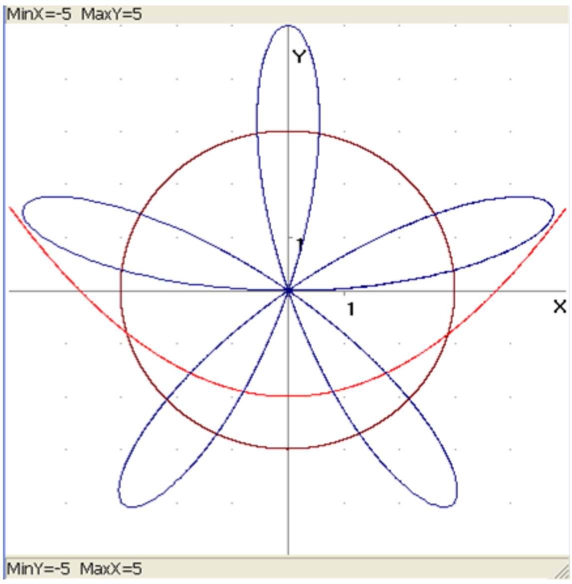

Figure 10: Dependence graphs.

4 CONCLUSIONS

The research examines the GRAN software complex, known in Ukraine and abroad.

Its expediency and effectiveness of use in the educational process of secondary and higher schools is confirmed by many years of practice, numerous research results for obtaining scientific degrees of doctors and candidates of sciences in the field of teaching mathematics and informatics (Vlasenko et al., 2020).

The approach to the study of mathematics, proposed by Myroslav Ivanovych Zhaldak, gives a clear idea of the concepts being studied, develops figurative thinking, spatial imagination, allows one to penetrate deeply enough into the essence of the studied phenomenon, to solve the problem informally. At the same time, clarification of the problem, formulation of the problem, development of the appropriate mathematical model, and material interpretation of the results obtained with the help of a computer come to the fore. All technical operations related to processing the built mathematical model, implementation of the solution search method, design, and presentation of the results of input data processing rely on the computer. It was to implement this approach that the GRAN software complex was developed.

Some selected problems proposed in the study demonstrate the expediency of using the GRAN complex for in-depth study of mathematics. Namely: the ability to conduct the necessary numerical experiment; quickly perform the necessary calculations or graphic constructions; to test the hypothesis; check the problem-solving method; to be able to analyze and explain the results obtained with the help of a computer; find out the limits of use. When learning mathematical methods, the use of a computer or the chosen method of solving a problem is extremely important.

The problems presented in the work were successfully used by the authors of the study during classes in various informatics disciplines, including computer modeling and computer mathematics.

A significant improvement of the GRAN complex has recently been its transfer to the cloud, which provides access to its services from any platform through a browser (Zhaldak and Franchuk, 2020). To get to the virtual desktop on a remote server, you must access the browser services and in the input line above the desktop enter the address https://gran.npu.edu.ua, then press the Enter key on the keyboard (or in the list of appropriate symbols on the screen “press” the label with the word “Go” in the case when using a smartphone or other laptop computer where there is no keyboard). As a result, a virtual desktop will open on which in the line “Username” you should select from the proposed list one of the available names, such as “gran”, and then in the line “Password” enter password “gran” (Zhaldak et al., 2021).

Currently, the expediency and possibility of transferring the entire GRAN complex of individual services into a mobile application is being investigated.

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Improving the Health-Preserving Competence of a Physical Education Teacher on the Basis of Spatial Value Interpretations of Nikolai Bernstein's Theory of Construction of Movements

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Keywords: Health-Preserving Competence, Physical Education Teacher, Post-Graduate Education, Virtual Reality, N. Bernstein, Biomechanics, Methodology, Pedagogy of Health, Ecologization, Spatial Approach, Spatial Value.

Abstract: In the article, based on the integrative use of Nikolai Bernstein's theory of movement construction, virtual reality technologies, and spatial and ecological approaches, ways of improving the methodology of developing the health-preserving competence of a Physical Education teacher in the conditions of postgraduate education are considered. Based on the use of AR/VR technologies a software application "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" was developed. The stated model is one of the tools of the "Methodology of development of the health preserving competence of a Physical Education teacher on the basis of Nikolai Bernstein's theory of the levels of movement construction". The experimental study determines that the application of the virtual model within the stated methodology is an effective tool for the development of the health preserving competence of a Physical Education teacher. The application of the virtual model allows the actualization of the health preserving, conceptual, gnoseological, biomechanical, inclusive, corrective potentials of Nikolai Bernstein's theory of movement construction.The use of the virtual model presents the ways of targeted and meaningful use of Nikolai Bernstein's theory of the levels of movement construction by a Physical Education teacher and the improvement of physical and recreational technologies and concrete physical exercises and movement modes. Due to the application of virtual reality tools, health-preserving, preventative, corrective and developmental strategies are being formed among which the significant ones are: "Application of synergistic movements to adaptation to movement activity, and recreation", "Application of spatial movements for actualization of the orientation and search activities and development of spatial thinking", "Use of movements with a complicated algorithm for intellect development". In order to ecologize and anthropologize and for the health-preserving oriented disclosure of human bodily-motor-spatial phenomenology, a spatial approach was applied and positive results were obtained in the training of Physical Education teacher.

1 INTRODUCTION

The application of digital technologies in education is a priority vector of innovative development, which gives the chance to disclose the potential of a personality and education. Burov et al. (Burov et al., 2020) speak of the significance of digital technologies for education, "…integration of virtual reality technologies into the educational process would facilitate the increase of the quality of education". These scientists note that this would facilitate the achievement of the "flexibility of the educational process". The stated scientists emphasize that the use of modern digital technologies in the field of education can be viewed as an opportunity for improving education accessibility for children with disabilities as well as children with special educational needs (Osadchyi et al., 2020). An important idea of these authors is that "the described technologies will allow to minimize the link of the educational process to a certain place or time as well as

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enable the access to educational resources in a form that would suit the learner. . . " (Burov et al., 2020).

The stated digital technologies are significant for the development of a health preserving competence of a Physical Education teacher in conditions of post-gradual education (Klochko et al., 2020a,b). This is caused by the need of an educator to perceive a person in conditions of movement activity at a qualitatively new level. The demand for such a perception, apart from health preservation, is the importance for prevention of various disorders as well as the need in the improvement of the skills of a Physical Education teacher related to working with the movement sphere of a person (Klochko and Fedorets, 2022). We actualize the need to use digital technologies, particularly, of virtual reality technologies, to increase the qualification level of a Physical Education teacher in conditions of post-graduate education, first of all, for the study of complicated movements spatial and anthropological phenomena and theories, which they disclose.

Movement as a manifestation of human nature and a way of existence, personality formation and development and its corporality in the professional activity of a Physical Education teacher is a central phenomenon that he or she works with. Therefore, a person's health is also perceived and interpreted in the format of movement activity (Klochko and Fedorets, 2022). At the same time, the nature of movement activity, which includes the knowledge and the practically oriented perception of its in-depth, neurological and systemic mechanisms is currently not fully understood by a Physical Education teacher. Consequently, the knowledge about movement as the essence of human existence is not fully used in the professional activity, primarily, within the health preserving aspect. The insufficient understanding of the in-depth and systemic physiological, neuro-physiological and psychophysiological mechanisms of movement activity by a Physical Education teacher is caused by a number of factors. Among the above mentioned factors, the following main ones can be singled out: the complexity and specificity of the issue; the insufficient understanding of its practical and technological significance; the need to study the neurological foundation of movement; domination of practical and technological training without proper consideration of the knowledge about the nature of movement; underestimation of the importance of the theoretical knowledge about the nature of movement for a professional and thus its insufficient operationalization (in the sense of transformation of theoretical concepts into practices and technologies) as well as targeted use in health preserving technologies and practices of physical education. The stated vector, which discloses the nature of movement activity, is primarily, even though incompletely, studied within the framework of formation and development of the professional competence.

In Ukraine, an important factor of insufficient actualization of knowledge about the nature of movement activity, were the limitations to studying biomechanics, which existed in the former Soviet Union. In the former Soviet Union,the foundations of biomechanics as a science that discloses the nature of movement were made by an outstanding scientist Nikolai Bernstein (Klochko and Fedorets, 2022; Bernstein, 1990; Devishvili, 2015; Latash and Latash, 1994; Bernstein, 2020; Talis, 2015; Bongaardt and Meijer, 2000; Meijer and Bruijn, 2007) at the end of 1940-s. One of the focal points of biomechanics is the theory of the levels of movement construction developed by Nikolai Bernstein. In the 1950-s, Nikolai Bernstein and his movement theory were severely criticized and essentially forbidden, and the scientist was persecuted (Klochko and Fedorets, 2022; Talis, 2015; Meijer and Bruijn, 2007) because of the fact that sociocultural processes, including the educational ones, are somewhat inert, biomechanics as a science that discloses the nature of movement and is even currently insufficiently used in the training a Physical Education teacher and development of his health preserving competence. Accordingly, this also applies to the issues of insufficient application of biomechanics, namely, Nikolai Bernstein's classic theory of movement construction in the course of post graduate training of Physical Education teachers.

The current processes of European orientation and humanization of the Ukrainian education as well as the active use of the child-centric, inclusive (Fahr et al., 2020; Safonicheva and Ovchinnikova, 2021), competence based and innovative approaches, determine the new intellectualized and humane format of Physical Education (Klochko and Fedorets, 2022; Aksonova, 2010; Barnard, 2000; Bykhovskaya, 1991; Dmitriev, 2014; Donskoy and Dmitriyev, 1999; Efimenko, 2011) as a diverse creative anthropological practice and as a variant of a "technology of self", improvement of both the movement sphere and corporality as well as self-realization and personal development and creativity. In this aspect the application of a personality-oriented approach is relevant as it includes the need to consider the personal and age biomechanical peculiarities of a child. One of the main aspects in setting this problem is the introduction of inclusive education. The inclusive paradigm determines the need for a Physical Education teacher to develop intellectual skills of taking into consideration the sensor and motor capabilities of children with special educational needs. Accordingly, in this aspect it is important that an educator gains knowledge and skills that make it possible to correct the sensor and motor disorders with Physical Education (Fahr et al., 2020; Safonicheva and Ovchinnikova, 2021).

The above mentioned tendencies determine professionalization and a central vector in post-graduate training of a teacher. This creates a need for a practice oriented disclosure of the mature of movement, both in the state of norm and pathology caused by certain motor disorders. An important aspect of actualization of the stated problem is also the issue of primary diagnostics of the state of the motor system, which includes the teacher's understanding of the peculiarities of its neurological foundations in order to personalize and optimize the motion activity at Physical Education lessons (Klochko and Fedorets, 2022). Diagnosing of the peculiarities and the state of the motor system, based on the knowledge about its nature is significant for health preservation as it allows the teacher to design and organize movement activities of the pupils using a targeted, conceptual and nature corresponding approach as well as correct those activities in the course of the classes. In conditions of commercialization and competition it is important for a Physical Education teacher from the point of their professional and social adaptation and self-realization.

The peculiarity of Nikolai Bernstein's theory of the levels of movement construction (Klochko and Fedorets, 2022; Bernstein, 1990; Devishvili, 2015; Latash and Latash, 1994; Bernstein, 2020; Bongaardt and Meijer, 2000) is its systemic nature and the fact that it is rather difficult for perception as well as practical application. That is why, effective representation tools are needed in order to present this theory in conditions of post-graduate education and with the focus on its practical implementation. The possibility of using the augmented reality technologies is one of such effective tools. Apart from general tendencies towards digitalization of education, the determining reasons for choosing technologies of virtual and augmented reality include the possibility to work with spatial objects, which is important for biomechanics, which studies mostly spatial changes and movement of a human body; another important factor is the time factor – the need to cover complex scientific theories in the context of their practical application within a short period of time, which is always the case in conditions of post-graduate training; another significant factor is the representative and sense-forming potential of augmented and virtual reality.

The need to use a spatial approach in this methodology is determined by the visual turn and spatial turn, which are important trends in modern science and the socio-cultural sphere, including education. An important factor in the actualization of the spatial approach, in addition to the indicated paradigmatic transformations, is the bodily-spatial, motor-spatial, spatial-cognitive and visual-spatial of physical culture and sports. This determines the need to know the motor sphere of a person not only as a being that moves in a "neutral" space.

The application of the spatial understanding of a person and his motor activity reveals ways to the development of the student's intentions, visions, interpretations and understanding of himself as a person who is spatial and is closely connected with the planet Earth and its landscapes, which are considered as special "spatial earthly values" and "value-meaning contexts". Spatial understanding is also aimed at the student's awareness of himself as a person of culture. This spatial approach is ecologically and anthropoculturally oriented. Accordingly, it represents human nature through its value-oriented spatial interaction with the planet Earth, which we consider as one of the central intentions in maintaining health. In the system of spatial and ecological interpretations of the phenomenon of man, his corporeality and motor activity indicated above, human health is considered classically as agate (well-being), which includes eudaemonia (happiness) (according to Aristotle). The implementation of the indicated "health-well-being" and "health-happiness" becomes possible under the condition of harmonization of man and the Earth.

In the scientific pedagogical literature, the problem of the integrative application of N. Bernshtein's movement theory, augmented reality technologies, and spatial and ecological approaches for the development of the health-preserving competence of the Physical Education teacher in the conditions of postgraduate education is not sufficiently disclosed. Together with the health preserving significance of Nikolai Bernstein's theory of the levels of movement construction, which is being disclosed using augmented reality, it is relevant for the development of the professional competence of a Physical Education teacher as well as for working with children with special educational needs. The mentioned aspects of problematization together with the scientific and practical significance of the problem presented above aimed at preserving the health of students, environmentalization and digitalization of the educational process, as well as at the professional development of the Physical Education teacher define this research as relevant.

Purpose. Improvement of the methodology for the development of the health-preserving competence of a Physical Education teacher in the conditions of postgraduate education based on the integrative use of Nikolai Bernshtein's movement construction theory, virtual reality technologies, and spatial and ecological approaches.

2 SELECTION OF METHODS AND DIAGNOSTICS

The following approaches were used in the study: analysis of the scientific literature; competence based; systemic; morphological-functional; anthropological (Tkhostov, 2002); biomechanical (Klochko and Fedorets, 2022; Bernstein, 1990, 2020; Devishvili, 2015; Bongaardt and Meijer, 2000; Dmitriev, 2014; Donskoy and Dmitriyev, 1999; Efimenko, 2011); ontological, neurophysiological, spatial, pathopedagogical (V. Fedorets); hermeneutic, inclusive (Klochko and Fedorets, 2022; Fahr et al., 2020; Safonicheva and Ovchinnikova, 2021).

The following concepts were applied: anthropologization Ushinskii (Ushinskii, 1950a,b) and knowledge transfer Nonaka and Takeuchi (Nonaka and Takeuchi, 1995).

Anthropologization. The methodologically defining idea of anthropologization was formed by Ushinskii (Ushinskii, 1950b). He presents the essence of anthropologization in his classic work "Man as a subject of education. Experience of pedagogical anthropology" (Ushinskii, 1950a,b). In this book, Ushinskii (Ushinskii, 1950a) reveals the fundamental system-organizing methodological message, – "If pedagogy wants to educate a person in all respects, then it must first of all get to know him in all aspects" (Ushinskii, 1950a). In the context of the ideas of anthropologization, the teacher must know, understand the child and interpret his nature and problems humanly and multidimensionally. At the same time, the teacher should consider the child as a special anthropic, biomechanical, spiritual, psychological, cultural, age-related, physiological, existential phenomenon. Anthropologization is considered as a determining factor in the professionalization of the Physical Education teacher and the development of his vision-saving and professional competences based on the actualization of a multidisciplinary, multidimensional, holistic and systemic vision of the child. This, first of all, also includes the teacher's knowledge of certain specific phenomena of a different nature (biomechanical, spatial, psychological, etc.). In this study, we integratively consider mainly biomechanical and spatial phenomena. The indicated idea of anthropologization is a way of both humanizing the teacher and the educational process, and it is also a way of implementing the child-centered and humanistic ideas embedded in the Concept of the "New Ukrainian School" (Anosov and Stanishevska, 2018; Elkin et al., 2017; Ministry of Education and Science of Ukraine, 2019; Zhorova et al., 2022). Anthropologization, in addition to general ideas about human nature, also includes knowledge of certain specific anthropological phenomena and private problems. Therefore, anthropologizing as an idea and as a direction is one of the fundamental methodological directions and, accordingly, it determines the logic of this research. Anthropologization as a way of humanization and professionalization is the methodological basis of this pedagogical system, a fragment of which is presented in this study. Anthropologization corresponds to the modern ideology of the anthropological turn in philosophy, in education, which includes humanistic and existential (Abbagnano, 1969) transformations of educational practices and traditions.

Knowledge transfer. We apply the concept of knowledge transfer as one of the central and cross-cutting strategies. Knowledge transfer is applied in two directions – "methodical professional-personally oriented" and "methodological-innovative". It is part of the foundations of the methodology of this pedagogical system and, accordingly, of this study. The first "methodical professionally and personally oriented direction" of applying knowledge transfer is based on the SECI model (Nonaka-Takeuchi model) (Nonaka and Takeuchi, 1995). This model reveals the process of transition of implicit (tacit, implicit, background) knowledge (Chergui et al., 2020; Hélie and Sun, 2010) into explicit (explicit, formalized, codified) knowledge (Weinberger and Green, 2022). The SECI model also represents the following transformation of explicit knowledge into implicit knowledge. The indicated metamorphoses of knowledge constitute one cycle or circle of knowledge, which is a component of the spiral of knowledge. To clarify, we note that the specified SECI model defines four interrelated epistemological processes of knowledge transformation: "S" – socialization, which consists in the formation of collective implicit (tacit) knowledge by a group of persons; "E" – externalization is the transformation of implicit knowledge revealed in the process of socialization into explicit knowledge; "C" – combination consists in the fact that the formed explicit knowledge through combination, systematization, categorization and integration acquires a new qualitative level by being represented in understandable verbal formulations; "I" – internalization is manifested by the fact that the formed explicit knowledge is transformed into the implicit knowledge of a specific teacher, entering into his intellectual potential

(Nonaka and Takeuchi, 1995).

The SECI model is used in the educational process for health-oriented understanding of N. Bernstein's movement theory. This model is used for the purpose of deepening, expanding, updating, specifying knowledge, as well as for the formation of new knowledge. The SECI model is also used for health-preserving, anthropologically valuable and ecologically valuable interpretations and practical directions of knowledge, as well as for their axiologisation, anthropologization, phenomenology, aestheticization, existentialization, technologization, and psychologization. In the context of the integrative application of N. Bershtein's theory of building movements and the spatial approach, a significant and relevant aspect of knowledge transfer is the growth of knowledge and its practical orientation, direction and concretization. The indicated epistemological transformations of knowledge are, first of all, necessary for the teacher to acquire the ability to solve a certain amount of specific practical problems of a biomechanical nature aimed at preserving the student's health. The decisive factor in this aspect is that the student's specific "biomechanical" problems, which are related to his motor sphere and physicality, respectively, can be solved on the basis of the optimal organization by the Physical Education teacher of children's motor activity based on his application of N. Bershtein's theory of building movements.

As a result of the process of knowledge externalization, professional experiences and practically directed personal knowledge of biomechanics and health preservation are formalized and unified. Accordingly, such knowledge becomes available, comprehensive and understood by participants of the educational process both for theoretical understanding and for practical application. It is significant that such knowledge becomes conventional, that is, recognized as relevant by the professional community. In turn, as a result of the process of internalization, theoretical knowledge of biomechanics and theoretically understood professional experiences are included in the intellectual potential of the teacher. Accordingly, the specified internalized knowledge is included in the cognitive-value component of the health-preserving competence of the Physical Education teacher. In this component, knowledge of human biomechanics and preservation of health become the knowledge base of health-preserving thinking. This includes the teacher's formation of metacognitive strategies (Fedorets et al., 2022), as well as typical health preservation strategies and algorithms.

The second "methodological and innovative direction" of the application of knowledge transfer, which is the main one in this study and is innovative in its essence, represents the process of transformation of scientific (in this case, biomechanical) and applied knowledge into educational and professional knowledge (Levchenko and Zhukova, 2011). The considered educational and professional knowledge is necessary for professional development in the conditions of postgraduate education. This direction also includes the application of the SECI model (Nonaka-Takeuchi model) (Nonaka and Takeuchi, 1995) for methodological and educational purposes. The formed world-professional knowledge is directed to the targeted use in the final epistemological process in postgraduate education and the professional activity of a teacher, which is the internalization of knowledge, as a result of which it becomes personal (according to Polanyi (Polanyi, 1964)). In this pedagogical system, knowledge transfer is used for the formation of educational and professional health-preserving knowledge, which is carried out using knowledge of biomechanics, medicine, hygiene, neurophysiology, psychophysiology, psychology, anthropology, and systemic, existential, and spatial approaches.

The indicated "methodological and innovative direction" of the application of knowledge transfer is implemented within the framework of a significant modern trend – the knowledge triangle (Unger and Polt, 2021). The concept of the triangle of knowledge is aimed at effective innovative interaction, and in fact the integration of science, education and innovation. In this study, we reveal the scientific knowledge of N. Bernstein's theory of movement construction and their educational and practically oriented understanding in the conditions of postgraduate education, representing it in an innovative aspect with the use of digital technologies (AR/VR technologies) and a spatial approach. The innovative aspect consists in the creation of a new educational product through the spatial-valued understanding and practical-technological orientation of N. Bernstein's theory of building movements. Although the specified theory is basic in biomechanics, at the same time, it is not sufficiently applied in health pedagogy and in the educational health-preserving practices of the Physical Education teacher. From the innovative and economic standpoint, the application of the knowledge triangle concept in this study has the final economically and socially significant goal of preserving and forming the health of students. The implementation of the indicated goal by improving the health-preserving competence of the Physical Education teacher contributes to the development of health capital, which is a basic component of human capital (Ogundari and Awokuse, 2018), which ensures innovative development in which education and health are important (Iacopetta, 2010).

Digital technologies. Digital technologies were used (Prokhorov et al., 2022; Semerikov et al., 2022; Osadchyi et al., 2020; Klochko et al., 2020b,a). The study worked with the Internet-resources of the technology of virtual reality, namely the software application "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" (Fedorets & Klochko, 2022; CoSpaces Edu, 2023). The CoSpaces Edu software was used to develop and view the virtual reality software application (CoSpaces Edu, 2023).

Methods of mathematical statistics. Wilcoxon's rank sum test (Wilcoxon, 1945; Wilcoxon et al., 1963). In order to confirm the statistical significance of the difference in the results of solving the control problems of Physical Education teachers before and after the experiment, we used Wilcoxon's rank sum test. The criterion is used to compare the indicators of the same sample in two different conditions. In this case, the "typical" shift is considered to be a shift in the direction of increasing the values of the studied feature.

We formulate hypotheses:

H_0: The values of the indicators after the experiment exceeds the values of the indicators before the experiment at the level of significance $p < \psi$.

H_1: The values of indicators after the experiment are less than the values of indicators before the experiment at the level of significance $p < \psi$.

The calculation of the sum of the ranks of "atypical" shifts T_{emp} is carried out according to the formula

$$T_{emp} = \sum_{i=1}^{k} r_i, \tag{1}$$

where k is a number of atypical shifts, r_i is the ranks of atypical shifts $(i = 1 \ldots k)$.

T_{cr} is found in the table for a given n (number of indicators) according to the level of significance ψ. ψ is determined in accordance with the problem $0,05$ or $0,01$, ie $p < 0,05$ or $p < 0,01$. If $T_{emp} \leq T_{cr}$ at the level of significance p¡ψ, the shift in the "typical" direction in intensity with high probability prevails, we accept hypothesis H_0. If $T_{emp} > T_{cr}$, with an intensity with high probability is dominated by a shift in the "atypical" direction, we accept hypothesis H_1 at the level of significance $p < \psi$.

Methodological concepts developed by V. Fedorets and O. Klochko. The developed "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" is the determining, conceptualizing and system organizing part of the study. The stated virtual model is a part of the "Methodology of development of the health preserving competence of a Physical Education teacher on the basis of Nikolai Bernstein's theory of the levels of movement construction" (developed by V. Fedorets). This methodology is formed on the basis of using pedagogical tasks, analysis of movements and movement modes as well as on the study of practically all significant situations, issues and biomechanical and anthropological phenomena in the normal and pathological states. A significant component of the methodology is the implementation of tasks aimed at the development and correlation analysis of physical exercises and movement modes based on the application of N. Bernstein's theory of movement construction (Klochko and Fedorets, 2022; Bernstein, 1990, 2020; Devishvili, 2015; Bongaardt and Meijer, 2000; Dmitriev, 2014; Donskoy and Dmitriyev, 1999; Efimenko, 2011). The important approaches used within the framework of this methodology include problem based learning and flipped learning as well as game-based teaching methods and Socratic (maieutic) methods. The analysis and study of pedagogical, movement and sport experiences and practices of Physical Education teachers seems important.

Within the stated methodology, we use our own methodological technique "Wheels of problems and senses". This technique represents a broadened and adapted to practical use "version" of the hermeneutic circle. In the course of its development we used the holistic and systemic approaches as well as ideas of contextual learning. The developed "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" (developed by V. Fedorets and O. Klochko.) (Fedorets & Klochko, 2022; CoSpaces Edu, 2023) was used throughout the stated methodology and represents its "central" and sense-forming component.

Methodology of control over the efficiency of application of "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" as a part of the methodology (developed by V. Fedorets). The basis of the control methodology is presented by 10 interrelated questions. The questions are given in the form of a test (Yevtuch et al., 2021b). A Physical Education teacher needs to choose one correct answer of the four suggested options. This is done to form a systemic and practically oriented understanding of this issue in a teacher as well as to develop his skill of conceptualizing relevant issues of motor activity in a practical way with the focus on health-preservation. Here is the list of the question.

Question (Yevtuch et al., 2021b):

1. From the list of movements select those in which level A is the leading one.
2. From the list of movements select those in which

level B is the leading one.

3. From the list of movements select those in which level C is the leading one.
4. From the list of movements select those in which level D is the leading one.
5. From the list of movements select those in which level E is the leading one.
6. Which movement level (choose from A, B, C, D, E) domineers in dancing or physical exercises that have a relatively complex algorithm or scenario? How can this be used at the lessons of Physical Education from the point of health-preservation and personality development?
7. At which level of movements (choose from A, B, C, D, E) the movements are implemented with minimal energy losses? How can this be used from the point of health-preservation in organization of workout process at Physical Education lessons?
8. Development of which level of movements (choose from A, B, C, D, E) is the basis of praxis? How can this be used at the lessons of Physical Education from the point of health-preservation and personality development?
9. At which movement level (choose from A, B, C, D, E) basic motor disorders are formed in conditions of infantile cerebral paralysis? Is it possible to consciously and arbitrarily influence this level?
10. Which of the levels of movements (choose from A, B, C, D, E) is associated with orientation and search activity, and can be fully realized thanks to the visual analyzer. The formation of which thinking is facilitated by the actualization of this level of movements? How can this be used at the lessons of Physical Education from the point of health-preservation and personality development?

Spatial aspect of methodology. An important professional aspect of considering a person as a spatial being in relation to the earth's space is both a philosophical-methodological and a purely practical-technological issue, which is determined by the complex biomechanics of a person. Clarifying this provision, we focus on the phenomenon of spatiality, which is contextually present both in biomechanics and directly in the practices and technologies of physical culture and sports. In his professional activity, in the process of organizing motor activity, a Physical Education teacher constantly works with the spatiality of a person, with the existentiality of space, with the existentiality of corporeality (Binswanger, 1942), and also reveals for himself the phenomenology of cultural space, physical space as the space of the Earth, presented in the format of its natural and anthropogenic landscapes.

In this pedagogical system, for an ecologically valuable, health-oriented and aesthetic understanding of the phenomenology of the spatial organization of the human body, its physicality and motor activity, as well as the space of the Earth, terrestrial landscapes as natural and anthropogenic, in particular, architectural structures, the theory of construction is used movements of M. Bernstein and its "digital illustration" "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction". Accordingly, the theory of M. Bernshtein is interpreted culturally, ecologically-valuably, aesthetically and health-oriented.

The "Methodology for the development of the health-preserving competence of the Physical Education teacher based on M. Bernstein's theory of the level construction of movements" includes consideration of environmental and health-preserving problems. These problems are considered based on the application of a spatial approach. For this purpose, appropriate health-preserving and ecologically oriented narratives, "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction", photographs, diagrams and images of people and natural and anthropogenic landscapes, objects, as well as architectural structures and works of art were used. The use of images, architectural, works of art and images of landscapes and landscapes also aims to aestheticize the learning process and activate emotional intelligence and stimulate the emotional and aesthetic factor of creativity and intellectual activity.

To diagnose the effectiveness of training, we used the questionnaire developed by us "Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of M. Bernstein's theory of movement construction", which is presented below.

"Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of N. Bernstein's theory of movement construction".

When processing the questionnaire, it is necessary to choose one of three answers.

1. A person's own inner space and world in bodily-motor representation can to some extent be represented by the level of tonic movements (level A) according to N. Bernstein. Under the influence of external conditions, social and psychological factors of a person at the indicated level can be

formed (according to V. Reich) ... .

Variants of answers: muscle clamps and carapace of the character, protrusion, blood circulation disorders.

The correct answer: muscle clamps and armor of character.

2. In a person, his inner space and world, which in motor activity is represented by pendulum-like, repetitive, balancing movements that create a spatial effect of "mixing" and close interaction of the inner human and outer earthly space, represented by the level of synergistic movements according to N. Bernstein, determines the relevant for health preservation ... aspect.

Variants of answers: neuronal, recreational, volitional.

The correct answer: recreational.

3. From an ecological and value point of view, the implementation of "level C – Spatial movements" according to N. Bernshtein, which defines the possibility of active movement of a person in space, can be considered as a universal way ... .

Variants of answers: formation of stress resistance; harmonization and knowledge of the Earth, the world and man; development of entrepreneurial competence.

The correct answer: harmonization and knowledge of the Earth, the world and man.

4. Level D – substantive actions according to N. Bernshtein, which determines the formation of a special anthropogenic space of objects, tools, buildings, which from the standpoint of the concept of sustainable development should be ... to the earthly world and space.

Variants of answers: ecophobic and competitive; ecophilic and harmonized; active and enterprising.

The correct answer: ecophilic and harmonized.

5. The development of "level E – intellectual (speech) movements", according to N. Bernstein, is an anthropogenic and mental prerequisite for the formation of a special shell of the Earth, which V. Vernadsky defined as ... .

Variants of answers: lithosphere, hydrosphere, noosphere.

The correct answer: noosphere.

Let's consider the main ideas and meanings on the basis of which the "Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of N. Bernstein's theory of movement construction" was developed. The questionnaire is based on a worldview concept inherent in many secular and religious systems, namely, the ancient anthropocosmic idea of the macrocosm – the harmonious world in which we exist, and the microcosm – the special inner world of man, which is within us. The microcosm is essentially seen as a version of the big cosmos (microcosm). Therefore, by influencing the inner world, we can change the outer world. The microcosm of a person, as well as his essence as a whole, manifests itself through motor activity.

The methodological and worldview value of N. Bernstein's theory of building movements lies not only in its systematicity but also in its cosmos. It reveals the motor sphere of a person as a special harmonized World – "Cosmos of movement". Cosmos in classical ancient Greek ideas is a harmonized, aestheticized, ordered, stable and living world. Ancient ideas are indicated, which fully correspond to the currently dominant concept of sustainable development, which is aimed at building a harmonious "anthropo-earthly" world.

N. Bershtein's theory reveals to us a unique cosmos of motor activity, which is primarily based on harmony between different levels of movements. Violation of this harmony forms pathologies. Thus, the "internal" (anthropic) cosmism of the motor sphere of man as a manifestation of his high "spiritual-motor" nature revealed by N. Bershtein in the specificity of the organization of certain levels (A, B, C, D, E) must be correlated with the "external" anthropocosmism earthly world. We consider motor activity as spatial and oriented towards the disclosure and formation of ecological values and intentions. This is realized through a person's understanding of its spatiality, spatial values in interaction with the disclosure of the value of earthly spaces (landscapes). The questionnaire contains five questions, which corresponds to the number of levels in N. Bernstein's theory of movement construction. Accordingly, in each question, in addition to the characteristics of a certain level of movements, the spatial, anthropological and ecological aspects that it reveals are reflected.

Question № 1 – "A person's own inner space and world in bodily-motor representation can to some extent be represented by the level of tonic movements (level A) according to N. Bernstein. Under the influence of external conditions, social and psychological factors of a person at the indicated level can be formed (according to W. Reich) ..." (Gilbert, 1999) – the presence of changes at level A in the format determines the "bodily-spatial" phenomenon, which is important for the corrective and preventive work of a Physical Education teacher – muscle tension. The essence of the phenomenon of muscle tension is that under the influence of both external life (psychological-physical-social) factors and conditions, tension zones (muscle tension) may appear at the said level. The specified tension zones are subsequently fixed and manifest outwardly over time in barely noticeable peculiarities of a posture and motor activity. Internally, a human feels discomfort in certain areas of the body. In addition, bodily changes relate to certain psychological problems and affect a personality and the quality of life. The concept of the character armour, which is formed by fixing muscle tension, which was introduced by an outstanding Austrian psychologist Wilhelm Reich, is relevant in the practice of body psychotherapy. The character armour is a bodily, psychological as well as spatial and motor phenomenon at the same time. In the character armour, the peculiarities of a human's interaction between himself/herself and the outside world are reflected to a significant degree. Therefore, we consider the said problem from the standpoint of the need to harmonise a human with himself/herself, terrestrial landscapes and other people. Accordingly, the practices and technologies of intellectualised, ecologised, and psychologised physical culture can be ways of harmonisation. Motor activity in this case is considered to be recreation, self-therapy and reflection, which are implemented through "spatial, bodily and motor" practices. Physical culture becomes a way of understanding and cognition of oneself, and a way of restoration of harmony with oneself, the Terrestrial world and social environment.

Question № 2 – "In a person, his inner space and world, which in motor activity is represented by pendulum-like, repetitive, balancing movements that create a spatial effect of "mixing" and close interaction of the inner human and outer earthly space, represented by the level of synergistic movements according to N. Bernstein, determines the relevant for health preservation ... aspect" – reveals important vital and motor features of synergistic movements (level B) according to N. Bernstein. These movements are economical, "pulsating", rhythmic. These characteristics determine their ability for recreation, which is one of the important aspects of physical culture. At the same time, synergistic movements can be "easy", rhythmic and have the "natural potential" of spontaneity. In turn, a person who is tired or who has certain life and psychological problems that "lock" him in the armor of his character partially loses lightness, fluidity, rhythmicity and spontaneity. The rhythmicity of synergistic movements integratively reflects the metaregularities of the human macrocosm and microcosm, which exist and develop as megasystems of synchronized, harmonized rhythms. In this pedagogical system, special attention is paid to the ability of the Physical Education teacher to use the vital, recreational and motor potential of synergistic movements, as those that harmonize a person with himself and the world through motor activity. An example of effective movement for a person in which a synergistic component is prominent is gait. Accordingly, walking has powerful recreational and intellectual effects.

Question № 3 – "From an ecological and value point of view, the implementation of "level C – Spatial movements" according to N. Bernshtein, which defines the possibility of active movement of a person in space, can be considered as a universal way ... " – reveals ancient ontological and worldview-forming ideas of movement and path (for example, there is the Chinese tradition "Tao Te Ching") as a manifestation and formation of life, as ways of existence. Implementation of "Level C – Spatial movements" a priori requires movement in space. In physical culture, purposeful motor activity within the specified level is one of the main ones. This level C (spatial movements) integratively ensures the development of both the body and sensorimotor intelligence. From the ecological and geopsychological point of view (Mindell, 2007), the actualization of this level is significant in the knowledge of the world and the harmonization of man with the earth's spaces (landscapes). Activity at this level is also a way to oneself, i.e., a way of self-discovery through understanding oneself as a part of the great earthly world, which occurs in the process of moving in space and contemplating landscapes. The main movements in this level are walking and running. Walking and running are also based on synergistic movements (level B according to N. Bernstein).

Question № 4 – "Level D – substantive actions according to N. Bernshtein, which determines the formation of a special anthropogenic space of objects, tools, buildings, which from the standpoint of the concept of sustainable development should be ... to the earthly world and space" – reveals the special space of human activity and its results – objects of material culture and the phenomenon of architecture. Emphasis is placed on the need to implement human activity in an ecologically oriented manner in accordance with the ideology of the Concept of Sustainable Development.

Question № 5 – "The development of "level E – intellectual (speech) movements", according to N. Bernstein, is an anthropogenic and mental prerequisite for the formation of a special shell of the Earth, which V. Vernadsky defined as ..." – reveals deep philosophical and worldview ideas about the special shell of the Earth – the noosphere, which is considered as the highest manifestation of the spiritual-mental and motor-metal nature of man. We interpret the noosphere as a manifestation of human nature integrated with planet Earth. In this case, man is to some extent derived from her, from Terra Mater (lat.) – Mother Earth. These ideas contribute to the development of intentionality, values, and meanings aimed at preserving the Earth as a planet, as a human environment, and as its "cosmic" homeland. The actualization of the phenomenon of the noosphere contributes to the development of anthropocosmic consciousness and a holistic perception of the Earth as a special and unique anthropoearthly world for humans (Yevtuch et al., 2021a). In such a world, space is interpreted and has a metric as "telus-existential – res extenza".

Thus, each level highlighted in N. Bernstein's theory of movement construction corresponds to its own special "telus-anthropic" and cosmic understanding of space. Each level reflects its specificity of interaction of the motor sphere of a person with space and with itself, and forms a certain systemic multi-level integrity in the perception of oneself and the world. The actualization of different levels of human interaction with the earthly space is also a method of self-reflection and physicality. In his imagination, a person almost always imagines himself not separately, but connected to some fragment of reality in which there is a distinct spatial aspect. That is, a person always reflects a fragment of some artificial or natural landscape in his mental reality. Psychologically, it is essentially inseparable from Terra Mater – Mother Earth.

3 RESULTS AND DISCUSSION

Improving the health-preserving competence of a Physical Education teacher in the conditions of postgraduate education is a defining and system-organizing educational precondition for the effective preservation of the health and life of children in the conditions of the educational process. Guided by the paradigm of competence approach and the ideas of inclusion, creativity, child-centeredness and humanization, we define the *health-preserving competence of a Physical Education teacher* as an integrative professional and personal ability of a teacher aimed at preserving the life and health of students with typical development and special educational needs in the educational process by forming a healthy lifestyle, prevention and correction of disorders; by promoting the formation of children's competence in personal health-preserving, physical activity, corporeality, physical image, personal freedom, as well as the development of socially adapted, harmonious, ecophilic and life-creating personality through the use of physical culture means. A relevant component of improving the health-preserving competence of Physical Education teachers in postgraduate education is the use of virtual and augmented reality technologies to deepen and expand practical knowledge about motor activity as a manifestation of human nature and as a way to his or her health.

Let us consider the ways and peculiarities of using the virtual model ("Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction") as a system organizing model within the "Methodology of development of the health preserving competence of a Physical Education teacher on the basis of Nikolai Bernstein's theory of the levels of movement construction" (Yevtuch et al., 2021b). In this methodology, the virtual model is the central and sense-forming element, representing a spatial image-semiotic system. We formed the stated methodology on the basis of methodological idea of cyclic, repetitive, rhythmic, step-by-step development of knowledge and senses as well as on the "panoramic" and holistic perception of reality. Together with knowledge development, we actualize the formation of corresponding senses, values, intentions, reflections, interpretations and professional health preserving attitudes. Cyclicity and repetitiveness, being the determining structural and didactic ideas of knowledge representation and sense shaping, are initially defined by systemic nature and a "multi-dimensional" and diverse specifics of N. Bernstein's theory of movement construction (Bernstein, 1990, 2020; Bongaardt and Meijer, 2000). Within the framework of this theory five levels of movements are defined – A, B, C, D, E. Being interrelated and interdependent, these levels represent a complex hierarchic system. It is relevant that every level of motor activity is relatively autonomous and specific and may be considered as a determining and defining for movements that are characterized by common features. At the same time, a certain level is presented as a necessary component or the basis for the next, "higher" level of movements. According to the above described understanding, movements activity may be presented either by all levels or by one, two (e.g. balancing movements), three (e.g. walking) or more (up to five) levels.

Highlighting the essence of N. Bernstein's theory, we characterize each level of movements in the relation to other levels and thus disclose the phenomenology of movements activity as a whole. At the same time, we highlight one key determining aspect (vector) and a few additional ones. These additional aspects facilitate a deeper, widened and interpretation oriented disclosure of the key aspect by supplementing its senses. In this pedagogical system the key aspects (vectors) are presented as *problem-conceptual lines*. These lines differ from the aspects (in a narrow sense) as they are clearly directed, aimed at problem setting, interpretation and constructing of new knowledge. The orientation towards knowledge and sense construction, transfer and transformation includes the actualization of an individual problem as well as the formation of complex and general understandings about movement perceiving the peculiarities of all five levels. Thus, the consideration of the issue of movements activity is being actualized through its consideration within the "individual-general" system, which is one of the central correlations in hermeneutics (Dilthey, 1996). The stated "individual-general" correlation is reflected in the concept of a hermeneutic circle. In our pedagogical system of didactic positions, the central and main differences between the problem-conceptual line and aspect lie in the fact that it is primarily viewed and formed as a certain epistemiological, hermeneutic, value-conceptual and practically and technologically oriented subsystem with the corresponding orientations. The consideration of a certain problem-conceptual line (aspect) discloses the nature of all five levels of movement as a complex system and accentuates each of these levels as a particular "movement ontology". By actualizing each next aspect as the previous one we "take it through" all A, B, C, D, E levels (Yevtuch et al., 2021b).

For instance, while disclosing the nature of movement through the representation of "Key manifestations of movement" and "Movement characteristics", we analyze and illustrate it with the help of a virtual model. The movement is structured into subsystems represented by a certain level: A (tonic movements) – ensures muscle tonus, mimic movements, trembling from cold and stress, etc. (figure 1); B (synergistic movements) – synergistic, economic, balancing, reciprocal (movements in which antagonist muscles contract and relax in turn), smooth, "round" movements etc. (e.g. body movements when a person stands, balances or does physical exercises without lifting the legs from the surface or changing his or her position) (figure 2); C (level of spatial movements) – movements that ensure active spatial movements: jumps, walking, running, thrusts (figure 3); D (level of concrete actions) – movements that ensure an effective and targeted work with objects, tools – praxis (figure 4); E – intellectual movements: language movements and dances and "motion scenarios", which have a complicated structure (figure 5) (Yevtuch et al., 2021b).

We briefly represent another important problem-conceptual line, which is a group of interrelated aspects – "Movement as a manifestation of existence, movement as a body scheme, movement as a spatial and orientation phenomenon" (Yevtuch et al., 2021b). Level A – level of tone – is a manifestation of existence as a given; is "discloses" the space of the body as a self-sufficient, self-referential and self-reflective system; the level of tone (A) essentially "forms" the "vital body" as a self-referential phenomenon both in the consciousness and in reality; this level ensures the formation of a "primary" scheme of the body; discloses the corporal "self" as the one that is in the body in general, actualizes it; existential of corporality; forms a certain orientation within one's body, which is relatively independent from the environment. Level B – level of synergy – swaying, synergistic movements form: movement as such, which is characteristic of a body and the movement of body parts relatively to the body as well as swaying shifts (sways, bends etc.) of a body in space; discloses the corporal "self" as such exists in the body through synergistic movements; actualized the existential of space (Besoli, 2017), the existential of corporality as the existential of movement (Klochko and Fedorets, 2022) by shifting parts of the body (limbs and the body itself) relatively to it; discloses the existential of temporality through movements, which are repetitive and periodical, forming a "temporal-biochemical-swaying" process, which facititates the perception of time; forms orientation within one's body with regard to and depending on the movement of parts of the body (arms, legs) relatively to it and while making swaying movements, also taking gravitation into consideration; balancing movements give the realization of gravitation and thus form a close connection with the Earth as a planet and the foundation of life; these movements are a precondition for forming spatial metaphors, which represent the basis of the sensor-motoric thinking. Level of spatial movements – C: represents and "unveils" the space, landscape and the Earth with the existing objects and perspectives; presents movement as a "spatial" existence through spatial movement; discloses the existential of spatiality and temporality; actualizes the existential of corporality and the existential of locomotion (Klochko and Fedorets, 2022) through movement of the body in space; forms an orientation and goal setting in space; is a precondition of forming spatial metaphors as the basis of thinking and values (Lakoff and Johnson, 1980). Level of concrete actions – D; "forms" a "world of things" in the consciousness (the object domain); discloses the orientation within the objects and actions; "creates" praxis as an ability for

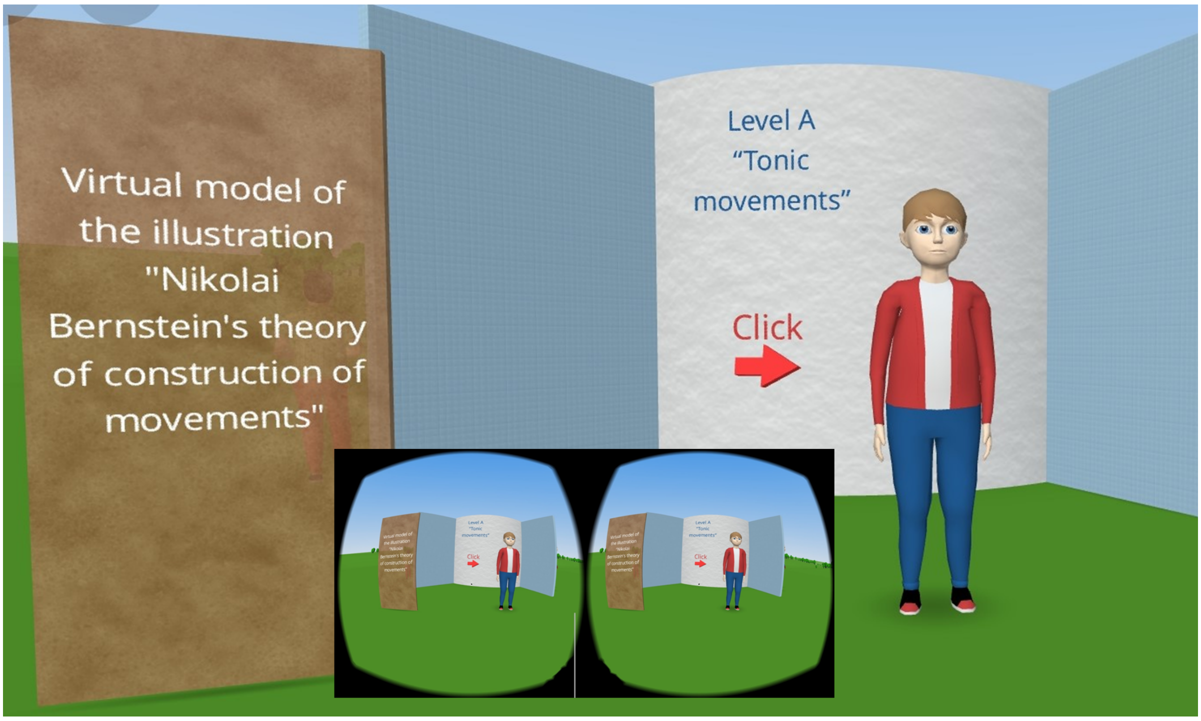


Figure 1: Level A – Tonic movements (Fedorets & Klochko, 2022). The figure shows a man standing. This is provided by the tonic level (A). A person can jump sharply. This is an example of changes in the tonic level – ballism. Movement: muscle tone, statotonic, coordination-tonic, facial expressions, trembling in the cold, grouping when falling. Level basis (is the "background level") – B, C, D, E. Characteristic of movement: unconscious (automatic), the involvement of all muscles of the body, basic and background for all levels, associated with the subconscious. Attitude to space and orientation: own body (Yevtuch et al., 2021b).

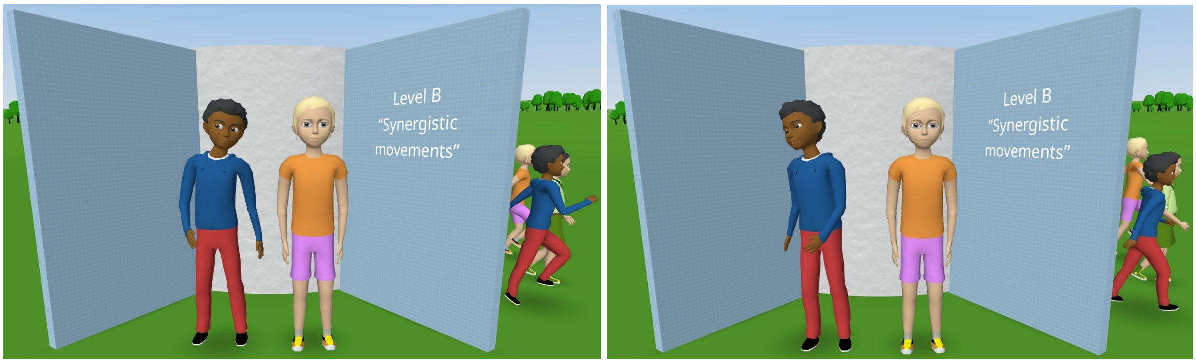


Figure 2: Level B – Synergistic movements (Fedorets & Klochko, 2022). Movement: base walking and dancing (rhythmic), maintaining balance and balancing, facial expressions. Level basis (is the "background level") – C, D, E; rhythm of speech and intonation. Characteristic of movement: movements without taking into account the spatial structure of the environment, economical, balancing, stereotic, equilibrium, "pulsating", rhythmic, repetitive, smooth and precise, partially automatic, the basis of walking, may be partially automatic and unconscious. Attitude to space and orientation: own body and the immediate surrounding space (Yevtuch et al., 2021b).

targeted, creative and "transformational" work with objects, tools and the environment and to a certain extent as a "specific" interaction with people and animate objects (plants, animanls). Level of intellectual movements – E: forms mental and corporal activity as a semiotic-conceptual and intentionally-targeted, in the formats of language and communication; discloses the language and dialogue as existence and a mental-communicative way of existing in it; determines the spaces and fields of concepts, senses and values; discloses intellectual activity as a human way of being; actualizes the existentials of love and health

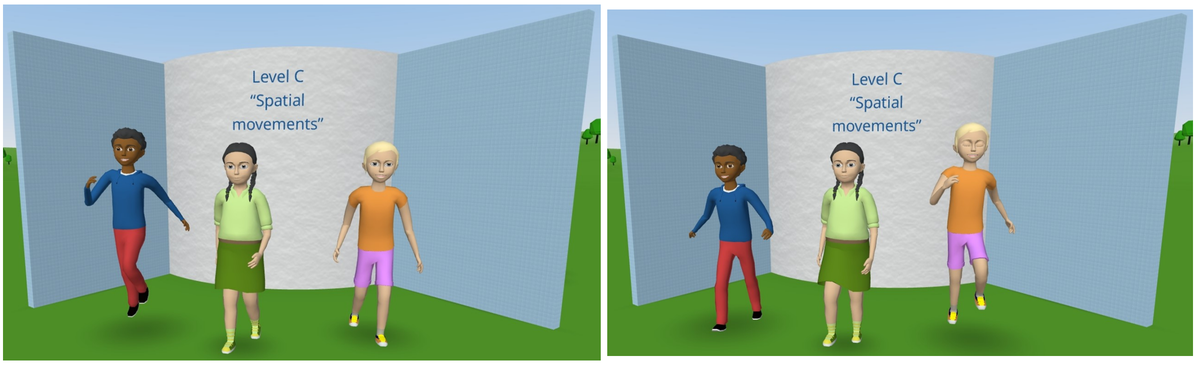


Figure 3: Level C – Spatial movements (Fedorets & Klochko, 2022). Movement: movement based on orientation in space, walking, running, throwing, jumping. Level basis (is the “background level”) – level D, E. Characteristic of movement: spatially oriented, differentiated, precise, conscious, conscious movements. Attitude to space and orientation: Three-dimensional Space (Yevtuch et al., 2021b).

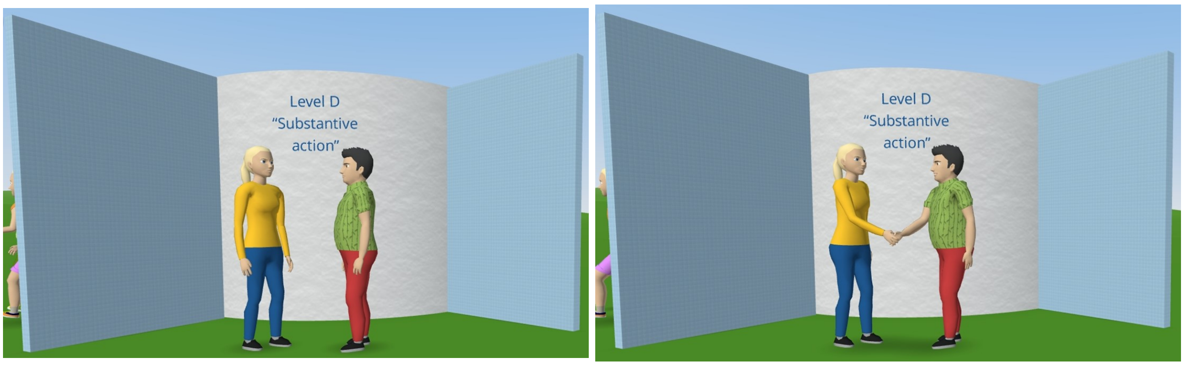


Figure 4: Level D – Substantive action (Fedorets & Klochko, 2022). The figure shows the idea of movement of level D – Substantive action. It is primarily formed through contact in the “man-man” system as a contact. In this case, the participation of level A (tonic movements) is relevant – which forms the possibility of contact with another person, and later (in the process of human development) with the object (tool). Movement: actions and work with objects, praxis. Level basis (is the “background level”) – level E. Characteristic of movement: has a complex algorithm, is targeted, subject-manipulative and meaningful, system-forming and meaning-forming factor is the goal and the result is focused on the action with the objects, this level is semantic and objective, conscious movements. Attitude to space and orientation: “space” of objects and tools that are in three-dimensional Space (Yevtuch et al., 2021b).

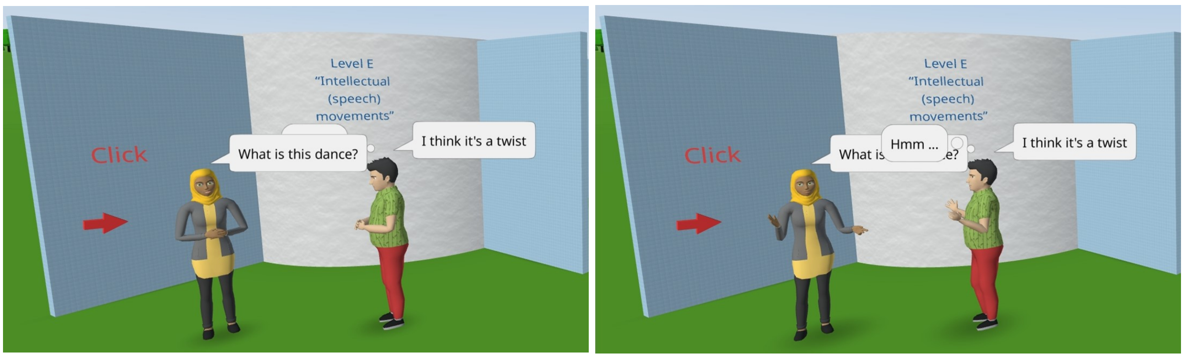


Figure 5: Level E – Intellectual (speech) movements (Fedorets & Klochko, 2022). Movement: intellectualized movements – sign language and partly body language and dance (understood as complex choreographic actions), reading, spoken and written language and reading. Characteristic of movement: characteristics related to speech, physical communication, complex dances and motor scenarios, conscious. Attitude to space and orientation: for language – space of objects and ideas, ideal (virtual) spaces of values, values; for dances and complex motor scenarios – three-dimensional space, space of speech, “space” of tools and objects, space of ideas, values and meanings.

as a manifestation of human nature.

The presented brief overview of the three problem-conceptual lines (aspects) in the learning process discloses with the help of the "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" the essence of movements activity in a consecutive, "layer-by-layer", cyclic way. In the course of this process the knowledge from various fields (knowledge transfer) is used, which is then naturally integrates into a certain epistemological system. Such a variety of knowledge facilitates the actualization of the hermeneutic potential of N. Bernstein's theory, which accordingly launches the active formation of interpretations, reflections, understandings and senses. From the didactic point of view, the stated methodology of knowledge representation and perception allows to present the knowledge in various ways, not being limited to a fixed hierarchic model. Problem-conceptual lines may be represented in any order and combination. This creates a corresponding learning diversity, facilitates spontaneous manifestations and is a precondition for creativity and active dialogue-based interaction. Physical Education teachers can independently choose the aspect that needs to be analyzed in the context of N. Bernstein's theory. This may further be used for a formal description of the methodology for the improvement this virtual reality model of the stated issue and creation of a corresponding interactive model.

Within this pedagogical system we present the repeated and multi-dimensional highlighting of the nature of movement, together with the actualization of its various aspects and with a corresponding subsequent formation of complex understanding of the movements field and a human being, as a methodology (methodological technique) of cyclic and layer-by-layer shaping of knowledge, values and senses, calling it the "Wheel of problems and senses". The axis idea of this methodology is the cyclic and repetitive knowledge formation, reproduction, transfer and transformation in various aspects, contexts, formats and in correlation with various problems and aims of movements activity and corporality. This, in turn, determines the hermeneutic and sense forming potentials of the methodology as well as the existence of knowledge in the form of a problem. Accordingly, in the course consideration of various aspects and their analysis in correlation with the nature of various levels of motor activity organization, knowledge is being constantly updated. The very existence of knowledge in the form of problematization, as a problem and as interpretations, facilitates its preservation, development, growth and widens the opportunities for a value based and practical orientation of creativity. Using the ideas expressed by Frank (Frank, 2016), we may characterize such knowledge as "living knowledge". Thus, thanks to its multi-dimensional, systemic, representative nature, N. Bernstein's theory allows to disclose the phenomenology of movement using the "Wheel of problems and senses" methodology, which is a practical and targeted application of the idea of a hermeneutic circle and which, speaking metaphorically, forms new knowledge and senses in the course of its "movement" within the "knowledge space".

The "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" forms the foundation of the above presented practical implementation of the ideas of a layer-by-layer and cyclic shaping of knowledge and senses about movement with the help of the "Wheel of problems and senses" methodology (methodological technique). The stated model contains anthropic images, typical situation (e.g. a person is running – level C, or talking – level E) and "motion spaces" in which the peculiarities of every level of movements is being disclosed. The virtual spaces of the stated model as well as the corresponding anthropic images are used to study the peculiarities of various levels of movements and are also subsequently used as sense-forming contexts to highlight and particularize the relevant issues of the motion sphere, health preservation and disclosure of the human phenomenon as a whole.

Thanks to the use of the "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction", the "Wheel of problems and senses" and the problem-conceptual lines, which form it to a great extent, motor activity is disclosed as a manifestation of the poly-ontological human nature (Nosov, 1999). Accordingly, the motor activity is represented as a particular "existential-vital-movements-activity-intellectual ontology", and is not reduced (simplified) to mechanic movements. Motion is viewed as a continuum of anthropological phenomena – from purely "biological-corporal" ones (levels A, B) and "corporal-spatial" (level C) and "corporal-praxeological" to "gnoseological-linguistic" and spiritual ones (level E).

For a "dialogue-based" "immersion" of course participants into the "biomechanical essence of movement", the initial demonstration of the virtual model includes the actualization of maieutic and interactive practices. The idea of this aspect is to disclose movement as a complex, multi-level anthropic system. In the virtual model, the five levels are demonstrated in the form of anthropic images and are a spatial formation. Such a presentation is essentially a "spatial" as well as "anthropic" metaphorization. It creates the effects and levels of movements are presented using real examples and in real situations, which are considered with the relation to and together with the use of the virtual model.

While focusing the attention of course participants on the phenomena of complexity and consistency as the determining ones in movement construction, we analyze when the stated complexity is distorted by considering the virtual model. Therefore, the fine interaction between the levels of movements is also distorted. The fact that probable distortions really exist, can be modelled and thus "extracted" from N. Bernstein's level theory poses a special methodological interest (Klochko and Fedorets, 2022; Bernstein, 1990; Devishvili, 2015; Latash and Latash, 1994; Bongaardt and Meijer, 2000). We suggest that the course participants model probable distortions on the basis of knowledge about the nature of movement disclosed with the help of the virtual model. The stated aspect of decomposition with the subsequent "construction" of movement is possible even after the basic familiarization with N. Bernstein's theory.

Using the virtual model and, consequently, the "layer-by-layer and periodic consideration", we present various aspects of movement, each time quickly analyzing the peculiarity of all five levels. In the course of this process, the movements, sport, life and professional experiences of Physical Education teachers are being actualized. As an example, we will consider the problem of sense as a significant component of organizing movements activity by analyzing three levels (A, B, C) of N. Bernstein's theory.

A – "The level of tone" – reflects the sense of corporal existence. In this aspect we focus on the existentiality of corporality, remembering classical ideas of Binswanger (Besoli, 2017). We consider the stated aspect in the spirit of existential pedagogics (Bollnow (Bollnow, 1955)). Thus, it is significant for the humanization of the educational process and the formation of a kind attitude of a teacher towards a child, which corresponds to the child-centric ideas of the "New Ukrainian School". While analyzing the "A" level, we indicate that the main "purpose" of a child is the existential perception of self as a possibility and a reality – "I AM" and "BE".

Senses of the next level B ("Synergistic movements"), which is well represented in the virtual model, is also characterized by human corporality. At the same time, relevant senses of human existence in the environment are added. This level is directly linked with the Earth, namely with gravity. Balancing movements are also included into this level. Thanks to this level, the essential initial contact with the Earth is created. I this aspect, we actualize the ideas of Embodied Cognitive Science within the framework of which the relevant aspect of intellectual activity is the body and human corporality, which are "inscribed" and interact with the environment.

Senses of level C ("Spatial movements") are primarily disclosed through a possibility to shift the position in space, which is effectively presented in the model. Thus, through the realization of this level, the orientation and search activity, which is one of the preconditions of the intellect and a manifestation of the vitality and spatial nature of a person, is manifested and developed.

The main reason for actualizing the idea of senses of motor activity is for the teacher to understand the ways and possibilities for motivating the pupils to work out and lead a healthy lifestyle. For instance, at level A (tonic movements) the educator works with the senses of corporal being and being as such. This includes beauty, health, the sense of life (Klochko and Fedorets, 2022; Besoli, 2017). This is the "source" of motivation and not the fact that a child "must" workout.

Level B ("Synergistic movements"), just as the previous one, allows a person to understand himself in relation with "himself" and the "environment", with the Earth. At this level, in order to form senses and influence a pupil, it is necessary to be congruent. In our opinion, this level is linked with a person's perception of his/her body. To a certain extent, it may be called "corporal reflective". It discloses the corporality dynamically, in synergistic movements and through rhythms (it is the basis of dances).

At level C ("Spatial movements"), it is important to use the informative-value and vital potential of the "Earth space" in order to form senses and motivations for motor activity and healthy lifestyle. A relevant point is the environmentally friendly application of landscape pedagogics, spatial metaphors etc.

In the course of implementation of this virtual model, we consider the issue of inclusion (as one of the central problem-conceptual lines) in order to give the teacher an understanding of the ways of improving pedagogical interaction with as well as teaching the children with special educational needs (Fahr et al., 2020; Safonicheva and Ovchinnikova, 2021), and also to broaden the professional abilities of an educator in terms of correction of sensor-motoric and other disorders with the help of Physical Education tools.

Motor health-preserving strategies are formed on the basis of N. Bernstein's theory of construction of movements. Based on the practical and technological understanding of the features of biomechanics, psychology and neuronal foundations of different levels of movement revealed in N. Bernstein's theory and through the reception of pedagogical and sports experiences of Physical Education teachers the strategies are developed that are considered as health-preserving and prophylactic ones. The very same strategies are to some extent corrective and developmental. These strategies can be used for health-preserving improvement of existing physical culture and health technologies and practices as well as for the development of new ones. We will briefly present the main aspects of motor health-preserving strategies.

Motor health-preserving strategy “Application of synergistic movements to adaptation to movement activity, and recreation” is developed on the basis of practically oriented understanding of synergistic movements – level B. The feature of these movements is economical, adjusting, pulsating, repetitive, rhythmic, balancing and to some extent “recreational” nature (figure 2). This strategy can be applied to the formation of new motor actions (in the sense of physical exercises), as well as used in the already existing ones with the actualization of the synergistic component. That is, already known exercises can be performed in a “synergistic mode”. Such movements are balancing, rhythmic, repetitive and are realized with a sense of ease. The movements can also be performed partially in an automated mode, which creates the effect of rest, comfort of the movement itself, “comfortable” feeling of your body, as well as calming due to the actualization of the rhythmic component. The application of spatial and body-spatial motor metaphors is relevant, in which there is an orientation in the directions up/down, forward/backward, right/left, the movement around own axis. The application of this “synergistic strategy” is necessary for the “soft entry” into motor activity, which corresponds to human nature i.e. for warming-up and getting out of the load – for a hitch. “Entering” and “exiting” motor activity should be delicate and inconspicuously synchronize the work of the cardiovascular and respiratory systems and musculoskeletal system, taking the body to a qualitatively new level of functioning systematically, smoothly, rhythmically, not abruptly, quickly, “avalanche like” and not synergistically. Synergistic movements also play a setting and tuning role for a particular activity or other movements. Let’s remember the soft, delicate, oscillating and rhythmic movements when a woman shakes a baby. In the same semantic series there are synergistic (rhythmic, oscillating) combat or “marriage” (expressed in animal dances) movements, both in humans and in animals that have a corresponding reflection in dances.

The motor health-preserving strategy “Application of spatial movements for actualization of orientation-search activity and development of spatial thinking” is formed on the basis of actualization of orientation-search activity which has expressive spatial character (figure 3). In the implementation of this activity, visual and auditory analyzers are activated as the main ones that provide adaptation in space. The development and active functioning of the mentioned analyzers (visual, auditory) is a sensory prerequisite for the formation of spatial thinking, orientation and imagination. To implement this strategy, we recommend using outdoor activities, the potential of landscape pedagogy and tourism, as well as the demonstration of landscapes and spatial objects and their discussion. It is important to use motor games with elements of orientation in space and complex-coordinated movements and movements on various including circular trajectories and their subsequent analysis and discussion. The application of spatial motor metaphors, elements of theatrical pedagogy, which includes reincarnation into various images in which the motor and spatial-motor components are expressive, is relevant.

The motor health-preserving strategy “Application of movements with a complex algorithm for the development of intellect” is formed on the basis of updating the intellectual potential of the level E – intellectual movements) (figure 5). We recommend using relatively complex motor scenarios, including choreographic and those that can be performed both individually and collectively, as well as to teach to work with spatial images, routes and actions, thinking about their trajectory and method of implementation. An example is the performance of combat movements in martial arts combined into a special system (dance) – kata. The combat motor actions are integrated and transformed into a sequence of movements and a sequence of actions (if movements with objects or weapons) in kata. Motor actions are thus interconnected and “intercurrent” successive combat movements that are integrated into a system. They represent “motor-spatial algorithms” and a system of body-movements “tools” of influence and action. The spatial-temporal integration of motor actions is based on: principles and cultural traditions and experiences of combat, ideas about the enemy and the combat situation, modeling and reflexive understanding of the probable problem, concentration and meditation techniques, knowledge of biomechanics and human psychology. Thus, the kata from the standpoint of cognitivistics can be considered as a “body-space-activity” semiotic system defining characteristic, which is cognition. It is interesting to use the representative potential of movements, which includes the ability to communicate through motor activity and demonstrate complex ideas, feelings, which is also considered in the framework of theater pedagogy. The use of music and the arts in general, including poetry, is important. The use of elements of play, carnival, imitation of life scenarios, as well as narrative and communicative skills of a teacher is important for the actualization of this level.

We recommend using augmented and virtual reality technologies in the implementation of all these motor health-preserving strategies, which will allow implementing them at a new quality level.

One of the significant results of contemporary European centric transformations of the Ukrainian education is the formation of intellectualized, axiologized, "human-centric", psychology driven and "humaniticized" physical culture (Aksonova, 2010; Efimenko, 2011). Such physical culture is considered as a relevant component of movements activity, development and existence of a child and not only as a school subject. Thus, it is represented as a system of personality-oriented and culture-corresponding techniques of the body, which we view in correlation with mental, spiritual and health preserving practices as well as, to a certain extent, their inseparable components. Judging from the anthropological-cultural and humanistic positions, it is important that the teacher perceives the cultural heritage and includes it into the value-conceptual contexts of the educational process, namely, for the organization of motor activity, development of corporality and the corporal image of the pupils.

In the light of such views, physical culture may be viewed not only as a corporal technique and a motion practice of a particular culture, but first and foremost as a culture forming unit. We believe that corporal techniques make up the basis of preserving physical as well as psychological, existential and spiritual health.

N. Bernstein (Klochko and Fedorets, 2022; Bernstein, 1990; Devishvili, 2015; Talis, 2015; Bongaardt and Meijer, 2000; Meijer and Bruijn, 2007) defined a person and his/her locomotor sphere as a set of super complex integratively functioning intentional systems, which have a certain potential for autonomy (in a modern auto-poetic understanding). This made his views radically different from the views of a simple person (lat. Homo simplex) and a reflex person, mechanic person, automated person. N. Bernstein's ideas are disclosed and have undergone value based comprehension with the help of virtual reality and they lead us to an idea that movement is a manifestation of the higher nature of human existence as well as to an understanding of metaphysical and ontological for mans of motor activity.

An experimental study. To analyze the efficiency of using the "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" within the "Methodology of development of the health preserving competence of a Physical Education teacher on the basis of Nikolai Bernstein's theory of the levels of movement construction" in the Communal Higher Educational Institution "Vinnytsia Academy of Continuous Education" and study was conducted in 2019 among 165 Physical Education teachers, who were taking the professional growth training course. The experimental group was made up of 85 people.

Let us prove the statistical confidentiality of the obtained results. The number of tasks that had to be completed by the Physical Education teachers before and after the using the methodology of development of health-preserving competence of a Physical Education teacher in the conditions of postgraduate education on the basis of N. Bernstein's theory of construction of movements with the use of virtual reality technologies. The results showing the number of correct answers of Physical Education teachers to questions before and after using this methodology are considered at $n_1 = 10$ and $n_2 = 10$ (figure 6) (Yevtuch et al., 2021b).

Let us confirm the statistical significance of exceeding the values of the indicators of the results of solving control problems by Physical Education teachers after the experiment over the values of the corresponding indicators before the experiment using the Wilcoxon's rank sum test (Wilcoxon, 1945; Wilcoxon et al., 1963).

We find the difference between the values of the corresponding indicators of the results of solving control tasks by Physical Education teachers before and after the experiment (table 1) (Yevtuch et al., 2021b).

We arrange the obtained absolute values of the differences in the indicators of the studied trait before and after the experiment in ascending order. Rank them in ascending order of absolute differences with using average ranks (because there are related ranks) from 1 to 10 (table 1) (Yevtuch et al., 2021b).

Analysis of the table data showed that there are no "atypical" shifts. So, calculated by formula (1)

$$T_{emp} = \sum_{i=1}^{k} r_i = 0.$$

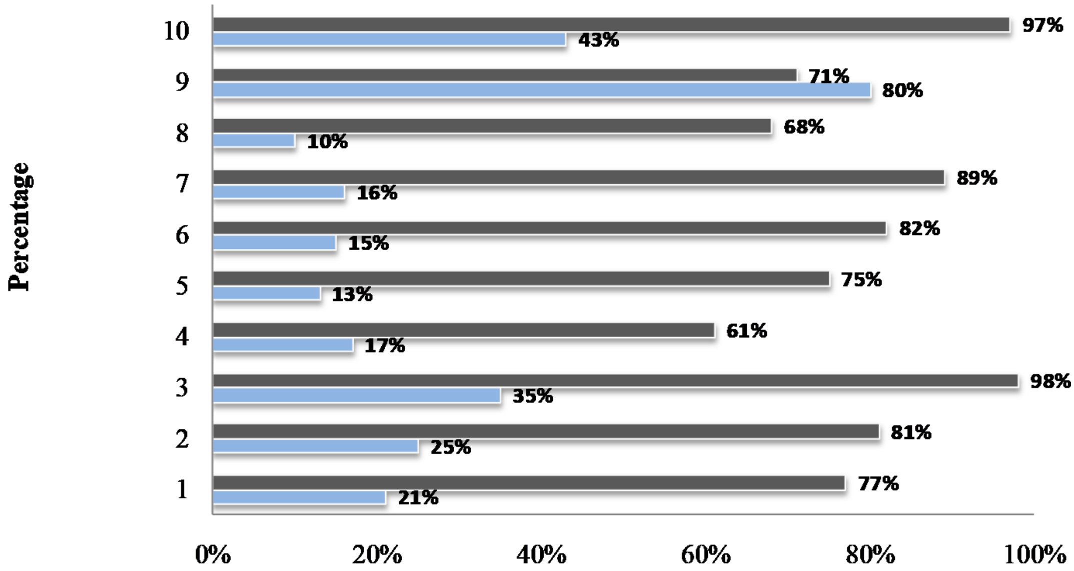
Find the critical value for the Wilcoxon's rank sum test for $n = 10$, using the data in table 1:

for $p < 0{,}05$ the $T_{cr} = 10$,

for $p < 0{,}01$ the $T_{cr} = 5$.

The empirical value $T_{emp} = 0 < T_{cr} = 5$ at the significance level $p < 0{,}01$.

Hypothesis H_0 is accepted. The values of the indicators of the results of solving control tasks by Phys-



	1	2	3	4	5	6	7	8	9	10
After the study	77%	81%	98%	61%	75%	82%	89%	68%	71%	97%
Before the study	21%	25%	35%	17%	13%	15%	16%	10%	80%	43%

Figure 6: The results showing the number of correct answers of Physical Education teachers to the question before and after using the methodology of development of health-preserving competence of a Physical Education teacher in the conditions of postgraduate education on the basis of N. Bernstein's theory of construction of movements with the use of virtual reality technologies (Yevtuch et al., 2021b).

Table 1: The value of the corresponding indicators of the results of solving control tasks by Physical Education teachers before and after the experiment, their difference and ranks of absolute values of differences.

Order number of the task, n	Before the experiment, x_{before} (%)	After the experiment, x_{after} (%)	Difference, $x_{after} - x_{before}$ (%)	The absolute value of the difference (%), $\lvert x_{after} - x_{before} \rvert$	Ranks of absolute values of differences, r_i
1	21	77	56	56	3,5
2	25	81	56	56	3,5
3	35	98	63	63	7,5
4	17	61	44	44	1
5	13	75	62	62	6
6	15	82	67	67	9
7	16	89	73	73	10
8	10	68	58	58	5
9	8	71	63	63	7,5
10	43	97	54	54	2
Sum total	-	-	-	-	55

ical Education teachers after the experiment statistically with a high probability exceed the values of the indicators before the experiment at the level of significance $p < 0{,}01$.

We will present the results of research on educational effectiveness "Methodology for the development of the health-preserving competence of the Physical Education teacher based on N. Bernstein's theory of the level construction of movements" using a spatial approach (figure 7). The specified spatial approach was aimed at the ecological-value and spatial-value understanding of human motor activity based on N. Bernshtein's theory of movement construction. The study was conducted at the Communal Institution of Higher Education "Vinnytsia Academy of Continuing Education" in 2022. The studied sample consisted of 32 Physical Education teachers.

Let us prove the statistical confidentiality of the obtained results. The number of questions that had to be completed by the Physical Education teacher before and after the introduction of the "Methodology for the development of the health-preserving competence of the Physical Education teacher based on N. Bernstein's theory of the level construction of movements" with the use of the "Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of N. Bernstein's theory of movement construction" is $n = 5$ (figure 7).

We find the difference between the values of the corresponding indicators of the results of solving control questions by Physical Education teachers before and after the experiment in table 2.

Analysis of the table 2 data showed that there are no "atypical" shifts. So, calculated by formula (1)

$$T_{emp} = \sum_{i=1}^{k} r_i = 0.$$

Find the critical value for the Wilcoxon's rank sum test for $n = 5$, using the data in table 1:

for $p < 0{,}05$ the $T_{cr} = 0$,

The empirical value $T_{emp} = 0 \leq T_{cr} = 0$ at the significance level $p < 0{,}05$.

Hypothesis H_0 is accepted. The values of the indicators of the results of solving control tasks by Physical Education teachers after the experiment statistically with a high probability exceed the values of the indicators before the experiment at the level of significance $p < 0{,}05$.

Theoretical and conceptual understanding of the use of the spatial approach. The "Concept of tellus-existential – res extenza" was developed (V. Fedorets, O. Klochko). In this space-value understanding of man, the consideration of space and spatiality not only as the "res extenza" (lat.) of Descartes or the ideal space of physicists, in which, or against the background of which motor activity is realized, is a relevant direction. Understanding space as a special earthly spatial reality and as a cultural space with which people interact becomes significant. Accordingly, a person is presented as a "bodily-motor-spatial being". Space is considered not only as physical, but above all as earthly and as human and cultural space. With such an "anthropo-telus" (in the sense of "human-terrestrial") representation of space, in addition to its 3 physical dimensions, additional "dimensions" – earthly and human – are also actualized. The specified humanitarian-aesthetic, ecological and anthropocultural understanding of space translates it into the category of living objects. Accordingly, the physical space is transformed into the world or cosmos, as it was imagined by the ancient Greek philosophers, namely, into a harmonious, balanced, aestheticized, stable, anthropologically oriented. We present the above methodologically oriented interpretations of physical space as the "tellus-existential" (res extenza, lat.) educational concept. To clarify, let's note that the word "telus" is used in the "tellus-existential" (res extenza, lat.) concept, which comes from the name of the ancient Roman goddess Mother Earth – Tellus (lat.). The educational meaning of the specified methodological metamorphoses is the disclosure to man of high meanings and significance, ontological meanings and the beauty of space, as a harmonized anthropo-earthly world. This is the basis for determining the ways of preservation and harmonious existence in the Earthly world. The "tellus-existential" (res extenza, lat.) concept reveals the deep existential meanings of the existential of spatiality and the existential of corporeality (according to L. Binswanger) (Binswanger, 1942). This concept also at the level of methodology represents the deep meanings and perspectives of the anthropological and valuable understanding and reception of the concept of sustainable development.

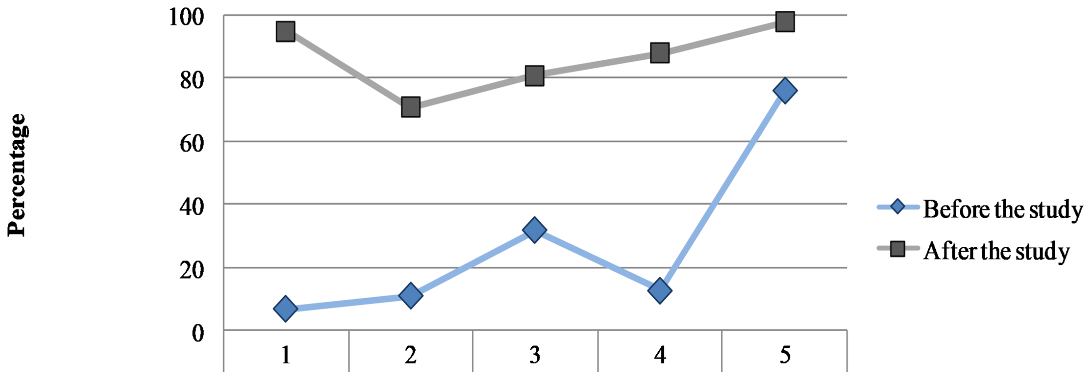
4 CONCLUSION

The application of virtual reality technologies for health and practically oriented perception of the phenomenology of movement activity, the essence of which is disclosed in Nikolai Bernstein's theory of movement construction, is an important innovative tool for improvement of the health preserving competence of a Physical Education teacher in conditions of post-graduate education. Based on the use of AR/VR technologies a software application "Virtual Model Illustrating Nikolai Bernstein's Theory of Movement Construction" was developed. This virtual model is an effective tool for the development of the stated competence.

The results of the analysis of the research aimed at the study of the efficiency of the virtual model within the "Methodology of development of the health-preserving competence of a Physical Education teacher on the basis of Nikolai Bernstein's theory of the levels of movement construction" using the Wilcoxon's rank sum test prove the statistical significance of the efficiency of application of the given methodology, namely, a statistically viable positive

Table 2: The value of the corresponding indicators of the results of solving control tasks by Physical Education teachers before and after the experiment with the use of the "Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of N. Bernstein's theory of movement construction", their difference and ranks of absolute values of differences.

Order number of the task, n	Before the experiment, x_{before} (%)	After the experiment, x_{after} (%)	Difference, $x_{after} - x_{before}$ (%)	The absolute value of the difference (%), $\lvert x_{after} - x_{before} \rvert$	Ranks of absolute values of differences, r_i
1	7	95	88	88	5
2	11	71	60	60	3
3	32	81	49	49	2
4	13	88	75	75	4
5	76	98	22	22	1
Sum total	-	-	-	-	15



	1	2	3	4	5
Before the study	7	11	32	13	76
After the study	95	71	81	88	98

Figure 7: The results showing the number of correct answers of Physical Education teachers to the questions of the "Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of N. Bernstein's theory of movement construction" before and after the introduction of the "Methodology for the development of the health-preserving competence of the Physical Education teacher based on N. Bernstein's theory of the level construction of movements".

dynamics of the educational achievements of Physical Education teachers have been determined. With the help of the virtual model the health-preserving, intellectual, gnoseological, hermeneutic, representative, axiological, praxeological, technological and sense forming potentials of Nikolai Bernstein's theory are being disclosed. This facilitates the formation in a teacher of systemic views and structural-functional, holistic and value-conceptual understandings of movement as the basis of life and health as well as the "existential-vital-movement-activity-intellectual ontology".

Disclosing the theory of movement construction through the application of the virtual model and other tools as viewed as a gnoseological precondition of fundamentalization of the health-preserving knowledge and the corresponding competence and it is also a cognitive factor of the health-preserving oriented professionalization and axiologization of the work of a Physical Education teacher. The use of a virtual model for the representation of Nikolai Bernstein's theory in the methodology of the health-preserving competence of Physical Education teachers is a necessary condition for the development of the stated competence both in the context of its integration with the professional competence as well as to raise the scientific, fundamental and technological level. This also facilitates the effective practically oriented application of the state theory by a Physical Education teacher for the analysis and improvement of physical and recreational technologies as well as of concrete physical exercises and movement modes.

Nikolai Bernstein's theory of movement construction, virtual reality technology, and spatial and ecological approaches were used integratively for ecologization, anthropologization, and for the health-care-oriented disclosure of human bodily-motor-spatial phenomenology.

"Methodology for the development of the health-preserving competence of the Physical Education teacher based on N. Bernstein's theory of the level construction of movements" includes the representation of environmental and health-preserving issues using a spatial approach. The "Virtual Model of the Illustration of N. Bernstein's Theory of Movement Construction" and photographs, diagrams and pictures of people and natural and anthropogenic landscapes, objects, and architectural structures were used to implement the indicated methodology. As a result of studies of the educational effectiveness of the specified methodology, the positive dynamics of educational results were determined using the "Fedorets Questionnaire for the definition of ecological value and health-preserving reflection of the earth's space and human motor activity based on the spatial interpretations of N. Bernstein's theory of movement construction".

Accordingly, a Physical Education teacher gains professional opportunities for the application of Nikolai Bernstein's theory in the health preserving and correction-development work with children with special educational needs as well as in inclusive education practices. On the basis of the health-preservation oriented disclosure of the nature of movement, health-preserving, preventative, corrective and developmental strategies are being formed among which the significant ones are: "Application of synergistic movements to adaptation to movement activity, and recreation", "Application of spatial movements for actualization of the orientation and search activities and development of spatial thinking", "Use of movements with a complicated algorithm for intellect development".

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The Use of Immersive Technology in the Study of Mathematical Logics in Secondary School

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Abstract: The majority of information which a person perceives during their lifetime is received through the perception of visual images. This rule is observed during the performance of any kind of activity. Therefore, not taking into account the visual presentation of new knowledge during the learning process as well as its quality are a mistake, which becomes an obstacle for the new generations to receive a quality education. Taking into account the current realities and demands on the knowledge, skills and abilities acquired during the training, the problem of using high-quality visual educational content is closely related to the development and use of information and communication technologies. The work examines and analyzes the current state of the use of immersive technologies in education, examines the possibilities and specifics of the use of virtual worlds in the educational process. The practical results of approbation of virtual tools in the educational process are given. A pedagogical experiment aimed at determining the effectiveness of immersive technologies in the realities of Ukrainian education system has been launched.

1 INTRODUCTION

The tendencies of modernization of education depend on the globalization processes in the world, the needs of the labor market, external factors such as, for example, the quarantine caused by COVID-19, and so on. Considering this, the digitalization of the education system opens up many prospects for quality improvement in the educational process. Thus, under the conditions of the rapid development of information and communication technologies (ICT), the ways of teaching at schools of general education are changing.

For many years in a row, teachers have been using videos during classroom lessons to present the theoretical part of the new material in the classroom. Nowadays the flipped classroom technology is gaining popularity. The implementation of the technology is not possible without the use of educational information, which is based on video. However, the increase in the level of learning with the help of electronic educational resources based on the use of video clips in the "Let's Plays" genre cannot be seen. We note that unlike previous generations of students who interacted with websites, blogs, and educational channels based on social media, the current generation learns more through YouTube Let's Plays and Twitch-based video streams. The current younger generation does not use books, web pages, or any of the technologies traditionally used by older people.

The formation of a new format of digital literacy is necessary for the participation of young people in these, mostly special, educational environments. First of all, it is the ability to record and edit videos, "capturing" and broadcasting gameplay and other activities on the screen, a high level of technical communication, and the ability to inform and teach others by performing complex tasks. The so-called immersive technology, i.e. the technology that integrates the virtual environment with the physical environment, becomes relevant, which allows users to naturally inter-

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act with the mixed reality, which includes two main types of reality, as augmented (AR) and virtual (VR) (Arbogast, 2019).

2 RESEARCH METHODS

In the process of the study, the theoretical and general scientific methods were used to solve the tasks set in the work: the analysis of psychological and pedagogical resources on the problem of the research to understand the state of development of using immersive technology in the study of mathematical logics in secondary schools, the identification of the areas of research, the principles and approaches to the use of immersive technology in teaching; a summary of national and foreign experience in the use of immersive technology in secondary schools to identify the tendencies of development, the clarification of the basic conceptual and terminological framework, the establishment of the conceptual foundations of the study; theoretical analysis, systematic analysis. In order to solve the set tasks such empirical research methods were used: the experimental study of the use of immersive technologies in the study of mathematical logics in the secondary school, the expert evaluation of the results of the survey, the observation of the initial activities with the use of immersive technologies in the educational activities.

3 LITERATURE REVIEW

Among the researchers, the problem of immersive technologies in education was addressed by Babkin et al. (Babkin et al., 2021), Burov and Pinchuk (Burov and Pinchuk, 2021), Klochko and Fedorets (Klochko and Fedorets, 2022), Kovalchuk et al. (Kovalchuk et al., 2020), Mintii (Mintii, 2023), Mintii and Soloviev (Mintii and Soloviev, 2018), Shepiliev et al. (Shepiliev et al., 2021). The concept of immersive technologies is interpreted differently, so, for example, Sokolyuk (Sokolyuk, 2021) defines it as a complex of people's sensations, which are located in an artificially created three-dimensional world, in which they can change their viewpoint, zoom in and out the objects, and so on.

According to Sergeev (Sergeev, 2013), the exposure of the subject to the environment of learning, in particular to the immersive environment, and the orientation in it allows us to examine the processes of including the subject into the "worlds" of learning, which can live according to their own laws and not correspond to the worlds of physical reality. The researcher specifies three types of exposure: exposure to the subjective world, exposure to the physical environment and exposure to the virtual environment.

Among the investigators of the problem of edutainment, which is learning through play, in modern pedagogy we can see such scholars as Buckingham (Buckingham, 2013), DeVary (DeVary, 2008), Kazanci and Okan (Kazanci and Okan, 2009), Tokarieva (Tokarieva et al., 2019), Varina (Varina et al., 2022). Addis (Addis, 2005), a professor at Bocconi University in Italy, points out that edutainment is a specific activity that is based on learning and satisfaction with one's own curiosity.

Semerikov et al. (Semerikov et al., 2022) analyze the approaches to the definition of "immersiveness", "immersive educational environment", "immersive approach in education", "immersive educational resources" (IER), which were used to identify the relationship between the virtual environment and the learning environment, which is being implemented, the pedagogical aspects of learning in immersive environments are examined.

Video games for education form an essential segment of educational content today. Digital-Game Based Learning is becoming increasingly popular. A study by Tokac et al. (Tokac et al., 2019) presents the effectiveness of video games-based mathematics training. In their work the researchers claim that video games contribute to the improvement of mathematical knowledge in comparison with traditional ones. Wouters et al. (Wouters et al., 2013) have studied the influence of "serious games" on learning in detail. They have proved that those who learn through serious games have learned more compared to those who learned through conventional teaching methods. Scientists have different opinions on the use of games in teaching. One part of them says that for the success of digital-game based learning it is necessary to have "correct" games for teaching. Another part believes that teachers should take an active role in developing educational activities with the help of digital games (Cayatte, 2014; Gallagher, 2014). Teachers should adapt digital games as part of their teaching tools.

In the study by Chen et al. (Chen et al., 2020) the effect of competition in digital game learning was analyzed. According to the data obtained during the research, competition in digital game-based learning (DGBL) was effective for mathematics, science, and language. It was effective for students of schools and college students. The highest effect was observed during the task performance in puzzle games, strategy, role-playing games and modeling, but not in action games. As a result, it was discovered that the competition in DGBL was equally effective for cognitive and non-cognitive results.

Similar results of the research on the use of games in K-12 mathematics education were acquired by Byun and Joung (Byun and Joung, 2018). First of all, this paper examines the current trend of digital learning based on games by analyzing the research on DGBL for mathematics learning and achievements in mathematics learning. Secondly, the future directions of DGBL research in the context of mathematics teaching have been noted. Researchers have analyzed 296 studies, of which only 33 were identified as empirical and were systematically analyzed to investigate current trends. In addition, due to lack of statistical data, only 17 out of 33 selected studies were analyzed to calculate the overall effect of digital games on mathematics education.

A related study was conducted by Clark et al. (Clark et al., 2016). The authors analyzed the published results of research on the overall effect of digital games on learning outcomes from 2000 to 2012. They took into account 1040 papers, of which only 69 had information about the unique empirical research use of digital electronic games in education. A total of 6,869 respondents were involved in the selected studies. As a result the researchers concluded that games as a medium certainly provide new and powerful opportunities, but it is the active creative activity in the game environment that determines the effectiveness of the learning environment.

Gunter et al. (Gunter et al., 2008) analyzed the RETAIN model (Relevance, Transfer, Adaptation, Immersion, Naturalisation) model, which is based on the following positions: relevance represents the correspondence of the materials to the students' needs; concordance – the necessity of presenting the academic content in accordance with the game plot; integration based on the existing experience of students in other spheres, as well as the possibility of using the knowledge in real life; adaptation – change of behavior as a result of integration from the virtual into the real world; engagement – intellectual involvement in the game process; implementation of the skills acquired in the game and their use in real life.

Apart from the above-mentioned issues, the relationship between game, pedagogical, and realistic components in serious games is no less important. Harteveld (Harteveld, 2011) says in his work that the attributes of serious games are: pedagogy, low resource intensity, timeliness, harmony, experience, unambiguity, research, game elements, attributes, interactivity, involvement, learning goal, goal groups, organization, reality and challenge. Pedagogy declares the necessity of reflexion, but the game, ideally, encourages it. The highest results are achieved by learning by doing, which means that students must not just read the text, but live the learning process internally. The low level of informational intensity of resources allows children to form the ability to make self-evaluations and make decisions.

An important issue is also the efficiency of digital learning on the basis of games. There is a variety of methods for evaluating DGBL, which leads to controversy in determining the reliability and validity of certain methods. All et al. (All et al., 2016) investigated various methods of assessing teaching effectiveness, which were developed by experts in the field of psychology and pedagogy by means of structured meetings in order to identify the most important methods for conducting DGBL effectiveness studies. The suggested improvements in the methodology of determining the level of efficacy relate to the implementation of the intervention both in the experimental and control groups. The participants of the experiment themselves determine which elements should be omitted during the exercise (for example, the instructor's supervision, additional elements consisting of essential information), and which elements will be important (for example, procedural support, training). The investigators determined the parameters for which the similarity between the experimental and control conditions (e.g., time of influence on the workout, instructor, day of the day) can be achieved. Regarding the testing of methods, the suggested improvements concern the exposition of participants to the conditions (e.g., parameters to be taken into account when using blocked randomized design), the general design (e.g., the need of an initial test and a control group), and the test development (e.g., the need to design and run a parallel test), the need for an initial test and a control group) test development (e.g., developing and running parallel tests) and testing (e.g., next steps after at least 2 weeks of training).

Gamification is the use of certain elements of games in non-gaming practices. Salen and Zimmerman (Salen and Zimmerman, 2004) define a game as a system in which players are involved in an artificial conflict, which is defined by the rules and is expressed in a quantitative result. Gamification is distinguished from other game formats by the fact that its participants are focused on the purpose of their real activity, not on the game as such. Game elements are integrated into real situations to motivate specific forms of behavior under given conditions.

4 RESEARCH RESULTS

The research of recent years shows that the market value of educational software in 2018 was \$2.3 billion, and by 2025 this number will be doubled. This assumption indicates the active implementation and use of software in all spheres of education and culture. And these interactive tools include immersive technologies, i.e. the technologies of full or partial inclusion in the virtual world, as well as different kinds of virtual and mixed reality. But first we need to find out what kind of technologies allow to create modern content, and what the difference between them is.

- Real reality (RR) – the objective reality in which we are and which we perceive by our senses.
- Augmented Reality (AR) – the technology of visualization, which is associated with the combination of real world objects and information, combined through the use of computers, is able to project digital information behind the screens of devices and connect virtual objects to the real environment. PokemonGO, which has been popular for a few years now, is a great example of AR technology.
- Virtual Reality (VR) is a technology that transports people into a artificial world where the natural environment is completely altered. In general, virtual reality means the creation of an imitation of real world experience, in which people can enter at any time with the help of technology.
- Mixed reality (MR) is the latest development in the technology of virtual reality, which can cause a variety of sensations. Mixed reality occurs not only in the physical or virtual world, but it is a mixture of the reality of our world and virtual reality, which can be seen as a supplement to reality and a supplement to virtual reality.
- 360-photos, video is a content consisting of one 360° or several stitched photos and videos. This is the process of creating photos of a certain object, which are taken from different sides and combined into one package. Viewing 360-photo gives you the opportunity to see a lot more details, so to say to feel them at the physical level.

The use of immersive technologies opens up a lot of new possibilities in teaching and education, which are quite complicated, time-consuming or costly for traditional approaches. They outline nine facts in favor of immersive technologies, such as clearness, concentration, maximum involvement, safety and effectiveness. With the help of AR and VR, learning a subject is a much more effective way than standard teaching. The majority of publications on this problem indicate the possibility of using VR and AR technologies in the educational sphere for the purpose of visual modeling of educational material, supplementing it with more knowledge, developing children's spatial ideas, skills of research and experimentation, extensive projecting, which saves time on learning information, accelerates learning and makes this process fun and active.

It is known that the number of different natural and social sciences, which usually act simultaneously as a consumer and provider of scientific and practical results for the field under consideration – physics, mathematics, linguistics, biology, psychology, etc., belong to the number of calculating sciences. An important place among computational sciences is occupied by the relevant part of mathematics, which has various names: theoretical informatics, mathematical theory of calculations, cybernetics, etc.

The part of mathematics, which is a numbering science, is also not homogeneous. It includes branches of mathematical physics, the theory of numerical methods of differential equations, the theory of mass maintenance, which is used for creating operational systems, in the theory of games and so on. However, the central place in this field of mathematics, which is connected to the computational sciences, belongs to mathematical logics and algorithm theory. Often these two disciplines are combined under the joint name "mathematical logics", considering algorithm theory to be a part of mathematical logics in the broad sense of the word.

Since among mathematical disciplines mathematical logics is the only discipline that studies the relationship between texts and their meaning, The mathematical description of this relationship is of primary importance when texts are transformed from a means of communication between people into a means of interaction with a computer.

Nowadays mathematical logics is becoming more and more important, it is a theoretical basis for informatics, which middle school students study in grades 10-11, so it is very useful to develop and refine the concepts of mathematical logics at an early school age. It is necessary to introduce it to students as early as possible, using it in practice. We therefore propose to introduce mathematical logical elements in the school mathematics course. This approach can be closely connected with the program of developmental teaching, which is now being implemented in many schools.

But many children find it difficult to learn mathematics at school and one of the reasons is the loss of motivation for learning or the subject itself. To get rid of this problem, elements of mathematical logic should be introduced in the primary and secondary schools through educational games. In the process of games children memorize different logical tasks, which form certain logical operations without noticing. Thus, the basis for learning the number of words, one of the sections of mathematical logics, is laid.

Game techniques have always been used in school education. Tests and examinations, passing from one class to another, final tests – all of these have elements of the game, but they are not always valid. The problem is that classical educational methods often ignore the simple but important fact that learning should bring joy and satisfaction, should be entertaining. It is known that the human brain is set up for the positive, that is, when instead of struggling with boredom there is a drive and positive emotions, information is absorbed more easily.

The main reason for play-based methods is to focus on mistakes. Teachers at school always focus on mistakes, but rarely praise for correct answers or solutions. The fixation on mistakes causes students to concentrate more on grades than on knowledge. In computer games, on the other hand, faults are accepted and are the main tool for achieving success. Let's take the game Angry Birds, which at least once played all modern children. It vividly demonstrates how with each failure the player tries new variants of successful achievement of the goal – to kill the pigs. By playing, we know that there is nothing wrong with failure – the sooner we do something wrong, the sooner we can find a good solution. Game is one of the ways of motivation, the development of logical thinking, but not universal peremptory mean. Gamification without high-quality educational content will not work.

In order for the learning process to be called gamifiable, it must contain the 4 characteristics that McGonigal (McGonigal, 2010) revealed in her TED talk:

- clearly defined goals that provide motivation to participate in the game;
- logical and step-by-step rules that set the limits and framework for achieving the goals;
- a stable communication system ensuring that the objectives can be achieved and the players comply with the rules;
- a voluntary agreement to participate in the game and follow the rules for achieving the goal.

Werbach and Hunter (Werbach and Hunter, 2020) emphasize on the motivational function of gamification. They believe that gamification allows to activate people's learning activity. Moreover, gamification allows not only to create new games, but also to use their components for motivation. According to them, any game component can be used behind the game format to shape people's attitudes toward a certain environment.

Among the many applications of digital learning, Lifeliqe's main product, the Digital Science Curriculum, deserves special attention. This project (https://www.lifeliqe.com/products/lifeliqe-app) focuses on the K-12 science curriculum, involving students in an open-ended interaction with STEM subjects. This interaction is enabled by interactive 3D models, more than 1,500 available in AR/VR, and a large number of animated videos. Thanks to this, users can use more than 1,000 prepared and ready-to-use activities with great efficiency. An important factor of handy use is that the available digital content is fully compatible with the main natural science textbooks used in the U.S. educational system.

One of the games that has become very popular among children and teachers is Minecraft (https://minecraft.net). Minecraft is a virtual community where players can wander and interact with the world from blocks. Since its release in 2011 the game has become a cultural phenomenon. Over 200 million units were sold worldwide (data as of August 2020) (Chiang, 2020). Due to this success, a special version of Minecraft: Education Edition (Minecraft EDU, https://education.minecraft.net/) was released.

The Minecraft EDU educational game process is structured as follows: the teacher controls the virtual map where students play; the teacher can integrate lessons and assignments into this map. To prevent teachers from doing too much extra work, the game offers a rich library of previously created "worlds" as well as a collection of previously created lessons. The Minecraft EDU learning environment provides you with a wide range of options. For example, finding the perimeter of that particular area or distinguishing dinosaur remains from other digs. The teacher gives each student access to the buildings and places on the virtual map, thus coordinating his or her activities. This makes it possible to teach many people at the same time individually (Fedorenko et al., 2021).

Due to its flexibility, the game is easily adaptable to different educational subjects. For those who have decided to try Minecraft EDU in their classes, you may want to consider these suggestions:

1. Before the game, discuss together with students the rules of behavior in the virtual world. No one will be pleased if a classmate destroys a copy of the Arc de Triomphe you've been working on for a couple of sessions.
2. Confirm that your world is set up for the task of the lesson, before the start of his students.

For those teachers who are too busy, Minecraft EDU offers a ready-to-use starter kit of core school subjects (https://education.minecraft.net/class-resources/lessons/).

3. Make a paper copy of the instructions, assignments, questions, or suggestions for your students. This will help them concentrate on the task.
4. Allow time for an introductory lesson to show children the basics of the game: click on the menu, perform the main actions. It is better to combine beginners players with experienced, to facilitate learning. It's important to remember that this is just a game that helps us accomplish a certain task. Combine the secondary educational environment – books, textbooks with the Minecraft environment.
5. Take a break every 30 minutes. At this time, ask students to share their accomplishments or difficulties, as well as their feelings with the class.

Let's look at a few already existing Minecraft EDU worlds that can be used by teachers of various school subjects. The first world is called Tutorial-world and is a guide to the Minecraft world. In fact, it is necessary for those teachers and students who are not familiar with Minecraft, or for those who need to update their memory about the basics of the game and the means of controlling their actions, for example, in the creation of objects. To use this guide you only need to download the file .mcworld and import it into Minecraft: Education Edition. During the course of the course you will be accompanied by two guides – Jessica and Stephen. However, you should not forget that to get the best results, you should get the maximum amount of information, which you can get from the special knowledge base.

Fantastic-mr-fox's world is Mr. Fox's fantastic world, which gave us the idea of creating a fantastic world of our own. The use of this world in the teaching process has the following goals: to learn to recognize the meanings of individual words and whole phrases; to learn how to describe characters and events and to write stories based on the text, using the details found in the text itself. As one of the variants for the development of the teaching process itself, you can use the previous viewing of the final of the animated film "Fantastic Mr. Fox" with the subsequent analysis of the events and attempts to invent a continuation of the story. That is, students are encouraged to invent their own history of how the stars will live in the future, what kind of resources they will need, what kind of housing and its modifications they will need. "Practical" activity with the world of Minecraft Fantastic Mr. Fox is in the creation of housing for the own character in the underground zone of the virtual construction. In addition, the students are encouraged to use these coordinates, create tunnels to three farms. A separate task is to write an article for the newspaper or a story about a day in the life of the inhabitants of the underground city.

The geography teacher will enjoy worlds with such biomes as the savannah, mountains, taiga, and the ocean, for example, the world of secret-reef. This world is dedicated to learning about coral reefs, their possible structure, the most varied forms, sizes and colors. A coral reef is composed of several assemblages of coral blocks. Each of these assemblages has a certain type. For example, dead corals. Moreover, these assemblages can be realized with different forms. But there is no rule that necessarily some structure must be composed of one type of corals. More often for everything on one reef there are several types of corals. Depending on the edition, there may be different types of assemblages.

The world of project-storytelling offers its own variant of teaching, which will be useful for teachers of literature and Ukrainian language. Its purpose is to encourage the development of creative skills in writing texts. In this world, where the "Tree of Souls" is located, you will find yourself in a rural area with stores and houses. The temples of the 4 elements (Fire, Water, Air and Earth), 11 theme factories and buildings, 35 vacant lots for students to create their own buildings or businesses, 6 mini islands with unique possessions – so many opportunities encourage each of the students to create their own story.

For biology teachers there is a lesson on elephant life and protection called watr-humans-and-elephants. Interesting lesson lesson-hub-volume-i, where the author wrote that in this world there is a collection of educational activities you can engage in learning fractions or study the history of the United States in the mid-20th century. Physics teachers will find it interesting to study the properties of Redstone in the redstone-breakout and redstone-lodge worlds. In this educational virtual world you can create traps, automated crop farms, and much more. World-of-chemistry and lessons in chemistry-lessons will be of use to chemistry teachers. In these worlds there is a great table of chemistry elements of Mendeleev. Children are happy to learn the process of creation of air balloons. Teachers of informatics are interested in the program lessons/code-builder-for-minecraft-education-edition. In this course, it is necessary to use Code connection and be able to work with Scratch, CodeMake, Tynker, which also deals with 3D modeling and allows you to move the created objects in the Minecraft world.

The most interesting thing in Minecraft is the Redstone resource, which can be used to create logical schemes. Thus, the player can make their buildings interactive. The chains created with Redstone transmit energy from one unit to another, like electric chains, and the torch is needed to supply energy to the chain. If you install pins, buttons and other control elements and use them, the grader will be able to switch the lance from one position to another.

Minecraft allows players to create logical valves that perform simple logical operations. For example, by using two shafts, you can create an "AND" valve that lets "energy" through only when both levers are active, or an "OR" valve that lets "energy" through if either of the two levers are active. This system has a device of real electronics and Boolean logic, which allows to create complex mechanisms. Thanks to this feature the game can serve as a virtual constructor for programmers and engineers. The teacher can use not only ready-made lessons, but also create their own.

One of the most widespread and popular types of games are constructors, because they allow you to learn through the gameplay and discover the basics of technical skills. A variety of programs and web resources that allow you to look at the process of creating new devices or appliances are also the essence of the designers, if you look at them for the impact on the development of skills. The online resource Tinkercad (https://www.tinkercad.com) is a web tool that allows you to model objects of any complexity, which in the future can be built on a 3D printer. Tinkercad does not have any restrictions in the professional context. In particular, it is possible to create electronic circuits and connect them to the Arduino virtual circuit board simulator. These powerful tools make it much easier to learn how to design and program new circuits for those who are just starting to use Arduino.

We investigated two virtual learning environments, one created with Minecraft EDU and the other created with Tinkercad and their practical use on the topic "Logical operators".

According to the curriculum, the subject "Logic operators" is studied during the study of the subject "Informatics" (8th grade) and is related to such issues as the basics of algorithmization and programming, processing and storage of information. For a better understanding of the educational material is needed not only sources of information, but also working digital models. To implement these models on the basis of real mechanics or electromagnetic devices is quite difficult and ineffective, because the students, for the most part, will not be able to understand the existing analogues. In this case, it is better to use the virtual learning environment for everything, which is in fact a virtual world where most of today's children feel "at home".

Despite the large number of researches on gamification, this educational trend has not become popular in the Ukrainian education system, as evidenced by the survey conducted as part of the MoPED (Morze et al., 2018). Only 7.5% of lecturers, 18.6% of students, and 15% of teachers considered gamification as one of the three most important educational trends. The reasons for this result lie in the weak technical base of universities, partial awareness of the teaching staff in the information and communication sphere, the use of English language in most Internet platforms, the lack of methodological methods of using gamification, the lack of financial resources for paid subscriptions.

Partly this problem can be solved by training prospective teachers to use gamification technology in the educational process of the school within the framework of university educational programs. Training of future teachers for the use of serious games must be a process that is purposeful, planned, multilevel and multi-stage nature with the organized interaction of all participants in the educational process and aimed at mastering the knowledge and skills of using serious games in educational activities with constant monitoring of the achieved results. This makes it possible to assert the necessity to include in the vocational training of future teachers disciplines aimed at acquiring knowledge and skills in the field of gamification in the educational activities of schoolchildren.

Educational training programs for future teachers of mathematics, physics and informatics do not include educational components that form competencies for using serious games in professional activities. However, the elements of such training should be included in the educational components, taking into account the departmental spheres of professional training. The topic "Logical operators" is related to such educational components as mathematical logic, algorithm theory, discrete mathematics, programming, teaching methods, etc. The inclusion of elements of gamification in these educational components will form the basis for the further use of gamification in professional activities. For this purpose it is necessary to use every opportunity. Thus, in our opinion, such possibilities can include:

- visual materials for lectures (screenshots created in the game environment or in its background, product placement);
- practical tasks with elements of gamification (full or partial use of serious games);
- independent work performed in game environ-

ments (additional points for use in the process of playing games);

- laboratory works on teaching methods (results are aimed at creating educational content and taking into account students' desire to use games).

Special attention should be paid to the training of future teachers for the knowledge and skills of using serious digital games in teaching in the teaching discipline Methods of teaching by branches of knowledge. It is necessary not only in theory but also in practice to study the stages of organization of educational activities on the basis of serious games, such as:

- to identify the target audience of the educational content;
- to set the instructional goal;
- to create the structure of the educational content;
- to identify the elements that can be gamified;
- to implement the selected elements through a digital game;
- to use the developed educational content;
- to perform monitoring of the educational process on the spot and at the end of the day;
- to analyze the results obtained.

During the training at the HEI, future teachers need to be prepared to use serious games based on the advantages and disadvantages of gamification. Advantages include: the ability to use distance learning (both individually and collectively); the ability to use a variety of multimedia tools and modern technology; strengthening the creative abilities of individuals, development of creative thinking, self-organization, self-control and self-discipline; less academic pressure, increasing independence in learning and self-development; increasing interest in learning through an interesting presentation of the material, which increases the level of mastering the material. The disadvantages of gamification are: the presence of deficit of communication during the training; the possibility of the emergence of irrational judgments; increased number of hours that people spend at the computer; possible technical failures in the work; the need for special training of teachers and a certain amount of time for learning new technologies; a considerable amount of time for the development and implementation of game technologies; high financial and time costs.

During our research we carried out an survey among the students of the State Higher Educational Institution "Donbas State Pedagogical University", who are studying on the educational programs of secondary education (mathematics), secondary education (physics), secondary education (informatics) or on their combination with other educational programs. Respondents were asked the following questions:

1. How do you feel about the use of any games in the educational process? (positive/negative)
2. Are you familiar with the concept of gamification? (yes/no)
3. How do you feel about limiting the use of mobile devices in educational institutions? (supportive/not supportive)
4. How do you feel about the increasing influence of mobile devices on children's education? (positively/negatively)
5. Do you support the teaching of children at school through computer games as a necessary element of the teaching process? (I do/I do not)
6. Do you support the training of adults through computer games as a necessary element for improving qualification and acquiring new knowledge and skills? (I approve/not approve)
7. Did you have your own experience of learning through the computer game? (yes/no)
8. Do you know someone who has had some experience with learning through a computer game? (yes/no)
9. Should the teaching of methods that use gamification in the teaching process be a necessary element of pedagogical education? (yes/no)
10. Are you ready to learn how to use games during your own professional activities? (yes/no)

A total of 102 students took part in the survey. The results of their responses are presented in table 1.

Table 1: Results of answers during the survey.

Question	yes / positive / support	no / negative / do not support
Q1	85	17
Q2	76	26
Q3	22	80
Q4	63	39
Q5	74	28
Q6	55	47
Q7	19	83
Q8	24	78
Q9	63	39
Q10	69	33

The results show that most of the students are familiar with the concept of "gamification", are ready to learn by playing and to teach others. Most of the respondents are ready to learn new methods and support new forms and means of learning and do not understand the restrictions on the use of mobile devices that can be useful in educational activities. However, the number of those who have used or interacted with them is very small, although there is a tendency for the number of students who learn through games to grow.

As it was mentioned in the theoretical part of our research, we introduced elements of gamification into the educational disciplines of teaching methods. We have been offered the laboratory tasks of working out the educational scenarios of “Logical operators” in the Minecraft EDU environment (figure 1) and creating the educational project in the Tinkercad environment (figure 2). As a result of the group project, several teaching tasks were created and tested during the students’ production practice at educational institutions.

The aim of the educational project in the Tinkercad environment is to demonstrate the principles of algebraic logic and the construction of tables of truth, which the students studied as part of this subject. However, this material was theoretical for them, because it did not create an idea of how it could be implemented in real life. Therefore, the main condition for the effectiveness of the lessons was to create conditions for a clear demonstration of the work of logical elements. The most optimal variant in this case is to conduct lessons with additional study of materials related to electronics and circuit engineering.

The students were given the task to independently create tables of truth for logical “AND” and “OR”, design an informational model of the circuit in the Tinkercad environment, test it on the basis of the principle circuit, and, in case of a successful result, build this circuit on the breadboard.

After the scheme was created, it should be tested and the results of the work should be compared with the results of the tables of truth. The result of this project is the creation of a physical object as a proof of the correctness of the truth tables for logical elements. This was successfully achieved due to the fact that all subject areas were taken into account in the necessary proportions with the successful implementation of the interdisciplinary approach. The goal was successfully achieved and the results of their work resulted in an electrical scheme, which fully corresponded to the results of their calculations and reflected the principles of logical “AND” and “OR” operation.

With the help of the Tinkercad environment you can introduce students to the concept of relay-contact circuits. We explain, under the contact we mean the physical body, which can exist in only two states – “on”, “off”, which we will denote as 1 and 0 accordingly. Connecting contacts in series corresponds to the operation “conjunction”, and connecting them in parallel corresponds to the operation “disjunction”. By opening contact we denote a contact that does not conduct current, which corresponds to the negation operation of the algebra of statements. In other words, we show that the algebra of relay-contact circuits, which is isomorphic to the algebra of statements, is created. The analogous equivalences of the algebra of statements correspond to equivalences of the algebra of relay-contact schemes. Using examples, it can be shown that each of the investigated schemes is described by the corresponding formula of the algebra of relay-contact schemes. Thus, the practical significance of mathematical formulas is explained.

The students’ reports on the internship and their own observations revealed a significant interest in the suggested tasks. Despite the fact that the topic “Logical Expressions. Changes of Logical Type. Logic operations” in the 8th grade belongs to the section “Programming” and is often difficult to understand, the material was studied at a high level. This is evidenced by the fact that further use of the knowledge gained during the study of the topic “Logical Expressions. Changes of Logical Type. Logic operations” in such topics as “Algorithms with branching” and “Cyclic algorithms” did not cause any difficulties in learning these new topics. Moreover, the homework assignment, which students often do without enthusiasm, was completed successfully and absolutely by all students without exception (boys and girls), indicating their interest in this educational tool. The survey of students showed that close to 18% of 8th grade students had active Minecraft accounts and participated in collaborative game sessions. This difference did not have much effect on the results of the tasks. Children who already have Minecraft game accounts completed the tasks quicker than their peers. However, the virtual learning environment created by the Tinkercad tools has caused more interest among children who are engaged in robotics. This can be explained by the fact that robotics has a more realistic realization than the imaginary world of Minecraft.

5 CONCLUSIONS

The development of computer technology and a general increase in digital literacy on the one hand and the complication of conditions for achieving education on the other (COVID-19) contribute to the search for new, more effective, ways and methods of learn-

Figure 1: Example of creating a logical operator in Minecraft EDU.

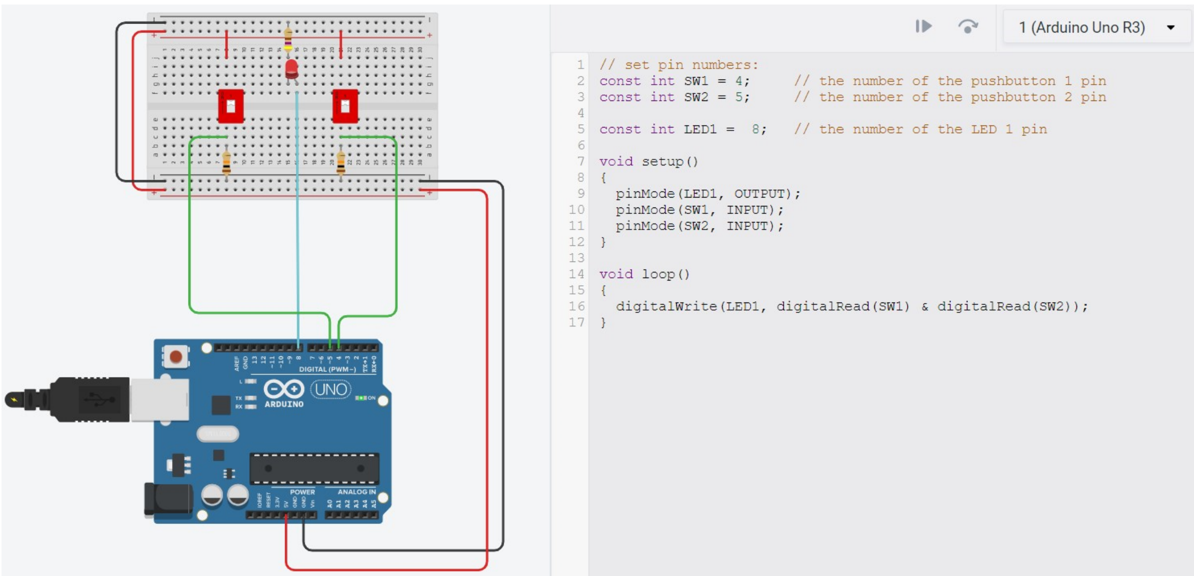

Figure 2: An example of creating a scheme for the logical operator "AND" in Tinkercad.

ing. Besides the use of electronic educational resources in the form of websites, blogs, channels, there is a need to implement learning through technologies that provide a high level of visualization in combination with the "interaction" with the physical environment. In other words, there is a need to teach using immersive technology that integrates the virtual environment with the physical environment and allows users to naturally interact with mixed reality, which in turn includes the augmented (AR) and virtual (VR) realities.

Practical use of immersive technologies in the educational process is best combined with gamefication – the use of certain elements of games in non-game practices. So, in order to motivate specific forms of behavior in given conditions, game elements are integrated into real situations. The positive results of this synergy can be seen through such examples as the Lifeliqe – an educational program for the digital sciences (Digital Science Curriculum), the special version for teaching Minecraft: Education Edition, and an online resource Tinkercad – a web tool that allows you to simulate objects, which in the future can be built on a 3D printer.

During the practical part of the research it was found that most of the students are familiar with the concept of "gamification" and are ready to learn and use this methodology in their educational activities. At the same time, studying the topic "Logic Operators" in the Minecraft EDU environment and creating a teaching project in the Tinkercad environment showed a growing interest in mathematical logics and the quality of work results among the students as well as among the students.

So, we can conclude that such a relatively new form for Ukraine as gamefication of the educational process and educational processes in general is a promising tool to improve the quality of education for children, adolescents and adults, deepening the level of acquired knowledge, more effective use of skills and abilities, given the creation of a clear procedure for its implementation in the education system and following the key stages of the creation of a game mechanism. The review of methods of using digital game content, the creation of a library of digital electronic educational resources, methods of teaching the use of gamefication for further use are the new topics for further scientific research and development.

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Pre-Service Teachers’ Preparation for Students’ Computer Modeling Skills Formation (on the Example of GeoGebra)

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Keywords: Modeling Skills, Skills Development Methodology, Cloud Service, GeoGebra Cloud Service, Constructive Approach, Modeling, Interesting Curves, Math Problems, Professional Training.

Abstract: Modeling as a leading method of scientific knowledge and a means of developing intellectual skills of young people. The students’ modeling skills can be successfully formed under the condition of appropriate advanced teacher training, and therefore models and methods of pre-service teachers’ preparation for students’ modeling skills formation are in demand in modern society. The model of pre-service teachers’ preparation for the formation of students’ computer modeling skills is based on the consistent achievement of three goals: 1) mastering GeoGebra computer tools; 2) formation of pre-service teachers’ skills to model (on the material of interesting curves in Analytical Geometry or word problems in secondary school); 3) formation of students’ skills to select and/or formulate author’s problems that can be solved by the modeling method in GeoGebra. The content on which the model is implemented was a special course on mastering GeoGebra and two experimental modules “Modeling interesting curves” and “Word problems modelling”. According to the sign test the developed model allows successful pre-service teachers’ preparation to develop students’ computer modeling skills.

1 INTRODUCTION

Modern science operates with various methods, among which modeling is one of the most popular. This method allows you to move away from the object’s ideal representation and use its analogue, which retains the most important characteristics that allow you to talk about the object properties after certain changes or influences on it.

The development of computer technologies has contributed not only to the revival of the modeling method, but also led to the emergence of specialized environments, where it became possible to model various objects (processes) based on a constructive approach. At the same time, the widespread use of smartphones and tablets that have access to the Internet has led to the emergence of cloud services, which also allow you to model objects of different nature. However, methods of using cloud services to develop modeling skills are just beginning to be developed and implemented, and therefore are not well established and need experimental confirmation.

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2 LITERATURE REVIEW

The authors believe that the pre-service teachers’ preparation for the formation of students’ computer modeling skills is based on the perception of a constructive approach as the leading one in the formation of modeling skills.

The importance of developing constructive skills of youth is emphasized in the findings of Laksha (Laksha, 2011), Kononenko (Kononenko, 2010), Ivanina (Ivanina, 2010), and the formation of modeling skills by individual scientists is associated with the formation of research skills (Bilousova et al., 2022). Ziatdinov and Valles (Ziatdinov and Valles,

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2022) think that "while the model is being constructed, the student can stumble upon a pathway that results in a better understanding of the connection present amidst the model world and reality". Flehantov et al. (Flehantov et al., 2022) performed a study to investigate the effectiveness of GeoGebra in gaining and cultivating knowledge on mathematical modeling. Marciuc et al. (Marciuc et al., 2016) emphasize, that use of GeoGebra offers a specific, constructivist, teaching approach that allows students to independently build their own models while offering guidance.

Analysis of the problem shows that with the advent of specialized mathematics software its solution has focused not so much on understanding the algorithms of elementary constructions, but on the ability to use computer tools and the ability to visualize the result. The latter, in particular, is emphasized in the findings of Bilousova and Zhytyenyova (Bilousova and Zhytyenyova, 2017). For example, Lenchuk and Franovskyi (Lenchuk and Franovskyi, 2016) consider it possible to expand the visual presentation of information in the field of planimetry by reproducing the real state of operation of its objects, resorting, as a priority, to visual methods of activity based on constructive modeling. Regarding the ability to use tools, it should be noted the emergence of cloud services, including specialized services.

Different aspects of educational using of cloud technologies and services are examined in the studies of (Shakeabubakor et al., 2015; Smith et al., 2014). For example, Shakeabubakor et al. (Shakeabubakor et al., 2015) explore advantages of using cloud technologies in research, such as availability of various tools and applications for analyses and collecting data, for managing and organizing references, for communication with peers and experts, the absence of constraints, the access to cloud resources from anywhere any time that has an active Internet connection, etc. (Smith et al., 2014). They offer the approach to applying of cloud services for enhancing the productivity of university research activities, increasing competitiveness and flexibility of educational institutions.

Shyshkina and Popel (Shyshkina and Popel, 2013) consider the problems of implementation of cloud technology services in the educational process, describe the current state of development and use of cloud technology services in educational institutions and analyze the content of educational and scientific components of cloud-based educational environment.

The use of specialized software for modeling mathematical objects is mentioned in (Sheng, 2014). Rubio et al. (Rubio et al., 2015) emphasize that by fusing modeling and digital technologies through simulation, there are obtained learning environments that promote the development of knowledge and skills of scientific thinking in students. The teaching of students to model is discussed in (Çekmez, 2020). Author discuss the pedagogical value of a real-world phenomenon selected for a modelling activity, followed by the implementation sequence of the activity in the classroom. Çekmez (Çekmez, 2023) believes that pre-service mathematics teachers should be familiar with the potential use of computers in mathematical modelling.

Currently, cloud versions of well-known environments with mathematical modeling capabilities are available, including SageMath. We can also add GeoGebra cloud service to this list, because it "can be considered a very creative tool for mathematical modeling" (Ziatdinov and Valles, 2022).

Experience in using GeoGebra cloud service (visualization of mathematical objects; organization of not only analytical but also empirical search for answers in determining individual characteristics of mathematical objects; organization of home computer experiment) (Drushlyak et al., 2021a; Hrybiuk, 2020; Semenikhina et al., 2019b,a) allowed us to consider GeoGebra as means for formation of students' modeling skills.

However, the analysis of scientific findings confirmed the lack of established models of pre-service teachers' preparation for the formation of students' modeling skills based on GeoGebra, which determined **the purpose of our study**: to develop and experimentally test the model of pre-service teachers' preparation for the formation of students' computer modeling skills (based on GeoGebra).

3 MATERIAL AND METHODS

Experimental base was Makarenko Sumy State Pedagogical University. The total number of respondents is 51 people (students, pre-service mathematics and computer science teachers).

The model of pre-service teachers' preparation for the formation of students' computer modeling skills is based on the consistent achievement of three goals: 1) mastering GeoGebra computer tools; 2) formation of pre-service teachers' skills to model (on the material of interesting curves in Analytical Geometry or word problems in secondary school); 3) formation of students' skills to select and/or formulate author's problems that can be solved by the modeling method in GeoGebra.

To test the effectiveness of the developed model, a pedagogical experiment was organized, which lasted 3 years (2019-2021) and was conducted among pre-service mathematics and computer science teachers.

The model was implemented using the free GeoGebra software (https://www.geogebra.org) in the study of the disciplines "Dynamic Mathematics Software" for pre-service mathematics teachers and "Computer Mathematics Systems" for pre-service computer science teachers (2nd year). Within the discipline "Methods of teaching mathematics" and "Methods of teaching computer science" (3rd year) were introduced experimental modules "Modeling of interesting curves" (10 hours – 2 lecture hours and 8 laboratory hours) to achieve the second goal; "Modeling of word problems" (6 laboratory hours) to achieve the third goal.

Testing the effectiveness of the methodology involved two tests: after mastering GeoGebra and after studying the second module.

Students were offered two typical problems for modeling the Conic sections by its geometric definition (the problems differed from each other in the initial conditions, for example, the distance between the foci was different or one of the foci was at a specific point in a given coordinate system, etc.) and motion word problem.

The solution of the problems was evaluated by the following indicators (table 1, 2).

Since the results of the tests were dependent and each time provided for the accumulation of marks, the

Table 1: Indicators of the formation of modeling skills (Module "Interesting Curves").

No	Indicators	Marks
1	Ability to take into account the analytical relationship between the elements	1
2	Ability to take into account the geometric relationship between the elements	1
3	Ability to use Locus	1
4	Ability to use Trace	1
5	Ability to demonstrate the change of the curve shape when changing the input data	1
6	Ability to construct a model visually correct (location, color, size and style of geometric objects)	1
7	Ability to add dynamic text to study numerical characteristics	1
8	Ability to write an algorithm for constructing a model	1
9	Ability to reproduce the steps of the algorithm to construct the model	1
10	Ability to interpret the result of a computer experiment	1

Table 2: Indicators of the formation of modeling skills (Module "Word Problems").

No	Indicators	Marks
1	Ability to analyze the problem	1
2	Ability to establish a relations between data and questions	1
3	Ability to use Slider	1
4	Ability to use Dynamic Text	1
5	Ability to use Button	1
6	Ability to use Check Box	1
7	Ability to use Image	1
8	Ability to construct a model visually correct (location, color, size, etc.)	1
9	Ability to write an algorithm and reproduce the steps of the algorithm to construct the model	1
10	Ability to interpret the result of a computer solution	1

sign test was used. The number of respondents, whose total score decreased ("–"), did not change ("0") and increased ("+"), was fixed.

In accordance with the experiment purpose and the sign test, the null hypothesis was formulated: the developed model does not provide successful pre-service teachers preparation for the formation of students' computer modeling skills. Then the alternative hypothesis was "the author's methodology contributes to the formation of such skills".

The constructed hypotheses define the one-sided sign test for checking the dependent samples. According to the decision-making rule (Grabar and Krasnjanskaja, 1977) the null hypothesis of inefficiency / effectiveness of the author's methodology was accepted or rejected.

4 CONSTRUCTIVE APPROACH

The constructive approach is characterized by the fact that acquaintance with the properties of concepts begins with constructive activities for their "discovery" and assimilation with a gradual transition to definitions and logical proofs. This, in particular, simplifies the perception of the Geometry course, makes it more accessible, while raising the scientific level through the intensification of educatees' research activities.

The use of the constructive approach contributes to the fact that the activity is manifested in the gradual transition of actions for the construction of objects from the executive level (is characterized by external regulation), then to reproductive (is marked by internal regulation of actions in the construction of known structures), then to the applied level (using the method of construction), and, finally, the creative level (involves the construction of new objects) (figure 1) (Tukholko, 2018).

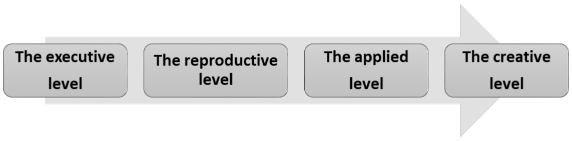


Figure 1: Constructive approach activity levels.

We consider constructive tasks to be one of the means of implementing a constructive approach. Many authors use the term "constructive tasks" in a sense identical to construction problems. However, the peculiarities of the constructive approach require the use for its implementation and other tasks, the solution of which requires the implementation of a particular constructive activity. Therefore, for example, Lisimova (Lisimova, 1997) considers constructive tasks as tasks for construction, imaging, measurement, geometric design and structural-geometric modeling. Dalinger (Dalinger, 2012) considers constructive tasks as "problems in the process of solving which reveal the material conditions of geometric figures. Their purpose is to identify the essential features of ideas that are formed through the material conditions of their origin".

Constructive tasks can be a base for establishing new properties of figures (concepts formation), for the consolidation of knowledge, for repetition, control, intensification of research activities. "The peculiarity of constructive tasks is that they can be solved both logically and figuratively or visually effective" (Dalinger, 2012).

When solving constructive tasks, there is a productive activity that motivates to think independently (methods of constructing have to be developed independently), and not reproductive activity, which is often not an independent mental process, but is a repetition of known steps (Dalinger, 2012).

Mastering the system of knowledge and skills can take place on two levels: constructive and analytical. The main feature of the constructive level of mastery of the material is its visual and constructive awareness. This is manifested:

- in the ability to recognize objects that belong and do not belong to the content of this concept, give examples, demonstrate the existence of the studied figures by construction;
- in the knowledge of their most essential properties and the ability to apply known properties in solving problems.

The constructive approach provides "points of support" for Geometry study at a higher abstract level, which is characterized by the ability to formulate definitions of concepts, statements and prove already in formal language, rather than the language of geometric images.

5 MODEL OF PRE-SERVICE TEACHERS' PREPARATION FOR STUDENTS' COMPUTER MODELING SKILLS FORMATION (BASED ON GEOGEBRA)

The model of pre-service teachers' preparation for the formation of students' computer modeling skills (based on GeoGebra) is based on the perception of a constructive approach as leading in the formation of modeling skills and requires the use of certain forms, methods and teaching purpose (figure 2). Let's dwell on them in more detail.

The purpose of implementing the developed model is pre-service teachers' preparation for students' computer modeling skills formation.

The content on which the model is implemented was a special course on mastering GeoGebra and two experimental modules.

Module "Modeling interesting curves"

Nowadays, their study in the classical course of Analytical Geometry is possible in three ways:

- analytical description and further study of curves – at first analytical (parametric, implicit, explicit) equations, usually of conics, are given and then they are investigated;
- study of curves as locus with a given property – at first the geometric definitions of curves are given, on the basis of which their analytical equations are written (as a rule, these are conics, conchoid of Nicomedes, limaçon of Pascal, strophoid, cissoid of Diocles, lemniscate of Bernoulli, Cassini oval);
- study of curves generated in the kinematic way (as the trajectory of a point), usually cycloidal curves (figure 3), folium of Descartes, witch of Agnesi, logarithmic spiral.

Module "Word problems modelling"

Among other things, the general method of solving word problems includes knowledge of the solving steps. The solving steps include: analysis of the problem text; translation of the text into the mathematics

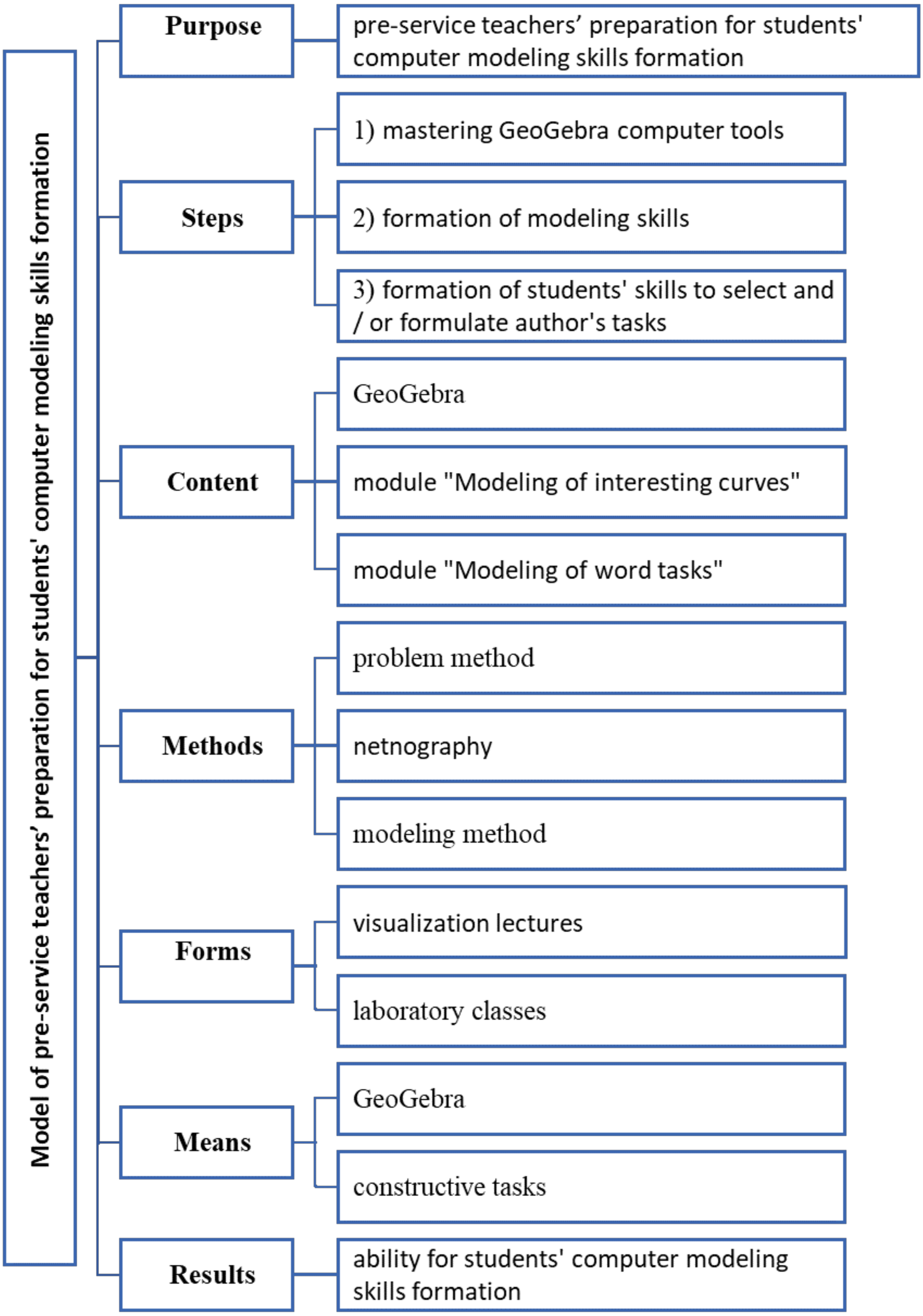


Figure 2: Model of pre-service teachers' preparation for students' computer modeling skills formation.

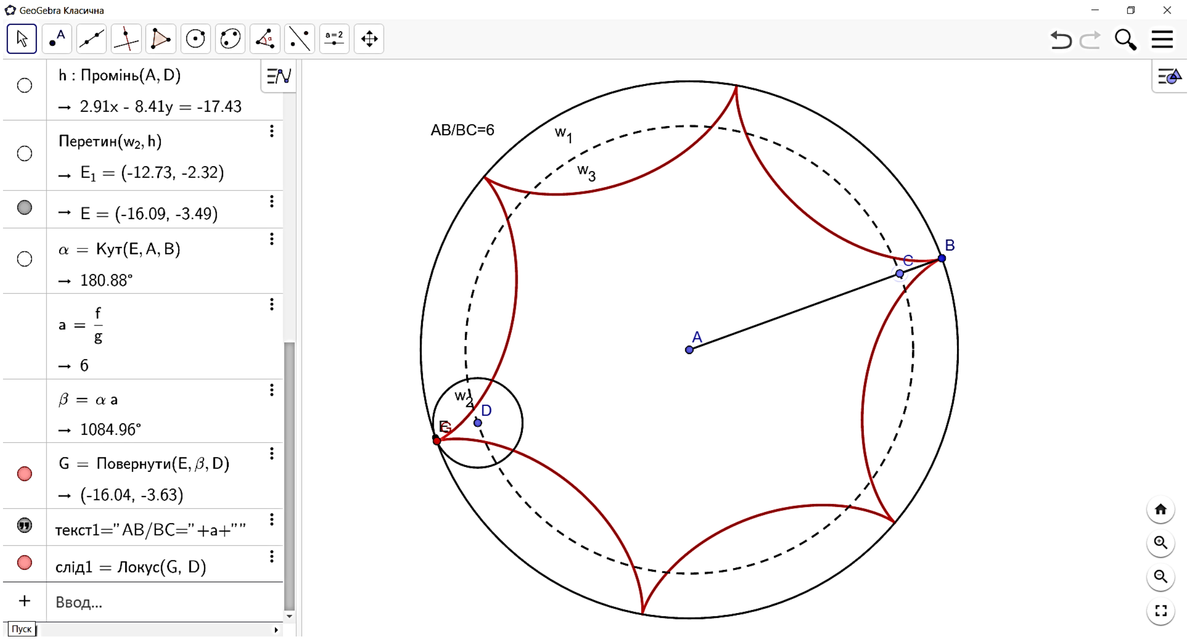


Figure 3: Construction of a hypocycloid using the Locus tool.

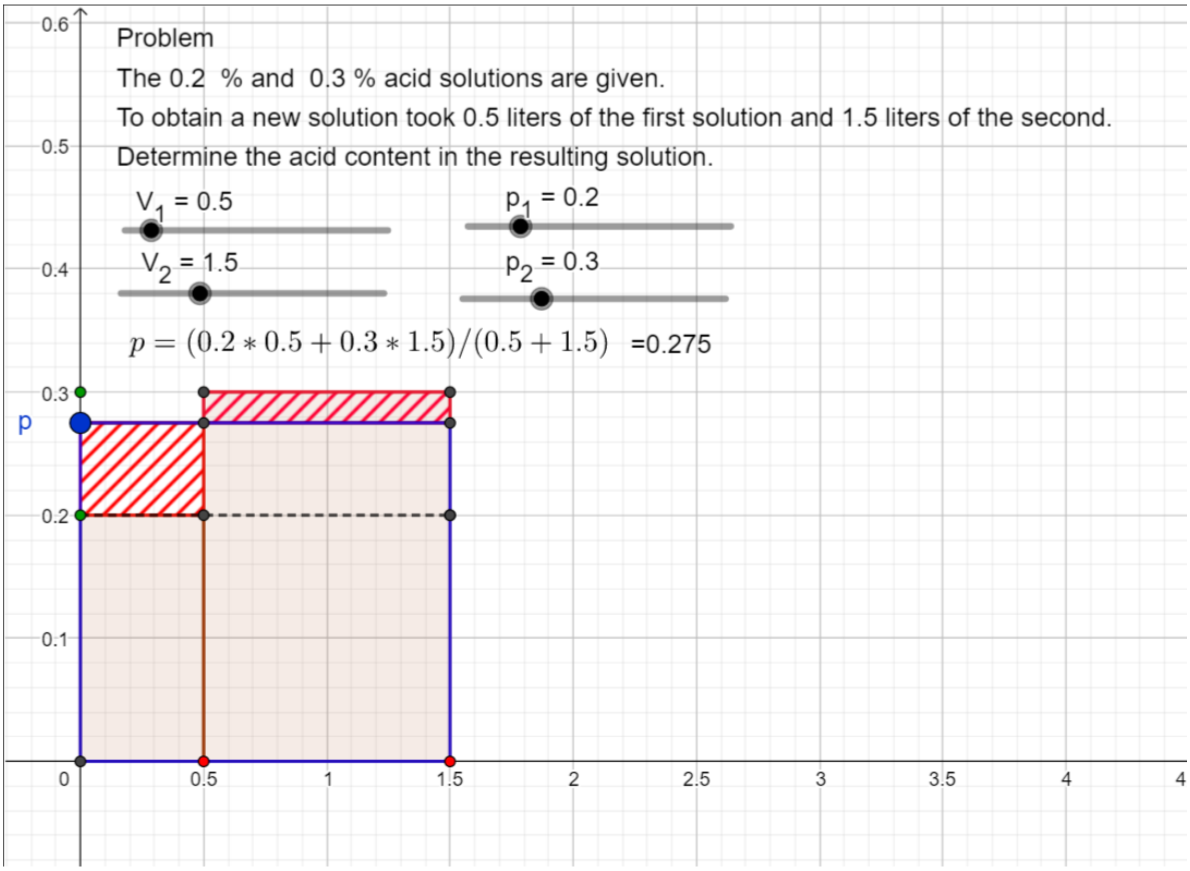


Figure 4: Word problem modelling based on GeoGebra (https://www.geogebra.org/m/fmupxx5a).

language (modeling); establishing the relationship between the input data and the problem question; drawing up a problem solution plan; implementation of the solution plan; checking and evaluating the problem solution.

The essence of the method of modeling in solving word problems is to translate the text of the problem into the language of visual models of various kinds: drawings, diagrams, graphs, tables, symbols, formulas, equations, etc. The translation of the text into the form of a visual model allows you to identify properties and relationships that are often difficult to detect when reading the text (figure 4).

Learning forms of the model are visualization lectures and laboratory classes.

Among the teaching methods used problem method, modeling method and netnography.

GeoGebra, constructive tasks and instructional materials are learning means.

The model of pre-service teachers' preparation for students' computer modeling skills formation is implemented in three stages:

1) mastering GeoGebra computer tools;
2) pre-service teachers' preparation to modele (on the material of interesting curves in Analytical Geometry or word Math problems in secondary school);
3) formation of students' skills to select and/or formulate author's problems that can be solved by the modeling method in GeoGebra.

In the first stage, GeoGebra computer tools are mastered: students get acquainted with the possibilities of using GeoGebra to solve different classes of math problems. Particular emphasis should be placed on tools of geometric constructions and sliders, thanks to which it is possible to change the constructed structure in an interactive mode.

The methodology of forming the skills to model interesting curves is as follows: the teacher on a common online platform informs about constructive approaches to the construction of various curves, which were studied in ancient times (the netnography method). He briefly tells about how such constructions were done (compass and ruler, one compass, two compasses, one or two rulers, etc.), or gives an example of practically oriented problems that are solved using interesting curves. After that, the teacher demonstrates one of the described constructions in GeoGebra cloud service, and then asks students to write an algorithm for the above construction (the problem method).

Then the teacher asks students according to the algorithm (provided to each student) to reproduce the construction and demonstrate the result, to analyze errors, and if not, to analyze possible limit cases. After that, students are offered the definition of curves generated in mechanical way together with the algorithms of their construction in the cloud service; students must model this type of curve according to the existing algorithm. Then together with students, the task of the following type is carried out: algorithms of curves construction are offered and after their construction, students need to characterize properties of the modeled curves, to give them definitions or kinematic characteristics. After completing this type of task, students are offered only the definition of the curves or their kinematic characteristics, and they must model the curve themselves.

The methodology should be briefly described as follows. Step 1 – the teacher offers an example of a curve model through the definition (the teacher step by step models the curve), and students must independently compile an algorithm for constructing the model. Step 2 – the teacher offers a description-definition of the curve and provides a ready-made algorithm according to which students model the curve independently. Step 3 – the teacher offers an algorithm for constructing a curve model, and students need to characterize the properties of the curve or give its definition based on the results. Step 4 – students are offered definitions of curves that they have to model them.

More details about the methodology in (Drushlyak et al., 2021b).

The method of the second stage described by us differs from the traditional one, as the latter usually involves only step 2 and step 4, which does not allow students to understand the algorithms involved in building a model, to develop the ability to compare step-by-step ideas and steps. There is also no practice of qualitative analysis of the algorithm (which is provided by step 3 and which is supported by the "step-by-step playback service" in GeoGebra). This is what we consider to be fundamentally important for the effective learning of modeling skills and what makes the GeoGebra service possible.

Mastering the module "Modeling of word problems" involves providing students with instructional materials with examples of solving word problems in GeoGebra. At the first lesson, students must complete tasks on modeling word problems of the school mathematics course on the model and independently. For the second lesson, students have to prepare 10 word problems, up to 5 of which provide instructional materials for solving in GeoGebra. Students must exchange developed didactic materials, solve problems and return them for testing. For the third lesson, stu-

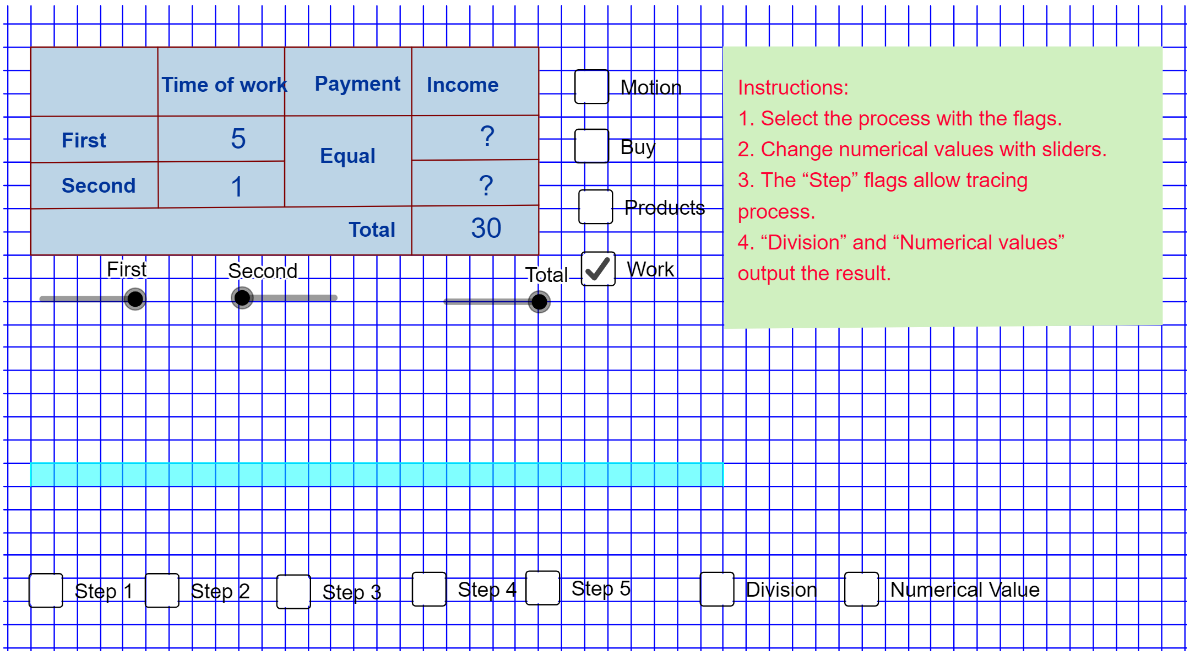
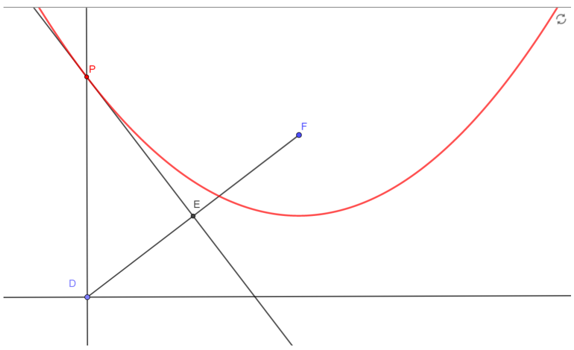
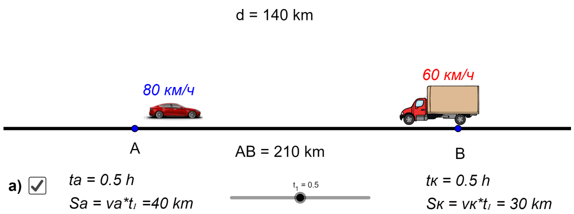


Figure 5: The problem of proportional division (author Nataliia Kishchuk, https://www.geogebra.org/m/bhw6xbcp).



(a) Construction of a parabola, Locus tool.



(b) Visual model of the motion problem.

Figure 6: Visual models.

dents should check the tasks performed by another student and analyze the errors, which should be presented to the general public for discussion.

We will describe in more detail the method of teaching this module.

The method of forming the skills to model word problems is as follows: the teacher on the cloud service https://www.geogebra.org/ introduces students with examples of visual models for word problems (the method of netnography, figure 5). This briefly dwells on how such constructions were carried out (using Slider, Text, Button, Check Box). After that he demonstrates one of the described constructions in GeoGebra cloud service (figure 4), and then asks students to prescribe the algorithm of the given construction (the problem method).

Then the teacher asks students according to the algorithm (provided to each student) to reproduce the construction and demonstrate the result, to analyze possible errors.

Briefly, the technique should be described as follows:

Step 1 – the teacher offers an example of a visual model of a word problem, and students must independently create an algorithm for a model constructing;

Step 2 – the teacher offers a ready-made algorithm by which students independently reproduce the visual model;

Step 3 – students are offered a type of word problems (motion problems, work problems, alloy mixtures problems, etc.), they select the appropriate problem and independently construct a visual model.

It should also be noted that in the conditions of distance learning, GeoGebra service allows the demonstration of shared constructions and the ability to work with models at any time from anywhere.

Table 3: The results of students' tests.

Student	Mark 1	Mark 2	Student	Mark 1	Mark 2	Student	Mark 1	Mark 2
1	10	10	18	13	12	35	17	17
2	13	11	19	11	16	36	12	13
3	12	12	20	9	10	37	11	13
4	5	9	21	8	8	38	11	13
5	14	14	22	9	11	39	9	12
6	6	7	23	9	11	40	9	13
7	9	10	24	9	9	41	9	11
8	10	12	25	9	9	42	9	11
9	12	12	26	7	16	43	7	10
10	12	11	27	15	15	44	9	12
11	11	12	28	13	14	45	7	10
12	11	15	29	14	15	46	8	9
13	6	6	30	11	11	47	13	11
14	5	9	31	11	12	48	15	14
15	7	12	32	11	12	49	16	16
16	9	9	33	12	12	50	12	13
17	9	11	34	7	9	51	12	11

6 STATISTICAL ANALYSIS OF RESULTS

The effectiveness of the developed model was tested on the basis of two tests. Students had to solve problem 1 (for example, to build a curve for which "A point and a line, the distance between which is equal to a are given. A line is drawn through an arbitrary point X of the line and the point. The points at a distance b from point X are marked. Find the locus of such points", figure 6 (a)) and problem 2 (for example, to build a visual model for the problem "From points A and B, the distance between which is 210 km, car and truck moved to meet each other. The speed of a car is 80 km/h, and a truck – 60 km/h. What will be the distance between the machines in half an hour?", figure 6 (b)) before the experiment and after the experiment.

Assessment of the solutions of problem 1 was carried out through the assessment of skills: take into account the analytical and geometric relationship between the elements; use the Locus and Trace tools; successfully visualize the model; add dynamic text to demonstrate numerical characteristics; develop an algorithm for model constructing; reproduce the steps of the algorithm for the model constructing; interpret the result of a computer experiment (in more detail in table 1). Assessment of the solutions of problem 2 was carried out through the assessment of skills: the ability to analyze the text of the problem; establish a relationship between the input data and the question; use Slider, Text, Button, Check Box, Image; successfully visualize the model; to develop an algorithm for a model constructing; reproduce commands of the model construction algorithm; check and evaluate the computer solution of the problem (more details in table 2).

The results of the tests are presented in table 3.

These marks were used to determine the number of respondents whose total score decreased ("–"), did not change ("0") and increased ("+") (table 4).

Table 4: Dynamics of scores based on the results of students' tests

Dynamics of scores	Number of respondents
Negative, "–"	6
Without changes, "0"	13
Positive, "+"	32
Number of changes, n = "–"+" + "	38

7 CONCLUSIONS

1. The development of information technology has actualized the perception of modeling as a leading method of scientific knowledge and a means of developing intellectual skills of young people. Thus for the decision of many mathematical problems the method of modeling which is realized on the basis of the constructive approach is used.

2. The students' ability to model can be successfully formed under the condition of appropriate advanced teacher training, and therefore models and methods of pre-service teachers' preparation for students' modeling skills formation are in demand in modern society.

3. The developed model of pre-service teachers' preparation for students' modeling skills formation (based on GeoGebra) is based on the perception of a constructive approach as a leader in the development of intellectual skills of young people. Its implementation is based on a special course on mastering GeoGebra and two experimental modules "Modeling curves" and "Modeling word problems", mastering which involves the use of appropriate forms (visualization lectures and laboratory classes), methods (problem, modeling and netnography) and training means (GeoGebra, constructive tasks and instructional materials).

4. The model of pre-service teachers' preparation for students' modeling skills formation is implemented in three stages: 1) mastering the GeoGebra computer tools; 2) formation of pre-service teachers' skills to model; 3) formation of students' skills to select and/or formulate author's problems that can be solved by the method of modeling in GeoGebra.

5. The developed model is focused not only on the pre-service teachers' preparation for students' modeling skills formation with GeoGebra, but also thanks to the role-playing game in the third stage of its implementation allows awareness of their own mistakes in future professional activities and typical mistakes of students.

Further scientific research is needed to implement the methodology: in the training of teachers of natural specialties (biology, chemistry, geography); in the conditions of mobile training; based on other specialized software.

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Comparative Study of the Support of Academic Clouds Based on Apache CloudStack and Proxmox VE Platforms

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Keywords: Cloud Computing, Academic Cloud, Apache CloudStack, Proxmox VE, Google Workspace.

Abstract: Cloud technologies provide users with efficient and secure tools for data management, computing, storage and other services. The article analyzes the projects for the introduction of cloud technologies in education and identifies the main advantages and risks in creating a cloud infrastructure for the university. Such startups contribute to the formation of a new paradigm of education. It involves the virtualization of education, the introduction of mobile and blended learning, ie the combination of cloud computing with modern learning concepts. In this paper, we compare some aspects of deployment and supportin our experience in improving the academic cloud for the training of a bachelor's degree in computer science. This is through the integration of the Proxmox VE platform into existing computing power by deploying the Proxmox VE system. In the study, we reveal some technical and methodological aspects of the organization of the educational process using this corporate cloud platform. The scheme of the organization of physical components of cloud infrastructure (nodes, virtual networks, routers, domain controller, VPN-server, backup system of students' virtual machines) is given. All characteristics of this environment and possibilities of their application are studied.

1 INTRODUCTION

Today, many universities are creating their own cloud-based learning environments (CBLE). Although there is currently no single concept for CBLE, scientists understand it as similar concepts (Glazunova and Shyshkina, 2018; Korotun et al., 2020; Bykov et al., 2020; Vakaliuk, 2021; Spirin et al., 2022). In general, it can be understood as an IT system consisting of cloud services and providing learning mobility, group collaboration of teachers and students to achieve educational goals (Lytvynova, 2018).

As the analysis of the literature shows, many university CBLE are usually deployed according to the hybrid model (Shyshkina, 2016; Markova et al., 2019; Vorozhbyt, 2017; Vakaliuk et al., 2021). One of the most important components in the structure of this environment is the private academic cloud (Glazunova, 2015). It is now deployed according to the most productive IaaS service model. A hybrid cloud is a cost-effective way to solve the problem of insufficient computing resources. The private academic cloud allows the university to meet the peak demand of students and faculty through a combination of local infrastructure and one or more public clouds (Wang et al., 2020).

Various commercial and free platforms are used in universities to build private academic clouds (AL-Mukhtar and Mardan, 2014; Ilin et al., 2016; Amiel et al., 2020). A productive method of deploying private academic clouds is to use solutions from leading cloud vendors such as Google, Microsoft, Amazon and others. Google offers researchers, universities, faculties, faculty and students grants and loans for teaching and research. In particular, leading European educational institutions can access Google Cloud within the Internet2 project (Internet2, 2023). Unfortunately, these opportunities are not currently available for our country (Ukraine). For example, Microsoft Educator Grant is a program designed specif-

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ically to provide access to Microsoft Azure to college and university professors teaching advanced courses. As part of this program, faculty teaching Azure in their curricula are awarded subscriptions to support their course (Microsoft, 2023). In general, these programs are very useful and productive. However, they are usually provided on a temporary basis and therefore cannot completely replace the cloud-based IT infrastructure of universities and colleges.

Among the free platforms for cloud infrastructure deployment, CloudStack, Openstack, Proxmox VE, and Eucalyptus are the most suitable. Each of them has its advantages and disadvantages. There are many attempts to compare these platforms. The authors of articles comparing such platforms state (Microsoft, 2023; Fylaktopoulos et al., 2016):

- OpenStack has large community, offers wide integration with storage, network and compute technologies, but is too complex to deploy and configure;
- Eucalyptus the longest-standing open source project is banking on its very tight technical ties to Amazon Web Services (AWS). The platform is configurable, but not very customizable;
- Proxmox is open source platform. It can provide easy way to deployment cloud infrastructure. But it is not very suitable as a platform for a private cloud in the CLBE;
- CloudStack has well rounted GUI, can provide an advanced cloud infrastructure, but it is very GUI centric built on single Java core.

We have been deploying a private academic cloud based on the Apache CloudStack platform for the past 8 years. For the last 2 years we have been deploying an academic cloud based on Proxmox VE as well. Apache CloudStack deployment is housed in the infrastructure building. It contains a management server, 4 hosts, 4 primaries and 1 secondary storage. We decided to use hypervisors instead of containers. This is because the former are more versatile. In addition, the use of hypervisors is safer than containers. To save computing resources, we have installed primary storage on the hosts. We used VLANs to distribute traffic across individual networks. These networks can be allocated to groups or individual students.

We have so far rented one refurbished physical server based on a used Intel Xeon processor with 32 Gb of RAM for deployment of Proxmox VE. This was also done because Ukraine is currently at war and it is difficult to say whether servers will be available as they are in university buildings.

In general, our private academic cloud provides (Fylaktopoulos et al., 2016):

- Development and Execution of student virtual machines;
- Aggregation of computing resources of several hosts;
- VM migration between repositories;
- VM connections to each other through guest networks;
- Launching VMs within other VMs;
- Integration with Active Directory;
- Distribution of student accounts according to their academic groups.

There are many advantages and disadvantages to using Apache CloudStack and Proxmox VE as an academic cloud platforms. There are some problems happens in the process private academic cloud using.

The purpose of the article is to compare some tasks in maintenance of academic clouds based on Apache CloudStack and Proxmox VE platforms.

The following tasks are required to achieve the goal of the research:

1. Analysis of maintenance tasks of academic clouds in foreign and Ukrainian universities.
2. Definition of maintenance tasks of academic clouds based on Apache CloudStack and Proxmox VE platforms.
3. Describe and compare methods for solving these tasks.

We used a set of research methods such as theoretical (analysis of scientific, technical literature, experience; generalization of experience of using cloud computing in education) and empirical (modelling, designing, developing of scripts).

2 THE PRIVATE CLOUDS MAINTENANCE TASKS

As the experience of cloud infrastructure maintenance shows, this is an ongoing process. It requires constant attention from engineers, network system administrators, teachers, and student involvement. Scientists describe the experience of deploying an academic private cloud, including determining the performance of hypervisors and storage (Spirin et al., 2018). The biggest challenge for researchers was the transition from a prototype of an academic cloud to a productive one. In this context, they addressed the problem of load balancing, elastic hypervisors, security threats. Storage backup tasks are also important for such clouds.

Rao and Nayak (Rao and Nayak, 2014) offer the concept of backup to cloud storage. They say that both the cloud provider and the cloud consumers have to take comprehensive steps to ensure appropriate configurations, hardening of the CBLE, appropriate design and development, appropriate interoperability, and adequate testing.

Rusyn et al. (Rusyn et al., 2019) have developed an effective method of deduplication and distribution of data in cloud storage during the creation of backups. Researchers have developed an intelligent system for such deduplication and tested it.

Tian et al. (Tian et al., 2020) also studied cloud data backup. The authors propose a scheme for data separation and backup and encryption. They state that their own scheme resolves the conflict between data security and the survivability of the IT infrastructure with the help of encrypted backup.

The Apache CloudStack cloud infrastructure redundancy model developed by Paul Angus is very useful for our study. It creates a vendor agnostic API and UI in CloudStack for end users. The author's Framework abstracts the specifics of solutions, such that through the use of a plugin, a 3rd party solution can deliver backup and recovery solutions (Khmelevsky and Voytenko, 2015) .

Here are some tasks for servicing our sample private academic cloud:

1. Making changes to the cloud infrastructure.
2. Creating and verification of the academic cloud performance model.
3. Designing and realization an academic clouds' backup model.

Let's consider these tasks in more detail.

3 MAKING CHANGES TO THE CLOUD INFRASTRUCTURE

Maintenance of our developed cloud infrastructure involves the implementation of tasks such as:

- changing the parameters of the components of the cloud infrastructure – zones, clusters, hosts, storages;
- creating and routing of virtual networks for individual groups or students;
- creating and modifying templates of compute offering services that determine the performance of VM;
- creating and modifying network offering service templates such as VPN, DHCP, DNS servers, Firewall, Load Balancer and others;
- creating projects for VM sharing by students.

This task also involves creating student and faculty accounts. We authenticate users of the academic cloud from a centralized database – LDAP-directory (Microsoft Active Directory). This approach makes it possible to use single registration data to access all hybrid IT infrastructure services. We used CloudStack domains to distribute students according to academic groups. Adding users to them is possible in automatic (using links at the first successful authentication) and manual mode. Unfortunately, due to the incompatibility of our users' logins with the Apache CloudStack platform, we had to choose the manual mode. To reduce the technical work involved in finding LDAP directory entries, we have created several queries to filter user account data.

Proxmox VE also provides authentication based on the LDAP directory (Active Directory). To do this, cloud administrator need to specify some parameters such as socket to connect to the domain controller, user data for reading data from the directory, some user attributes, filters to restrict access.

To log in to the system, the administrator can add it manually, for example using the web interface. However, it is possible to automatically synchronize the directory with the *pveum realm sync <realm>* command. Like Apache CloudStack domains, Proxmox VE can create groups. For these groups, cloud administrator can define privileges for access to cloud infrastructure.

Apache CloudStack users automatically have access to their own VMs. This is good for students to complete individual tasks. The creation and providing permission to VMs isn't a trivial task in the Proxmox VE Platform. We offer two approaches to do this. The first involves the administrator creating copies of VMs and giving students access to these VMs. Permissions may vary depending on the operations to be performed with these VMs. For example, cloud administrators can provide students with administrative access to such VMs. Another approach involves students cloning their own machines from the templates. It requires providing some rights. They are displayed as a table 1.

Creating permissions that match the last row of the table requires defining *<students_login>* - *<VM_ID>* pairs. Finally, permission is granted through the command:

```
pveum acl modify /vms/<WM_ID> <username>
  -role Administrator
```

Table 1: Permissions are required to clone student VMs from templates.

Permissions	Path	Propagate
PVEAuditor	/	+
PVEDatastoreUser	/storage	+
PVETemplateUser	/pool	+
PVEVMUser	/nodes	+
Administrator	/vms/VM_ID	−

Later, using a script, we obtained a list of users from the LDAP directory and set the appropriate IDs for them. It is important that when cloning VM, students must indicate the ID provided by the teacher for VM.

3.1 The Academic Cloud Performance Model

Performance calculations are needed to understand the number of VMs that can run in the cloud. It is also needed to understand the computing performance of these machines, which is required to create their templates.

Both platforms use CPU and memory redundancy depending on the number of VMs. VE allows cloud administrators to do this more flexibly when running containers instead of VMs.

When creating the service offering templates, we compared the characteristics of the hardware hosts (CPU frequency, RAM) with the minimum guest OS requirements and the number of students. To do this, we used the inequality:

$$FRQ = N_{st} * F_{OS} < FRQ_{hosts},$$

where FRQ – the total frequency of VMs processors; N_{st} – amount of students; F_{OS} – the minimum frequency is recommended for the guest OS; FRQ_{hosts} – total frequency of hardware host processors. The last value can be found from the ratio:

$$FRQ_{hosts} = \sum_{i=1}^{n} (N_{ci} F_{ci}),$$

where N_{ci} – the number of cores in the processor of the i-th host, F_{ci} – CPU frequency of the i-th host.

Unlike Apache Cloudstack, Proxmox VE does not have performance templates. Appropriate parameters must be set for each VM during its installation. If a student clones a VM from a template, he/she cannot change its performance settings. Instead, when using the VM, these parameters are available for change. However, the last two formulas are also valid for the Proxmox VE platform. In order to compare the computing capabilities of the studied cloud platforms, we will consider the hardware characteristics of the respective servers (table 2).

Table 2: Main characteristics of academic cloud's hardware.

N	N_{ci}	F_{ci}	MEM_{ci}	FRQ_{hosts}
Host0	4	3200	16384	12800
Host1	4	3100	24576	12400
Host2	4	3100	16384	12400
Host3	4	3700	32768	14800
CloudStack	16		90112	52400
Proxmox VE	8	3500	28000	31980

As table 2 shows, the private academic cloud based on Apache CloudStack has a total frequency of about 50GHz. And the total amount of memory is about 90 Gb.

Unfortunately, we do not have the equipment to deploy identical academic clouds based on the CloudStack and Proxmox VE platforms. However, we can assume that the performance of the physical server with Proxmox VE should be equal to the computing power of the two servers with CloudStack (Host0 and Host2). Therefore, in the CloudStack deploymengt, we disabled Host1 and Host3. During the testing, Host1 stayed online as a management server in the CloudStack infrastructure. But it didn't run any VMs.

Regarding the frequency, two other opposite factors should be taken into account:

- table 2 shows the base frequency, and processors can run faster thanks to Turbo-Boost technology;
- hosts run other software (OS, databases, management servers, hypervisors). It also consumes resources.

It is well known that the frequency of a modern processor is not constant. It can increase or decrease depending on the mode of operation of the CPU. That's why we use Processor Base Frequency in the tables and formulas above. Processor Base Frequency describes the rate at which the processor's transistors are open and close. The KVM hypervisor measures this processor frequency. It is software for launching and executing virtual machines in the Apache CloudStack and Proxmox VE platforms.

Similarly, to determine the required amount of memory we used the inequality:

$$MEM = N_{st} * MEM_{OS} < MEM_{hosts}$$

3.2 Verification of the Academic Cloud Performance Model

To check computation performance of both clouds we loaded the same VMs on two clouds until their CPU load was 90%.There were several types of test virtual machines (table 3). These types corresponded to the VM templates that were created for the various training courses. For example, templates LinuxGUI, WindowsWs were used in the course of operating systems, AdvLinux in the course of computer networks, WindowsSrv in the course of administration. The Linux OS with CLI worked as Proxmox VE containers and as regular VMs in CloudStack. We use the EVE-NG platform based on AdvLinux template for modelling in the study of computer networks. It launches its own VMs inside the main Apache CloudStack VM (Spirin et al., 2019). Such nested virtualization requires more resources.

Table 3: Some templates types of our academic cloud's performance.

Template	F_{OS}	MEM_{OS}	N_{st}	FRQ	MEM
LinuxCLI	500	500	20	10000	10000
LinuxGUI	1500	2000	20	30000	40000
WindowsWs	1000	2000	20	20000	40000
WindowsSrv	1500	2000	20	30000	40000
AdvLinux	2500	4000	20	50000	80000

The number of VMs that were loaded is shown in table 4.

Table 4: Comparison of the number of VMs running on Apache CloudStack and Proxmox VE platforms.

Template	CloudStack	Proxmox VE
LinuxCLI*	50	120
LinuxCLI	112	120
LinuxGUI	18	19
WindowsWs	20	22
WindowsSrv	16	16
AdvLinux	12	8

Comparing the data in table 2 and table 3, we can conclude that our deployments of both platforms provides about 50 VMs with Linux with command line interface (CLI), more than 40 VMs with Windows Workstation, about 35 VMs with Windows Server and OC Linux with GUI (see table 4). This test showed that the number of virtual machines loaded on Proxmox VE is slightly higher than in Apache CloudStack (except for the template AdvLinux).

To verify the performance model, we performed academic cloud testing. The experiment was performed according to the method described in the article (Algarni et al., 2018). The authors' model used traditional benchmarking systems to measure system performance and individual components like CPU, memory, cache and disk performance. Like the previous case, we compared the performance of two CloudStack hosts and one Proxmox VE. To test performance of clouds we have created 16 identical VMs (8 on Apache CloudStack and 8 on Proxmox VE). They had equivalent 2-core processors, the same amount of RAM (2 Gb) and the size of disks (14 Gb). The same Ubuntu server 20.04 x64 was installed on all these VMs.

We have performed real-tasks tests such as:

- Ab is a tool for benchmarking Apache web server. Ab was used for measuring of time taken for the system to respond to a request from a web client. This can estimate the response efficiency of each VM by measure the number of static web page requests a server can fulfil in one second.
- The LZMA benchmark measures the amount of time consumed in compressing a file using its own compression algorithm.
- John the Ripper is a tool for measure CPU throughput. In this benchmark, the efficiency of the process management of the hypervisors is evaluated. This benchmark is a common decipher application which uses diverse ciphers such as DES and MD5.
- IOzone benchmark is used to evaluate performance of file system. IOzone generates and assesses many file operations such as read, write and random read.

Ab was used for measuring of time taken for the system to respond to a request from a web client. This can estimate the response efficiency of each VM. Our script have completed 100000 requests with concurrency level 1000 simultaneous requests. The results of all test available by the URL https://drive.google.com/file/d/1m-3oS7cOWyCFUVeBe8t4EnHOcll6ApyX. Shared table contains the designations of VMC for VMs Cloudstack and VMP for Proxmox VE ones. The average values of ab-test are given in the table 5.

Table 5: Ab benchmark results.

Platform	Requests per sec	Transfer rate, Kb/s
CloudStack	2115,68	95150,89
Proxmox VE	1787,62	80437,84

In the Apache benchmark, CloudStack performance is 18% higher in terms of both the number of requests and transfer rate. A slightly smaller advantage of Apache CloudStack (near 7%) was shown by the LZMA test. We performed John the Ripper benchmarks for the case of coding according to DES 128 and MD5 algorithms. Because the test was run on a single CPU core, the "real" and "virtual" results were the same. We analyzed the results for the single-salt case. They indicate (table 6) that Apache CloudStack has significantly advantage under Proxmox VE (38% and 54% for DES 128 and MD5 algorithms).

Table 6: John the Ripper benchmark results

Platform	MD5 hash	DES 128 hash
CloudStack	14526,13	61055,88
Proxmox VE	10503,75	39524,38

Similar results were obtained in the performance test of virtual HDDs (figure 1).

Therefore, it is reasonable to predict that the performance of the virtual machines themselves will be higher on the Cloudstack platform. It is hoped that students will feel this in their academic research work. However, another important factor in this assessment is the functionality and usability of the interface. The Proxmox VE console interface is more advanced than Apache Cloudstack. This fact, together with a good mobile version of the platform allows you to work with the cloud from different devices.

The previous test concerned the performance of the virtual machines themselves. We decided to investigate the performance of hardware servers (hosts) with their running hypervisors. This test will allow us to evaluate the efficiency of the use of computing resources by cloud platforms. To do this we used the formula to rank hypervisors' performance proposed by Reddy and Shyamala (Reddy and Shyamala, 2016). According to it, the hypervisor's score scores of its CPU and memory.

$$Score_{HSI} = Score_{HCPU} + Score_{HMEM}$$

Each of these scores is calculated as the sum of the CPU and RAM performance of any VM in the cloud.

$$Score_{HCPU} = \sum_{i=1}^{n} CP_{VMi}$$

$$Score_{MEM} = \sum_{i=1}^{n} MP_{VMi}$$

The CP_{VMi} and MP_{VMi} values are calculated as follows

$$CP_{VMi} = \alpha_{CPU} \times \frac{ACPU_{VMi}}{HCP_{VMs}}$$

and

$$MP_{VMi} = \alpha_{MEM} \times \frac{AM_{VMi}}{HMP_{VMs}},$$

where α_{CPU} and α_{MEM} are CPU and memory weight factors; $ACPU_{VMi}$ and AM_{VMi} are available CPU and memory resources of VMi; HCP_{VMs} and HMP_{VMs} are all VMs relative CPU(RAM) utilization with respect to host.

The formulas for calculating the values HCP_{VMs} and HMP_{VMs} are as follows

$$HCP_{VMs} = \frac{TotalCPU - \sum_{i=1}^{n} ACPU_{VMi}}{Total_{CPU}} \times 100,$$

$$HMP_{VMs} = \frac{TotalMEM - \sum_{i=1}^{n} AMEM_{VMi}}{Total_{Memory}} \times 100,$$

where $ACPU_{VMi}$ and $AMEM_{VMi}$ are available CPU(RAM) of VMi.

Alpha coefficients are the ratio of processor resources (memory) of one VM to all VMs. Since we have all 8 machines the same, for each platform $\alpha_{CPU} = \frac{1}{8}$ and $\alpha_{MEM} = \frac{1}{8}$.

We applied the above formulas and obtained the following values for the studied platforms (table 7).

Table 7: The obtained scores of Cloudstack and Proxmox VE platforms.

	AB	lzma	iozone
Score_CloudStack	77,24	68,55	349,29
Score_Proxmox	79,03	87,18	284,85

Thus, we can state that the score of both platforms based on the Apache benchmark test is almost the same (the difference is about 1.5%). Proxmox VE showed the best results in the lzma test (about 27%). The opposite result of the advantage of Apache Cloudstack is observed in the iozone test. However, we have doubts about this case, because the disk subsystems of the two platforms are significantly different (Proxmox VE uses a software raid, and Cloudstack generally contains two separate physical hosts with HDDs). Diagrams of the obtained ratings are shown in the figure 2.

So, based on the verification of the cloud platform performance model, we can say that the Apache Apache Cloudstack and Proxmox VE have roughly equal ratings. In naked academic clouds, the performance of 2 physical Apache Cloudstack hosts is approximately equal to the performance of one Proxmox VE host. In this case, other factors of the cloud platform at the university will be decisive.

4 DESIGNING AND REALIZATION AN ACADEMIC CLOUDS' BACKUP MODEL

The backup model depends on which platform will be stored. There are general backup principles that are valid for both platforms. However, the technical implementation will be different. We had to develop scripts for the Apache Cloudstack. Proxmox VE has powerful built-in backup tools.

Experience shows that the task of backup is very important and time consuming. This is primarily due to the large amounts of student VMs data in the private academic cloud. Large companies develop a dis-

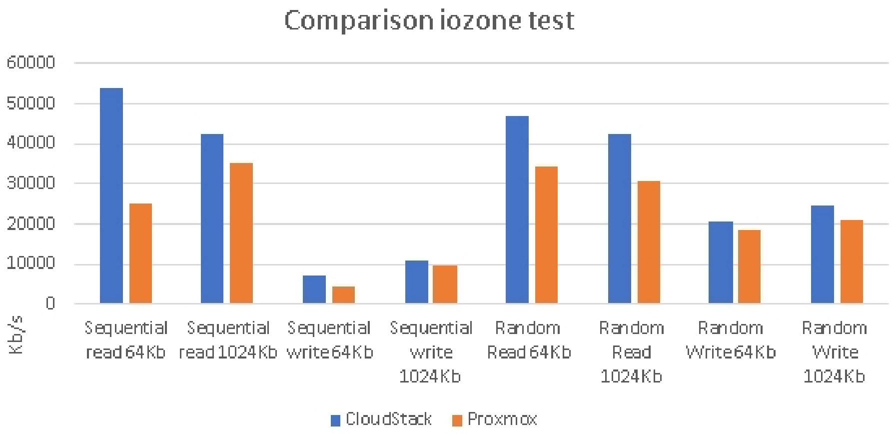

Figure 1: Comparison of the results of iozone test.

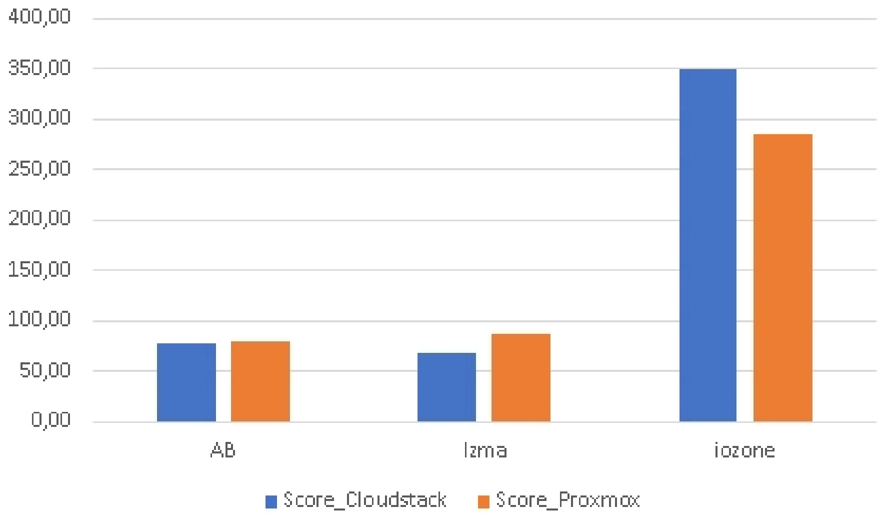

Figure 2: Comparison of the Apache CloudStack and Proxmox VE scores.

aster recovery plan in this case. But in educational institutions, IT services work to perform such tasks. Therefore, they need to develop a model, identify potential risks in the IT infrastructure, consider and implement an appropriate backup system.

The development of a backup strategy requires the definition of the main goals and objectives of the backup, tools and regulations. In general, the problem of back-up is relevant for almost all IT infrastructures. When choosing a backup method, the following criteria are important (Angus, 2019):

- backup time to the storage;
- recovery time from backup;
- the number of copies that can be stored;
- risks due to inconsistency of backups, imperfection of the backup method, complete or partial loss of backups;
- overhead costs: the level of load on the servers when performing copying, reducing the speed of service response, etc;
- the cost of renting all services and storage.

Currently, there are 3 main backup schemes such as:

- *Full*. This type of backup creates a complete copy of all data.
- *Incremental*. In this case, only files that have changed since the previous backup are copied. The following incremental backup only adds files that have been modified since the previous backup.
- *Differential*. The backup program copies each file that has changed since the last full backup. Differential copying speeds up the recovery process (Paulsen, 2011).

To save material costs, we use almost no server equipment and powerful and high-speed network storage in our academic cloud installation. Instead, we decided to use cloud services. For example, the Google Drive service within the Google Workspace for Education Fundamentals package offers virtually unlimited disk space (Oleksiuk et al., 2017). The disadvantage of such a repository is the significant time to upload or download backups. This speed will be limited by the bandwidth of the university's Internet channel. The latter requirement can be considered acceptable, as our implementation of the academic cloud is used primarily for training rather than for production.

To use Google Drive in our own scripts, we need to use the API of this service. This interface is accessible through Google Developers Console, a software developer service. First you need to create your own project. Credentials were created to access this project. We have chosen to access OAuth 2.0 accounts. OAuth is an open authorization standard that allows a user or application to give and access data without having to enter a login and password. Access tokens are used for this purpose. Each access token provides access to a specific client to specific resources and for a specified period of time (Oleksiuk et al., 2017). After adding a new project, we created new data for authentication, selected the type of application (desktop) and activated the appropriate API (Google Drive API).

Because templates and ISO images in the CloudStack infrastructure do not change, but only new ones are added, we chose the incremental method to back up the secondary storage. Its implementation was based on the use of a ready-made utility for synchronizing storage files. Unfortunately, there is currently almost no such high-quality utility like Google backup and Sync, which is developed for OC Windows. We analysed several tools such as:

- Gdrive (grive2). Google Drive client with the support for the new Drive REST API and partial sync. It can't provide continuously wait for changes in file system or in Google Drive to occur and upload.
- Gnome-online-accounts. It is system utility located within system's settings in Gnome GUI. But it can only be executed in a graphical interface.
- GoSync is a Google Drive client with GUI support for Linux. It is designed under the GNU General Public License. The client is not perfect enough, for example, it has automatic regular synchronization every 10 minutes.
- Google-drive-ocamlfuse is a FUSE (Filesystem in Userspace) filesystem for Google Drive, written in OCaml. FUSE is a free module for the kernel of Unix-like operating systems. It allows developers to create new types of file systems available for users to mount without the root privileges of Google Drive on Linux (Yallop et al., 2018).

We used the latest utility. Here are its main features:

- full read/write access to ordinary files and folders;
- read-only access to google docs, sheets, and slides;
- multiple account support;
- duplicate file handling;
- access to trash;
- storing Unix permissions and ownership;
- support symbolic links;
- streaming through read-ahead buffers.

Some problem was that the utility requires authorization using a browser in a graphical interface. Therefore, we used an alternative authorization mode. Since we already had our own OAuth2 client ID and client secret, we specified them in the command:

```
google-drive-ocamlfuse -id
   12345678.apps.googleusercontent.com
   -secret abcde12345
```

As the command tries to start the browser on the server where there is no GUI we formed the necessary URL as it is written in the documentation on Google Developers Console. After going to this address, we received a verification code. This code gave access to folder synchronization to the Google Drive.

For security reasons, we decided to sync not the Apache Cloudstack secondary storage itself, but a copy of it from the backup drive. So, we first synchronized local folders with the command:

```
rsync -azvh /export/secondary
  /export/sync_secondary/arch_cloud
```

where */export/secondary* – the secondary storage of Apache CloudStack infrastructure;
/export/sync_secondary/arch_cloud – the local copy of this storage.

To synchronize the */export/sync_secondary/arch_cloud* folder, the following command has been added to the server task scheduler:

```
google-drive-ocamlfuse
  /export/sync_secondary
```

It runs every time a server with secondary storage is loaded.

A backup of all databases is required to restore the Apache CloudStack cloud infrastructure. These are such databases:

- *Cloud.* It contains all objects of cloud infrastructure.
- *Cloud_usage.* A database that contains generalized data on resource consumption by the end user. It is used to obtain statistics and compile reports.

Since the backup of these databases is quite small, we decided to store all backups in the cloud storage (Backup_Database task, figure 3). The traditional database for the Apache CloudStack platform is MySQL. The main utility for backing up MySQL databases is mysqldump. Its syntax involves entering a login name and password. Because the shell script in Linux is written as a plain-text file, it will contain the name of the user's password (usually the root) of the database. This is a potential security risk for the entire server. In order not to leave open the data for authorization of the database user, we used the "login path" option. A "login path" is an option group containing options that specify which MySQL server to connect to and which ac-count to authenticate as. To create or modify a login path file, we have used the mysql_config editor utility. In general, the commands for creating and archiving a database dump are as follows:

```
/usr/bin/mysqldump
  --login-path=DailyBackup -u root -A >
  $BACKUP_DIR/"_cloud_all_""$date_daily"".sql"
```

The variable *$date_daily* contains the current date of the archive. This allows you to see the date of archiving directly in the file name.

```
tar -czf
 $BACKUP_DIR/"archive_cloud_all_$date_daily.sql.tgz"
 $BACKUP_DIR/"archive_cloud_all$date_daily.sql"
```

To upload the files to the server, we used a ready-made script from GitHub. Here is its launch:

```
upload.sh "arch_cloud/DB" "$entry" $upl_file
  folder_ID "application/x-gzip"
```

where

- *arch_cloud/DB* – folder for uploading files;
- *$entry* – full path to the file;
- *$upl_file* – file name to download;
- *folder_ID* – Google Drive folder ID;
- *application/x-gzip* – file MIME-type.

A special refresh_token token is required to provide long-term access of the up-load.sh script to Google Drive. It can be obtained by curl-calling a URL such as:

```
curl -silent "https://accounts.google.com/o/\
  oauth2/token" --data "code=<access_token>&
  client_id=<client_ID>&
  client_secret=<client_secret>&
  redirect_uri=urn:ietf:wg:oauth:2.0:oob&
  grant_type=authorization_code"
```

In general, the scheme of backuping of Apache Cloudstack infrastructure is shown in figure 3.

Performing backup of primary repositories (Backup_Primary task (cloud0,cloud1,cloud2,cloud3)) has some difficulties. An analysis of Internet sources, management server databases, and storages files showed that the Apache CloudStack platform does not typically use full copies of disk templates for each VM. This means that full backups should be made to reduce the risk of inconsistencies in primary repository archives.

Additionally, it is necessary to prepare a cloud platform, stopping all VMs. Of course, students need to form an understanding of the need to turn off their own VMs. However, in practice this is not always possible. Therefore, it is necessary to stop all VM programmatically, by means of a script. This can be done using the API features of the Apache CloudStack platform. Using API functions allows the developer to access data about cloud infrastructure objects. It is also possible to change the state of these objects. To generate a query that contains API functions, you must specify:

- URL of the management server;
- Service construct "api?". It contains the path to a certain API-function, and indicates the beginning of the parameters that are transmitted using the GET method.
- Command. It is the name of the API-function.
- ApiKey. The key, that can be generated for each user account.
- Additional query options separated like GET queries using the "&" character.
- Response format (JSON or XML).
- Signature of the request.

Regardless of the protocol (HTTP or HTTPS) used to access the Apache Cloud-Stack API functions, the request must be signed. This allows the platform to confirm that the request was sent from a trusted accounting request that has the authority to execute the appropriate command. To sign a request, the developer must have an API key and an account secret key. They are generated by the platform administrator (OAuth, 2020).

Here is our bash-script to stop all working users' VMs

```
mysql --login-path=DailyBackup -D cloud
  -e "SELECT uuid FROM vm_instance WHERE
```

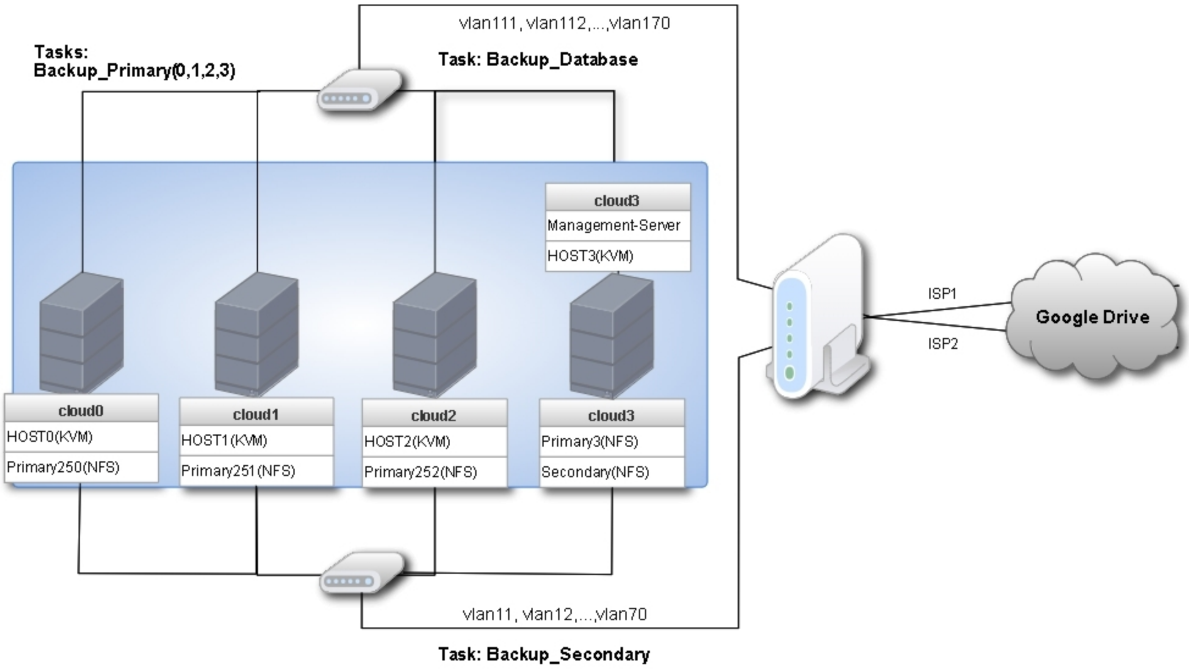

Figure 3: Apache Cloudstack infrastructure backup scheme.

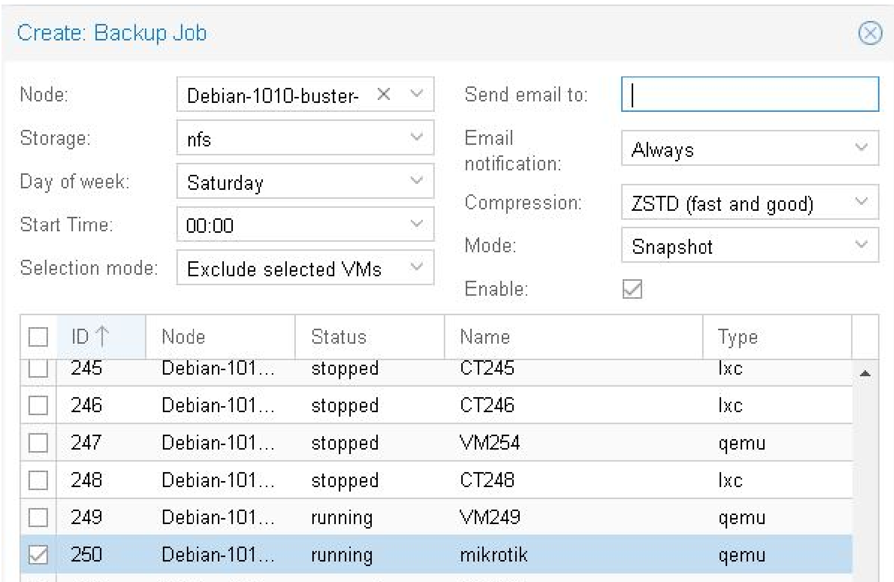

Figure 4: Proxmox VE backup job.

```
  type = \"User\" and state = \"running\";"
  > uuid.txt

sed -i '1d' uuid.txt

while read LINE; do php -q
  cloudstackapi.php "$LINE" ;
  done < uuid.txt
```

In the first line we receive in a file from a database the list of user VM with a running state. The next command clears the first line because it does not contain a VM. The third line runs the cloudstackapi.php script. It generates a signature and calls the stopVirtualMachine API.

Another way to back up the current state of the VM is to create their snapshots. The Apache CloudStack platform provides 2 types of images (Rusyn et al., 2019):

- VM Snapshot – a hypervisor-driven point-in-time image of a virtual machine's disks. The exact mechanism of this is dependent on the hypervisor.

- Volume snapshot – a point-in-time image of a specific volume. The process usually involves taking a VM snapshot and then copying the required volume to secondary storage and the deleting the VM snapshot.

This approach requires additional space on the secondary storage or data coping on the user's local disk. Such images can be taken by students from the web interface of the Apache CloudStack platform. Performing this action and turning off their own VMs after the end of their use are important components of ICT competence of the student.

However, experience shows that not all students perform these actions. Therefore, these are also worth automating with scripts. Among the API functions of the Apache Cloudstack platform are relevant (Sneddon, 2017).

Another task of backing up our academic cloud is to estimate the time required to upload data to the cloud storage. Currently (June 2022) the sizes of our academic cloud storage is approximately as follows:

- primary250 – 132 Gb;
- primary251 – 70 Gb;
- primary252 – 126 Gb;
- primary253 – 88 Gb;
- secondary – 110 Gb.

Since we make a full copy of the primary storage, we need to download about 400 GB to the cloud storage each time. Let the speed of the Internet channel at night be 80 Mbps (10 Mbytes per second). Then it will take 11 hours to download 400*1024 MB. That's a lot. Therefore, we balanced Internet access through 2 providers. At the time of backup, our router routes hosts cloud0 and cloud1 through the first provider, and cloud2 and cloud3 through the second. In this case, a full backup takes about 6 hours. This time is also significant, but is acceptable.

Another disadvantage of our scheme is the significant time required to download backups from the Google Drive service. However, this time will be significant if the management or storage servers fail. This means that we must back up the entire OS of the management server to fast local area network storage.

As mentioned earlier Proxmox VE provides many tools, including storage and backup types. To back up all cloud infrastructure, it is advisable to install and configure Proxmox Backup Server. It is an enterprise backup solution, for backing up and restoring VMs, containers, and physical hosts. By supporting incremental, fully deduplicated backups, Proxmox Backup Server significantly reduces network load and saves valuable storage space. Unfortunately, we do not have the physical resources to install a separate Proxmox Backup Server. Nevertheless, we have performed some tasks from the cloud infrastructure backup model.

Stop Students' VMs. There is no need to use Proxmox API to perform this task. We already have student VM_ID (used them to establish access rights). To stop these VMs on the Proxmox host, we executed the commands `qm shutdown VM_ID` or `pct stop container_ID`. It is advisable to use such commands to enable (disable) student VMs and containers at the beginning (end) of classes.

VM Reservation. We have set up a scheduled task to back up the cloud infrastructure to an NFS share. It is connected to our university local network via an OpenVPN tunnel. This allows us to save the condition of all machines.

Standard Proxmox VE tools allow cloud administrator to perform this task flexibly. The following backup options are available (figure 4):

- host (node) to be copied;
- storage for which to perform job;
- date and time of the task;
- backup objects such as some VMs, all VMs, all except some VMs;
- compression method (LZO, GZIP, ZSTD, without compression)
- copy mode (snapshot, suspend, or turn off VM)
- email notification about the status of the job or errors during its execution

The advantage of this method is the reservation of working VMs "on the fly". Like Apache CloudStack we use VMs backup from Proxmox VE cloud infrastructure into Google Drive storage.

5 CONCLUSIONS

The private academic clouds should be used in cloud based learning environment, as they are necessary for education of future ICT specialists. Despite the availability of educational grants from leading cloud vendors, many universities are deploying their own private academic clouds. Cloud administrators have a lot of work to do to maintain and support these academic clouds. Among these tasks, one of the most important is to ensure the productivity and elasticity of the cloud. Solving them will allow them to load the maximum number of VMs in the cloud infrastructure.

In this study, the performance of academic clouds based on Apache Cloudstack and Proxmox VE was evaluated. Despite some assumptions in comparison, we can state that the platforms have approximately the same performance and therefore can provide the same amount of VM for students. This is because they both use the same KVM hypervisor. As our experience has shown, the process of cloud deployment based on Proxmox VE is technically simpler and faster. This is even though we have installed Apache CloudStack many times and Proxmox VE for the first time.

An important task in the maintenance of the academic private cloud is the backup of its components. To solve it effectively, you need to use different backup schemes such as full, incremental, differential. To save data, it is advisable to use both cloud and local storage. In any case, administrators should determine how long it will take to build and restore the entire cloud infrastructure. It is also advisable to use the API functions of the cloud platform. This will automate some maintenance tasks.

To back up Apache Cloudstack, we had to use API and develop our own tools. In any case, this process requires large repositories and fast networks. If the first requirement is not met, it is advisable to use cloud storage. We did so and copy the backups to Google Drive. Backup of Proxmox VE infrastructure is technically simpler. To ensure the full functionality of this process, it is advisable to install a Proxmox Backup Server. All of the above factors indicate that it is time to migrate our academic cloud to the Proxmox platform. Maybe for a while we'll use them both together.

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Structurization and Processing of the Scientific Studies in the Form of Digital Ontologies

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Abstract: Nowadays, there is a wide variety of scientific articles. Due to this fact, it is hard to read and be familiar with all of them. Also, it is hard for a young scientist to understand the complicated terms and methods used in a specific research domain. This problem was partially solved by bibliographic management software and other specific software. This article aims to develop an approach for structuration and processing sets of studies using the IT Platform Polyhedron using an ontology-based hierarchical model. The ontological graph is complex because it has additional branches from child nodes in its structure. The basis of our solution was IMRAD (Introductions, Methods, Results, Abstract, Discussion structure) which has been represented in the view of nodes. Those nodes have been connected with specific representations of IMRAD elements. Specific articles have been represented in the view of leaf nodes. That could help to use the taxonomies for the structuration of the articles. Each data block is in the form of separate attributes of the ontological node. The proposed solution allows to obtain structured sets of studies and separate their characteristics. Thus, the proposed ontology allows viewing all methods, measured parameters, etc., of the studies in a graph node structure and using them to find the used studies. The usage workflows to demonstrate mechanisms of the system's usage are presented. The method of merging a few graphs of studies is developed and presented.

1 INTRODUCTION

Usage of information technologies (IT) in various fields of research activities and the capability of software support in science to automatically classify and structure information, e.g., in publication data, becomes increasingly important. Nowadays, vast amounts of research data are available that is not structured, e.g., publications, presentations, etc. It is complicated for young researchers and scientists to use such large amounts of publication data. During the research process, young scientists are looking for, e.g., examples of research methods and parameters. However, this task is challenging at the early stage of their scientific career. When preparing papers and reports, such literature search and analysis problems (e.g. state of the art) are challenging for every scientist (including youth and school researchers). For instance, according to Lens.org, the number of articles on biogas in 2002 was approximately 134, then in 2014, the number grew to almost 1164, as shown in (figure 1).

So, it is relevant to provide a solution that can simplify processing and information/knowledge extraction in scientific publications. There are two hypotheses in our study. The first one is about structuring and digitalizing the data, which can simplify finding the details about the research method. The second one is about structuring the results of previous studies, which can be represented as data of the informational system. Previously, this goal was partially achieved using metadata for data processing. In this paper, we further contribute with a semantic ontology and a more expressive semantic metadata approach.

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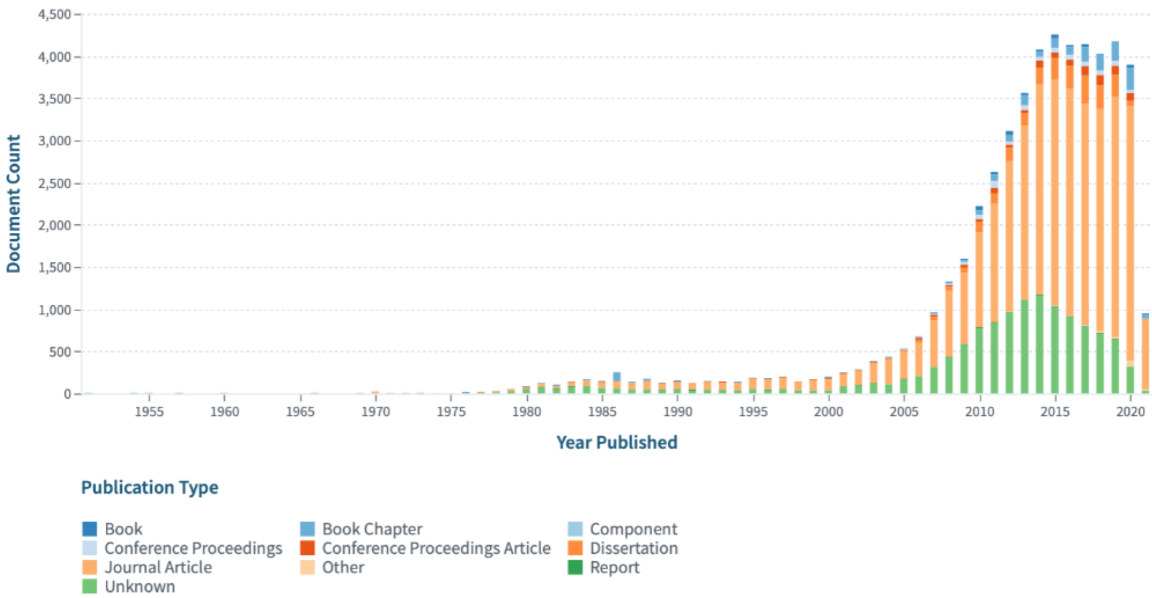


Figure 1: Dynamic of the number of papers on biogas.

1.1 Using Metadata to Provide Data Management in Science Publications

It is relevant to use metadata about each paper to support publication data management. This metadata represents the data about the publication. In this case, the metadata can represent relevant information about each specific publication. Metadata can include, e.g., contact information, year of publication, author details, instrument and protocol information, survey tool details and much more (Noyer et al., 2009).

For instance, reference management software maintains a database of articles and creates bibliographies and reference lists for the written works. This software simplifies the record of metadata. Several popular reference management software, for example, Refworks, Mendeley, EndNote and Zotero are used worldwide (Kumar Basak, 2014; Parabhoi et al., 2017; Salem and Fehrmann, 2013; Ram and Paul Anbu K., 2014). These managers can save profiles, build a database of citations, save PDF files, extract metadata, and import references from library catalogues, websites, and other citation managers (Ivey and Crum, 2018; Butros and Taylor, 2011; Cuschieri et al., 2019).

However, these systems only use limited metadata vocabularies without expressive semantic models. For instance, such systems do not support metadata concepts such as “Results,” “Materials and methods,” “References”, etc. As a result, all these systems do not provide a systematic approach, and they are not entirely semantically structured and not hierarchical.

1.2 Using Metadata Information of Scientific for Automatic Literature Review Processing

There are different types of metadata information that we can use to structure the articles, for example, by the relation to source, function, purpose, language, and publication date.

With using the a “Relation to Source” metadata the user defines the type of text that can be included in a classification program. A classification composed of extracts having exact sentences of a source document is known as an extractive summary. That is the simplest type of classifier.

With using a “Function” metadata the user can use any helpful and relevant information from source documents, for example, an abstract of a scientific article or the reviewers’ opinion on the quality of work.

With using a “Purpose” metadata structures the article’s purpose or main idea. The user needs to write down the general purpose or sense of the text in the program by himself.

With using a “Language” metadata, a classifier can be monolingual or multilingual is used. The monolingual classifier uses only one language and produces an output classification in the same language as the input document. In contrast, the multilingual classifier uses multiple languages and gives an output classification in one of the languages from the input document.

With using “Publication date” metadata, it is possible to arrange the articles by the time of their publication. To do so, the user must enter the article’s publication date in the system, and then the system will arrange the article in an appropriate section.

There is a lack of methods for the structuration of scientific articles. Also, it is necessary to add metadata “By the Results” (each specific results that has been obtained during study) and “By the methods” methods (each specific method that has been obtained during study).

“By the Results” this method structures the article by its results. It provides possibility to process new numeric and semantic data that was obtained during research.

“By the Methods” this metadata is used structure studies by the scientific methods and matherials used in the study.

Considering that most articles have a typical IMRAD (Introductions, Methods, Results, Abstract, Discussion) structure, it seems advisable to build an algorithm that uses data from many specific articles to create ontological graphs that can be integrated with specialized educational institutions environments for young scientists.

1.3 Instruments for the Creation of Ontology-Based Learning Environments

A learning environment is a diverse platform where users engage and interact with learning new skills. While learners can learn in various settings, the term typically refers to a digital alternative to the traditional classroom. To improve learning efficiency and adaptability, formalized information resources that provide a high degree of structuring should be used in learning. An ontological approach could support this. The ontological approach provides a holistic and systematic approach to the study of various information sources and a specific subject domain, ensures the conceptualization and taxonomization of terms within the subject area and the existence of relationships between the terms of different subject areas to ensure multidisciplinarity. Computer ontologies are one of the effective mechanisms for ensuring a stable digital learning environment.

In recent years significant progress was made in developing ontologies. In this article, an “ontology” is a term that means a software or web system that consists of nodes with data. All ontology nodes are arranged in a specific hierarchical order, often referred to as an ontological tree or ontological graph. The node from which all branches start is called the root node. The other nodes are called subsidiaries.

One of the most promising solutions, in our opinion, are ontologies (Parveen, 2018). For example, we can use hierarchies with multi-criteria techniques during the classification of metadata of various articles. Ontologies aim to capture the domain knowledge generally and ensure a common understanding of the domain.

IsaViz is a virtual environment for viewing and creating RDF models in the view graphs. IsaViz imports RDF/XML and N-Triples and exports RDF/XML. Apollo is the program for modelling knowledge systems. Apollo’s knowledge system base consists of hierarchically organized ontologies that can be inherited from other ontologies. SWOOP contains OWL (Web Ontology Language) validation and offers various. OWL presentation syntax views. In SWOOP, Ontologies can be compared, edited, and combined. Protégé 3.5 is a knowledge-based ontology editor that provides a graphical user interface. It ensures better flexibility for meta-modelling and enables the construction of domain ontologies.

1.4 Ontological Problems

Nowadays, most standard systems (such as Mendeley, Scopus etc.) provide support for displaying data but not for comparison and providing search functions. Also, given that articles in the same domain have the same indicators, the metadata of the results can be represented as ontology node attributes and then processed.

Previously, ontological graphs were used to systematize scientific articles (Parveen, 2018; Amami et al., 2017; Boughareb et al., 2020; Perraudin, 2017; Poulakakis et al., 2017). Systematization and structuring in such ontological systems were based on different approaches, such as using of scientific article recommendation system (Amami et al., 2017), a Scientific Articles Tagging system (Boughareb et al., 2020), machine learning and automatic summarization (Parveen, 2018). However, none of the proposed ontological approaches (Parveen, 2018; Amami et al., 2017; Boughareb et al., 2020; Perraudin, 2017) can provide a decent level of structurization and systematization.

We have proposed to use the cognitive IT platform Polyhedron (Stryzhak et al., 2019; Velychko et al., 2017; Strizhak, 2014) for this aim. The core of the Polyhedron system consists of advanced and improved functions of the TODOS IT platform described in previous works. Moreover, the Polyhedron is a multi-agent system that provides transdisciplinary and interactivity in any study (Stryzhak et al., 2014). Besides, the cognitive IT platform Polyhedron contains a different variety of special functions like auditing (Stryzhak et al., 2014; Globa et al., 2015, 2019), semantic web, information systematization and ranking (Nadutenko et al., 2022), transdisciplinary support (Nicolescu, 2008; Dovgyi and Stryzhak, 2021), internal search and have all advantages of ontological interface tools (Globa et al., 2015; Popova and Stryzhak, 2013; Martyniuk et al., 2021) Due to active states are hyper-ratio plural partial ordering (Nicolescu, 2008; Volckmann, 2007), cognitive IT-platform Polyhedron is an innovative IT technology of ontological management of knowledge and information resources, regardless of the standards of their creation.

The proposed solution can be used with other applications in the field of structuration studies like a virtual educational experiment (Slipukhina et al., 2019), the use of mobile Internet devices (Modlo et al., 2019), using the technology of augmented reality education (Bilyk et al., 2022; Nechypurenko et al., 2023), and smart physiological tools (Shapovalov et al., 2022), distance learning in vocational education and training institutions (Kovalchuk et al., 2023), on-line courses (Vlasenko et al., 2020; Vakaliuk et al., 2023), educational and scientific environments (Tarasenko et al., 2021b; Shapovalov and Shapovalov, 2021), different tools to provide development of ICT (Information computer technologies) (Modlo et al., 2018).

2 MATERIALS AND METHODS

2.1 Ontology Creation Mechanism

Systematization of the scientific studies is provided using the cognitive IT platform Polyhedron (Shapovalov et al., 2021b). Graphs were made in one of two ways: using a single Google sheet file (that defines both structure of the graph and metadata of each node; or by using of specific constructor https://editor.stemua.science/ or http://work.inhost.com.ua/ that provided a generation of the XML file of both, structure and metadata. The first Google sheet document contained the data on the graph's structure. The second sheet of it contained a list of nodes that contains metadata, metadata of this node itself and the type of metadata (figure 2). When the file was filled, it was downloaded in .xlsx format and uploaded to the graph editors. Then, it was transformed into an XML file and stored in the graph's storage. This method was used to create massive graphs as it simplifies the creation of the graph structure due to no need to select the location of the nodes visually with the mouse but locates nodes automatically. Tools https://editor.stemua.science/ or http://work.inhost.com.ua/ are graphical editors used to create simple graphs and test if the structure and metadata of graphs built by Google sheet's method are processed well.

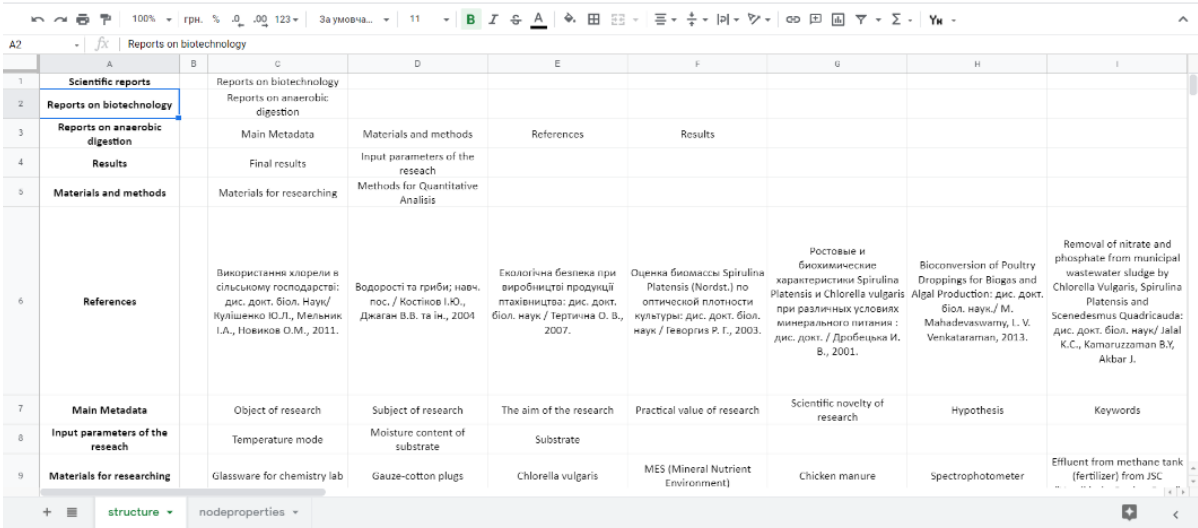
As the scientific works were written with an IMRAD structure, IMRAD was used as the core of each graph. For example, the field of anaerobic treatment of waste was chosen as general studies in this field also used IMRAD (Shapovalov et al., 2021a; Zhadan et al., 2021; Ivanov et al., 2019). To test using the approach for both high educational institutions students and schools' pupils (in the form of work of Junior Academy of Sciences of Ukraine), examples of such studies were used. As the example of master's study "Development a method for utilization of anaerobic digestion effluent at LLC Vasylkivska Poultry Farm" (study "A"); as an example of school student's study "Development a method for utilization of anaerobic digestion effluent (study "B"). Both studies were represented in the form of graphs.

To represent ontology graphs, the structure view in the form tools of view https://manlab.stemua.science/ and http://work.inhost.com.ua/ were used. In addition, ontology representer https://editor.stemua.science/ or http://work.inhost.com.ua/ has a structure view, table view and specific ontology prism view.

Metadata of generated graphs were used in filtering, ranking and audit tools. The simplest toll is filtering. It provides filtering of graph nodes by the presence of metadata in the nodes. The audit tool provides comparing of scientific studies with a standard graph. For science, this tool may provide two aims: define if such element of study (object, subject, keywords, etc.) was used previously to do not duplicate existing study; to provide simple (basic) antiplagiarism.

The ranking tool was used to compare numeric data in nodes and provide rank using users' requests. IT Polyhedron has a specific interface to input the importance of each metadata category that's numeric using a scale from 0 to 10. System process user's request by using values inputted by users and numeric data of nodes. Then it formed the rank of each node and showed it to the user.

To combine graphs, the first graph of scientific study that is IMRAD-based was downloaded to http://work.inhost.com.ua/ and then its tool "add XML" was used to add nodes and the link between them of the second IMRAD-based ontology graph of scientific study.



A2 Reports on biotechnology

	A	B	C	D	E	F	G	H	I
1	**Scientific reports**		Reports on biotechnology						
2	**Reports on biotechnology**		Reports on anaerobic digestion						
3	**Reports on anaerobic digestion**		Main Metadata	Materials and methods	References	Results			
4	**Results**		Final results	Input parameters of the reseach					
5	**Materials and methods**		Materials for researching	Methods for Quantitative Analisis					
6	**References**		Використання хлорели в сільському господарстві: дис. докт. біол. Наук/ Кулішенко Ю.Л., Мельник І.А., Новиков О.М., 2011.	Водорості та гриби; навч. пос. / Костіков І.Ю., Джаган В.В. та ін., 2004	Екологічна безпека при виробництві продукції птахівництва: дис. докт. біол. наук / Тертична О. В., 2007.	Оценка биомассы Spirulina Platensis (Nordst.) по оптической плотности культуры: дис. докт. біол. наук / Геворгиз Р. Г., 2003.	Ростовые и биохимические характеристики Spirulina Platensis и Chlorella vulgaris при различных условиях минерального питания : дис. докт. / Дробецька И. В., 2001.	Bioconversion of Poultry Droppings for Biogas and Algal Production: дис. докт. біол. наук./ M. Mahadevaswamy, L. V. Venkataraman, 2013.	Removal of nitrate and phosphate from municipal wastewater sludge by Chlorella Vulgaris, Spirulina Platensis and Scenedesmus Quadricauda: дис. докт. біол. наук/ Jalal K.C., Kamaruzzaman B.Y, Akbar J.
7	**Main Metadata**		Object of research	Subject of research	The aim of the research	Practical value of research	Scientific novelty of research	Hypothesis	Keywords
8	**Input parameters of the reseach**		Temperature mode	Moisture content of substrate	Substrate				
9	**Materials for researching**		Glassware for chemistry lab	Gauze-cotton plugs	Chlorella vulgaris	MES (Mineral Nutrient Environment)	Chicken manure	Spectrophotometer	Effluent from methane tank (fertilizer) from JSC

structure nodeproperties

Figure 2: Google sheet with data.

3 RESULTS

3.1 Model of Creation Ontology to Systemizing

As was noted before, IMRAD is widely used to prepare research and science papers. It is possible to provide structuration by using IMRAD components as parent nodes. So, the parent nodes can be represented by Introduction, Methods, Results and Discussion. An ontology cannot efficiently further structure the discussion part. Important part that it contains is the analysis and the comparison of the obtained data by the researcher. Specific parts of IMRAD will be used as branch nodes, and the study will be used as a leaf node. So, the general structure of the ontology that structures the research data is represented as:

$$REP \in I, M, R, P \tag{1}$$

where REP – set of reports, I – sets of Introduction of all study, M – set of Methods of all study, R – set of Results of all study, P – instruments of processing of the results of a set of studies discussions.

To provide better systematization, we have split the introduction into two different parts – basic metadata and literature review:

$$I = \langle BMD, LR \rangle \tag{2}$$

where BMD – is a set of basic metadata of study, LR – a set of Sources used for Literature Review.

The primary metadata node of the study is linked with the graph's leaf nodes that characterize primary data on the study, such as hypothesis, object, subject, practical value, scientific novelty, etc. So, the nodes of the report's basic metadata of the study can be presented as a further equation:

$$BMD = \langle H, O, S, PV, SN \rangle \tag{3}$$

where H – hypothesis or hypotheses of each specific study; O – object of the study of each specific study; S – the subject of each specific study; PV – practical value of each specific study; SC – the scientific novelty of each specific study.

The main advantages of using such a structure are that some parts of the Introduction materials and methods and results (measured parameters) of the study (reports) can coincide. A few specific studies that coincide will be linked by nodes (in case of methods and results) or by classes of data (in case of keywords or scientific novelty) due to using the same sub-nodes of the ontology. The representation of each work as a set of the Introduction, Methods, Results, and Processing of the data (Discussion):

$$REP_I = \langle I_I, M_I, R_I, P_I \rangle \tag{4}$$

$$REP_{II} = \langle I_{II}, M_{II}, R_{II}, P_{II} \rangle \tag{5}$$

So, these studies can be integrated into a single ontology using IMRAD:

$$O = \langle S_I, S_{II} \rangle = \langle I_I, M_I, R_I, P_I, I_I, M_I, R_{II}, P_{II} \rangle \tag{6}$$

The same approach will be applied to each element of the IMRAD structure study. Generally, it can be represented as:

$$M = (REP_I) = \sum_i^n M_I \tag{7}$$

where M_I – every separated scientific method.

In a different study, a different set of methods can be used. However, some of them can coincide. Thus, the set of methods used in two different studies may be represented as:

$$M = (REP_I) = M_a, M_b, M_c, M_d \quad (8)$$

$$M = (REP_I I) = M_b, M_d, M_f \quad (9)$$

And, so, M_b coinciding with both M_I and M_{II}:

$$M_b \in M_I, M_{II} \quad (10)$$

Therefore, in this case, and M_b can be used as a parent node that connects two different studies. The node M_b itself will contain general theoretic information on it, and node REP_I and REP_{II} will contain information on the specific case of its usage and measured parameters using it.

Similar mechanism can be provided by using specific ontology tools using metadata. For example, there will be a hierarchical approach for representing and usage of keywords:

$$Kw(BMD_i) = Kw_a, Kw_b, Kw_c, Kw_d, \quad (11)$$

where $Kw(BMD_i)$ – node of the basic metadata that integrates all keywords; Kw_i – specific keyword.

Also, as was noted in the introduction, the metadata of each work will be used for filtering the information, and for supporting specific processing functions of the IT solution Polyhedron. Such specifics mechanisms are AUDIT and RANKING. Metadata can be included in each node. For the parent node metadata will be used to represent the general information (for example, the essence of the method itself), and the resulting leaf node will contain the specific metadata related to a specific study (such as specific results of the study obtained using set methods M; for example, metadata: 5,35, and its class: "Ammonium nitrogen content, g/L"). So, metadata, with the same class, will be processed by using filtering by users request or by ranking using the ranks of the nodes for specific classes (or their set) based on the user's request.

So, the proposed approach uses IMRAD to collect and process the data with ontologies. In this way, the ontologies are constructed not by the specific structure of each work but by the generally accepted IMRAD structure. The parent node will be a specific area set to which the study belongs ($A = \sum inREP_{II}$ where A – specific area of the set of REP). The A node is linked with I, M, R, P nodes (representing IMRAD). Each IMRAD node is linked with the specific IMRAD type node (such as ammonia determination by Nessler's method (for methods) or "chicken manure" or "glycerine" (for subjects)). Moreover each specific IMRAD type node is linked with leaf nodes of ontology – specific studies where such entities were used.

3.2 Structuring of the Set of Studies in the Form of Ontology

To demonstrate the capabilities of the proposed ontological system, scientific works on anaerobic digestion were chosen. The general view of the resulting graph is shown in figure 3.

The root node of the resulting graph is the "Scientific reports" node. The ontological graph is complex because it has additional branches from child nodes in its structure. Child nodes are: "Reports on biotechnology" and "Reports on anaerobic digestion." From the child node, "Reports on anaerobic digestion" are going to the central sub-leaf nodes that reflect the basic principle of systematization of scientific works: "Results," "Materials and methods," and "References". This basic principle is shown in figure 4. A separate node of Main Metadata was also additionally created. This node contains the central metadata: object, subject of study; practical significance, the scientific novelty of study; hypotheses; keywords; abstract, conclusions.

The entire sequence and principle of filling and maintenance of data by users in the received ontology are shown in the Workflow diagram (figure 5).

The child nodes of these systematizing ontological nodes are the scientific works themselves. Each data block is in the form of separate attributes of the ontological node. This solution allows using all the information processing tools of the CIT Polyhedron system. In particular, such tools are general (for example, filtering) and specialized, such as ranking and auditing. An example of filtering is shown in figure 6.

An ontology prism is a specific form of ontology graph in cognitive IT Polyhedron. It provides the possibility to use nodes and their relation to the form of a prism. The most helpful form can represent the relevel of IMRAD and provide a high level of visualization of its sub-nodes. An example of an ontology cube representation of a graph is shown in figure 7.

3.3 Application of Ranking Mechanism in the Structuring of Scientific Works

All attributes can rank information using the "Alternative module" described in previous works (Nadutenko et al., 2022; Tarasenko et al., 2021a). The attributes of Each node are filled with numeric, textual, and mixed types of data. The following attributes are filled with text data: "References", "Methods for Quantitative Analysis", "Materials for researching", "Thermophilic", "Chicken manure substrate", "Spec-

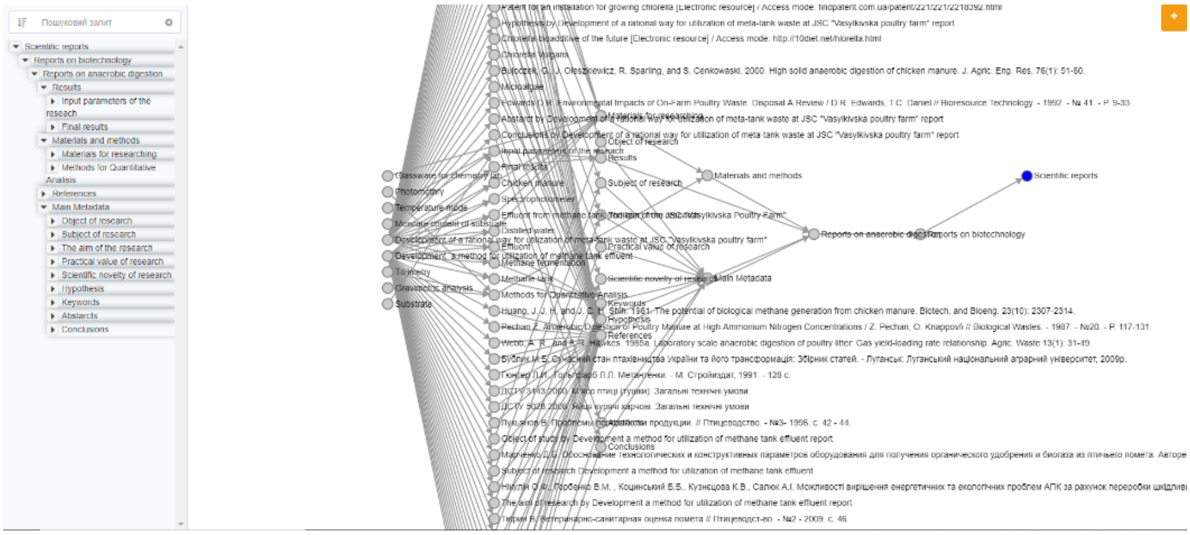


Figure 3: General view of the resulting ontological graph.

Figure 4: General view of the primary systematizing ontological vertices.

trophotometer parameters of the experiment", "The actual rate of reproduction of ", "Keywords", "Glassware", "Reagents", "Equipment", "Object ", "Subject of study", "The aim of the study", "Chicken". Numeric data contains the following attributes: "Initial pH", "Methane content, % Vol.", "pH of obtained solid product", "Ammonium nitrogen concentration, mg/L", "The concentration of volatile fatty acids (VFA) mg/L", "The dry matter content, %", "The ash content, %". The attribute "The native moisture content of the substrate" contains mixed-type data, numeric and textual. An example of incoming data maintenance panel for ranking is shown in figure 8.

For example, there may be a case when the user wants to arrange work on the pH. The ranking result is shown in figure 9. Other examples of usage of the Polyhedron IT platform are shown in table 1.

3.4 Application of the Audit Mechanism in Structuring Scientific Works

Users can also use the specialized audit module described in previous works (Stryzhak et al., 2014; Globa et al., 2015, 2019; Tarasenko et al., 2021a) for all attributes. The graph "Standard" is the ontology itself, containing works that will be supplemented and expanded. This solution will allow users to automatically check whether there is a particular work in the database. Also, this solution will allow checking the hypotheses for compliance with already completed studies. Also, the audit module will allow users to compare an existing METADATA and attributes available in the ontology at the same time. In particular, these attributes are the materials and methods of the results and the list of sources. Results that do not match the "standard" ontology attributes are em-

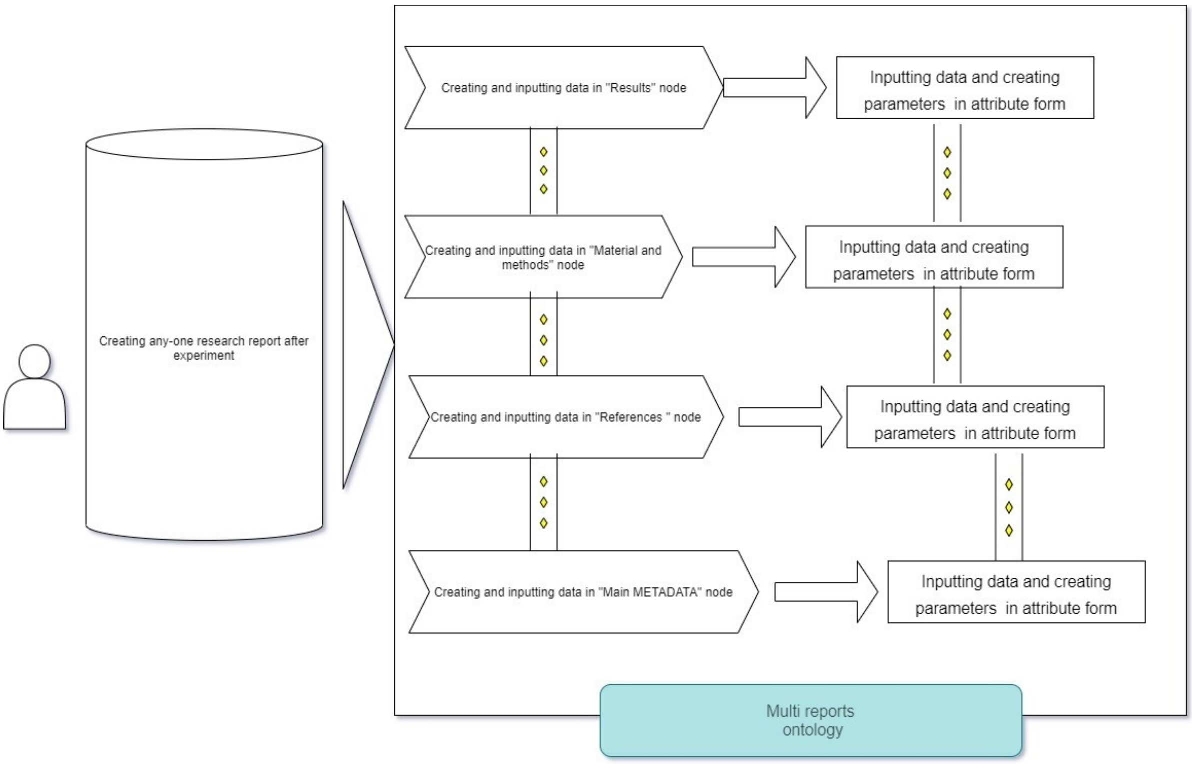


Figure 5: Workflow diagram of filling and maintenance of data by users.

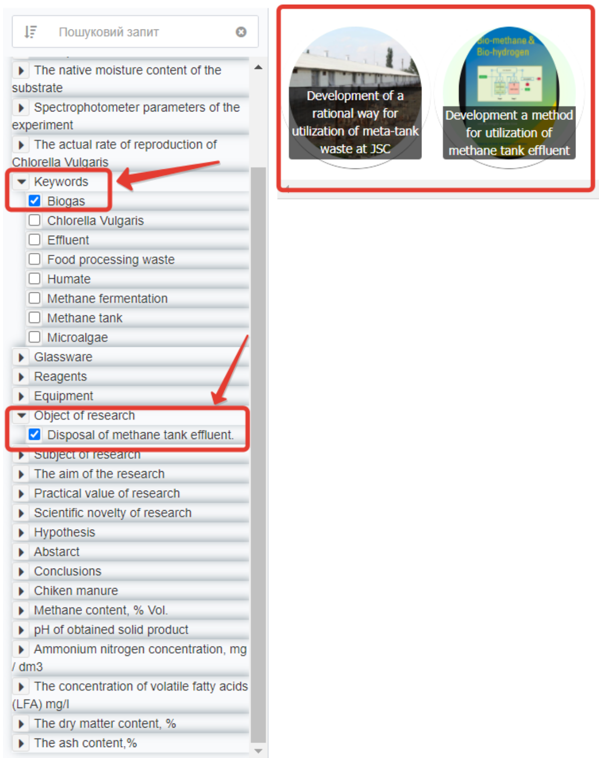


Figure 6: Example of attribute filter.

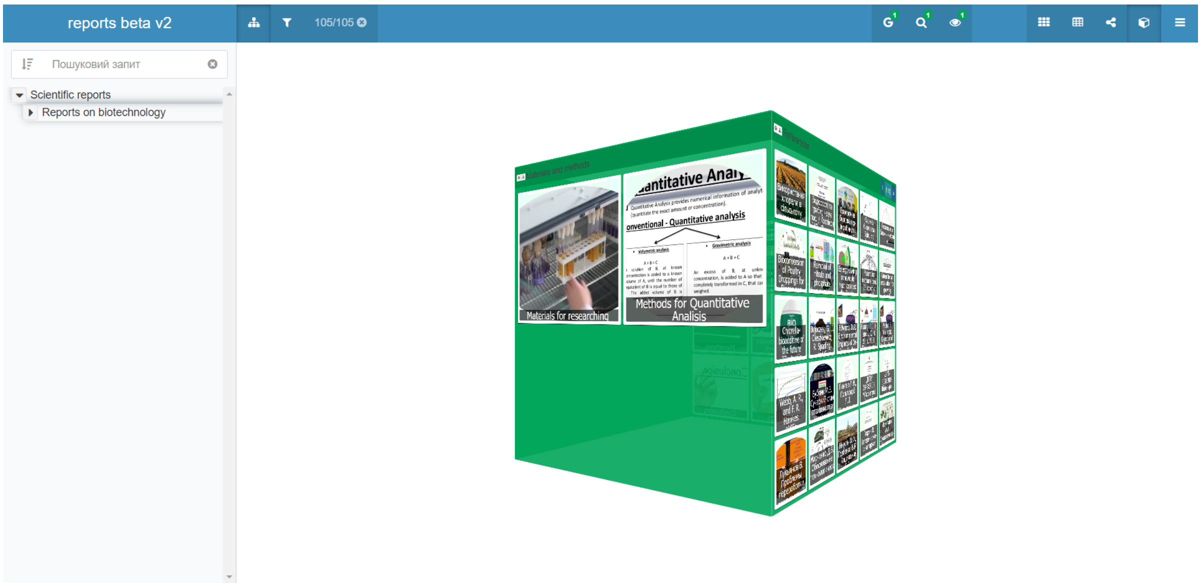


Figure 7: Ontology prism view of IMRAD-based graph of scientific studies.

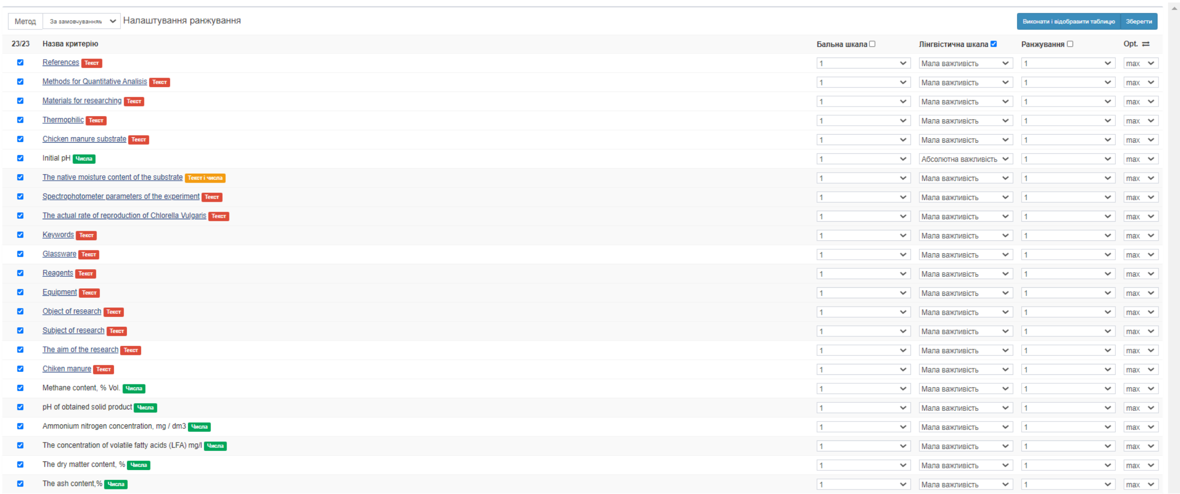


Figure 8: An example of incoming data maintenance panel for ranking.

phasized in red. An example of an audit fragment is shown in figure 10.

3.5 Interoperability of Ontology Graphs on Students' Scientific Studies

To make an effective personalized system, it is essential to provide interoperability between similar content of previous studies to allow users to create unique resources that will be used as the base of knowledge or literature review of the current researcher. So, interoperability is required. Moreover, using an IMRAD structure allows merging graphs because of the similar parent's nodes.

So, each student can use the developments made earlier. In addition, students can download a few existing ontology graphs from open data located on ontology.stemua.science and provide merging using MS Excel tool or specifically developed tools.

To solve this task, graphs-blanks (standards) are relevant to use. The standard consists of broad used categories for the field that will be filled by researchers who conduct studies. The general view of such graph-standard is presented in figure 11.

The researchers could input the specific data used during the research. Different researchers would have their specific graphs, but they were built by the same structure using IMRAD standard. Such graphs can be used to combine a single graph. Thus, the interoperability of different studies is provided. Therefore,

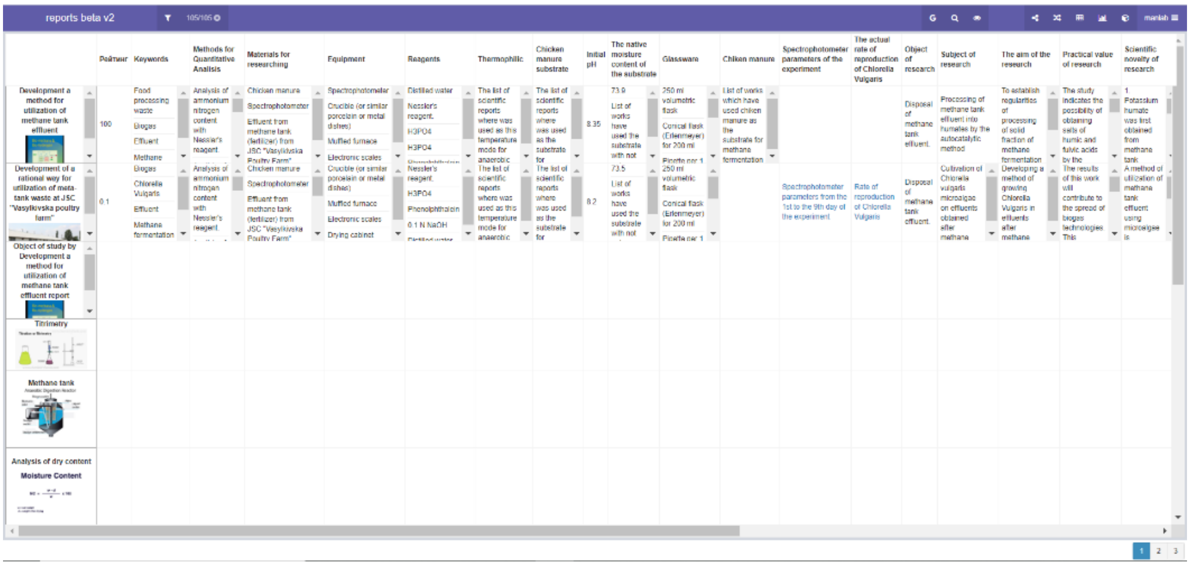


Figure 9: Example of ranking results.

reports beta v2
(Audit)

#	Indicators	Units	DSTU	Development of a rational way for utilization of meta-tank waste at JSC "Vasylkivska poultry farm"	Development a method for utilization of methane tank effluent
Abstract					
1	Keywords	Keywords	microalgae	Microalgae	Humate
2	Hypothesis	Hypothesis	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The solid fraction of methane fermentation of chicken manure can be recycled by the autocatalytic catalysis method.

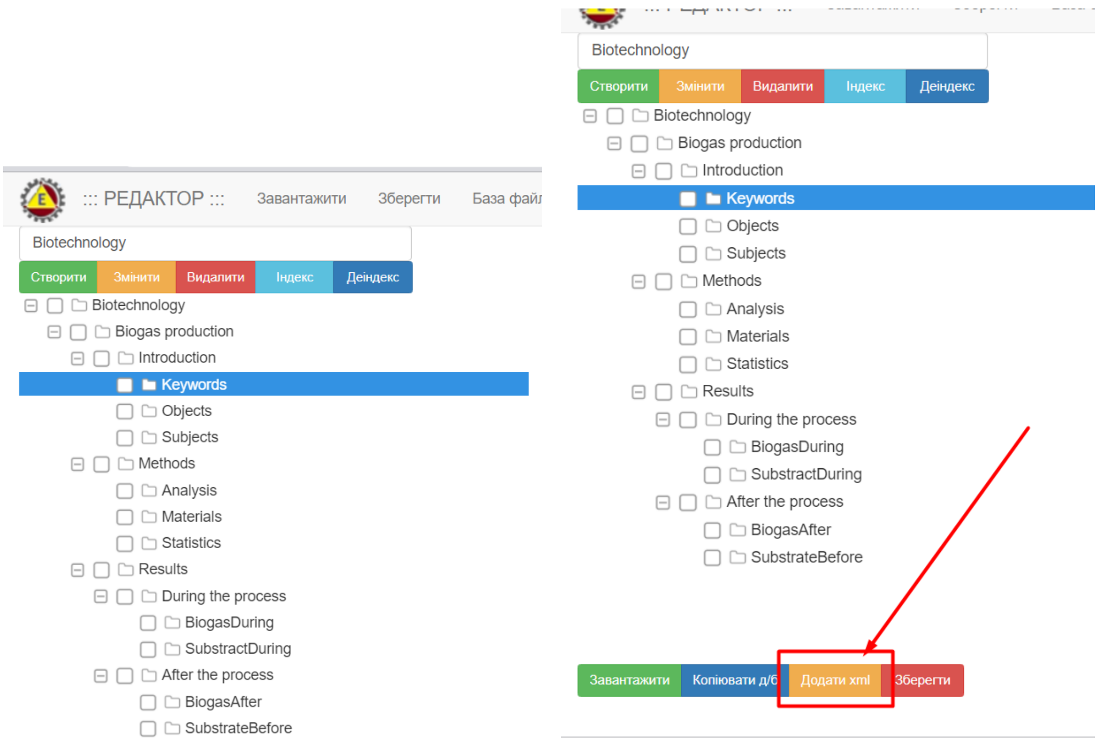
Figure 10: Example of audit results.

such graphs could contain more data on specific fields in the future.

As described in Section 3.1, the graph's combining will provide stability of IMRAD structure and the addition of sub nodes belonging to a specific study and the second to second. The two examples of filled studies to merge are presented in figure 12.

For example, the study "Anaerobic treatment under low moisture content" has a node "Biogas" related to node "Keywords". The same node also belongs to the second study, "Recirculation of the liquid phase of effluent during anaerobic digestion". After combining, the edge "Biogas" will have two subnodes "Anaerobic treatment under low moisture content" and "Recirculation of the liquid phase of effluent during anaerobic digestion" which provides belonging the keyword "Biogas" to both studies.

As for some other nodes that do not belong to both studies, they will also be represented in a combined graph, but they will contain only a single study to which it belongs. For example, such a case will be for nodes "Inhibition", "Ammonia", "Recycling", and "Water consumption". A general view of the result of combining is presented in figure 13.



(a) (b)

Figure 11: The structure of the ghaph, (a) The function of adding to the graph another graph (combining), (b).

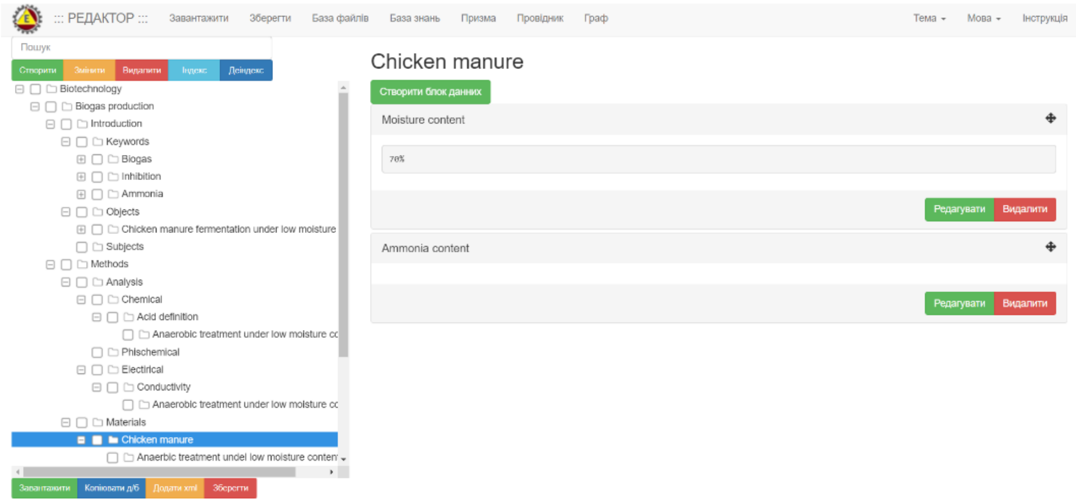
Table 1: Examples of Polyhedron IT Platform Ranking Module.

Name of filter (Ontological attributes)	Priority	Main results (list of ontological nodes)
Initial pH (type of data are numbers)	Absolute	Development of a rational way for utilization of meta-tank waste at JSC "Vasylkivska poultry farm", Titrimetry, Methane tank, Development a method for utilization of methane tank effluent Methods for Quantitative Analysis, Materials for researching, Abstract
Methane content, % Vol. (type of data are numbers)	Absolute	Development of a method for utilization of methane tank effluent, Development of a rational way for utilization of meta-tank waste at JSC "Vasylkivska poultry farm, Methods for Quantitative Analisis, Materials for researching, Abstract
The ash content, %	Absolute	Development of a rational way for utilization of meta-tank waste at JSC "Vasylkivska poultry farm, Development of a method for utilization of methane tank effluent, Methods for Quantitative Analisis, Materials for researching, Equipment, Reagents, Thermophilic, Chicken manure substrate
The dry matter content, %	Absolute	Development of a method for utilization of methane tank effluent, Development of a rational way for utilization of meta-tank waste at JSC "Vasylkivska poultry farm Keywords, Methods for Quantitative, Analysis, Materials for researching, Equipment, Thermophilic Chicken manure substrate

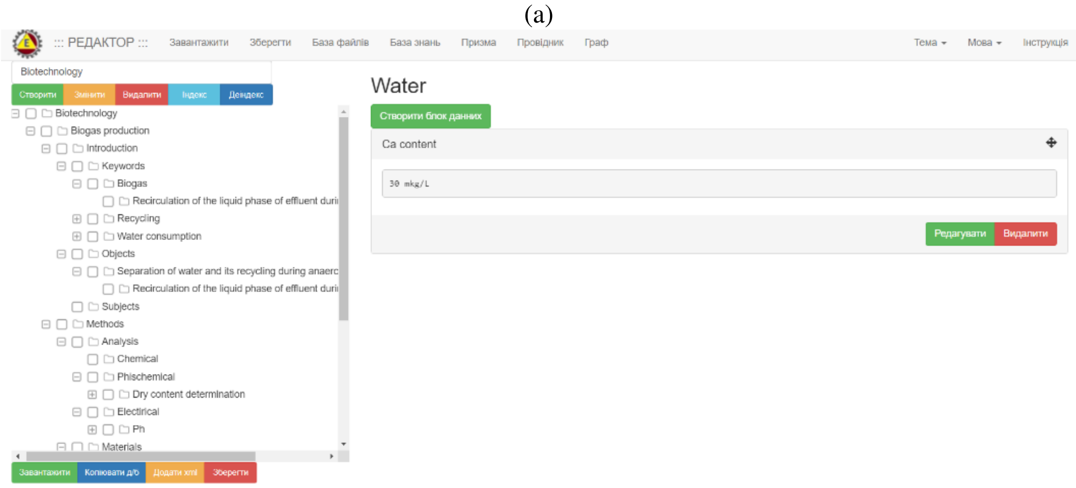
4 DISCUSSION AND CONCLUSIONS

4.1 Cases of Usage

Generally, it is possible to use such an approach in two cases "Personalized science study graph creation" and "Combining using Script editor". The first case foresees a simple scientific process, but the results of such a study and its description are provided by the creation ontology of such work using the graph template based on IMRAD. So, all researchers will prepare the description of their work using similar for-



(a)



(b)

Figure 12: Example of ontology “Anaerobic treatment under low moisture content”, (a) Example of ontology “Recirculation of the liquid phase of effluent during anaerobic digestion” (b).

malization. Furthermore, it provides the possibility to implement the “Combining using Script editor” use case. This use case is an easy way for the researcher to systemize all studies in his field that were done before. After combining, the obtained graph is merged as it was created from graphs with the same formalization. This graph is ready to use systemized literature review of the study for the scientist who provided it. Tools of Polyhedron will provide data processing of merged graph by using ranking, filtering and audit.

4.2 Role of Proposed System Among Existing Systems

Using of IMRAD as the primary approach to structure the articles in the form of a semantic ontology is proposed. The implementation of a universal ontological solution that can provide systematization and structuration of any scientific studies as proof of the concept is provided. The advantages and potential scenarios for using our solution have been demonstrated by the example of biogas studies. The potential of using ranking and auditing tools in the obtained ontological database has also been shown. Numeric and semantic characteristics were separated from the main text and used to process by specialized algorithms of IT Platform Polyhedron. For example, users can find studies where a specific method was used by both, using the structure and filtering of studies data. The numeric data of studies are processed by the ranking tool that assigns ranks to nodes depending on the value of these numeric characteristics. The created ontology allows to obtain the structured set of studies, separate their characteristics, provides the possibility to view

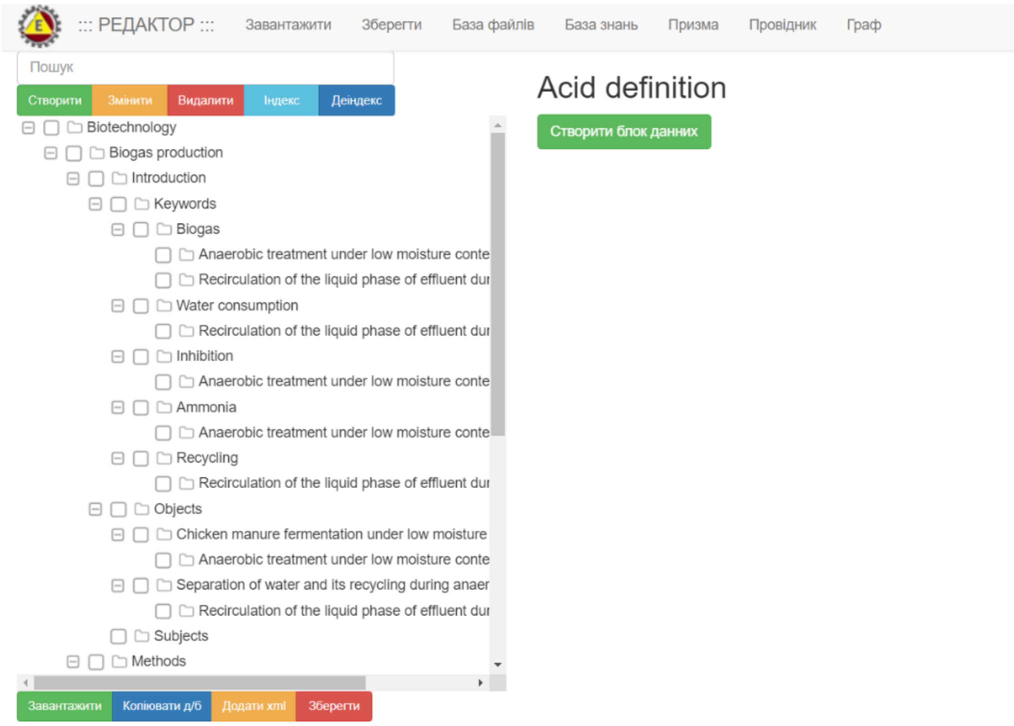


Figure 13: Combined graph of two studies.

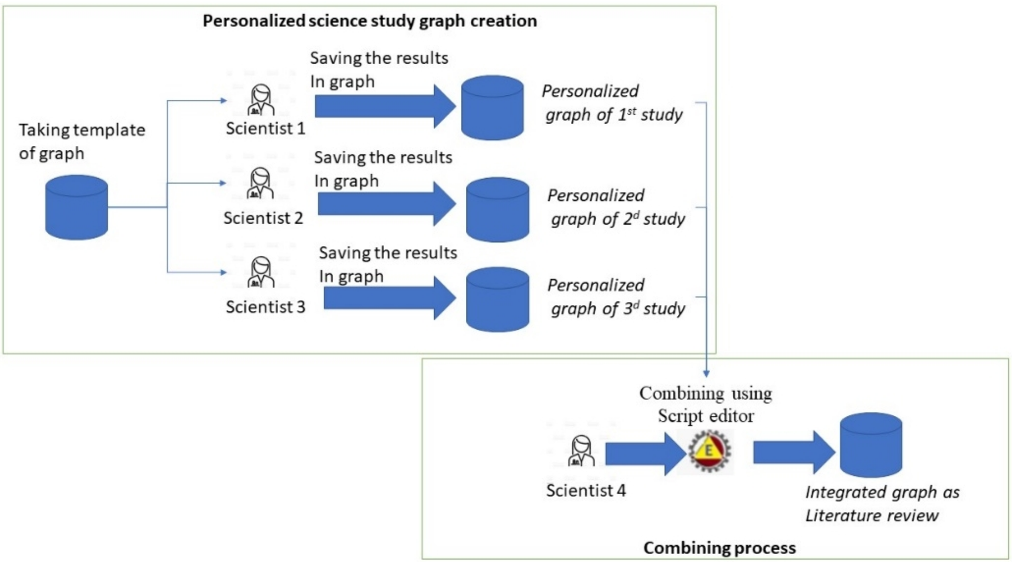


Figure 14: Use cases of the proposed approach.

all of the methods, measured parameters in the view of node and use them to find the studies where they were used. A detailed comparison of our ontological solution with the most common analogues is presented below.

As we can see from the table 2, proposed ontological solution has the essential functions of the most common software. Proposed solution can be used as bibliographic software and a scientometric database. In addition, our solution could provide such functions as ranking based on specific attributes, comparing different articles, visualizing the information given an ontological tree or ontology-based cube, and using the IMRAD approach to sort articles.

Mathematical interpretation of proposed model is based on that IMRAD foresees those papers consist

Table 2: Comparison of "Polyhedron" system with similar analogues.

	Personalized science study graph creation	Combining graphs using Script editor	Mendeley	Endnote	Scopus	Google Scholar
Automatic extraction of the information from any added PDFs	Present	Present	Present	Present	Absent	Absent
Tags, keywords, or search the full text of most PDFs functions.	Present	Present	Present	Present	Present	Present
Ability to cite articles in word/pages	Absent	Absent	Present	Present	Absent	Absent
Count citing	Possible	Present	Absent	Absent	Present	Present
Ability to use numeric data of the articles for ranking	Present	Present	Absent	Absent	Absent	Absent
Accentuation of important semantic characteristics for management of the wide range of articles	Present	Present	Absent	Absent	Absent	Absent
Ability to compare different articles	Possible	Present	Absent	Absent	Absent	Absent
Visualization of the information	Present	Present	Absent	Absent	Absent	Absent
Usage of IMRAD approach to sort articles	Present	Present	Absent	Absent	Absent	Absent

*proposed approach using CIT " Polyhedron"

for, Introduction, Methods, Results and Discussion. In form of detail systems, it is impossible to provide Discussion, but the similar results will be provided by data Processing. In turn, the formed graph of IMRAD that formed subject area is linked with specific to each study parts of each element of IMRAD (specific method or result). Therefore, the graph that describes few studies will consist from set of specific to each study parts of each element of IMRAD.

Such same formalization for different studies provides possibility to use specific features of ontologies. One of the most important is interoperability that is possible by merging few graphs of studies that has similar structure into single one. This feature provides possibilities to make digital ontology-based libraries of studies.

4.3 Further Research

The proposed approach may be much developed. The proposed approach foresees using Google Sheets and then transferring it into XML. However, it seems possible to simply such a process by generating ontologies exetly from Google Sheets and providing real-life synchronization.

Also, as the proposed approach is based on specific studies, it seems relevant and possible to provide scientometry. CIT "Polyhedron" is not a reference manager like "Endnote", "Mendeley", and it is also not a scientometric database, but in the nearest perspective, it is possible to convert the proposed technology into a functional analogue.

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The Use of Cloud Technologies in the Process of Professional Training of Future Mathematics Teachers

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Abstract: During the restrictions caused by the COVID-19 pandemic, the education system was forced to make an urgent transition to e-learning. The transition revealed problems not only in the material part of the organization of education (lack of access to digital technology in a significant number of both students and teachers) but also in the lack of accessible electronic educational resources needed for educational activities. There were problems with the appropriate training of practical teachers. It cannot be said that this issue was not addressed by the educational community and state authorities, however, the results speak of the formality of the solution of these issues. The general level of teachers' mastery of information and communication technologies remains the main problem, and mathematics teachers are not an exception to this problem, the readiness to use electronic educational resources is at a low level due to the specificity of the methodological design of the educational process. The problem of joint activities of students and teachers during the synchronous and asynchronous interaction remains unsolved. The solution of these problems lies not only in the widespread use of information and communication technologies during the practical training of future mathematics teachers and during the practical re-training of practicing teachers, but also in the construction of an open educational environment on the basis of cloud technology, which solves the problem of interaction between the participants in the educational process.

1 INTRODUCTION

Due to the introduction of quarantine measures as a result of the spread of COVID-19 in 2020-2021 and the military aggression of Russia in 2022, distance learning has been introduced in Ukrainian schools (Hamaniuk et al., 2022). The organization of distance learning is possible through the use of distance learning systems. Despite the active use of distance learning systems by educators, there are some problems in organizing teaching and improving teachers' qualifications. One of the main problems is the lack of methods of using copyright services, which are not localized, but free for use in educational activities. We assume that the use of cloud systems will make the educational process not only possible, but will also gain the traditional form of education, as much as possible.

News reports, social media, reports on webinars of educators and teachers speak not only about the possibility of achieving the goal of learning through e-learning, but also about the problems that arise in this process. These problems affect each of the subjects of educational activity: students, teachers, lecturers, parents, and the administrations of educational institutions. General problems are related to the low level of knowledge of information and communication technologies among teachers, especially older teachers, lack of understanding of the specifics of the educational process when using electronic educational resources, the specifics of the ongoing and post-summary control through the use of information and communication technologies, etc.

Let's look at the problems that arise for teach-

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ers and educators during the transition to e-learning. The transition to the online space and transfer of even one course read at a higher education institution or a secondary educational institution is a long and complex work of a whole team of professors. Some examples are the Coursera or Prometheus courses. All video materials are recorded by professional operators in the studio, with the lecturer's voice overlaying on the video presentation, with a very accurate and competent distribution of information on the hour intervals. The course consists of 10-15 minutes informative videos with tests, a large amount of materials for self-study, peer to peer review assignments, and so on (Velychko and Fedorenko, 2020).

To implement such a feature, the teacher has to be competent in information and communication technology, have the necessary material base for shooting, editing, data processing, etc. Such work takes much more time than preparing for lectures or lessons and making presentations to them. The results of mastering the material in most subjects, disciplines or courses cannot be assessed by taking tests, there is a need to check the written work, listening to auditions, etc. Thus, the amount of mechanical work added to the duties of a teacher or educator is significantly increased. To practice this you can, for example, open 20 e-mail letters, download 20 completed tasks and store them in the appropriate folder. We can see that even such primitive mechanical operations are very costly in terms of working hours.

In addition, there is a great psychological problem if during the lessons online listener is just a passive observer, who does not even appear on the screen. Not every teacher or trainer can talk for 40 minutes to a black screen without any feedback from the audience, even if from time they can hear the responses in the form of voice messages from time to time. Also no less important is the problem of keeping the audience's attention during the lesson.

The results of scientific and methodological work are still one of the unresolved issues. This is required by the duties of educators. It is very important to get good results in the conditions of urgent creation of electronic educational resources. It is also important that the electronic educational resources should have no less functionality of teaching in comparison with the planned, verified face-to-face education.

Research conducted by the scientists and statistical data of mass open online courses have shown that distance learning is effective for 20-25% of listeners. This is the exact number of those who successfully complete the distance learning course as compared to the number of registrants. There is also another side which is the specificity of the selection of material for distance learning, which is determined by the professional competence of the curator of the content. The search for educational material, its systematization, processing in accordance with the level, goals and content of the training makes it necessary to process a large amount of existing digital content.

Students and learners are also exposed to a lot of stress. This category of participants in the educational process has several problems:

- the procedure for evaluating the submitted assignments is incomprehensible, especially those of a summary nature;
- learning at home is more likely to be relaxing than mobilizing and motivating for learning activities, and it deprives the teacher of visual supervision;
- lack of own room to work remotely (presence of parents, younger or older siblings) and, therefore, the simplest decision that students make is not to participate in online classes;
- cases of lack of access to Internet resources both due to the lack of devices and communication channels.

Secondary and higher education institutions are making great efforts to organize distance learning by means of distance platforms. Distance learning seminars, webinars, trainings on forms, methods and tools of distance learning for teachers and educators are held on an urgent basis. Teachers and educators communicate with their students by any means possible, from e-mails, messengers, and available distance learning platforms to phone calls. It should be noted that due to the different activity of participants in the educational process there is a great difference in the results. Thus, the need to investigate the professional preparation of future mathematics teachers for educational activities in a distance form of organization of the educational process is extremely interesting for us.

2 RESEARCH METHODS

The research work is carried out on the basis of the systematic approach as a methodological basis for studying pedagogical and social facts, phenomena, processes; the position of psychological and pedagogical science in the use of information and communication technologies in the educational process of educational institutions.

To solve the tasks set in the work such theoretical and general scientific methods were applied: the analysis of psychological and pedagogical, philosophical databases on the problem of research to understand the state of development of the formation and development of the cloud-oriented systems of learning support, the identification of the research directions, the principles and approaches to the cloud-oriented systems of learning support; the analysis of existing standards and regulations on the use of digital services in the learning process and informatization of educational institutions; the generalization of the national and foreign experience in the use of digital services and technologies in the institutions of higher education to identify development trends, the clarification of the basic conceptual and terminological apparatus, establishing the conceptual foundations of the study; theoretical analysis, system analysis.

The empirical research methods were used to solve the set tasks: the experimental study of the use of cloud services in the institutions of higher education in Ukraine, the expert assessment of the results of the study, the monitoring of the initial activities with the use of cloud technologies in the educational activities.

3 LITERATURE REVIEW

The issue of using information and communication technologies, and cloud technologies in particular, in the process of professional training of future teachers of mathematics is the subject of active research of the scientists. We will consider in more detail some of those that are relevant to our research.

The professional preparation for the wide use of information and communication technologies in the educational activities of future mathematics teachers begins long before the entering the institution of higher education. Even during the study at the secondary general education institution, future mathematics teachers can extensively observe the forms and methods of using information and communication technologies. The research of the results of using information and communication technologies during the teaching in general secondary education institutions was presented by Vakaliuk et al. (Vakaliuk et al., 2020). The answer to question 13 of their survey is critical for our study: "Did any information and communication technology tools (curricula, multimedia, simulators, games, virtual laboratories, etc.) get used in the school/college by non-CS teachers?". Unfortunately, only 48.5% of respondents answered this question positively. The result suggests that every other future teacher has not acquired the necessary experience of using information and communication technologies in educational activities during his/her studies at a secondary general education institution. However, the variability at the time of answering question 14: "If the answer to the previous question is "Yes", in what lessons did the teachers use such tools?" (Vakaliuk et al., 2020)) indicate that some subject teachers, including teachers of language and literature, mathematics, physics, history, chemistry, biology and geography not only found the possibility of using information and communication technologies in teaching, but also that the use of these technologies was successful, otherwise they would not have been understood by the students. So, thanks to the introduction of information and communication technologies into the secondary school education system, future mathematics teachers are already occasionally familiar with the use of information and communication technologies in educational activities.

Let's review the approaches used in electronic education based on the results of the research by Proskura and Lytvynova (Proskura and Lytvynova, 2020) for Bachelors in Computer Science. The content analysis of the scientific paths of their colleagues and their own experience allowed the authors to develop "The Model of Web-based learning of Computer Science Bachelors" (see figure 1 in (Proskura and Lytvynova, 2020)). Considering such structural components as learning environment, web-oriented environment, control and evaluation unit, levels of students' educational achievements, the authors define the content of e-learning. E-learning components include cloud computing, working together classroom, web-automated knowledge validation systems and others. These components are realized through web technologies as a mean of data transport. Their appearance is conditioned by the presence of network technologies and they belong to the high quality services. Therefore, the need for the use of cloud services to support the training of future mathematics teachers is one of the current educational trends.

No less important for our research is the practice of online training of master's degree students in "Mathematics" for the practical training in universities. The research by Vlasenko et al. (Vlasenko et al., 2021) was focused on the organization of students' educational activities using the online course "Methods of Teaching Mathematics to Students of Technical Universities". The study examines the problems faced by the students during the internship in technical universities, and discusses the possibility of taking into account students' needs in developing the content of the course. This study provides a description of the activities of students while working on the course materials, requirements and recommendations to facilitate the learning process with the help of this course.

The active participation of students and their contribution to the discussion of the course, its content, and their support of the learning process implies that the implementation of the online course and its integration into the training program for master's students will increase their readiness for the internship.

Markova et al. (Markova et al., 2015) conducted a general review of the use of cloud computing in educational activities. The authors made a historical analysis of the stages of using computer technology in education, starting with the study of the problems of providing computer services conducted by Alan O. Mann and to the prospects for the use of cloud technologies in education in accordance with the forecast of their development. Researchers came to the conclusion that the consolidation of established and promising cloud technologies in education requires scientific forecasting of the development of cloud technologies in education based on taking into account historical trends in the development of ICT.

The logical continuation of our study is to identify specific tools to support the professional training of future teachers of mathematics. The specificity of professional training is determined by the specificity of the field of science. The specificity of mathematics is in its abstractness. The research of Vlasenko et al. (Vlasenko et al., 2020) discuss the requirements to modern web-based online courses for training of future mathematics teachers. The authors analyzed the ways of mathematical text presentation through the peculiarities of its formation and creation of mathematical content with a focus on measure use.

The study by Zhaldak et al. (Zhaldak et al., 2021) discusses the use of mathematical technologies in cloud calculations using Remote Desktop Ulteo OVD. As an example, the researchers examined in detail some examples of using pedagogical software for the educational purposes called Gran1. In particular, the calculation of approximate value of the subsumed integral; the graphical solution of two-dimensional tasks, the so-called linear programming tasks; two-dimensional problems including the convex programming – finding the highest value of a convex function (or the highest convex function) on a convex set of inequalities (including linear ones). However, the use in the educational process of any technology, including modern information and communication, as well as the content of the teaching must be pedagogically balanced, which will allow to avoid any negative influences on the formation of the personality of the future member of society, his mental and physical development.

Popel et al. (Popel et al., 2017) have investigated reasonable ways of using cloud systems to support student collaboration in mathematics courses. In particular, the researchers implemented a component based on SageMath that combines electronic resources for teaching several mathematical disciplines. They proposed a training methodology for using the SageMath in the training of educational personnel. In addition, the usefulness of implementing this methodology for the active development of innovative approaches, forms and methods of teaching mathematics using modern devices was proved. The experimental results of the implementation of the SageMath educational component and methods of its use which were developed in the course of the research are presented. The use of the proof-based method to improve the educational environment of the university, expand the possibilities of access to electronic teaching resources during mathematics teaching and involvement of the educational community into this process, as well as increasing their ICT competence is explained.

Shyshkina and Marienko (Shyshkina and Marienko, 2020) determined the content of necessary general skills and specific skills necessary for future mathematics teachers (see table 2 in (Shyshkina and Marienko, 2020)) based on professional functions and typical tasks that teachers of mathematics must be able to perform (see table 1 in (Shyshkina and Marienko, 2020)). The authors used Web-SCM CoCalc (SageMath) to conduct an experimental study that revealed the advantages of using the CoCalc cloud service in the professional training of prospective mathematics teachers.

Fedorenko et al. (Fedorenko et al., 2020) investigated the problem of studying virtual software through the use of cloud services. The results of this research had a positive result especially for the professional training of future mathematics teachers. Investigators have revealed the didactic capabilities of the cloud services, which allow you to run free software for mathematical orientation.

The GeoGebra environment is one of the most powerful systems of computer mathematics for dynamic visualization, calculations during problem solving, data processing and scientific and research work. Dubovyk and Rudnytskyi (Dubovyk and Rudnytskyi, 2022) have looked at the peculiarities of using the author's applets and other products of GeoGebra during the teaching of disciplines of differential geometry and linear algebra in the training of future mathematics teachers, in particular, their research describes the possibilities of using this tool to study the properties of space curves and to form practical skills and abilities to perform operations on matrices, finding the invertible matrices. The advantages and disadvantages of using the GeoGebra environment in the educational process of linear algebra and differential geometry are outlined.

Kholifah et al. (Kholifah et al., 2020) aimed to show how effective the use of blended learning model influences the learning motivation of vocational education students. The results obtained in the course of the research show that the use of the model of blended learning has a significant impact on the motivation of students of vocational education. Attard and Holmes (Attard and Holmes, 2020) investigated the willingness of teachers to use blended learning approaches. The study was conducted on teachers who taught mathematics classes in secondary schools. As a result of the study it was found that the use of technology expands the possibilities for students to study mathematics by providing multiple methods and access methods, and students can use mixed teaching approaches.

Kadirbayeva et al. (Kadirbayeva et al., 2022) have assessed the methods of using blended learning technology in school mathematics from the viewpoint of teachers. According to the results of the research, most mathematics teachers stated that the attitude of students to the mathematics lesson was ambiguous and negative. Most of the teachers who participated in the study stated that the combination of the wonderful characteristics of the classroom environment, the diversity of teaching and learning methods, the variety of teaching materials and increasing student success are the strengths of mathematics education in a mixed learning environment. Most teachers who participated in the study stated that a disadvantage of mathematics education in the mixed environment is the lack of educational programs suitable for mixed learning, the disadvantages of software and hardware that will be used in the course, and inability to use technology effectively and efficiently, and the learning environment.

4 RESEARCH RESULTS

The normative and regulatory documents that determine the content and organization of the educational process in institutions of higher education of Ukraine provide the main requirements for lectures. The implementation of these principles allows us to fully use the significant teaching and educational possibilities of this form of learning, to increase the impact of each lecture on the knowledge and feelings of the students. However, the lecture in some way trains the student to passive absorption of others' ideas, does not stimulate the desire for self-study, does not provide for an individualized, differentiated approach to learning. The leading role of the lecture in teaching disciplines associated with their contents aspect, organizing principles and methodological features. The main content consists of the central methodological, theoretical and practical problems. Not all questions of the topic are revealed, but the most important, the most essential, which require scientific discussion.

The pace of development of modern technologies significantly affects teaching methods and teaching models in general. This allows you to expand ways to implement the paradigm of competence in order to improve the quality of education. The model of blended learning has the greatest potential for optimizing the educational process. This model allows for the implementation of new technologies without disregarding the generally accepted teaching methods. Blended learning is a model for organizing the educational process because "it allows to increase the motivation of future teachers to learn, makes it transparent, interactive and guided, and ensures the constant involvement of students in the educational process" (Kukharenko, 2016) and continuous advancement of qualification. The aim of this form of learning is to combine the advantages of face-to-face learning and electronic educational resources through the combination of distance and traditional communication in an integrated educational activity. The integration of traditional and computer-based learning in the educational environment leads to a purposeful process of developing knowledge and skills and abilities in the classroom and post-attendance educational activities of the subjects of the educational process on the basis of the use of information and communication technologies. The existence of this form of learning is possible due to the effective combination of different ways of presenting educational content, teaching models and styles. It is based on the interaction between all participants in the educational process.

One of the forms of blended learning is implemented through Flipped Classroom. There are different ways of implementing the Flipped Classroom model, all of which are based on one basic principle: traditional learning takes place outside the classroom, while practical work and application of the acquired knowledge takes place in the classroom. In general, the essence of inverted learning lies in restructuring the key components of the educational process. With the help of this teaching model "the content of new educational material is mastered by oneself in the electronic environment, and then the acquired knowledge is used during practical lessons or discussions" (Hlazova et al., 2018).

The shortening of classroom hours (lectures, workshops, seminars, laboratory classes) leads to a failure of the traditional logics of the educational process. This fact leads to loss of quality of teaching. One of the ways to "renew the balance of the educational process is to use the mixed teaching model with Flipped Classroom technology" (University of Queensland, 2017). In this case, the key components of the learning process change places: the basic components of the new material are studied independently at home, and in the classroom the studied material is consolidated and the more complex issues and practical use of the teaching information are discussed together with the tutor. The Flipped Classroom technology is characterized by the fact that the necessary "theoretical knowledge is acquired in the classroom, and in the classroom the individual tasks are performed or a group project is developed" (Pieri and Laici, 2017).

Flipped Classroom technology was used in the study of mathematical disciplines "Mathematical Logic and Theory of Algorithms" and "Elementary Mathematics" at the 3rd year of the Physics and Mathematics Faculty of the Donbas State Pedagogical University. Taking into account the fact that the students of the specialty "Secondary education (mathematics)" specialization "Informatics" at the 3rd year of study have significant experience of educational activities, and the level of self-awareness is already sufficient for the personal motivation to learn, it is not only logical, but also quite profitable to use the elements of Flipped Classroom technology. Moreover, this model of learning does not interfere with the educational program, in which the main part of the years is allocated for the students' self-directed work.

Based on the practical experience of use, the following structure of the approach to each individual topic was formed:

1. Formulation of the topic and the goal.
2. Identifying the place of the topic in the work program of the discipline.
3. Suggesting sources of information.
4. Definition of types and content of control.
5. Control and evaluation.

Implementing the Flipped Classroom technology while teaching the course "Mathematical Logic and Theory of Algorithms" it is advisable to consider the following topics:

- Boolean n-ary functions;
- Zhegalkin Polynomial;
- Complete systems of Boolean functions;
- Mathematical theories of the first order.

For each of the proposed topics identified a place in the work program and sources of information, selected the content of tasks for the control of the type.

For example, to study the topic "Boolean function systems" students receive the following information (table 1).

The main reason for the implementation of the Flipped Classroom model of teaching in the educational process of the university is the active cooperation between the students and the teacher and, as a result, increasing the success and motivation of the students. A special feature of this model is the possibility of using group classroom sessions where students can discuss key aspects of lecture materials, test their knowledge and interact with each other. The task of the teacher is to explain the problems, comment on the work of students. Thus, we came to the need to have in their arsenal of specialized mathematical platforms for collaborative work. Through the use of collaborative platforms, or even mathematical platforms that allow the exchange of output data, with the results of calculations or developed electronic educational resources for mathematics courses, we get a mechanism for organizing blended learning with Flipped Classroom technology for future mathematics teachers.

It is necessary to review the training tools for future teachers of mathematics, which implement the above-mentioned ideas. The CoCalc Cloud Platform (https://cocalc.com/) is part of the SageMath Project (https://www.sagemath.org/) developed by William A. Stein. The main idea is that currently there is a large number of open and complete mathematical software already developed but they are implemented in various programming languages. The SageMath project integrates all existing developments and adds its own, and integrates them with the Python language. The cloud service CoCalc provides the opportunity not only to work online with SageMath worksheets via Jupiter notepad, but also to use the LaTeX language for the design of documents. Merzlykin et al. (Merzlykin et al., 2022) investigated the capabilities of the CoCalc system for scientific and educational purposes and came to the following conclusions:

- the use of cloud services leads to the formation and development of forms of learning focused on collaborative learning activities on the Internet;
- cloud services can be used in the training of mathematics teachers as tools: communication; collaboration; storage and processing of data.

An example of supporting the process of professional training of future teachers of mathematics is the use of computer-based mathematics systems in

Table 1: Information resources of the topic.

Topic	Complete Systems of Boolean Functions
Purpose	To learn the concepts of classes of functions that store zero, functions that store one unit, self-similar functions, monotonic and linear functions. To define the criteria of totality.
The sources of information (self-selection of sources of information is encouraged)	• Borodkina I. Teoriia alhorytmiv. Posibnyk dlia studentiv vyshchykh navchalnykh zakladiv. (A guide for students of higher educational institutions.) K.: Tsentr navchalnoi literatury, 2019. 184 p. • Zubenko V.V., Shkilniak S.S. Osnovy matematychnoi lohika: navchalnyi posibnyk. (The Fundamentals of Mathematical Logic: A Tutorial.) K.: NUBiP Ukrainy, 2020. 102 p. • Kaidan N.V., Pashchenko Z.D. Metodychni vkazivky do praktychnykh zaniat z kursu “Matematychna lohika ta teoriia alhorytmiv”. Rozdil “Matematychna lohika” dlia spetsialnosti 014 Serednia osvita (Matematyka) (The methodological guidelines for practical exercises in the course “Mathematical Logic and Theory of Algorithms”. Section “Mathematical Logic” for the specialty 014 Secondary Education (Mathematics)). Sloviansk: Vyd B. I. Matorina, 2019. 92 p. • Matviienko M.P., Shapovalov S.P. Matematychna lohika ta teoriia alhorytmiv : navchalnyi posibnyk. (Mathematical Logic and Theory of Algorithms: A Manual.) Kyiv : Lira-K, 2018. 211 p. • Rosen K.H. et al. Handbook of Discrete and Combinatorial Mathematics. 2000. 1183 p. • Discrete Mathematics. Lecture: Completeness criterion of a Boolean function system. Access mode: https://cutt.ly/jJaHyNj • “Collect the Crystals” game simulator. Access mode: https://cutt.ly/SJaHK3c • Simulator “Logical Elements”. Access mode: https://cutt.ly/0JaHMwY • A Simulator for Minimizing Logic Functions by the Quine-McCluskey Method. Access mode: https://cutt.ly/hJaH49v • Creating the Truth Table. PDNF. PCNF. Zhegalkin polynomial. Access mode: https://cutt.ly/IJaJqzR • Truth table. Access mode: https://cutt.ly/3JaJufo
Types of control	Test for the comprehension of the material (carried out remotely during class time), individual assignment to determine the completeness of the system
Date of control	Conducting a self-study test

the form of cloud services. One of these free services is Math Partner, available at http://mathpar.com. This service allows you to create your own cloud math “Workbook”, in which the user performs the necessary mathematical calculations. To ensure quality and comfortable work this service provides access to a large amount of guidance material with examples. The language of this service is Mathpar, based on TeX, a widely used by mathematicians special-purpose data layout language developed by Donald Knuth. There is a possibility to save both the statement of the problem and its solutions. You can save both textual and pictorial views. Although for studying mathematical logic Math Partner system does not contain expanded functions, the basic logical operations the system is able to process (figure 1).

In particular, Math Partner allows you to efficiently perform such common tasks as finding the shortest distances between all vertices of the graph (\searchLeastDistances(A)) and finding the shortest path between vertices (\findTheShortestPath(A,i,j)). It should be noted that this service is convenient to use for checking your own connections, because it gives the answer itself, without access to the intermediate results of the calculations.

The Graph Online service https://graphonline.ru/en/), which is available under the MIT License, is designed for graph visualization and execution of algorithms on the created graph. The graph is created using the complexity matrix or the incident matrix. Besides searching for the shortest path, you can also search for the connectivity component. The service

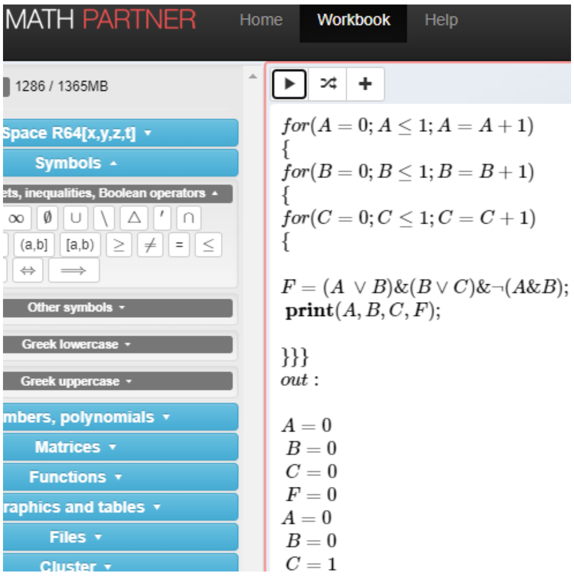

Figure 1: Calculation of logical function values in the Math Partner system.

supports work with directed graphs (digraphs) and non-directed graphs. You can save the result of the work, i.e. the generated graph, and continue working on it later. In addition, the cloud service Graph Online gives the user a number of additional functions to make the work easier. Graph saving and loading is available with maintenance of visual representation, quick conversion between all supported types, vertex, arc, background, constructor mode, etc.

Let us demonstrate the application of the presented services when solving the problem of finding the shortest distances between graph vertices, which are often encountered in practice. It is clear that for the possibility to find the shortest distances at least one path from vertex 0 to each other vertex must exist, i.e. the graph must be connected. For this problem the most well-known connectivity algorithm is the Dijkstra's algorithm. The idea of this algorithm is that at first each vertex other than vertex 0 is given a distance equal to $+\infty$, and then we decrease these distances step by step until we find the minimum distance $d(v)$ and the shortest path $p(v)$ for each vertex v.

Problem statement: In an arbitrary graph $G = (V,E)$, the set of vertices $V = \{0,1,2,3,4,5\}$, and the set of edges E is given by a matrix of weights:

$$E = \begin{pmatrix} - & 8 & 7 & - & 10 & 12 \\ 8 & - & 5 & 1 & 4 & - \\ 7 & 5 & - & 3 & - & 4 \\ - & 1 & 3 & - & 2 & 1 \\ 10 & 4 & - & 2 & - & 3 \\ 12 & - & 4 & 1 & 3 & - \end{pmatrix}$$

Use Dijkstra's algorithm to build a spanning tree of the shortest paths from vertex 0 to all other vertices of graph G and find the shortest distances.

Solution: Let's show the progress of the Dijkstra's algorithm in the table 2.

Table 2: The progress of the Dijkstra algorithm.

1	2	3	4	5
8	**7**	10 **9**	**10**	12 11 **10**
0; 1	0; 2	0; 2; 3 0; 1; 3	0; 4	0; 5 0; 2; 5 0; 1; 3; 5

During the execution of the Dijkstra's algorithm, the vertices were in this order: $2,1,3,4,5$. Thus, the shortest distance to vertex 1 is 8, $d(2) = 7$, $d(3) = 9$, $d(4) = 10$, $d(5) = 10$. The shortest path to vertex 1 is 0.1; $p(2) = 0.2$; $p(3) = 0.1.3$; $p(4) = 0.4$; $p(5) = 0.1.3.5$. Figure 2 shows these shortest paths in the form of a tree.

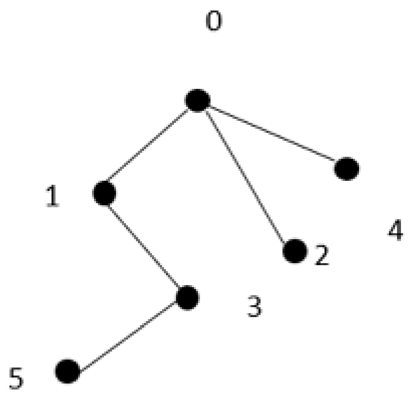

Figure 2: The spanning tree of the shortest paths from vertex 0 to all other vertices of graph G.

With the Math Partner service, we have the opportunity to check the correctness of the results in figure 3. But the visualization of the graph is better performed by Graph Online in figure 4.

The Robert Coleman SA403_FY17 project (https://cutt.ly/PKp7bJ4) on the CoCalc platform includes the implementation of popular graph algorithms. In particular, Dijkstra's algorithm was implemented (https://cutt.ly/FKp7eLy). Thus, we can conclude that during the professional training of mathematics teachers, the use of various cloud services is not only possible but also appropriate.

The students of the 2nd-4th years of Secondary Education (Mathematics) at the Faculty of Physics and Mathematics of the Donbas State Pedagogical University were repeatedly interviewed (the first one was described in the study (Velychko et al., 2021)) in order to find out what means of computer teaching are

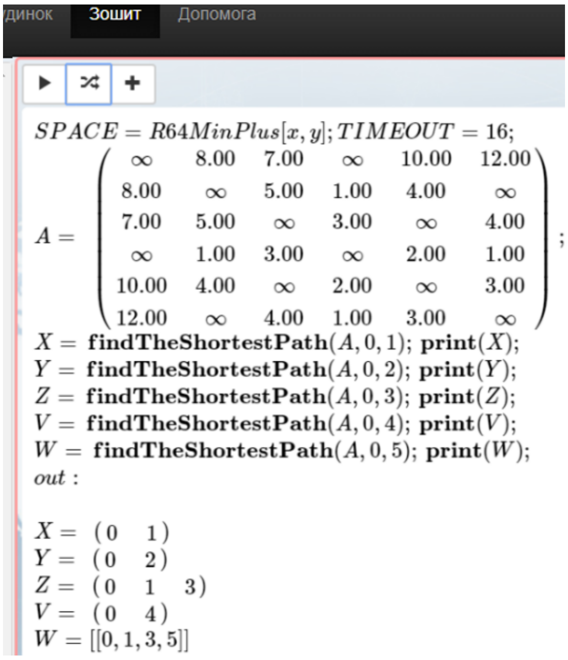

Figure 3: The shortest distances from the vertex 0 to all other vertices of graph G in the Math Partner service.

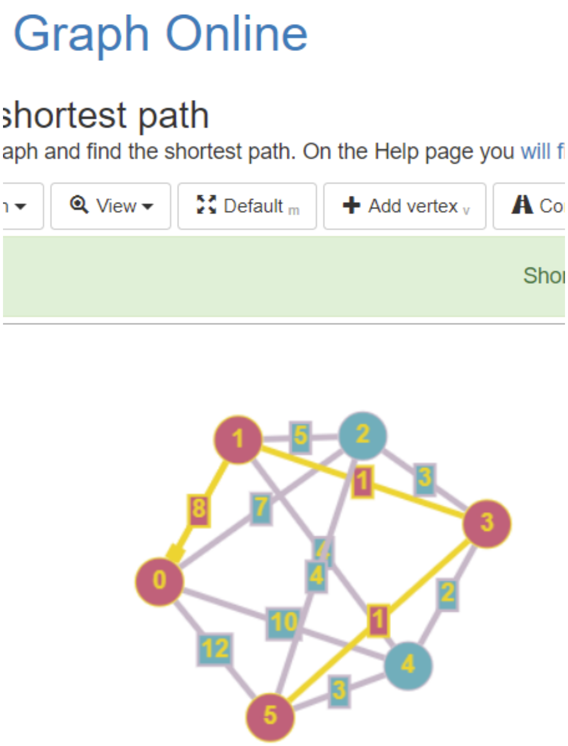

Figure 4: The visualization of the graph G and the shortest distance from the vertex 0 to the vertex 5 of the graph G in the Graph Online service.

used by future mathematics teachers in the process of their professional training, including during the self-study activity. A total of 80 students were involved in the survey (in the first one – 120 respondents). We asked the respondents the following questions:

1. Have you used electronic educational resources during your studies?
2. Did you use the cloud services during the study period?
3. Did you use the cloud services during self-study activities?
4. If the answer to the 2nd or 3rd question is positive, then what cloud services did you use?
5. If the answer to the second and third questions is negative, what kinds of software did you use during the training?

We received the following results:

- 100% positive result on the first question. This result indicates that future mathematics teachers understand the concept of "electronic educational resources" without regard to their diversity.
- The second question was answered positively by 92% of respondents (in the first survey – 82%). The result of the answer to the second question shows that not all respondents identify the concept of a cloud service. We reached this conclusion during the discussion of the results of the survey with the respondents since during the practical exercises that we described in the study all the students were involved in the use of cloud services.
- 76% of respondents (46% in the first survey) responded positively to our third question. This number is a good result of self-awareness activities.

The answer to the fourth question is shown in the figure 5.

It should be noted that there was a significant outpacing of cloud communication services due to quarantine measures caused by COVID-19 pandemic and cloud file-saving and collaborative work servers. In comparison with the first study, tools for creating infographics and interactive presentations appeared. A positive result of the study is an increased use of mathematical cloud services. The answer to our question 5 is shown in figure 6.

By comparing the results of the study with those described in the publication "The support of the process of training pre-service mathematics teachers by means of cloud services" (Velychko et al., 2021) we get both quantitative and qualitative changes. First of all, the respondents not only expanded their knowledge of cloud technologies, but also expanded their use in their own teaching activities. Software on the

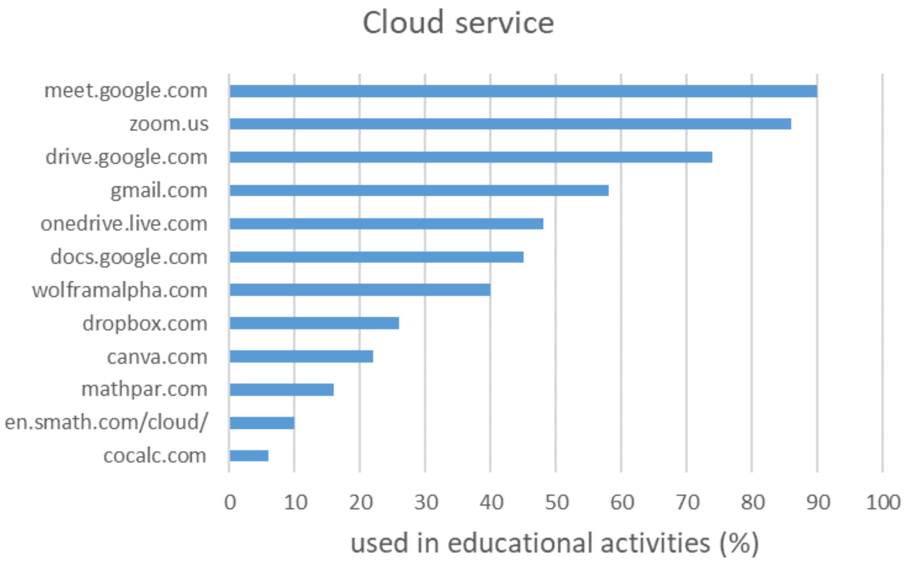

Figure 5: Cloud services which were used by the future mathematics teachers.

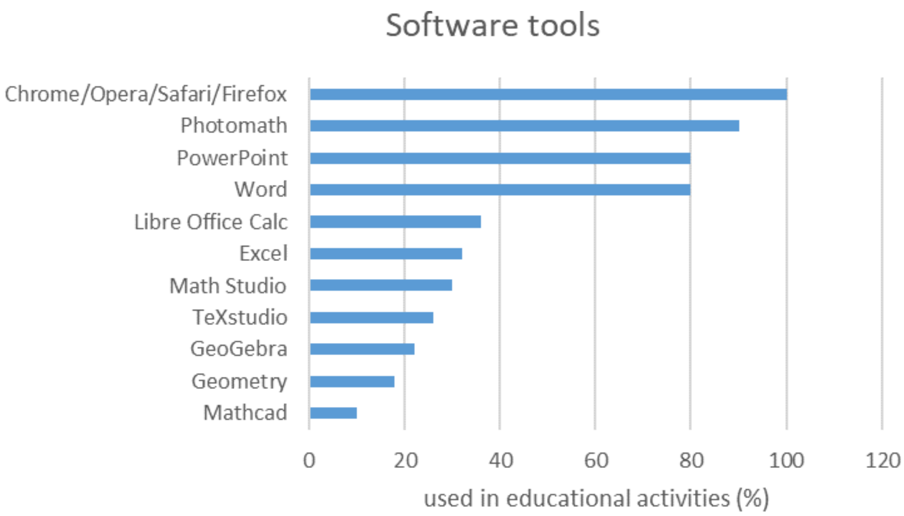

Figure 6: Software tools used by future mathematics teachers.

desktop system as well as on mobile systems has a greater focus on learning, the advantages are given to the available software. Respondents' responses are more demanding compared to the previous one. As before, special software for mathematical purposes is not used as often as desired, however, the rate of its use is increasing.

5 CONCLUSIONS

The learning process at a high school is implemented within a diverse and integral system of organizational forms and teaching methods. Each form carries out its own specific task, but the totality of forms and methods of learning creates a single didactic complex, the functioning of which is consistent with the specific psychological and pedagogical laws of the educational process. The advantages of the cloud services lead to their widespread use in educational activities. Experience gained in implementing cloud technologies in educational activities make it possible to begin to analyze the work carried out – what results were obtained, which are the best practices of their use. Quarantine restrictions and the rapid transition to e-learning has led to the creation of electronic educational resources, development of methods of e-learning, in which the cloud services play a significant role.

The results of the research allow us to conclude that cloud technology is used in the process of teaching mathematics in secondary schools. Future mathematics teachers have the opportunity to use cloud technology during their professional training. Modern cloud technologies have a wide range of use in mathematics education. The training of future mathematics teachers has begun to be based on new teaching tools and technologies.

The next step of the research is the accumulation of empirical data on the use of cloud computing in the process of professional training of future teachers of informatics and software for applied orientation. We have analyzed the trends in the use of cloud computing and software of mathematical orientation both during the professional training of future mathematics teachers and during the professional activities of practicing mathematics teachers. The problem of harmonious combination of digital technology and classical methods of mathematics learning, even in modern pedagogical teaching technology, is not solved. In our opinion, the feasibility of reduction of computing operations through the use of information technologies in opposition to the loss of skills of operational competence is interesting.

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Using of Resource Sources of Interactive Semantic Networks in Offline Translator Training

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Keywords: Interactive Semantic Network, Terminology Resources, Terminology Databases, Autonomous Learning, Translator.

Abstract: The article focuses on the use of resource sources of interactive semantic networks in translator training, particularly during offline and autonomous learning due to lockdown and martial law situations. The most common external terminology resources associated with interactive semantic networks are identified. The technology of selection and structuring of specialised terminology on the basis of interactive semantic networks for their further use in the study of foreign languages and mastering automated translation systems has been developed and proposed. The criteria for creating and supplementing terminological databases with appropriate structuring of the domain terminology selected on the basis of interactive semantic networks have been defined, namely universality, structurability, convertibility, extensibility. The possibility of further use of terminology bases for foreign language learning using mobile applications, mastering Computer Aided Translation (CAT) systems, mastering Computer Aided Interpretation (CAI) are outlined. Based on the experimental construction of an individual interactive semantic network based on external terminology resources, positive results are stated and directions for further research activities to strengthen the technological training of prospective translators are identified.

1 INTRODUCTION

In a changing world at the beginning of the 21st century, education is also changing rapidly. Learning is now seen as a lifelong process that is essential for adapting to new environments, and therefore for ensuring personal economic and social success. Such learning implies that people have to ‘learn to learn’. Consequently, providing students with the knowledge and skills to enable them to manage their own educational process effectively becomes one of the aims of higher education. During the evolution of the education system, the issue of autonomy has become one of the main themes of language education research, and in the context of recent global developments (the coronavirus pandemic, COVID-19, restrictive quarantine measures and lockdowns, the transition to distance learning) it has become particularly relevant.

At the same time, the new format of the educational process puts forward new requirements regarding the ways of realising learning objectives, methods of learning communication and teacher-student interaction, means of ensuring the effectiveness of learning subjects and achieving the programme learning outcomes envisaged in the standards and curricula for training specialists, including translators. Both in terms of learning activities and in terms of the future work of translators, technological training is becoming increasingly important. The present is forcing, on the one hand, a strengthening of the technological aspects of university translator training and, on the other hand, a rethinking of the organisational forms of training, the search for appropriate means, the combination of students’ independent mastering of individual study materials with the technologicalization of the

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educational process. Using elements of augmented and virtual reality can meet such complex objective requirements of the current situation.

2 THEORETICAL BACKGROUND

An analysis of the psycho-pedagogical literature has shown that there has recently been increased interest in certain aspects of autonomous learning by both domestic and foreign researchers in different fields of science. Benson (Benson, 2005), noting the recent increased attention to learning autonomy and self-organised learning, including in foreign language learning, emphasised the importance of different levels of student autonomy in distance learning. Cotterall (Cotterall, 2000) identified five principles on which a stand-alone language course should be based and attributed them to learners' goals; language learning process; theory – task, design; learners' strategies; reflection on learning. Hurd et al. (Hurd et al., 2001) emphasise one of the main problems of autonomy in distance learning, which in their view is the difficulty of selecting learning material for students to learn independently. This decision is complicated by two factors. On the one hand, in order to be successful in the programme, students must develop a number of strategies and skills that will allow them to work individually. At the same time, the syllabus of an academic course has a definite structure in which the scope, pace and content of the syllabus are determined by the teacher. Exploring the notion of autonomy in distance language learning, scholars have identified some of the skills that distance learners need to achieve successful outcomes. Similar views are held by Murphy (Murphy, 2006), who emphasizes that the success of autonomy in distance learning depends largely on the teaching materials, and demonstrates the role of the teacher in the process of autonomy in the language distance-learning programme of The Open University in the UK.

While considering the organisation of autonomous language learning, scholars have also explored the possibilities of using information technologies in this process. In highlighting the changes in educational philosophy reflected in the theory of language learning, Pemberton et al. (Pemberton et al., 1996) noted the need to adapt to the rapid changes in the areas of technology, communications, and the labour market and to realise that the ability to learn is now more important than knowledge. In his view, it is advisable to take full advantage of the opportunities for expanding educational services that come with the development of technologies. In this context, it should be noted that foreign scholars and practitioners are increasingly hoping for the integration of augmented reality elements into the training of university programmes in philology and translation. Indiana University, in particular, has initiated one such project, which involves the multidimensional deployment of elements of AR technology that can meet precisely the specific needs of these programmes in the form of individual modules: "We plan on compiling the following learning modules 1) listening comprehension; 2) pronunciation practice; 3) animated 2D and 3D vocabulary introduction; 4) vocabulary quizzes; 5) roleplay dialogues where students interact with an avatar and 6) videos with cultural content, geography, and history. In contrast to other digital technologies available at IU, such as embedded videos in Canvas, we will be able to bring real objects into language classrooms, such as cultural artifacts, culinary samples, maps and other objects, and connect them virtually to an augmented world" (Scrivner et al., 2016).

According to Reinders (Reinders, 2006), in order to provide students with easy access to learning materials during offline foreign language learning, it is advisable to create an appropriate e-learning environment. The main aim is to support students in their self-directed learning by structuring self-study by providing a recommended sequence of steps, providing students with information on learning strategies and conducting electronic monitoring of student work, with advice if necessary (Reinders, 2006; Scharle and Szabó, 2000).

Researchers whose academic work is related to foreign language teaching point out that special attention should be paid to the development of students' responsibility; otherwise, the learning process will not be successful (Scharle and Szabó, 2000). I. Moore even points out that student autonomy begins with students taking responsibility for both the process and the results of their learning: "In doing this: They can identify their learning goals (what they need to learn), their learning processes (how they will learn it), how they will evaluate and use their learning; they have well-founded conceptions of learning, they have a range of learning approaches and skills, they can organize their learning, they have good information processing skills, they are well motivated to learn" (Moore, 2010).

Little (Little, 2002) considers it likely that in the next few years much of the research on student autonomy will focus on the impact of autonomous learning, particularly when learning a foreign language, on everyone involved – students, teachers and educational systems in general. According to the researcher, the role of the teacher is to create and support a learning environment in which students can be autonomous. The development of their learning skills cannot be completely separated from the learning content, since learning how to learn a foreign language differs from learning other courses in some important respects.

At the same time, as the above list of issues examined by scholars from various countries shows, autonomous learning, in particular the learning of foreign languages, is associated by many with the using information technologies and the search for new approaches, not the least of which are nowadays augmented, virtual and mixed reality (Liu et al., 2017). Yagcioglu (Yagcioglu, 2015), focusing his research on new approaches to student autonomy in language learning, relies on UNESCO's declared role of information and communication technologies in learning: "Information and communication technology (ICT) can complement, enrich and transform education for the better" (UNESCO, 2022). Some academics, while extremely appreciative of the potential of augmented and virtual reality in learning, have expressed concerns about whether the education system is ready for the fundamental changes in the educational process that arise from these technologies, or even their elements. Ochoa (Ochoa, 2016) sees augmented and virtual reality as a new challenge for education.

The use of terminology resources is an important support both for training (face-to-face, remote, offline) and for the professional work of translators. It should be noted that, appreciating the importance of correct use and unification of terminology, the European Commission has created a specific database of terminology tools and resources (KCI, 2022). More recently, scholars have noted that the creation of terminological resources should aim at the possibility of using them during both human and machine translation: "In a globalised society, terminological dictionaries – including resources such as knowledge and terminological databases, ontologies, wordnets, "traditional" dictionaries, etc. – should comply with both human and machine needs" (Roche et al., 2019).

Given the importance of the factors for organising offline foreign language learning identified in the reviewed studies (students' motivation, choice and access to learning material, skills and strategies for offline learning, use of information technology, AR technology), we consider it advisable to introduce the use of augmented reality elements in this process, which can provide the above aspects. In previous studies to determine the possibilities of using AR technology in the process of learning a foreign language, a number of advantages of using elements of this technology have been identified: the involvement of different channels of information perception, the integrity of the representation of the studied object, faster and better memorization of new vocabulary, etc. (Tarasenko et al., 2020b). The study of a certain section of a foreign language's vocabulary – domain-specific terminology – is relevant both for specialists studying a foreign language and for translators who plan to translate the field. Therefore, continuing our research, we will focus on autonomous learning activities using AR technology in terminology work, which is the initial phase for several possible directions of further development of the educational process – language learning, scientific and technical translation, mastering automated translation systems (Tarasenko et al., 2020a).

The *purpose* of this paper is to consider the possibility of using interactive semantic networks as elements of augmented reality in the process of autonomous learning to improve the technological training of translators in the aspect of creating domain-specific terminology bases for their further use in foreign language learning and mastering automated translation systems.

3 RESULT AND DISCUSSION

Translation education at the current stage necessarily involves technological training of translators, which aims to develop competencies in the use of modern tools and techniques of translation, based on the use of information technologies. An important part of this training is for translators to acquire skills in working with electronic terminology resources, such as searching, structuring, storing, using terminology in computer-assisted translation (CAT) systems, computer-assisted interpreting (CAI) systems, interactive foreign language learning systems and the like. The search for effective technological training for translators is becoming increasingly urgent, but is complicated by the emergence of new tools and the rapid growth of their number. At the same time, there is a trend towards the increasing use of cloud services and online resources. All this makes it necessary to constantly update the content of the educational programme components. One of the ways of solving this problem could be the implementation of augmented reality elements into the educational process. The application of augmented reality (AR – augmented reality) technology will allow students to find and obtain the necessary information more quickly, which can be presented in symbolic, audio, graphic or animated form (Amelina et al., 2022). The use of such technology will be particularly effective in off-line learning, as its peculiarity is the absence of constant direct contact with the teacher and, consequently, the possible complications of acquiring certain knowledge. This necessitates a search for augmented reality technologies that were primarily aimed at building professional skills, particularly in the case of autonomous learning for translators in their technological training.

3.1 Technology for Selecting and Structuring Domain-Specific Terminology Based on Interactive Semantic Networks

One of the options for using augmented reality elements in the technological training of translators can be developed by us the technology of selecting and structuring domain-specific terminology based on interactive semantic networks for their further use in the study of foreign languages and mastering automated translation systems. A schema of this technology based on interactive semantic networks is shown in figure 1. This technology is designed to be used in the learning process by undergraduate students who have already acquired the skills of working with CAT and CAI (Tarasenko and Amelina, 2020). In developing it, we used existing interactive semantic networks, which are new online services and have only become available for use in the last few years. In particular, one such service has been developed in the framework of the EU Terminology as a Service (TaaS) project. The goal of the TaaS project was to provide operational access to up-to-date terms based on the exchange of multilingual terminology data and to create effective mechanisms for the reuse of terminology resources.

According to the developed technology (figure 1), the initial step is to use interactive semantic networks for the selection and structuring of domain terminology, which consists in the possibility of defining a semantic field within a certain domain to identify terminological entities for integration in the terminological database of the respective domain. In this case, to initialise the algorithm for the student's construction of his/her individual semantic network, he/she only needs to decide on any source term that relates to the domain with which he/she plans to work on the basis of the created terminological base. This term is entered into the relevant elements of the interface and a hierarchical structure of the semantic field with multi-level relationships between its elements is formed around it by means of the search engine of the interactive semantic network. In this way, the student is at the outset provided with a defined set of directions, each of which opens up a separate terminology pathway. At the same time, the system provides easy and clear visual identification of the elements in their hierarchical order and the different types of links between them. Figure 2 shows the initial phase of building a personalised interactive semantic network based on the source term "genetics".

Further action should be taken by the student to develop the semantic network in one or more directions that are appropriate for his or her individual task. The types of links between the elements of the network, which indicate the hierarchical relationship between them, can help the student to decide on the appropriate direction. In particular, the system can automatically establish four types of such links: exact, broader, narrower, related. The exact type of link means that it is an exact match or synonymy. In terms of moving along the development of a network with such a link, the system can provide additional opportunities to obtain search results in the form of related terms. Using the network development direction of the broader link, the student will be able to further search for terms at a higher hierarchical level of concepts and move to related domains, which will contribute to his/her understanding of the integrity of a particular domain. A 'narrower' link will allow the student to build a network in the narrower direction of the field and access a list of terms that under other circumstances he/she might have obtained after a lengthy search in the relevant reference books. This is an important aspect of using such online networks, given that the translator is usually not an expert in a particular domain and therefore cannot have a detailed understanding of the terminological vocabulary of that domain.

3.2 Resource Sources for Terminological Support for Interactive Semantic Networks

However, working with an interactive semantic web to find relevant terms can be effective not only in the direction of using the appropriate type of links between the network elements in a visualised mode, but also when using a system of interactive links to relevant terminology resource repositories. This can be used if a student is interested in a specific terminological element in a semantic network schema. When it is highlighted, the system identifies and generates a link to one so-called original site whose information better answers the created query. In most cases, the system identifies three main resources as original sites:

- the Agricultural Information Management Stan-

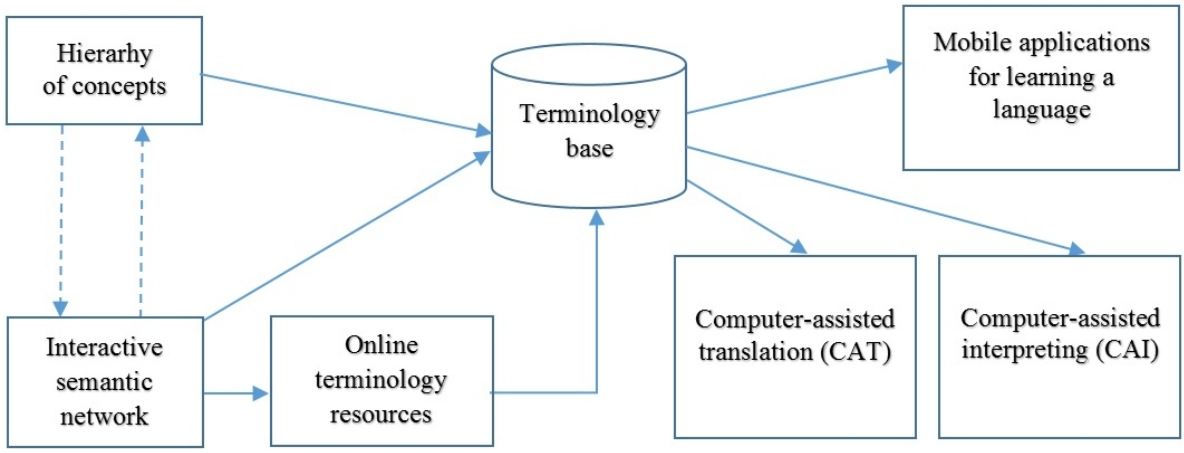

Figure 1: The scheme of technology for selecting and structuring domain-specific terminology based on interactive semantic networks for further use in foreign language learning and mastering computer assisted translation systems.

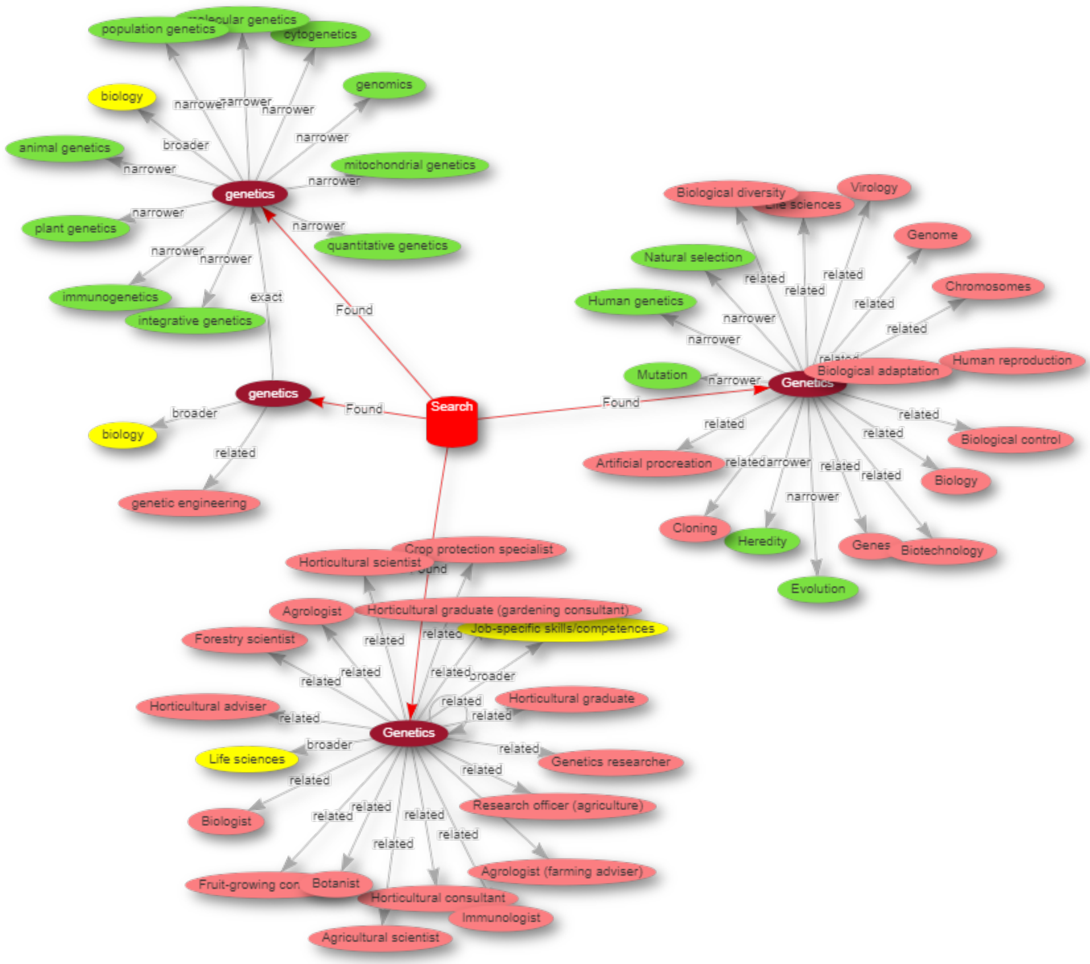

Figure 2: Initial phase of creating a personalised interactive semantic network based on the source term “genetics”.

dards (AIMS) portal of the Food and Agriculture Organization of the United Nations (FAO),

- the UNESCO Thesaurus, which is a structured list of terms used for subject analysis and searching

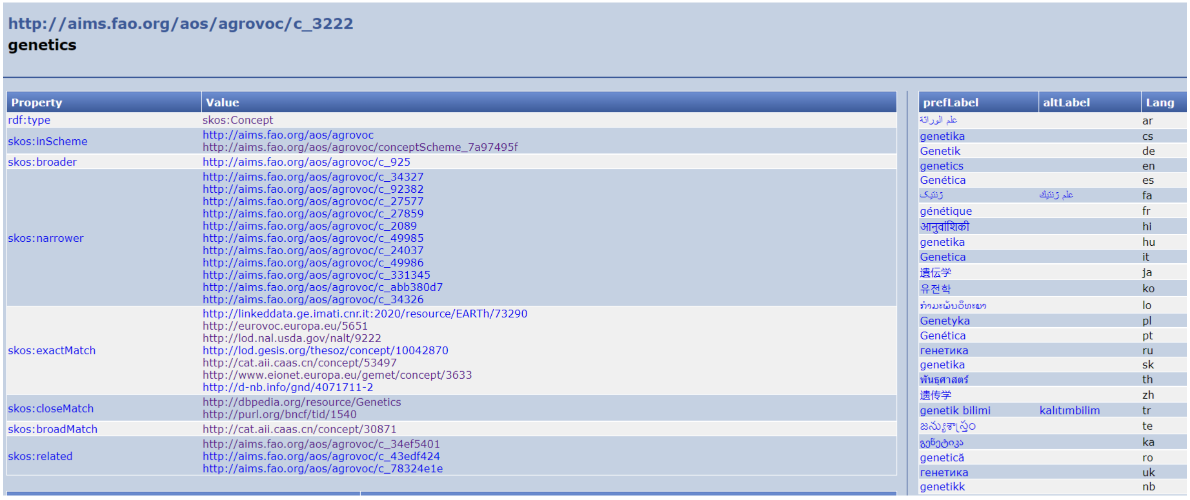

Figure 3: Agricultural Information Management Standards Portal (AIMS) page.

for documents and publications in the fields of education, culture, natural, social and human sciences, communication and information,

- the classification system of international standard nomenclature for the fields of science and technology.

It is important to note that all of these resources support a specific model of knowledge organisation for the World Wide Web, the so-called Simple Knowledge Organisation System (SKOS). This knowledge organisation system greatly facilitates interoperability between different information systems by standardising thesauri, classification systems, taxonomies and subject header systems.

The approaches to the use of these resources differ significantly. In particular, the peculiarity of using the AIMS portal is that in the initial phase of its use, in addition to providing specific information about a particular term, in particular the creation of a list of its entries in different languages, a hierarchical structure of URL links to the sites of a number of libraries, thesauruses, dictionaries, etc. where available terminological resources have a certain relation to the term for which the query is formed (figure 3) is also generated.

An extremely important feature of this portal is the hierarchical structure of the URL links, which allows students to consciously determine the further steps to take in order to find the necessary information about the relevant term. In particular, all links are concentrated into categories: broader, narrower, exactMatch, closeMatch, broadMatch, related. By organising the resource links into these categories, translators can focus their efforts on the resources that are of most interest to them in the context of their particular assignment. The exactMatch category is by far the most interesting as it groups the resources where you can find the most accurate information on a given term. However, the closeMatch category can also be interesting, as the resources offered there can significantly enhance the understanding of the nature of a term and its application and translation terms. Overall, the AIMS portal offers more than twenty of the world's leading terminology repositories, whose resources are very powerful. A list of the main ones is given in table 1.

An important resource that the Interactive Semantic Web uses as original sites in the initial search for information about a certain term is the UNESCO Thesaurus. It contains a verified and structured list of terms covering a rather broad thematic list in the branches of the different sciences – natural sciences, social sciences and humanities. Terms in the fields of information and communication and education are also presented. Structurally, the thesaurus is divided into seven main thematic areas, which in turn are divided into microthesauri. This clear hierarchical structure allows a quick understanding of the essence of the individual concepts and the connections between them. Each term is accompanied by an explanation of its meaning, which helps to avoid mistakes in its use, and the designation of the number and name of the microthesaurus to which it belongs. When available, synonyms of varying degrees of approximation to the meaning of the term are also indicated. These can be so-called broad, narrow or related concepts. A broad term is represented as a reference to a terminological element that is one level higher in the thesaurus structure. A narrow term, on the other hand, is reflected through a reference to a terminological element one level lower in the thesaurus structure. Related terms are essentially related concepts.

Table 1: Online terminology resources used when working with the Interactive Semantic Web.

The name of the online terminology resource	Support and accompaniment
GEMET (General Multilingual Environmental Thesaurus)	European Topic Centre on Catalogue of Data Sources (ETC/CDS) and the European Environment Agency (EEA)
The National Agricultural Library's Agricultural Thesaurus and glossary	United States government
IATE (Interactive Terminology for Europe)	European Union
TAUS (The language data Network)	
SKOS UNESCO Thesaurus SKOS UNESCO nomenclature for fields of science and technology	The University of Murcia (Spain), UNESCO Chair in Information Management in Organizations
Nuovo soggettario – Thesaurus	The National Central Library of Florence
DBpedia	University of Leipzig and Christian Bizer from FU Berlin (now University of Mannheim)
UNESCO Thesaurus	United Nations Educational, Scientific and Cultural Organization
Standard-Thesaurus Wirtschaft	Leibniz-Informationszentrum Wirtschaft
Katalog Der Deutschen Nationalbibliothek	Deutsche National Bibliothek
Skosmos THESOZ Thesaurus	
AIMS (The Agricultural Information Management Standards Portal	Food and Agricultural Organization of the United Nations (FAO)
The Library of Congress Linked Data Service	Library of Congress
Bibliothèque Nationale De France	
Chinese Agricultural Thesaurus (CAT)	Agricultural Information Institute of CAAS

The structuring of terms in the UNESCO Thesaurus is shown in figure 4.

A great advantage of using the UNESCO Thesaurus in a translator's work is that this terminology resource is quadrilingual, so the translator can use it both to gain knowledge in order to better understand the industry and therefore the context in which the term is actualised, and directly for translation if the target language is supported by this resource. There are various options to search for a term's description and relationships, which can be done through an alphabetical list or in a hierarchical structure. Hierarchical search options for a term are shown in figure 5.

A valuable terminology resource is of course the IATE (Interactive Terminology for Europe) database (figure 6), created and maintained by the European Union. It contains terminology that is used by EU institutions and agencies, so referring to this terminology database will enable a translator to use harmonised and standardised terminology.

A special feature of the IATE terminology database is that the search results not only match the term in the target language but also the word combinations into which the term is included (figure 7). This makes the translator's job a lot easier, as there can be direct matches for the purpose of his/her terminology search. On the other hand, the terms are given in their immediate context, which makes it easier for a translator who is not an expert in the relevant field to understand their meaning.

As shown in figure 7, the term crop production can be used in different sectors and domains – environment, agriculture, fish farming, and forestry. Therefore, the results of the search for correspondences to an English term in German are represented by these semantic fields and, as we can see, there are different terms in German as correspondences, depending on the sector.

Before the experimental part of the study, which involved the construction of an individual interactive semantic network by the students on the terminology of their choice, the experimental participants were introduced to the terminology resources described above and presented in table 1. The students could choose any of the suggested terminology resources to realise their goal.

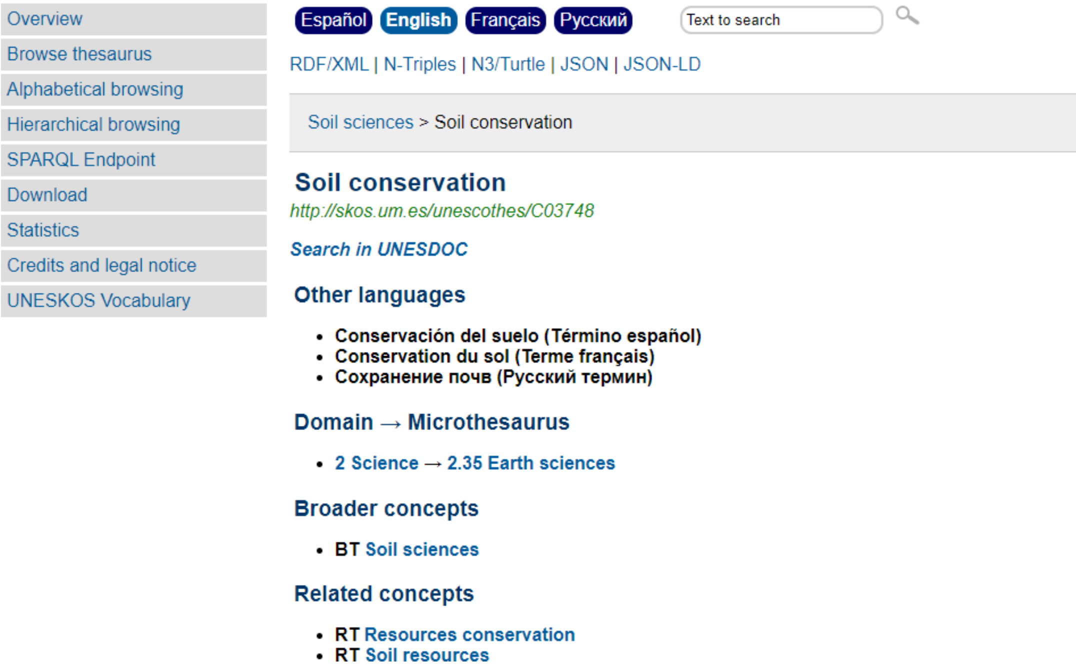

Figure 4: Structuring of terms in the UNESCO Thesaurus.

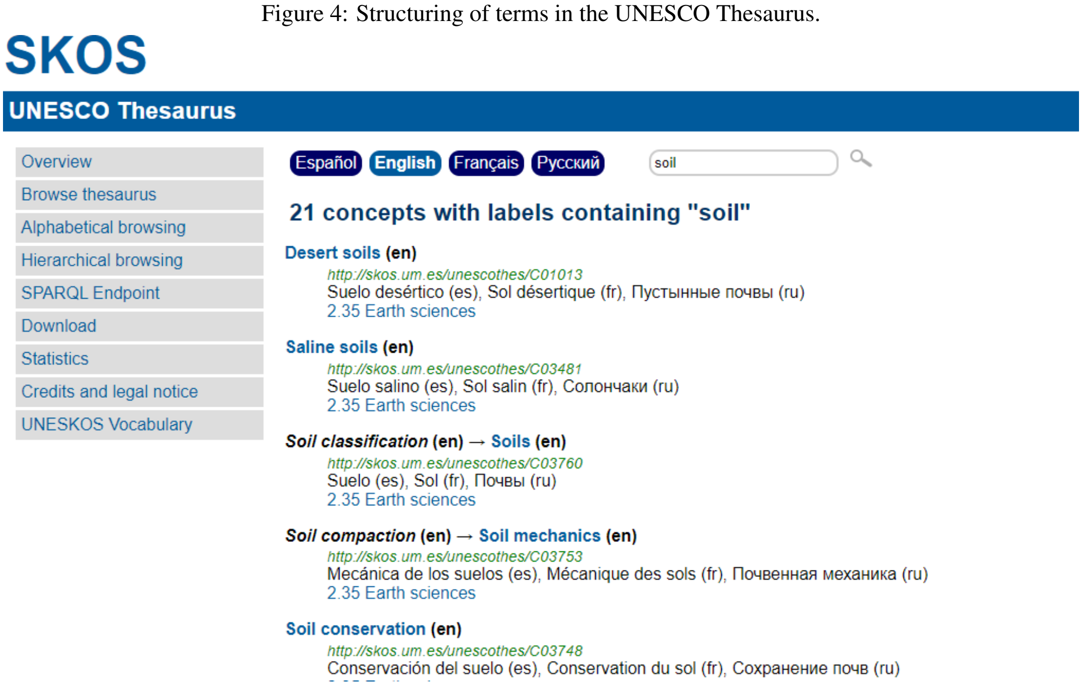

Figure 5: Results of a search for the term “soil” in the UNESCO Thesaurus.

3.3 Development of a Personalised Interactive Semantic Network with Support for External Terminology Resources

Given the development of the network to cover a wider terminological spectrum, it is advisable to move along the related type links. The results of the development of the individual interactive semantic network in different directions depending on the type of linkage are shown in figure 8.

At this stage in the implementation of the technology for selecting and structuring sector-specific terminology based on interactive semantic networks, students can already begin to extract selected terms

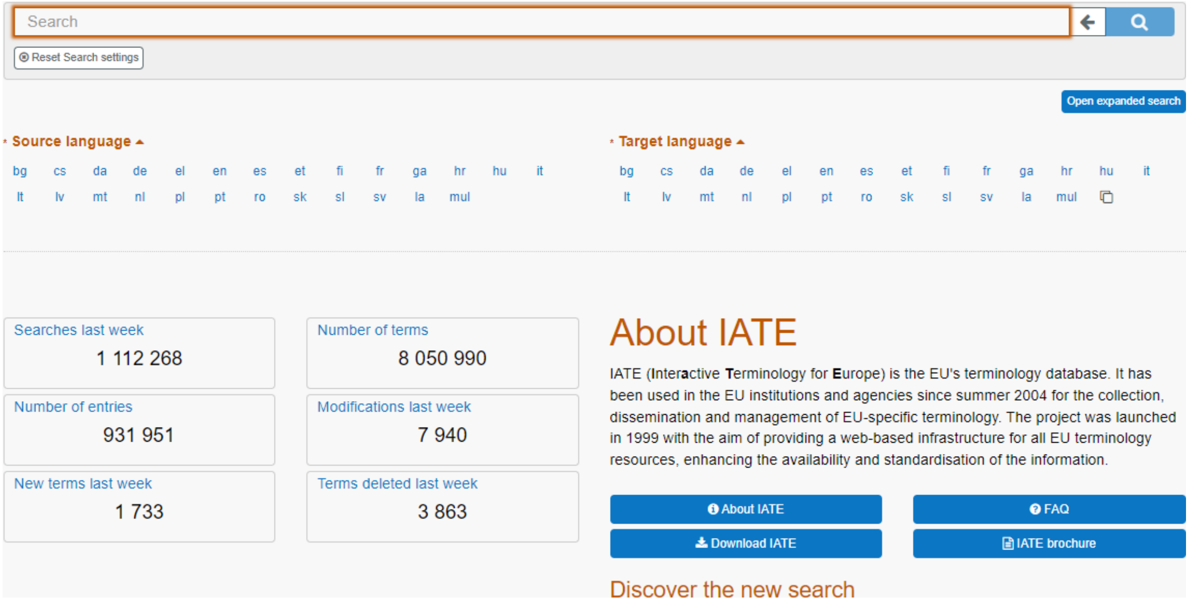

Figure 6: Interactive Terminology for Europe database.

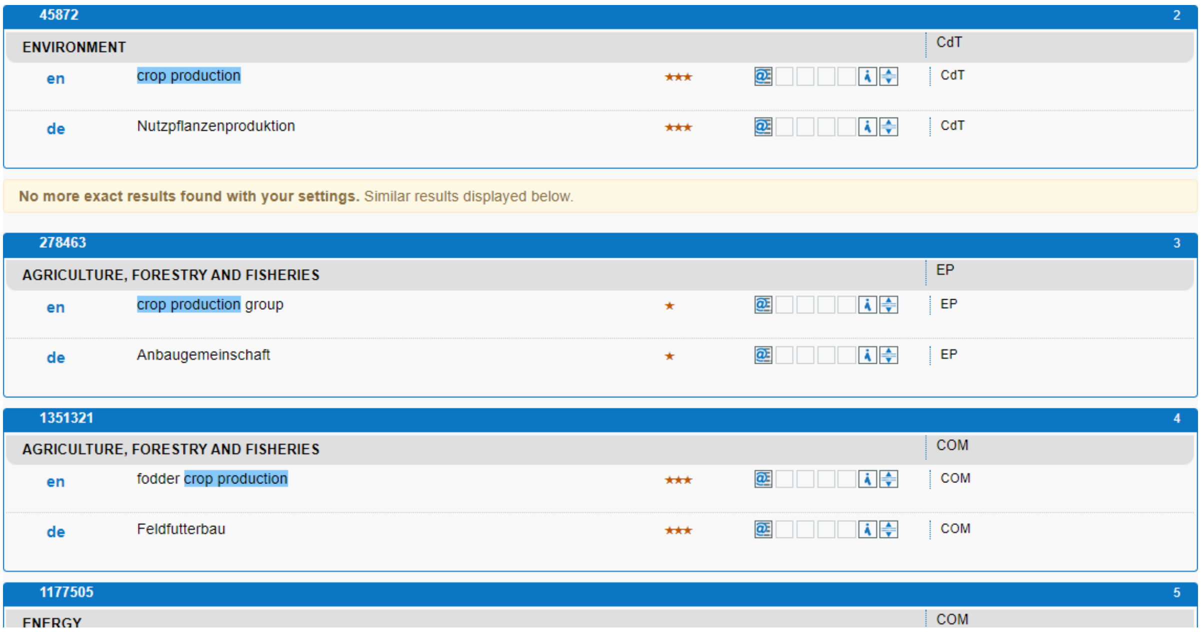

Figure 7: Search results for the term “crop production” with English as the source language and German as the target language.

from the constructed network and place them into the terminology database. In doing so, the students must be made familiar with the criteria we have defined for creating and completing terminology bases in which it is appropriate to structure domain-specific terminology derived from interactive semantic networks. In defining the criteria, we were guided primarily by the possibility of further use of terminology bases for such purposes as: learning foreign languages using mobile applications, mastering Computer Aided Translation (CAT) systems, mastering Computer Aided Interpretation (CAI) systems, which corresponds to the logic of the developed technology. To such criteria, we have classified:

- universality (ability to meet the need for terminological support for different processes directly or with minimal modification),
- structurability (possibility of placing terms), synonyms, matches and other additional information to the term in compliance with generally accepted

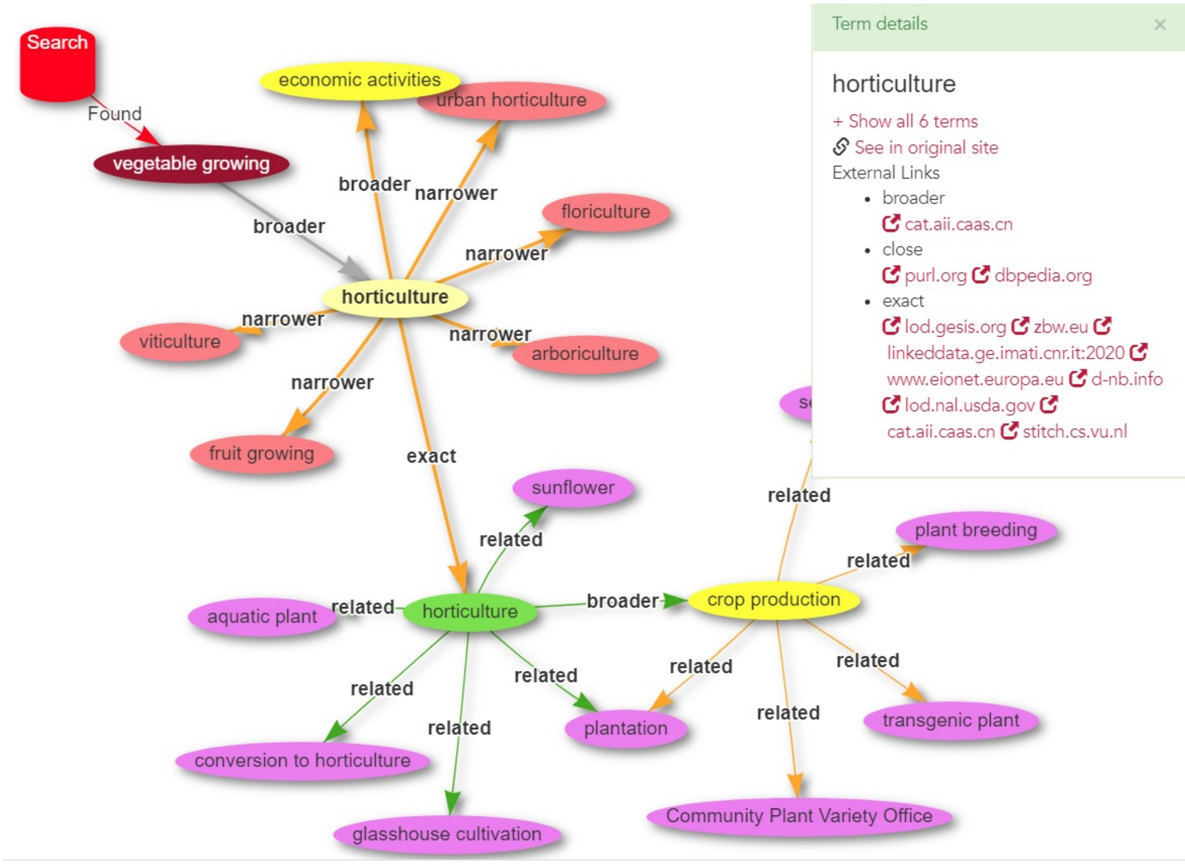

Figure 8: A individual interactive semantic network, developed along different lines depending on the type of relationship.

principles,

- convertibility (the ability to convert to other formats for the needs of other systems without changing the structure and content),
- extensibility (the possibility of changing the structure of the database to accommodate additional information in the entry at any stage of its completion, without loss of data).

After being introduced to these criteria, the students had to decide on their own about the software to create the terminology database, the format of the database and its initial structure. The autonomy given to the students to make such decisions was due to their experience with CAT and CAI and therefore with the terminology bases used in such systems.

However, using the specialised functions of the interactive semantic networks, the students were able to obtain extended information about the terms defined for entry into the terminology base, if necessary. This toolkit is based on the interactive use of online resources that can be accessed via external links and which concentrate a considerable amount of terminology indicating its affiliation to a domain, its interpretation, definitions of terms, their matching, etc. (figure 3). The online resources used include powerful bases such as: Interactive Terminology for Europe (IATE), General Multilingual Environmental Thesaurus (GEMET), National Agricultural Library's Agricultural Thesaurus and Glossary, LusTRE (multilingual Thesaurus Framework), TAUS (The language data Network) etc.

Using the resources of such databases makes it possible to extend the content of terminology bases beyond the simple structure, containing only terms and their matches, to the use of extended information. In particular, the extension of each terminology entry with additional information such as domain, definition, synonyms, etc. (figure 9) contribute to increasing their informative value. They can be useful when such databases are used with automated translation systems. In this case, the terminology databases should be structured with appropriate fields for structuring such information.

In the list of links to external online resources generated by the interactive semantic network, there can also be resources containing additional information in the form of multimedia documents, electronic

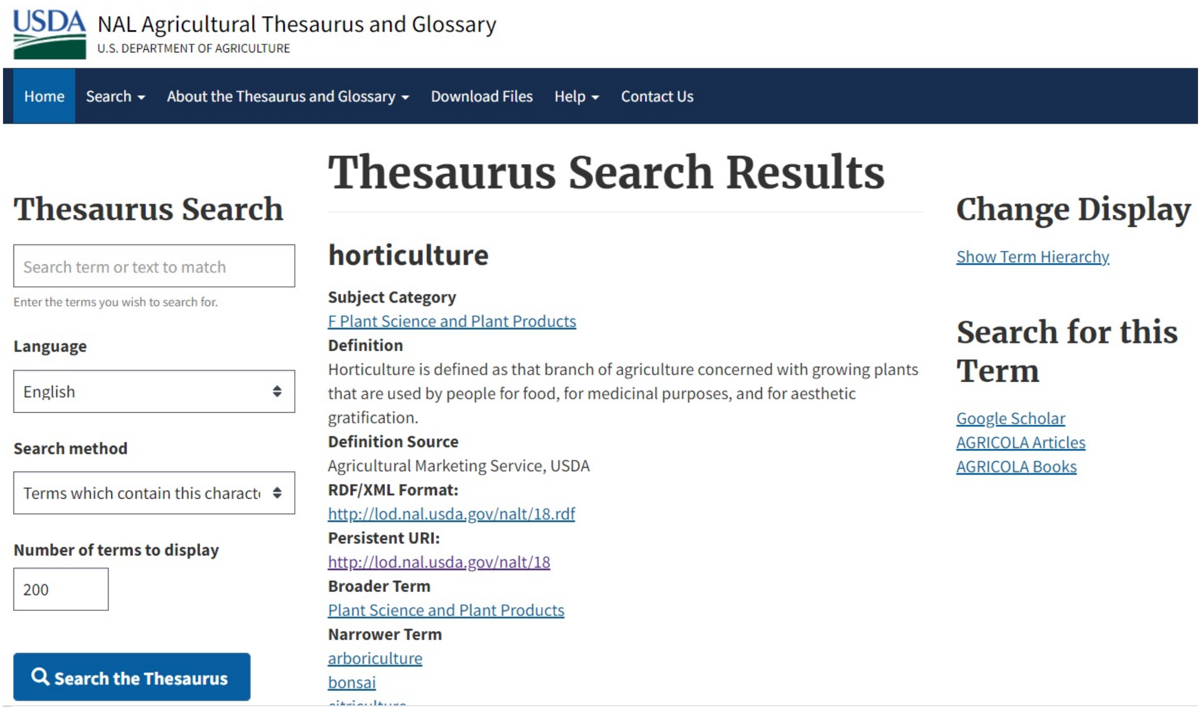

Figure 9: Structure of the presenting additional information on the term "horticulture" in the online resource "National Agricultural Library's Agricultural Thesaurus and Glossary".

documents, videos, books, images (figure 10). The value of such resources in autonomous learning lies not only in the selection of terminology for terminology bases, but more in the opportunity to understand in detail the nature of the term, the context of its use, and to form an idea of defining the object. With this technology of using semantic networks, students are able to learn more about the objects of a particular domain through a terminological apparatus without being overloaded with redundant information.

It is important to note that a developed interactive semantic network can be automatically converted into another format for displaying its elements, namely by hierarchical structure (figure 11). This format of presenting the network allows students to enhance their ability to explore the constructed network in terms of the interrelationship of its elements, in particular in the aspect of distinguishing more general concepts from highly specialised vocabulary.

According to the scheme of technology for selecting and structuring sector-specific terminology (figure 1), working in the Hierarchy of concepts representation of the interactive semantic network, students can also extract terms from it and add them to the terminology base, but without the possibility of obtaining additional information from the online resources.

3.4 Experimental Testing of the Use of Interactive Semantic Networks with External Terminology Resources in Translator Training

In order to identify the possibilities and ways of using interactive semantic networks with external terminology resources in the process of technological training of translators, we conducted a survey of students who were asked to experience them while they were in distance learning, which created a situation of autonomous learning. Thirty-eight students took part in this type of experiential learning, learning how to create terminology bases with a view to their future use in foreign language learning using mobile applications and mastering the use of computer-assisted translation systems. The questionnaire used for the survey contained 11 questions and provided two alternative answers to each question "Yes" or "No". The content of the questionnaire, as well as summarised quantitative data on the responses, are shown in table 2.

The responses to the first question show a positive effect on the learning of domain-specific terminology bases precisely in the aspect of term identification and selection technology in the lack of an in-depth understanding of the domain. This was made possible

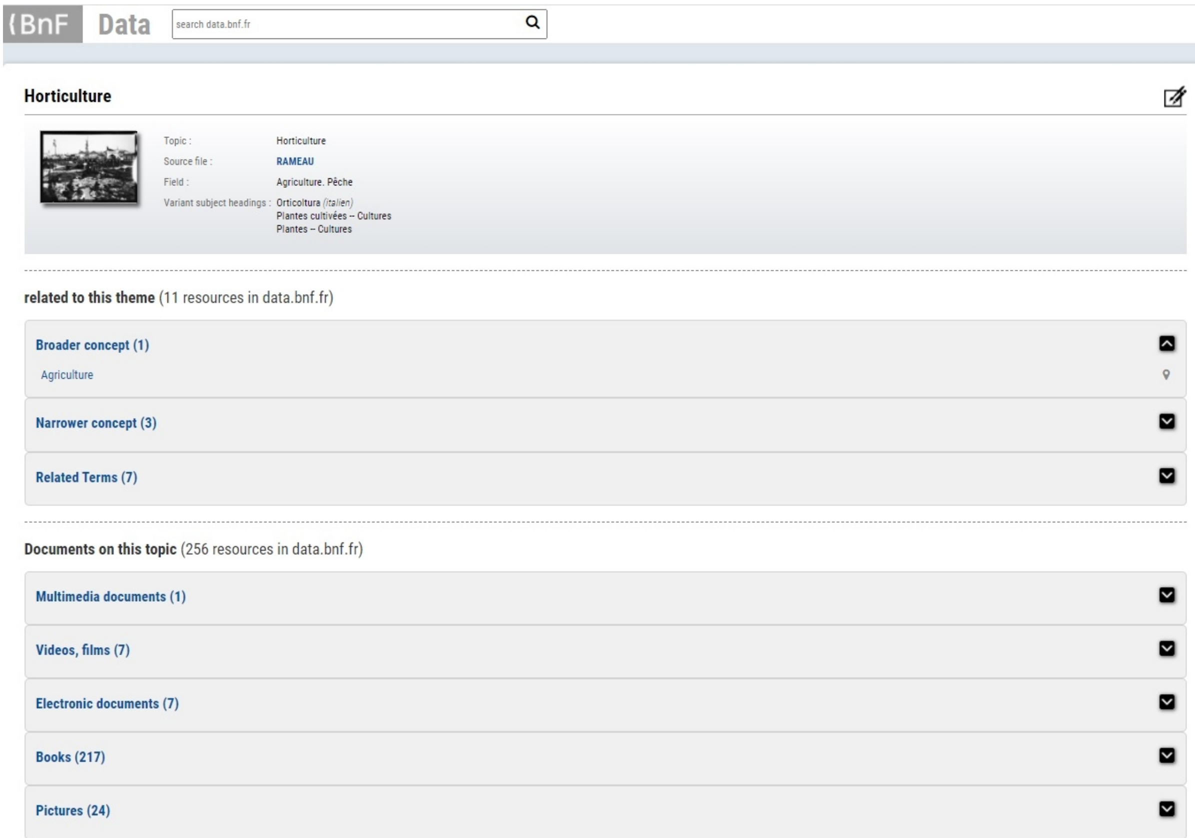

Figure 10: Structure of presentation of additional information about the term "horticulture" in online resources in the form of multimedia and electronic documents, videos, books, images.

Table 2: Results of a student questionnaire on the using interactive semantic networks.

Question	Response rate, %	
	Yes	No
Did the use of interactive semantic networks help you acquire the skills?	78.9	21.1
Has the use of interactive semantic networks contributed to the identification of related concepts and terms associated with a particular source term?	84.2	15.8
Has the visualised representation of the interactive semantic network contributed to an understanding of the integrity of a particular field in which you are not an expert?	81.6	18.4
Has the use of an interactive semantic network enabled you to understand better the range of components of a particular field in order to detail terminology in the right direction?	73.7	26.3
Does the presence of established relationships between the different hierarchical levels in the interactive semantic network help to outline a terminology dataset for input into the terminology database according to a certain logic?	76.3	23.7
Have you used MS Excel to create and complete your terminology database?	68.4	31.6
Have you used specialised CAT system modules to create and complete your terminology base?	21.1	78.9
Have you used the functionality of computer-assisted interpreting systems to create and complete your terminology base?	10.5	89.5
Did you fill your terminology database with additional information about the terms entered?	34.2	65.8
Have you used the specialised functions of interactive semantic networks to find more information about terms?	39.5	60.5
Have you needed to change the structure of your base in order to expand it?	13.2	86.8

Figure 11: Presentation of the created interactive semantic network with a hierarchical structure.

precisely using interactive semantic networks, as indicated by 78.9% of the students. A convincing proof of the effectiveness of interactive semantic networks was the responses to the second question of the questionnaire, as 84.2% of the students owe it to them to be able to identify related concepts and terms related to a certain source term. In other words, only 15.8% of the students could identify the lexical field of certain terms based on their own prior knowledge in a certain field.

The high number of affirmative responses to the third question (81.6%) is most likely due to the easier perception of information presented in visual form, which is generally an effective support for autonomous learning. In particular, the functionality of the interactive network to visually reproduce the terms of a particular area and the relationships between them contributed to an understanding of its integrity, even at an early stage of familiarity with it.

In addition, the use of an interactive semantic network to highlight terms of a particular domain allowed the students to detail the elements of the terminological system in the right direction quite effectively, as reported by 73.7%. This kind of activity is directly related to the filling of terminology bases and would have required significantly more time if done by other means.

The availability of an automated function in the interactive semantic network to generate relationships between terms across the four hierarchical levels proved to be an effective tool for 76.3% of the students, who indicated that it allowed them to identify the right set of terminology data to add to the terminology database aimed at solving a specific problem.

The responses to the questions on the software that the students used to create the terminology bases can be explained by the influence of two factors, namely the availability for use of a particular software product and the level of proficiency in it. The fact that 68.4% of students chose MS Excel to create and complete their terminology databases, confirms the fact that the programme is commonly available and the experience of using it is acquired not only in the study of specialised courses, but also in previous phases of mastering information technologies. However, it is important that 21.1% of the students created terminology bases using specialised modules designed to generate such bases when working with CAT systems. This indicates that a fairly large proportion of students have not only mastered these modules to a level which has enabled them to carry out such operations at a higher technological level, but are also aware of possible ways of obtaining and using them. It is important to note that although only 10.5% of students reported using the functionality of CAI systems to create and complete a terminology base, but due to the relatively low prevalence of such systems, this indicates that students valued certain aspects of these systems and gave them preference over others.

Judging by the responses to the question about finding and using additional information about terms, more than a third of the students used the available potential of interactive semantic networks for this purpose. This is an indication that some of the students were not only forming terminological bases, but also trying to understand the essence of the industry in more depth.

Analysing the high number of "No" responses (86.8%) regarding the need to modify the structure of the database in order to expand it, it can be stated that the students had sufficient experience in designing the structure of the terminology bases during the creation phase. This allowed them to predict the necessary fields for concentrating the information available in the semantic network about the term entered in such a way that, in the vast majority of cases, they met the requirements.

Overall, the results of the survey indicate the potential of interactive semantic networks in the process of technological training of translators, in particular for forming terminological bases for their further use in learning foreign languages and mastering automated translation systems.

Given the rather broad list of available external terminology resources related to interactive semantic networks, we also found out which of these resources the participants in the experiment preferred and why. The results of the students' choices are presented in table 3.

The reasons given by the students for their preference for a particular terminology resource were as follows:

- frequency of hyperlinks to this resource in the interactive semantic web,
- availability of more detailed information about this resource, obtained for familiarisation before the experiment,
- amount of terminology data presented in the database,

Table 3: Results of students' choice of external terminology resources.

Terminology resource name	Number of cases selected
UNESCO Thesaurus	17
IATE (Interactive Terminology for Europe)	11
The Agricultural Information Management Standards Portal (AIMS)	4
THESOZ Thesaurus	3
The Library of Congress Linked Data Service	3

- specific need for the terminology (e.g. a narrow domain).

In view of these student considerations, it should be noted that the small number of selections of some resources is precisely due to the specific terminological needs of the participants in the experiment and the corresponding orientation of their chosen base. Therefore, this in no way diminishes the value of any terminology resources. At the same time, we have concluded that attention needs to be paid to familiarising students in more detail with the large number of terminology resources available.

Overall, the results of the survey indicate the potential of interactive semantic networks in the process of technological training of translators, in particular for forming terminological bases for their further use in learning foreign languages and mastering automated translation systems. A separate value of this potential is external terminology resources linked to hyperlinks to interactive semantic networks.

4 CONCLUSIONS

In the process of technological training of translators, it has been found that it is advisable to implement elements of augmented reality in order to increase its efficiency. One of these elements can be interactive semantic networks, the technology of using which for the selection and structuring of industry terminology we have developed and tested in the conditions of autonomous learning. This technology allows:

- create a personalised, interactive semantic network to form a domain-specific terminology base,
- to develop a personalised, interactive semantic network along various lines, depending on the need for detailing and structuring domain-specific terminology,

- to select domain-specific terminology on the basis of its detailing, taking into account the types of hierarchical relationships of the interactive semantic network,
- to get more information about terms through the interactive use of external online resources, the links to which are automatically generated by the created semantic networks,
- to investigate the generated semantic networks in the aspect of distinguishing more general concepts from highly specialised vocabulary.

To structure the domain terminology selected on the basis of interactive semantic networks we defined the criteria of creation and filling terminological bases, with possibility of their further use for foreign language learning with mobile applications, mastering computer aided translation (CAT) systems, mastering computer aided interpretation (CAI). These criteria are universality, structurability, convertibility, extensibility.

The experimental use of the developed technology in the process of autonomous training of translators has shown a positive influence on their technological training, in particular in the aspect of the ability to define and select terms when there is no deep understanding of the domain, to detail elements of the terminological system in the right direction, to create terminological bases on the basis of selection and detailing of terms using interactive semantic networks.

In order to informational-terminological support of translators' training and activities and to enhance the use of interactive semantic networks, students were additionally familiarized with external terminological resources hyperlinked to the interactive semantic networks. Because of the experimental use of these resources in the process of building a customised interactive semantic network, it was found that they could meet the specific terminological needs of a translator.

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Program of Scientific Communication Development for Older Age Cohort Scholars

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Abstract: This paper is aimed at studying scientific communication as an integral part of a scientist's activity. The authors of this article analysed the development of informational technologies, which gave rise to a new paradigm of scientific communication Research 2.0. In the present study the analysis of research papers, describing models of scientific communication is done. The findings allow to define the structure and content of a comprehensive program of activities, connected to scientific communication in compliance with the Scientific Communication Life Cycle Model. In order to introduce a program, aimed at lowering scholars' emotional barriers in course of their professional interaction, a target group of older age cohort scholars in the fields of Mathematics and Methods for teaching Mathematics was chosen. The five-stage program of activities encouraged professional interaction of older age cohort scholars and introduced them to the methods of presenting research findings, elements of managing and mechanisms of applying the findings by means of Research 2.0. A constructive description of each module of the program is done, actions and a strategy are described, communication between participants and tutors through the platform Higher School Mathematics Teacher is arranged in this research. In order to assess the efficiency of implementing the program, Researcher Development Framework (RDF) is used. The study also presents the results of the activity of older age cohort researchers, who were engaged in the program. Following the change in the phase of the development of researchers' characteristic features and in compliance with RDF, a conclusion is made about a positive impact of the program on the development of scholars' interaction skills, the awareness of the procedures of actual professional conduct. The impact of the program on the scholar's emotional comfort in course of professional communication is proved as well.

1 INTRODUCTION

The scholars' effective performance is an attribute of sustainable development of the society. Factors, contributing to effective scientific activity. The development of intellectual and psychological qualities of a scientist, correlation between the process of thinking and creativity, phenomena of scientific discovery and genious were always of high interest for psychologists, educators, science historians. Numerous researches were done into specific attributes of a scientist, considering them from different theoretical perspectives. Attempts to identify personal qualities, which are central to the professional activity of a scientist, were made in classical research by Bogoyavlenskaya (Bogoyavlenskaya, 2021), Cox

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(Cox, 1926), Guilford (Guilford, 1959), Hollingworth (Hollingworth, 1926), Roe (Roe, 1961), (Terman, 1922), stated, that scientific communication (a complex of processes and mechanisms of transmitting scientific ideas inside a scientific community) is an integral part of a scientist's activity. Fast-paced development of modern science and the level of scientific achievements prompted scientists to search for new means of scientific communication.

The first aspect meant integrating skills of scientific communication into a basic set, which is identified by sociologists, employers and scientists (Brownell et al., 2013; Gray et al., 2005; West, 2012; Vlasenko et al., 2019) as critical for any scientist. Hence, courses in communication are introduced into curricula for postgraduate students in many countries, among which are the following: Great Britain (Quality Assurance Agency, 2019), the USA (American Association for the Advancement of Science, 2009, 2023), Canada (Ontario Universities Council on Quality Assurance, 2023) and Australia (Australian Qualifications Framework, 2014). In turn, in educational literature there are numerous papers (Levine, 2001; Mulnix, 2003; Gillen, 2006; Kozeracki et al., 2006; Jones et al., 2011; Cameron et al., 2020), which state, that such components of scientific communication as reading scientific papers by other scientists and promoting own scientific concepts can help budding researchers to develop core skills of a scientist and boost their confidence in scientific thinking. So, inspired by this idea, the authors in the present paper did an overall review of the history of communication in science. A paper by Vickery (Vickery, 2000) presents detailed means and attributes of oral and written communication in pre-digital era and shows a picture of prerequisites for modern methods of scientific communication. Special attention is given to the development of scientific communication in the 20th century. It's result from industrial research, occurrence of Big Data, computer networks and Internet communication. Early in the 21st century, Hurd (Hurd, 2000, 2004) offers a new paradigm of communication in science and shows that digital media offer new roles and functional opportunities to the participants. Thus, the development of information technologies changed the mode of scientific communication. The conventional system based on printing, which relied on a referred scientific journal as a key mechanism for presenting scientific findings, underwent transformation and turned into a system, dependent on digital means of transmitting information. As Hurd (Hurd, 2000) stated, scientometrics bases replaced conventional libraries and publications turned to electronic formats; communication in science evolves to the process, which counts more on on-line resources. This transition from printed to digital format changed the roles of all the participants of the scientific communication system. Transformation of contemporary science, namely its digital aspect, has a specific impact on older age cohort scholars. In many cases a well-established ethos of scientific activity contradicts new rules: lack of skills for searching digital information puts under threat relevance and timeliness of a research; absence of experience in disseminating scientific findings by means of digital resources obstructs partners' interest in those findings.

Though new policy of scientific communication, as well as academic rules, cannot be formally labelled as norms, they start dominating science universally. Non-compliance forces older age cohort scholars and researchers feel uneasy, to adapt, to find ways of internal and external solutions to the conflict. Recently the issue of adapting older age cohort scholars to new rules of scientific communication has become a pressing one.

1.1 Analysis of Scientific Papers

In educational literature, dedicated to academic education, scientific communication is considered from a point of view of positive impact on the process of developing scientist's core skills of a. In papers by Levine (Levine, 2001), Mulnix (Mulnix, 2003), a correlation between the skills level of processing scientific literature and efficient scientific activity is stated. Research by Gillen (Gillen, 2006) proves that though a majority of scientists are able to understand and absorb informative aspects of scientific articles, they often face difficulties interpreting the findings and analyzing them critically. As researchers might lack in strategies, necessary for building up credible criticism, then developing the skills of scientific communication becomes critical for engaging them into active scientific process. Research paper by Kozeracki et al. (Kozeracki et al., 2006) highlight, that designing courses, aimed at the critical analysis of articles in scientific journals and presentation of own research increases scientific literacy and self-confidence of researchers.

Researching the problem of developing a skill in scientific communication, Cameron et al. (Cameron et al., 2020) came to a conclusion, that behavior and attitude to scientific writing, speaking and presenting findings contribute to scientific identity. As the main factor of this process is its fulfillment in all the academic stages from a postgraduate student to a scientific advisor, it is indicative of a potential for engaging means of scientific communication for enhancing career perseverance. Research papers by Smyrnova-Trybulska et al. (Smyrnova-Trybulska et al., 2019), Kuzminska (Kuzminska, 2021), look into this issue. These works allow to state that introducing the scientific communication program into educational process ensures development and improvement in researchers such a skill as undertaking scientific communication; contributes to developing digital competencies and building up an image of a scientist, thus integrating into a single scientific community. The researchers confirmed that digital competencies concerning scientific competencies allow researchers to search for scientific and professional information more efficiently, to work with open systems of scientific research support, to analyse data and visualize them with the help of up-to-date informational computer technologies, to create and manage personal educational environment, a portfolio, etc.

Studying the problems, connected to developing professional skills in a scientist, experts emphasized the necessity to build models of scientific communication. One of the earliest models of scientific communication is the UNISIST model (UNESCO, 1971) (the United Nations Information System in Science and Technology), offered by the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the aim to improve scientific and technical communications. Taking into account ever-growing impact of the Internet technologies on communication between scientists, Søndergaard et al. (Søndergaard et al., 1972) presented an extended and revised UNISIST model. One more model by Garvey and Griffith (Garvey and Griffith, 1972) means to describe the communication process in science, but it lacks informational technologies support. In studies by Hurd (Hurd, 2000, 2004) this model is revised in order to consider the impact of digital technologies, such as electronic publications, self-publications and electronic libraries.

Kling et al. (Kling et al., 2003) offer a model of scientific collaboration STIN (Socio-Technical Interaction Network), which allows to understand better the character of professional relationships inside scientific communities. Swisher (Swisher, 2003) offer a linear step-by-step model which defines the stages that a new concept goes through in the system of scientific communication. In a cycle of research by Björk and Hedlund (Björk and Hedlund, 2003, 2004; Björk, 2007a,b) a model of SCLC (Scientific Communication Life Cycle) is presented. It describes the process of communication from the beginning of a research up to using the findings for the benefit of the society. This model covers both, formal and informal communication, but the main focus is on the life cycle of publications as well as readers' activity aimed at getting access to those publications. A systematized review of the characteristics of these and other models of scientific communication can be found in a study by Lugović et al. (Lugović et al., 2015). The scientists put focus on the development of technological innovations of Web 2.0 that resulted in occurrence of a new paradigm of scientific communication Research 2.0.

The analysis of papers by Luzón (Luzón, 2009), Ullmann et al. (Ullmann et al., 2010), Procter et al. (Procter et al., 2010), Koltay et al. (Koltay et al., 2015) shows, that the term "Scientific communication Research 2.0" determines new approaches in creating scientific knowledge, based on the notions of unity and collaboration. The scientists describe how generating and managing collective knowledge brings about new structures and systems of scientific communication. Kuzminska (Kuzminska, 2021) consider that scientific blogs, social networking sites for the collaboration of scientists ResearchGate and Academia.edu, applications for managing and sharing publications (Mendeley, Qiqqa, EndNote), services Open Peer Review, international and national bibliometric systems (in Ukraine – Open Ukrainian Citation Index, "Bibliometrics of Ukrainian science") and other make part of such structures. Though the main channel for publishing the research findings is still an article in a journal with a peer review, Research 2.0 provides wide opportunities for the improvement of research processes and can lead to changing the principles of research activity in future.

The research is dedicated to the development of a comprehensive program of activities, linked to scientific communication in compliance with SCLC Model and principles of Research 2.0. There is evidence among the objectives of the research, that introduction of the program in place into the process of the professional development of older age cohort scholars contributes to enhancing digital scientific communication skills and validates the role thereof as a catalyst for building up confidence and stabilizing scholars' personal comfort.

2 METHOD

2.1 Participants

During 2019-2020 the comprehensive program of activities, aimed at developing scholars' digital scientific communication skills was introduced into the educational process of professional development of older age cohort scholars at Ukrainian universities. 52

scholars aged 50+ participated in the experiment (figures 1, 2).

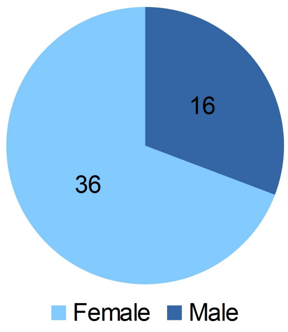

Figure 1: Gender sampling frame, % of the total number of participants.

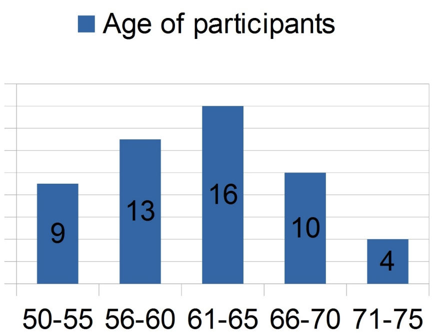

Figure 2: Age sampling frame, % of the total number of participants.

According to targeted selection, the sampling frame must comprise researchers working in the same area of knowledge. It was done, taking into account the specifics of the scientific communication system for different disciplines. The experiment was done at scientific schools, where the researchers work in the domain of Mathematics and Teaching Methods. The quality composition of the program participants in accordance with specialization and professional attributes is presented in figures 3–5.

Development of a comprehensive program of activities in scientific communication in compliance with SCLC Model. In the first stage of the program development with the help of the deductive content analysis of the research papers (Søndergaard et al., 1972; Kling et al., 2003; Swisher, 2003; Björk, 2007a,b), dedicated to the models of scientific communication, the authors of this study defined the structure of the program and the key aspects of the content, designed to provide its compliance with the paradigm of Research 2.0. Compared to other models, the SCLC Model Björk (Björk, 2007a,b) is more comprehensive, detailed and contains more constituents that reflect activity, findings, elements of governance,

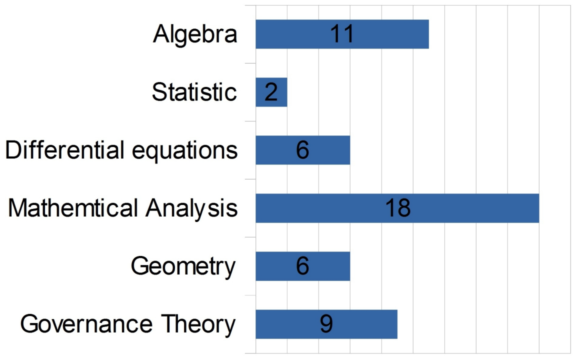

Figure 3: Specialisation of the participants of the experiment, % of the total number.

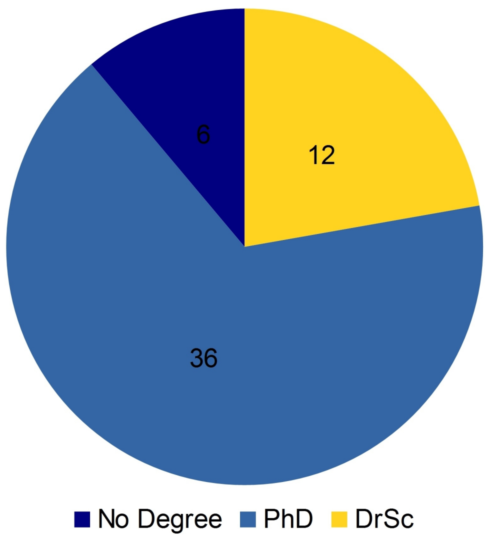

Figure 4: Qualitative composition of the participants of the experiment in accordance with professional attributes, % of the total number.

mechanisms, etc. when developing the program of activities, connected to scientific communication, the SCLC Model serves as a roadmap for positioning all the components of the system of scientific collaboration as a global interconnected informational system. The developed comprehensive program consists of five stages of different duration from 0.5 to 2 credits ECTS, each of them contains 2–5 modules (tables 1, 2).

In the second stage, when doing analysis concerning the nature of Research 2.0, Koltay et al. (Koltay et al., 2015), Sheombar (Sheombar, 2019) gave a constructive description of activities and projects, as well as actions and strategies which contribute to developing scientific research skills in young scientists and which are based on the principles of openness, collaboration, conversation and connectedness.

Communication between the program participants and tutors took place on the platform Higher School

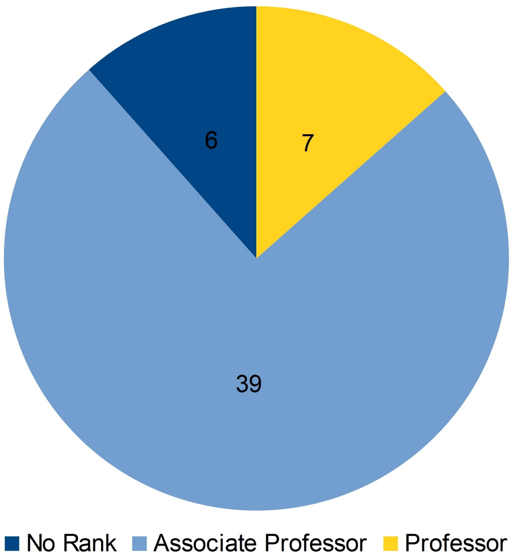

Figure 5: Qualitative composition of the participants of the experiment in accordance with professional attributes, % of the total number.

Mathematics Teacher (Vlasenko and Sitak, 2023). Forum, on-line chatting and electronic mailing were chosen as the means of communication. Through their personal accounts the participants got access to the description of events, activities and strategies for each of the stages of the program, listed below.

2.2 Developing Topics for the Informational Environment

Most of the older age cohort researchers have no proper information basis regarding digital scientific communication, which is connected to the fact that digital scientific communication is a rather specific activity, avoided by older people in everyday life. As a rule, even scholars, who are active in doing scientific research, have fragmented knowledge of scientific communication basics. The main goal of this stage is developing in researchers a systematic knowledge concerning scientific communication, its key components, new trends and technologies, basics of efficient work with information, research data management. Watching video-lectures allows the participants to understand how digital scientific communication happens nowadays, how open access, open science and licenses, research data management impact the life cycle of a research. Participation in seminars, trainings means applying best updated practices and search techniques in order to work with scientific sources, to use universal and specialized information resources, new web-applications for various types of research, etc.

Table 1: The structure of the comprehensive program of activities, concerning scientific communication in compliance with the SCLC Model. Stages 1, 2.

Creating the information environment	
Activities concerning scientific communication	Content of the activity
An on-line course in scientific communication	Watching video lectures, chatting
Practical assignments	Doing practical assignments on searching information, quoting, preparing presentations, designing a manuscript, etc.
Presentation of University programs, events by the Ministry for Education and Science and businesses, aimed at supporting scientists	Electronic mailing of video materials and samples of documents; meetings with management, representatives of the Ministry for Education and Science representatives of business, program alumni
Doing the research	
Searching for ideas, defining a topic for research	Getting acquainted with social networking web-sites for scientists; creating profiles and micro-networks.
Searching the information resources	Searching publications in databases, archives, bookmarks, getting (saving) the publications, paid and free subscriptions
Reading publications	Reading summaries, full texts
Doing the research itself	Communication in collaborations
Integrating the results into the context of a general problem	Work with references, quoting

The authors of the present study believe, that in the informational environment, dedicated to the problem of digital scientific communication, it makes sound sense to highlight the following topics:

1. General overview of key components and strategies of digital scientific communication, usage of new web-applications in all the stages of the research life cycle, especially when searching for information and spreading the findings. Social networks for scientists ResearchGate, Mendeley, Academia.edu.
2. Scientific information: main types of sources.

Table 2: The structure of the comprehensive program of activities, concerning scientific communication in compliance with the SCLC Model. Stages 3–5.

Presenting the findings	
Non-formal communication	Seminars, conferences, mailing colleagues, microblogs, subscriptions to the projects in social networking web-sites
Publication in a reviewed edition	Preparing a manuscript, searching publishing houses. Designing the manuscript, communication with an editor and a reviewer
Promoting sharing and search	Promotion in blogs, social networks for scientists, open libraries, University resources
Tracking the publication	Indexing, bookmarks, tags
Secondary publications	Monographs, publishing in mass media
Applying the findings	
Promoting the improvement of the standard of living (application in industry, IT, healthcare)	Getting acquainted with the process of standartisation, filing an author certificate/a patent
Education	Passing on knowledge through workshops, educational videos, one-to-one counselling
Feedback for science	Forecasting benefits for the future of science
Contests for scientists, grant programs	
Contests for young scientists by Universities and the Ministry for Education and Science	Filing documents
Contests organized by businesses	Preparing presentations, participation in startup-schools

Specialized search systems such as Google Scholar, ScienceDirect, DOAJ and databases (Web of Science, Scopus, ZbMATH, MathSciNet), strategies for efficient search on the Internet.

3. Tools for monitoring new publications on the research problems. Subscriptions (Mendeley Groups, ResearchGate). Scientist's profiles (Scopus Author ID, ResearherID, ORCID iD).
4. A scientific article in a reviewed journal as the main element of scientific communication. Academic publishing houses (Springer, Elsevier, Pleiades Publishing).
5. Studying various aspects of scientific papers and publication strategies. OJS/PKP journal systems.
6. Management of bibliographic references (applications Mendeley Web Importer, EndNote, BibTex, Zotero).
7. Key notions of scientometrics. Scientometric indices Web of Science, Scopus, Google Scholar, Open Ukrainian Citation Index et al.
8. Copyright. Creative Commons license.
9. Archiving the research data. Repositories DOAJ and ArXiv.

When creating the informational environment, educational materials published on the platforms Prometheus (Prometheus, 2020), EdEra (EdEra, 2019, 2018), YouTube channel (PC Technology Center, 2019; Research HUB, 2019) and own materials by the authors of this study were used (Vlasenko et al., 2021). As an illustrative basis for scientometric and bibliometric techniques, a cycle of research by Rovenska and Novikov (Rovenska, 2019; Rovenska and Novikov, 2020; Novikov and Rovenska, 2017a,b) was used.

As the main indicator of the efficiency of scientific work is receiving accolades and financial rewards, the authors of this paper believe it pertinent to share relevant links to grant programs and awards with the program participants, announced by university management, businesses and professional unions. Receiving an accolade by a researcher can serve as one of the criteria of developed skills in digital scientific communication and core skills in general.

2.3 Doing Research

The first module, which is to define the topic, initiates the research. Review of ideas is the main function of this module. Social media offer useful communication channel for finding new ideas and communicating with the world. Participants register and create own accounts in the main social networks for scientists, such as ResearchGate, Academia.edu and Mendeley. According to a research by Nentwich and König (Nentwich and König, 2014) on academic use of social networks, the function "Profile" comes top among eight most popular functions of social media for scientific purposes. The profiles created can be filled with publications that the participants already have. In this module the participants also create micro-networks with the representatives of a certain scientific school. When the topic is defined, social networking sites for scientists become an additional tool for searching partners for collaboration.

Since the research process is based on the competencies, related to searching, assessing and applying information, the second module is dedicated to developing skills in searching information resources. The development of Web 2.0 brought about easy and accessible means of receiving information. Still, access to information does not necessarily mean expanding knowledge. Research 2.0 resources allow to make changes in the methods of assessing information sources on their topic. The participants are offered to focus on the assessment of the accessible information, based on bibliometric indicators. The module gives an opportunity to master the specifics of work with both, interdisciplinary (Scopus, Web of Science, Google Scholar), and specialised (ZbMATH, MathSciNet) scientometric databases.

It is necessary to draw the participants' attention to the opportunities which subscriptions (both, free and paid) give as well as risks arising out of it. Not only using social media for private purposes, but also for academic ones requires preventive measures from spam and harassment from unscrupulous communities. Participants can also face challenges when receiving publications, for instance, if the publication is not accessible any more, or the publication was not digitalized. When such situations happen, it prompts finding alternative ways of receiving the publication, such as buying a hard copy, search in archives or among colleagues.

The third module is dedicated to the development of practical skills in reading publications. The participants work on the constructive methods for reviewing the content of a publication with the help of key words, summaries, reading full texts, creating bookmarks, comments and annotations in Mendeley, applications for tracking quotes EndNote, BibTex.

When doing own research, the need for expanding own scientific horizon through communication with single-minded scientists increases, and most of the older age cohort scholars scientists enhance live communication etiquette. However, the challenges of the time require mastering on-line modes of communication with colleagues. According to a recent research by the Ministry for Education and Science of Ukraine (MESU, 2020) the most common reasons that hamper the development of scientific communication among scientists are: psychological unpreparedness for new types, modes of scientific communications and underdeveloped network of personal connections and communication channels. For remote communication the participants are recommended (but not limited by) such means of communication as Zoom, e-mail, Viber, Facebook (Messenger), Telegram, Skype, WhatsApp. As the survey shows (MESU, 2020), these channels are the most widely used in professional communication among scientists.

The final module of this stage is dedicated to improving the practical skills in working with reference-messengers, such as Mendeley Web (functions Web Importer and Citation Plugin), EndNote (adding information about sources from Web of Science, from on-line libraries, websites of publishing houses, and own notes), Zotero and others.

2.4 Presentation of Findings

This stage comprises five modules, which are – informal communication, presentation of findings through publishing, sharing promotion, tracking and secondary publications. The main difference from communication within the first module is that an author has a complete control over those who become the receivers of the information about the findings. On top of conventional presentations at conferences, seminars, the participants also learn about informal communication channels which are accessible tools of Research 2.0, such as blogs, subscriptions for ResearchGate projects, tags and opportunities for joint work in Mendeley Groups. Using the resources of Research 2.0 increases the efficiency of scientific communication, as researchers receive a feedback (on-line comments) much earlier and can fix the errors, complete the article and send it for publication.

In the module, dedicated to presenting the findings through publication in a reviewed journal, the participants can learn about the proper formats of articles for academic publishing houses Springer, Elsevier, Pleiades Publishing (mastering AMS-LaTex is an obligatory prerequisite) and acquire the practices for communication with the editor and reviewers through Open Journal Systems. An important nuance of the module is that some participants experience communication with predaceous publishing houses and for the first time face academic plagiarism. Taking it into account, maintaining academic reputation becomes profoundly valuable.

Modules, dedicated to sharing, promoting search and tracking publications, encompass the whole spectrum of practical skills in using bibliometric means – from identifying the indices universal decimal classification (UDC) and Mathematics Subject Classification (MSC) to using descriptors (DOI, ISSN).

The basics of information search and scientometrics, which the participants learnt during lectures and seminars in the first stage, are now acquired through personal experience in using scientometric databases (Scopus, Web of Science, Google Scholar), archives (ArXiv), etc. The participants are recommended not only to create formal profiles Scopus Author ID, ResearcherID and ORCID, but also de-facto analysis of absolute and normalized indicators, namely h-index and impact-factor of the publication.

The final module of this stage concerns secondary publications of scientific findings. This module significantly falls behind the previous ones and is optional. Secondary publications make sense in terms of sustainable impact on the development of science, when they give other scientists or external experts an opportunity to learn more about the findings in solving a certain problem. Among the communication norms, which are also mastered in this stage are copyright for scientists, open access and research ethics.

2.5 Application of Findings

This stage highlights practical skills in transferring scientific knowledge in several directions in parallel – improving the quality of life through its application in industry, IT, healthcare; integration of the knowledge into education and learning; feedback in science. The participants are recommended to select a direction of application, depending on the kind of scientific research. Thus, in order to commercialize scientific knowledge, the participants are advised to register a patent or an author certificate. Application in education and learning means running classes and workshops for students, one-to-one counselling, creating educational videos, etc.

The specifics of scientific communication in Mathematics is to use the findings broadly in order to amass theoretical knowledge. The research findings, as well as the methods of receiving them can be used for further studying various issues of Mathematics, including Applied Mathematics, prognostication, hypothesizing and other. Secondary publications, for instance sections of monographs or a popular science article allow the participants to acquire the skills in digital communication with the audience outside their own scientific school.

2.6 Contests for Scientists and Participation in Grant Programs

According to Björk (Björk, 2007b), the global system of scientific communications performs two functions – the first is to pass on scientific knowledge, the second is to contribute to decision-making in supporting research from the side of University leadership, business, non-governmental organisations. This stage must be introduces into the program, as lack of understanding concerning the mechanisms of grant participation is a strong communication barrier in the general system of science and innovations support. Participation in contests is not obligatory, but is recommended to all the program participants. This stage allows to develop skills in preparing contest papers, presentations, startup projects.

2.7 Method of Assessing the Findings During the experiment

The assessment of the program implementation was done with the help of Domain B (Personal effectiveness), Domain D (Engagement, influence and impact) of Researcher Development Framework (RDF) (The Careers Research and Advisory Centre (CRAC) Limited, 2023), offered by a world leader in supporting professional development of researchers, the Research and Advisory Centre “Vitae”, Cambridge, UK. RDF is made of the empiric data, collected through surveying experts in order to identify characteristic features of researchers, defined in RDF as descriptors. Descriptors are structured into four domains and twelve subdomains that cover knowledge, intellectual abilities, methods and professional standards of doing a research, as well as personal qualities, knowledge and ability to ensure efficient collaboration with others, and a wider impact of research (figure 6). Each of sixty three descriptors contains three to five phases, that are separate development stages or the efficiency level within the descriptor (The Careers Research and Advisory Centre (CRAC) Limited, 2023).

2.8 Findings

In this work, we offer an overview of the developed program and the results of its implementation. Our study does not involve in-depth statistical analysis of the obtained results.

The comprehensive program of the activities, which is aimed at developing core skills of a scientist with the help of scientific communication means, was introduced into the process of advanced training of scientists in 9 scientific schools of and Teaching Methods of Donbas State Engineering Academy, Kryvyi Rih State Pedagogical University, Sumy State Pedagogical University, Berdiansk State Pedagogical University.

The assessment of the results of the program implementation was done through surveying partici-

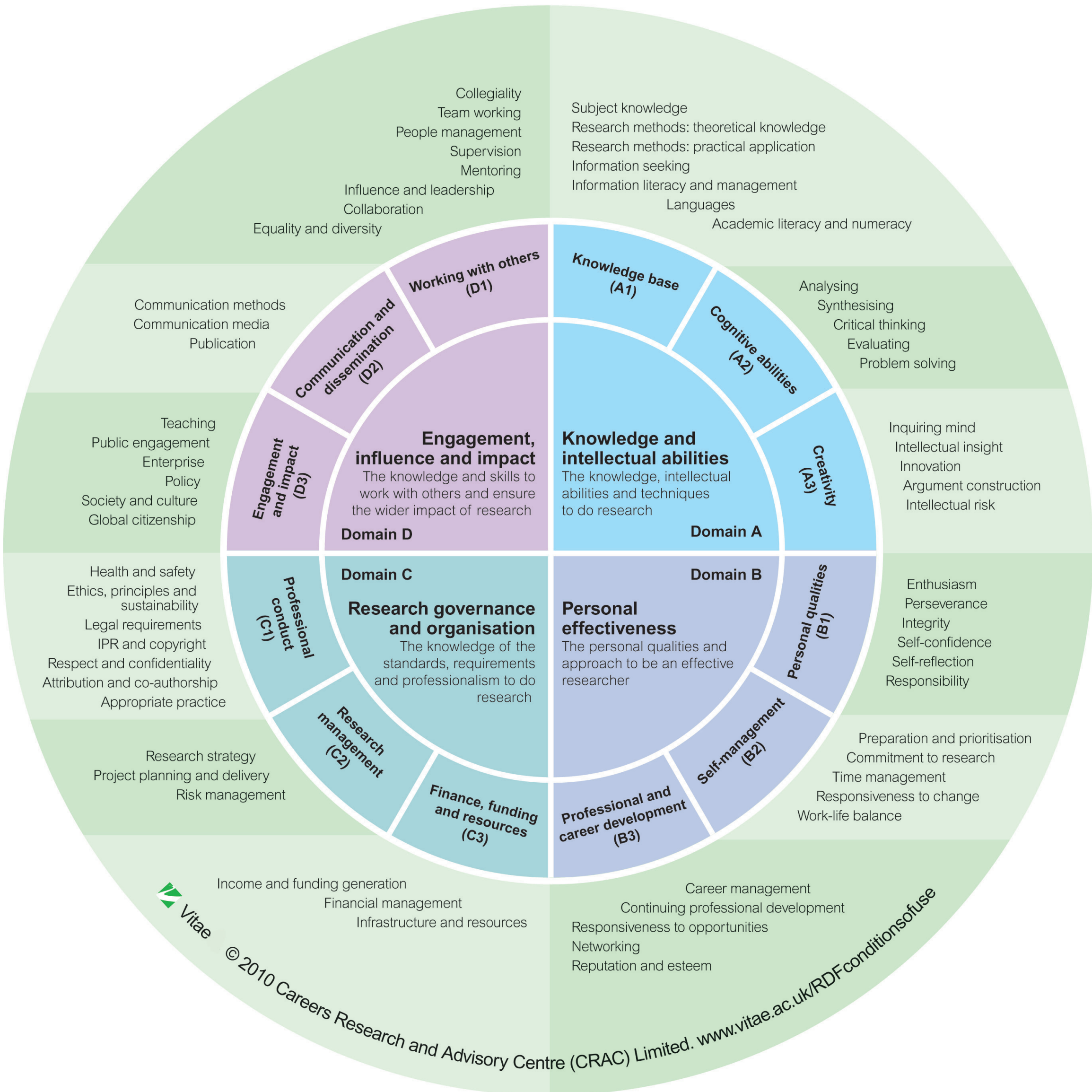

Figure 6: The Researcher Development Framework by Vitae (The Careers Research and Advisory Centre (CRAC) Limited, 2023).

pants. Every participant of the program was assessed by at least 2 stakeholders through an on-line surveying. The goal of the survey was to identify the skills level in the participant attributes that personal communication skills that prompt the progress in scientific activity and academic career.

The data concerning changes in the descriptor development or the level of efficiency within the descriptor in the program participants can be found in tables 3, 4.

Positive results of implementing the program (marked as "+") are confirmed by deepening of the development phase or the level of efficiency within 4 descriptors in 30–50% of the participants, 11 descriptors in 50–75% of the participants and 14 descriptors in more than 75% of the participants of the program. The program has the most significant impact on the development of career skills, necessary for responsibility and control over professional development; awareness of the standards, requirements and procedures of professional behavior; skills, necessary for interaction, management and influence on academic, social, cultural and economic context.

In course of detecting communication competence it is appropriate to test emotional difficulties in professional communication. For this reason, a method

Table 3: Changing the development phase of a descriptor or the level of efficiency inside a descriptor in the program participants (Domain: Personal effectiveness).

Descriptor/Subdomain	in 30-50% of the participants	in 50-75% of the participants	in more than 75% of the participants
Personal qualities			
Enthusiasm			+
Perseverance		+	
Integrity		+	
Self-confidence			+
Self-reflection	+		
Responsibility			
Self management			
Preparation and prioritisation			
Commitment to research			+
Time management		+	
Responsiveness to change			+
Work-life balance	+		
Professional and career development			
Career management			+
Continuing professional development			+
Responsiveness to opportunities		+	
Networking			+
Reputation and esteem		+	

"Diagnostics of emotional barriers" (Fetiskin et al., 2002, p. 166–167) was applied by the authors of this paper. After doing the course, based on the program in place, a number of persons who define their emotions as 'hindering interaction with partners' (N_1) or 'complicating establishing contacts' (N_2) decreased, as it was anticipated. The diagnostics findings are presented on figure 7.

Forming such skills as financial management of research, understanding of academic and commercial systems of financial support becomes an additional factor for the impact that the program has, which is proved by the data concerning the program participants' involvement in contests and grant programs for researchers (figure 8).

3 DISCUSSION

In connection with the present research it makes sound sense to mention the papers, dedicated to defining skills of researchers that characterize them as scientists in a volatile informational environment. Davies et al. (Davies et al., 2011) define a set of central skills of an efficient researcher that are linked to the adaptive nature of thinking. These authors consider that scientists do cognitive activity filtering information according to its importance, using various

Table 4: Changing the development phase of a descriptor or the level of efficiency inside a descriptor in the program participants (Domain: Engagement, influence and impact).

Descriptor/Subdomain	in 30-50% of the participants	in 50-75% of the participants	in more than 75% of the participants
Working with others			
Collegiality			+
Team working		+	
People management		+	
Supervision			
Mentoring			+
Influence and leadership			+
Collaboration			+
Equality and diversity		+	
Communication and dissemination			
Communication methods			+
Communication media			+
Publication			+
Engagement and impact			
Teaching		+	
Public engagement		+	
Enterprise		+	
Policy			
Society and culture	+		
Global citizenship	+		

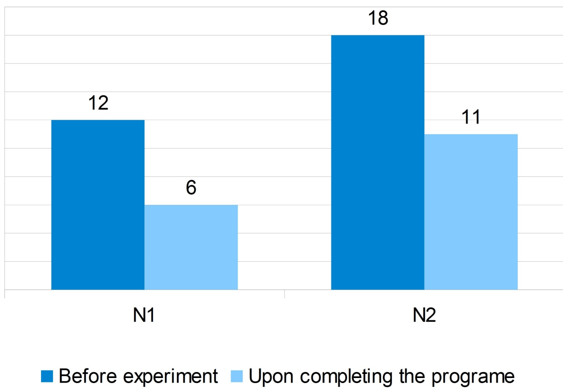

Figure 7: The findings of emotional barriers diagnostics of the program participants.

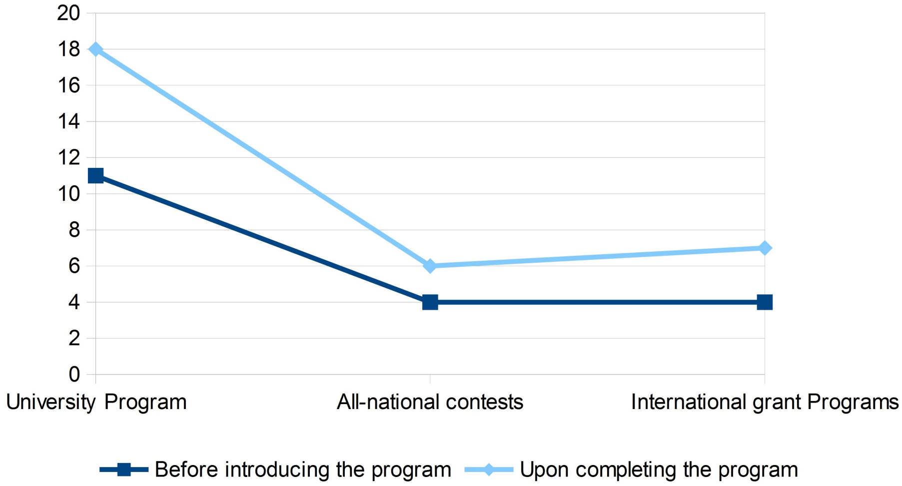

Figure 8: The number of co-participation in contests for researchers among the program participants.

tools and methods for it. Such an activity is defined by a certain type of thinking, which allows to use these tools and methods in the working processes, aimed at achieving the desired outcome. As Koltay et al. (Koltay et al., 2015) mention, researchers have to acquire skills, linked to innovative thinking and problem-solving. They also believe that the research process nowadays is defined by comprehending and justifying data, as the ability to find deeper meanings is more important than formal reading. Moreover, due to globalization and increased international cooperation a practical skill of working in social networks as well as cross-cultural communication skills are becoming more and more vital.

Comprehension, justifying, adaptive thinking, problem-solving and innovative activity depend on the information and define the circle of skills, necessary for a modern scientist. Contemporary resources of Research 2.0 have an impact on all the stages of the life cycle of a research, which are connected to information, starting with identifying an idea to spreading the results. Thus, Research 2.0 gives a wide spectrum of opportunities for personal growth of scientists, who nevertheless are reluctant to use these opportunities and excuse themselves by lack of time or experience. According to conclusions by the Social media and research workflow, Nicholas and Rowlands (Nicholas and Rowlands, 2011), Sheombar (Sheombar, 2019), Vlasenko et al. (Vlasenko et al., 2020b) only a few researchers make the most of all the tools that social media provide.

The authors of this paper believe that creating in researchers a quality experience of using Research 2.0 resources in professional communication could become a solution to this problem. As Mogull (Mogull, 2017) states, scientists often follow bad communication practices, reiterating typical mistakes. The most typical problems are: lack of ideas because the content is inadequate when the information is processed (inability to read summaries, incorrect application of search techniques); lack of clearly defined conclusions because of inability to integrate the findings into the structure of the general problem; poor choice of the edition for publications; ignoring the process of managing the publication, etc. By the present research the authors join such experts as Mogull (Mogull, 2017), Albert (Albert, 2000), Szklo (Szklo, 2006), Vlasenko et al. (Vlasenko et al., 2020a) who consider, that clear and transparent digital communication practices can make a difference to scientific thinking and improve the quality of scientific advancement. Thus, the suggested program of activities is based on acquiring by scientists some personal experience in research work through the usage of the means of digital communication.

The constituents of the program are aimed at improving core skills of scientists through their scientific communication. Each stage of their activity (from developing topics for the informational environment to presenting the research findings) is ensured by a program of activities, divided into several modules. Every module focuses on developing certain skills. The program means, that older age cohort scholars, who advance their qualifications, will master the basics of efficient work with information, research data management, and will get an insight into digital scientific communication, its components, new trends and technologies of scientific communication; they will learn how to use contemporary practices and search techniques when working with information resources. The attendees also master constructive means of reviewing the publications content, acquire the skills of creating bookmarks, comments and summaries as well as communicating with editors and reviewers through open journal systems. Communication between the program participants and tutors takes place on the forum and via an on-line chat on the platform Higher School Mathematics Teacher (Vlasenko and Sitak, 2023).

This assessment showed that combining means of digital scientific communication on a certain system and ensuring personal experience in using those means contributes to the development of skills of older age cohort scholars, necessary for responsibility and control over professional development; awareness of the standards, requirements and procedures of professional behavior, necessary for the efficient research management; development of the skills, central to interaction, management and influence on academic, social, cultural and economic context, for instance, skills in financial management of research, understanding of academic and commercial system of the financial support of science.

4 CONCLUSIONS

Fast-paced development of informational environment, opportunities for researchers to communicate with their colleagues and the whole scientific world via the Internet ensured new opportunities in strengthening the global system of scientific communication. This fact made it possible for researchers to improve their core skills through promoting scientific knowledge ensuring mechanisms of participation in contests, interaction, collaboration, personal development and justified the timeliness of developing the program of activities in digital scientific communication for older age cohort scholars, based on the principles of Research 2.0.

Analysing the research into the models of scientific communication and considering the experience of mature scientists, working in Mathematics and Teaching Methods, allowed the authors of the present paper to define the structure of a comprehensive program of activities, aimed at developing skills in scientific communication and core skills of researchers, as well as to devise educational and methodological materials for its implementation in compliance with the SCLC Model, which ensures acquiring personal user experience through the practice of using the means of digital scientific communication.

The above mentioned program of activities was structured in accordance with certain stages of a researcher's activity and involves scientific communication through the means of digital learning environment. Among such activities were: on-line courses in scientific communication, presentations of programs for supporting researchers, workshops, educational videos, one-to-one counselling.

The above mentioned activities encouraged the researchers to seek sources of information and integrate their findings into the context of the overall problem by digital means; to introduce scholars to social networks; to create accounts and micro-networks; to maintain informal communication at seminars, conferences, e-mailing colleagues; to submit publications through open journal systems.

Hence, those activities were aimed at forming communication skills and presenting research findings remotely; practical skills in using bibliometric means; skills in applying contemporary practices and searching techniques when working with sources of information; practical skills in imparting scientific knowledge; skills in preparing start-up projects. All in all, the participants' activity was focused on developing systemic understanding of the nature of Research 2.0, which is based around openness, collaboration, conversation and connectedness.

The participants evaluated the findings of the program introduction by means of Researcher Development Framework, which allows to detect the level of formation of researchers' specific features in such domains as Personal effectiveness and Engagement, influence and impact. Positive changes in the stages of the descriptor development or changes in the level of its efficiency prove the efficiency of implementing the program and its influence on the development of researchers' skills in scientific communication. It was also confirmed, that the latter became a significant catalyst for lowering emotional barriers in course of professional interaction. The analysis of the information on the participants' involvement in contests and grant programs for scientists proved the skills level of in financial management of research and understanding of the system of financial support.

The findings of this research allow to develop trainings for developing specific communication skills of the academia. Courses, developed on the basis of such a program, contribute to quality and speedy increase in communication competence, thus, to a scholar's personal emotional comfort. Communication competence along with emotional comfort, in turn, become instrumental to scholars' competitiveness in the ever changing environment.

The authors of this paper consider a vector of further study to be the detection of scientific activity of the program participants and correcting the model in accordance with the specific features of age cohorts.

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Digital Transformation in Education: Model for Higher Educational Institutions

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Keywords: Digital Transformation, Digital Transformation Model, Digital Transformation of Education, Higher Educational Institution.

Abstract: The paper is devoted to the analysis of the digital transformation processes that are currently taking place in education. Present research based on previous authors research that considered the some aspects of development a generalized digital transformation model. The research analyzes approaches to developing a model of digital transformation of education. In addition, the ways of its implementation are determined. Besides that, the generalized model of digital transformation of education is proposed. According to the results of the research, the model of digital transformation of the higher education institution was developed. In response to the impact of digital transformation, it can be used as a roadmap for solutions for the digital transition to an innovative model for the functioning of the modern university.

1 INTRODUCTION

The digital technologies have become a part of our modern everyday life: artificial intelligence, robotics, IoT, blockchain and 3D technologies, etc.

The use of digital technologies is transforming business models, resulting in new products and services; the format of works is changing (outsourcing, online platforms, improved automation, robotics, etc.). Real-time work with digital data fundamentally changes the ways of management, production, sale and use of products (Vishnevsky et al., 2020).

The report of the consulting company Accenture (for 2017) identifies five new digital technologies that can transform global economic development (Ford and Lobo, 2017): Internet of Things (IoT), Artificial Intelligence (AI), Blockchain, Big Data, Robotic Process Automation (RPA).

Thus, modern digital technologies, services and systems are extremely important for social development. Their introduction into the activities of enterprises and organizations, engineering and technology, production and non-production processes allows to expand the range of goods and services, improve their quality and compliance with consumer demand, increase productivity and form new value-added chains. This will ensure growth and creation of jobs in all economy sectors (from the smallest traditional enterprises to the latest high-tech industries).

However, the education system is failing behind the general state of digital transformation in society. In our opinion, the main problem is the lack of understanding by the participants of the educational process of the institutions (higher, secondary and vocational) what is the difference between the use of digital technologies and innovations provided by the transformational changes that digital technologies bring to the educational process, and comprehension of concepts, structure, required and sufficient conditions and processes of digital transformation in general and in education in particular.

Paper goals. The purpose of this research is to analyze and develop model of digital transformation model of education and digital transformation model of higher education institution.

2 RESEARCH METHODS

The authors have used the following research methods and tools for the investigation (2021-2022).

Quantitative methods: 1) scientific monographs;

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2) research papers; 3) study and analysis of documents about digital transformation; 4) analysis approaches for development digital transformation model, also in educational field; 5) (online) meetings, (video) conferences, seminars, workshops, etc.

Qualitative methods: survey and interview of the Ukrainian educators to determine their awareness about digital transformation of education.

3 THEORETICAL BACKGROUND

Digital transformation is the use of digital technologies (Negroponte, 1995) to fundamentally increase the productivity and value of enterprises (Westerman et al., 2014). Now this is the focus of managers and employees of actively competing industries around the world. Digital transformation is due to the use of rapidly developing digital technologies and their accelerated impact on society. Such transformation takes into account the changes that have already happened, happening and will happen in the future (i-SCOOP, 2021). The processes of digital transformation are affecting many areas of human activity. They are felt in all areas where there is mechanization and automation of data processing.

Figure 1 shows the areas in which fundamental changes are expected due to the digital transformation.

Digital transformation (DT) is the result of digitisation and digitalization of economies and societies. DT is an ongoing process. The introduction of digital technologies creates both new opportunities and new challenges.

Consider the challenges posed by a process, digital transformation, which is a complex phenomenon of different development. These challenges are related to the following issues:

- which areas are most affected by the digital transformation;
- how the digital transformation affects the labor market, training of future professionals, and social life in general;
- what are the ways to implement digital transformation for different industries;
- what steps need to be taken for the digital transformation of companies, production, ecosystem, and a particular industry as a whole;
- what changes in educational systems need to be made to adapt people and accelerate their inclusion into the processes of digital transformation.

One of the key issues for the implementation of digital transformation is changes in the way of thinking and requirements for the competencies of workers in the industry. First of all, it is connected with people's understanding of digital transformation processes and with their ability to use digital technologies effectively.

Our previous research focused on development of the digital transformation model (Morze and Strutynska, 2021). Based on the analysis of the considered researches (Pawlowski, 2019; Mergel et al., 2019; Bumann and Peter, 2019; Rof et al., 2020; Muluk, 2016; Patton and Santos, 2018; Wildan Zulfikar et al., 2018; Nguyen, 2018), the authors of this paper proposed a general model of digital transformation (figure 2).

The main components of this model are:

1. The reasons that lead to the need in digital transformation of the area/industry (the impact of digital technologies, new services, new requirements to life in a digital society, etc.).
2. The use of digital technologies to change business processes in the industry to increase its efficiency.
3. Preparation of workers, employers, the population as a whole for life in new socio-economic conditions (change of culture, way of thinking, abilities, skills, and mutual relations) and development of their digital competences.
4. Effective use of existing data, including the use of modern tools for their analysis with elements of Artificial Intelligence and Big Data.
5. The main results of digital transformation include new products, services, policies, markets, environment and development of the digital society as a whole.

4 DIGITAL TRANSFORMATION IN EDUCATION: IMPLEMENTATION APPROACHES

In the conditions of intensive development of digital technologies, digitalization, digital transformation of many branches of human activity, fast change of professions demanded in the labor market and, accordingly, professional requirements to competences of experts, educational activity needs updating of the maintenance and methods of training, search for innovative forms of training, expanding access to educational resources, and the implementation of learning

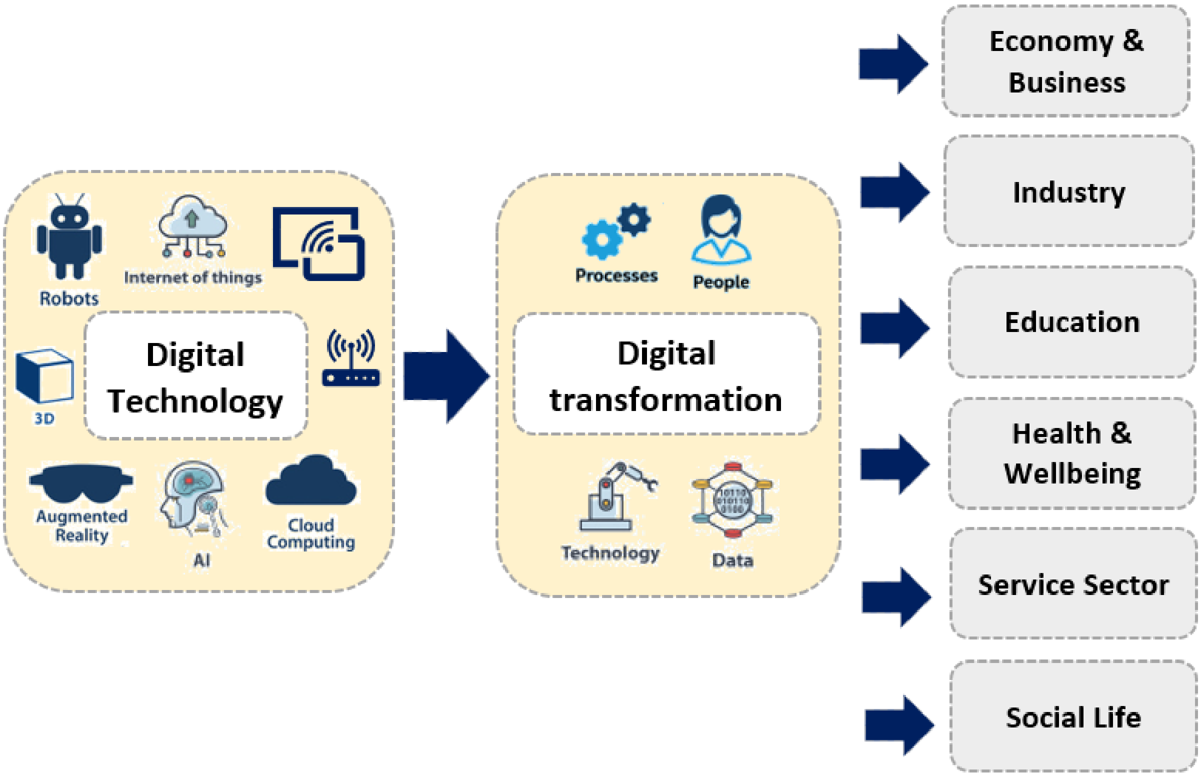

Figure 1: Areas in which fundamental changes take place due to the digital transformation (Morze and Strutynska, 2021)

opportunities without space- and time-based restrictions, the introduction of new approaches to the organization of educational services in general. Thus, the digital transformation of education is an integral part of the processes taking place in society today.

Technologies play a key role not only in enabling new ways of teaching and learning, but also in new business models required to drive the very transformation that educational institutions are trying to effect (Patton and Santos, 2018).

Digital transformation means a qualitative increase in the effectiveness and productivity of educational activities through:

- changes (updates) of goals and content of educational activities;
- review and optimization of teaching materials and organizational solutions, tools and services used in educational activities;
- updating the organization and methods of educational activities, focusing on maximizing the potential of each student, the transition from learning and educating of all to learning and educating of everyone (personalized learning);
- review of traditional business processes, inclusion of all stakeholder into this work (especially students and teachers), the use of digital technologies to automate all types of information processing.

The analysis of scientific publications (see above) has shown that now the development of models of digital transformation is a topical, but underdeveloped issue. In the field of education, the research (Rof et al., 2020), devoted to this, analyzes in detail the impact of digital transformation on the business model of traditional universities. Another research (HolonIQ, 2020) describes an open-source capability framework for higher education (4 dimensions, 16 domains and more than 70 capabilities). The Navitas Ventures research (Nav, 2017) is dedicated to identifying leaders and facilitators of change in the digital transformation of higher education, as well as the groups most affected by the digital transformation. Such studies show the need to develop a concept of digital transformation of education in Ukraine and develop an appropriate model.

According to the developed generalized model of digital transformation (figure 2), the model of digital transformation of education contains similar components taking into account the specifics of the industry.

Figure 3 shows the generalized model of digital transformation of education that is developed by the authors.

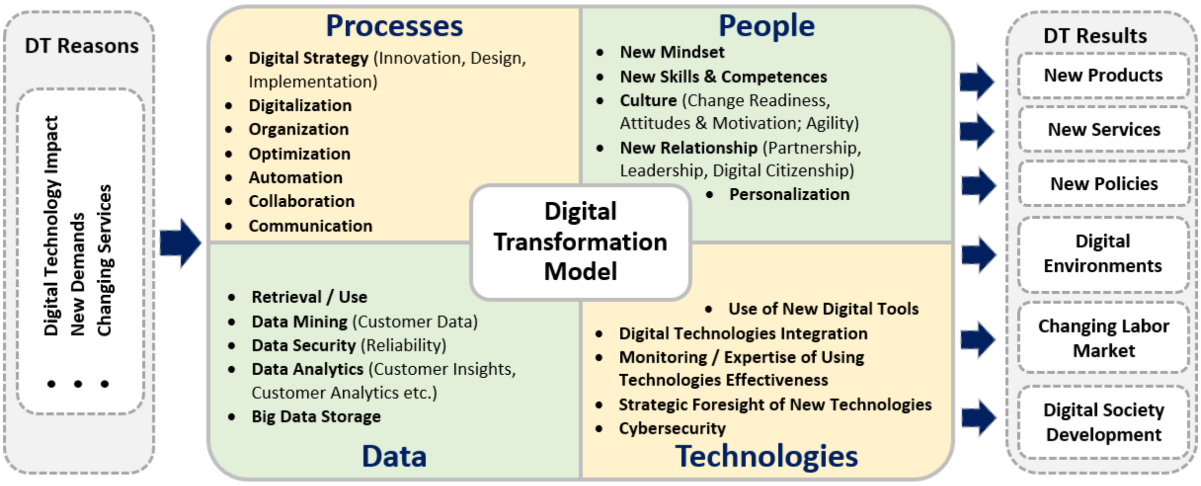

Figure 2: Digital Transformation Model (Morze and Strutynska, 2021).

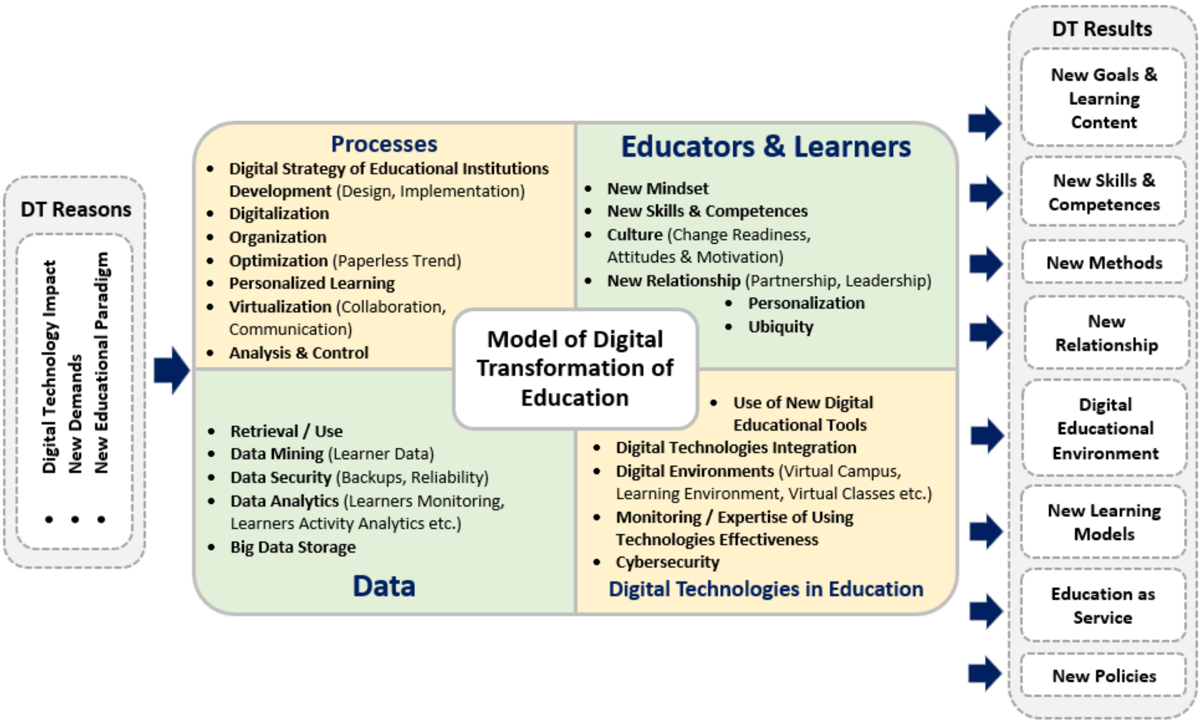

Figure 3: Model of Digital Transformation of Education

The proposed model takes into account the goals, features of the educational process and the conditions of using digital technologies to develop a modern educational ecosystem. The brief description is below.

Block **"Processes"**:

1. Digital Strategy of Educational Institutions Development (design, implementation).
2. Digitalization.
3. Organization.
4. Optimization (paperless trend).
5. Personalized Learning (Inquiry Based Learning, Project Based Learning).
6. Virtualization (virtual collaboration, virtual communication, virtual presence).
7. Analysis & Control.

Block **"People"** transforms into block **"Educators & Learners"**:

1. New Mindset (computational thinking, design mindset, emotional intelligence, social intelligence, etc.).

2. New Skills & Competences (digital skills & competences, soft skills, media literacy, transdisciplinary competences).
3. Culture (innovation culture, change readiness, attitudes & motivation for education; lifelong learning, non-formal learning, informal learning; agility).
4. New Relationship (partnership, leadership).
5. Personalization (personal learner profile, personal learning environment, personal educator profile, personal teaching environment, individual needs etc.).
6. Ubiquity.

Block **"Technologies"** transforms into block **"Digital Technologies in Education"**:

1. Use of New Digital Educational Tools (content management systems, learning content management systems, video conferencing tools, MOOCs, digital assessment tools, mobile learning tools & devices, Virtual Reality, Augmented Reality, Mixed Reality, 3D printing, robots in education, gamification, internet platforms for educational needs etc.)
2. Digital Technology Integration.
3. Digital Environments (virtual campus, learning environments, virtual spaces, virtual laboratories, virtual classes etc.).
4. Monitoring / Expertise of Using Technologies Effectiveness.
5. Cybersecurity.

Block **"Data"**:

1. Retrieval / Use.
2. Data Mining (learner data, data-driven decisions).
3. Data Security (backups, reliability).
4. Data Analytics (learners monitoring, learners activity analytics etc.)
5. Big Data Storage.

Thus, the areas of developing the digital transformation of education are following:

- transformation of goals, content and corresponding methods and forms of educational activities, which are associated with the penetration of new digital tools in various areas of human activity;
- educational institutions have to master new digital tools that increase the efficiency of the educational process;
- pupils/students should master new digital tools to increase the efficiency of their educational activities, and their digital competence needs developing;
- teachers should master:

(a) new digital tools to increase the efficiency of their professional activities;
(b) content, methods and forms of educational activities that are transformed due to the impact of new digital tools on various areas of human activity;
(c) new digital tools that increase the efficiency of the educational process, which is also changing;

- education leaders should master:

(a) new digital tools that increase the efficiency of their professional activities;
(b) digital tools that increase the efficiency of the organization of the changing educational process.

Higher education systems and institutions are particularly affected by digital transformation, which can enable new services and provide new opportunities for innovation and entrepreneurship. Higher education institutions (HEIs) embracing digital technologies can become drivers of growth and development for their own ecosystems (OECD and European Union, 2019).

Impact of digital transformation and recent research states that avoiding DT is not an option, and that HEIs need to adapt to technological changes if they want to stay relevant (Wildan Zulfikar et al., 2018).

Implementing new technologies is inevitable, that HEIs must obligatorily implement new technologies to be digitally relevant, and that the real challenge is the right execution of available digital plans and strategies, engaging and empowering students, staff, and the faculty in the process (Nguyen, 2018).

However, now the main challenges for universities today are:

- involvement of students into studying with the use of modern methods,
- providing teachers with more opportunities to fulfil their potential,
- restructuring of the educational process,
- optimization of university management and internal processes.

The key point is the digital transformation, not the creation of digital analogues of paper or other physical media and processes. To achieve this, it is necessary to restructure all the processes in the university, starting from the educational process and ending with the formation of new thinking of all its participants.

According to the models developed above (figures 2 and 3), we will consider the components that will change within the process of digital transformation of higher education institution (figure 4).

The main components of the proposed model include:

- educational environment (taking into account conditions of wide use of digital technologies there will be a virtualization of educational process, processes of communication, cooperation, and educational institution management);
- technology and tools used by teachers and students;
- conditions of teachers-students interaction within the digital environment; it is important to overcome the academic digital gap by developing professors' digital skills, as students are already highly motivated to use digital learning tools;
- management of university process and the internal process in general.

To determine the educators' awareness level in the field of digital transformation of education, as well as whether they are ready for these processes authors have conducted survey. The online survey was elaborated (in Ukrainian) using Google Forms. 134 Ukrainian educators have taken part in the present research (during December 2021). We guaranteed participants that only anonymized data would be shared. The survey contained information about processes of digital transformation of education. The gained data are presented in figures 5-9.

Q.*: Which of the following in your opinion causes the digital transformation of education?*

Survey responses on the causes the digital transformation of education are shown in figure 5 (multiple answers are possible, that is why the total responses can be more than 100%):

As we can see from figure 5, the largest group of respondents defines of the digital technology impact (79%) and new requirements for the competence of specialists (62%) as the main causes the digital transformation of education. At the same time, about 48% of educators suggest that emergence of new professions also impact on the digital transformation of education.

If compare these results with our previous research in (Morze and Strutynska, 2021) we can make conclusion about increasing awareness level of the Ukrainian educators about processes of digital transformation of education.

Q.*: What processes in your opinion need to be implemented for the digital transformation of education?*

Survey responses on processes need to be implemented for the digital transformation of education are shown in figure 6 (multiple answers are possible, that is why the total responses can be more than 100%).

Figure 6 are shown that the majority of respondents considered the most important steps for implementing the digital transformation of education are development of the digital educational environment (86%), development of the digital transformation strategy of an educational institution (83%) and digitalization of educational processes (66%).

At the same time, almost half of the respondents also understand the importance of taking other steps (introduction of paperless document management – 47%, introduction of paperless (electronic) document management – 36%, data analysis with the use of the digital technology – 36%). Thus, most educators correctly understand the processes that need to be implemented for the digital transformation of education.

Q.*: Which of the following in your opinion can result from the digital transformation of education?*

Survey responses on respondents opinion about results from the digital transformation of education are shown in figure 7 (multiple answers are possible, that is why the total responses can be more than 100%):

As we can see from figure 7, the largest group of respondents defines digital educational environment as the main result from the digital transformation of education (81%). Other survey answers also show that educators correctly appreciate the results of the digital transformation of education in general, which corresponds to the models developed by the authors in figure 3 and figure 4.

Q.*: What teachers need to do to implement an effective educational process under the conditions of the digital transformation in your opinion?*

Survey responses on respondents opinion about what teachers need to do to implement an effective educational process under the conditions of the digital transformation are shown in figure 8 (multiple answers are possible, that is why the total responses can be more than 100%).

Figure 8 are shown that the largest group of respondents believes that teachers need to master new digital tools (90%). At the same time, about 76% of educators suggest that teachers need to master new teaching aids. Thus, this means that educators understand that to implement the digital transformation of

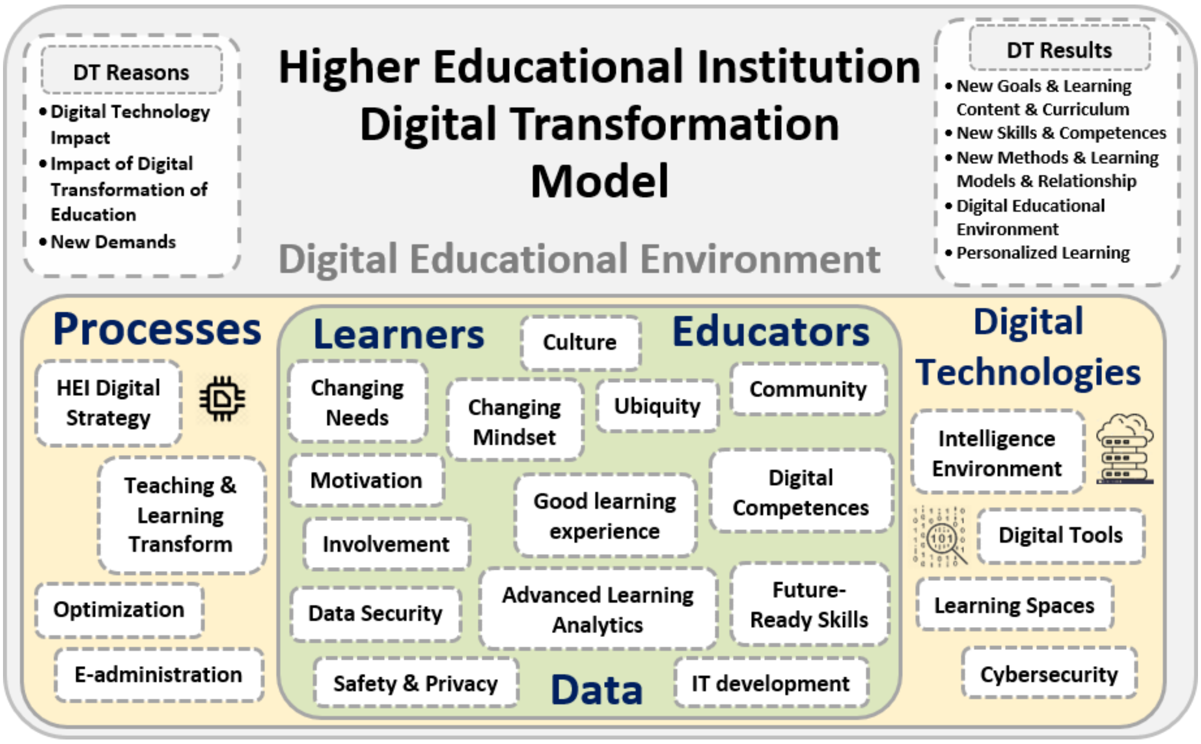

Figure 4: Higher Educational Institution Digital Transformation Model.

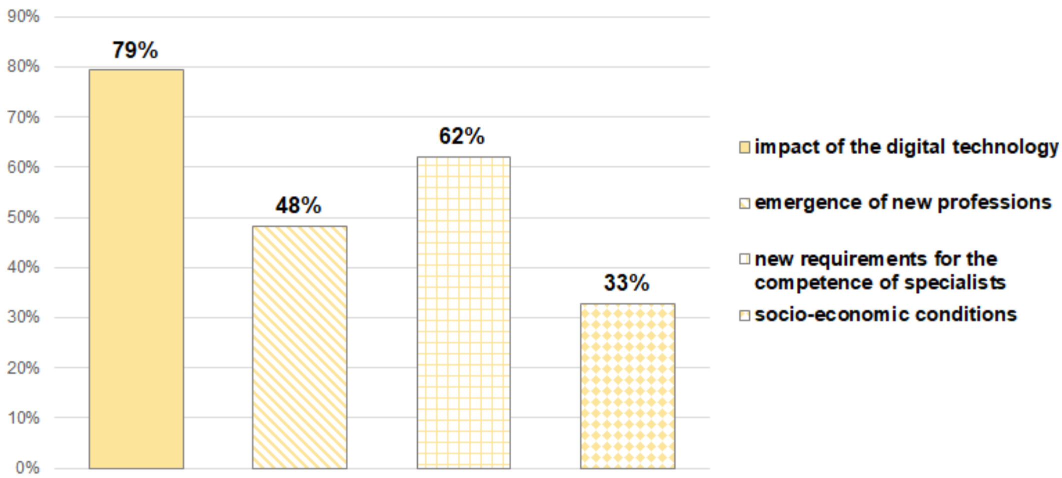

Figure 5: Survey responses on the causes the digital transformation of education.

education, first of all, it is necessary to increase digital competence.

Q.*: What students need to do for studying under the conditions of the digital transformation in your opinion?*

Survey responses on respondents opinion about what what students need to do for studying under the conditions of the digital transformation are shown in figure 9 (multiple answers are possible, that is why the total responses can be more than 100%).

Figure 9 are shown the very similar results as answers in previous question (figure 8). That is the largest group of respondents believes that students need to master new digital tools (78%). Also 71% of educators suggest that students need to change own motivation for e-learning.

Thus, an envisioned model in response to the impact of digital transformation (figure 4) can be used as a roadmap for solutions for the digital transition to an innovative model for the functioning of the modern university.

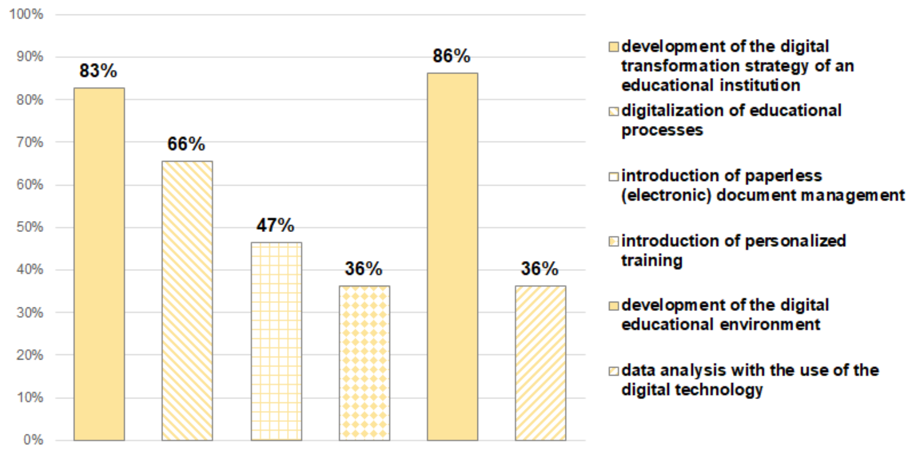

Figure 6: Survey responses on processes need to be implemented for the digital transformation of education.

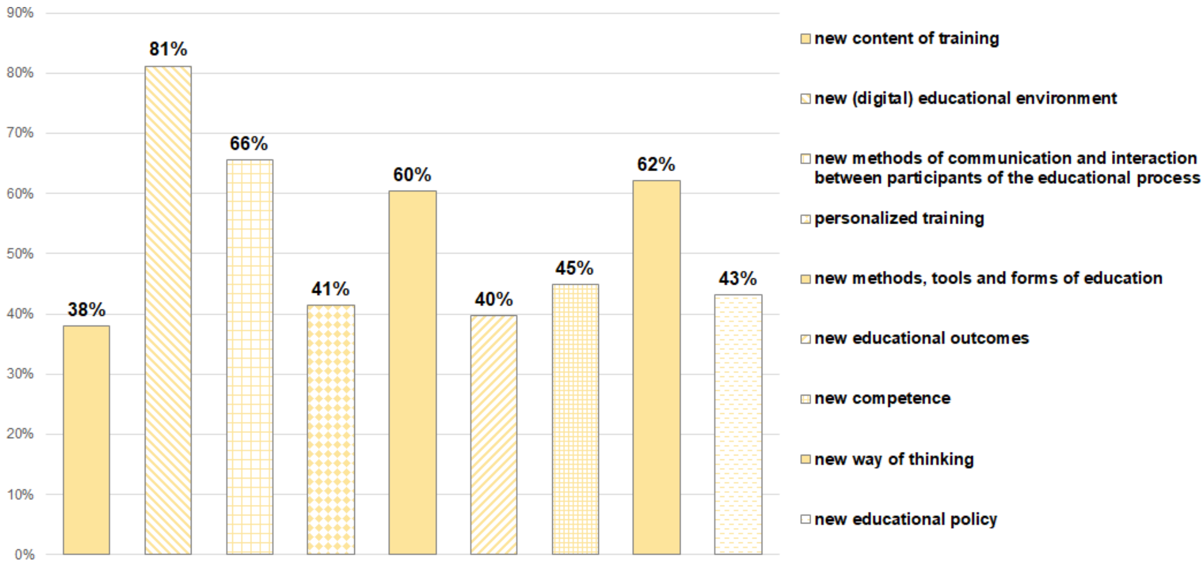

Figure 7: Survey responses on respondents opinion about results from the digital transformation of education.

5 CONCLUSIONS

Thus, the result of the digital transformation of education is:

- creating a modern digital educational environment to provide equal access to quality educational services and resources anywhere, anytime and in order to improve the quality of education;
- digitalization of all components of the educational process;
- effective use of modern digital technologies and data through the development of digital skills and competencies of all education stakeholders;
- formation of new competencies of the educational process participants, i.e., competencies which are necessary for a successful life in the digital society;
- defining requirements for digital competencies of heads of educational institutions and educational policy makers;
- developing special innovative courses for heads of educational institutions, which provided them with an understanding of the concept of digital transformation of education and ways to ensure its.

A number of important steps need to be taken at the state, regional and local levels to implement all the abovementioned in Ukraine. We define them taking into account the analysis and synthesis of similar experience and researches (Hrynevych et al., 2020; Strutynska, 2020; European Union, 2020; Sepúlveda, 2020; Morze et al., 2020).

State-level measures are:

- Creating a unified educational policy for the digi-

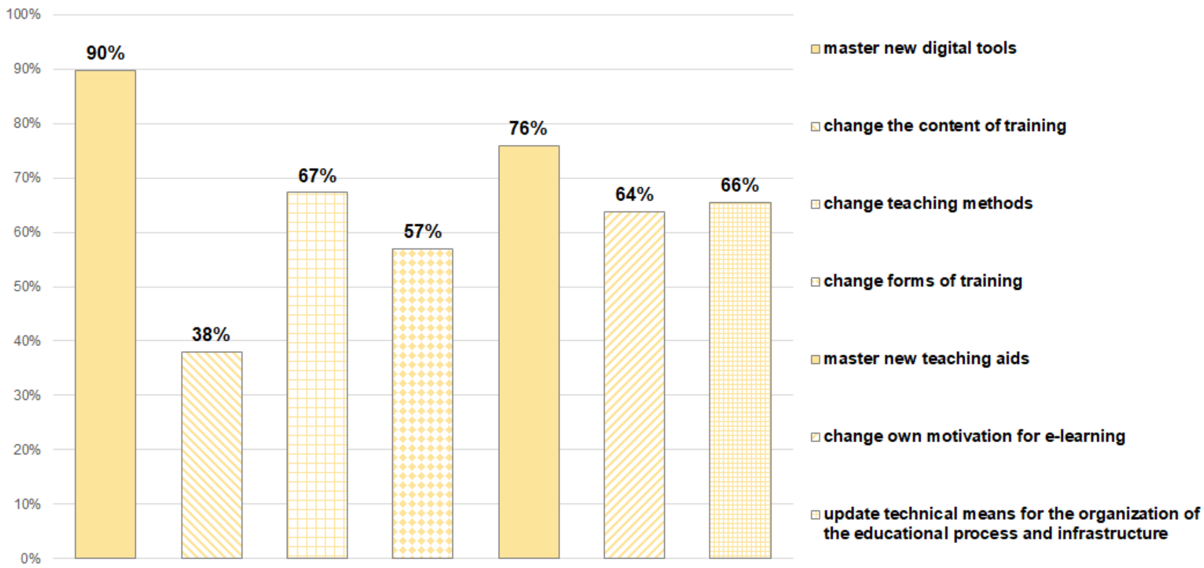

Figure 8: Survey responses on respondents opinion about what teachers need to do to implement an effective educational process under the conditions of the digital transformation.

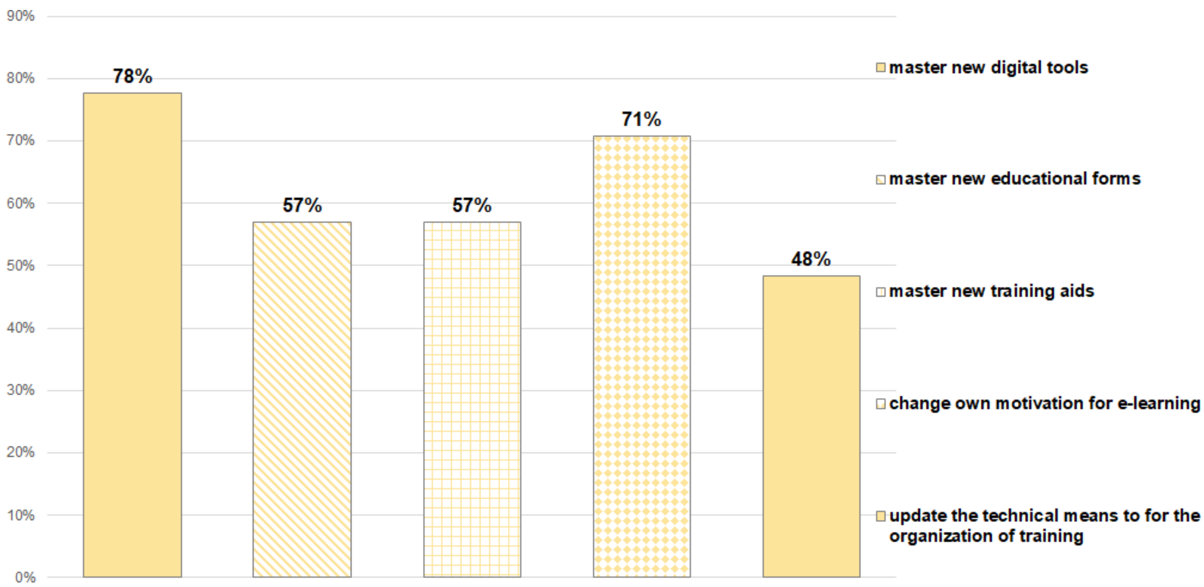

Figure 9: Survey responses on respondents opinion about what students need to do for studying under the conditions of the digital transformation.

tal transformation of education.

- Development of the necessary legal framework to ensure the digital transformation of education.
- Promoting the development of a highly efficient digital education ecosystem as a whole.
- Development and approval of the digital competence standard of the country citizen, including the teaching employee with the corresponding criteria of estimation of digital competence formation level.
- Strengthening cooperation and exchange of experience in models of digital education implementation with EU countries, support of interstate cooperation.

Regional-level measures are:

- Equipping educational institutions with modern computer equipment, as well as broadband connection of all educational institutions to the Internet, purchase of digital equipment, digital learning programs and platforms.
- Development of mechanisms for the implementa-

tion of the digital competence standard of teaching employees to improve the teachers' skills.

- Expanding the active use of distance and blended learning technologies through targeted training of heads of educational institutions and teachers.
- Updating the content of training of future teachers, especially on issues relating to use of digital technologies in the educational process, new approaches to educating of modern youth.
- Improving the digital skills and competencies of the population for digital transformation in general.

Institutional-level measures are:

- Increasing of access to distance learning technologies for teachers and students who have not had this access before (by providing access to the Internet and related equipment).
- Providing flexible curriculum taking into account models of full-time, distance and blended learning.
- Development of quality educational content based on the wide use of digital technologies and taking into account the principles of information security of all participants of the educational process while working with computer networks.
- Arranging of continuous training of educators.

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Formation Digital Intelligence of a Modern Economist: A Competence Approach

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Keywords: Digital Intelligence, Digital Security, Future Economist, Digital Economy, Digital Citizen, Digital Creator, Digital Entrepreneur.

Abstract: In the current context of the digitalization of various spheres of life, an important characteristic of participants in a digital society is the level of their digital intelligence. With the development of the digital economy, the skills of digital intelligence are required by all professionals in the field. The level of digital intelligence development of future economists during their university studies determines their successful employment and career development. The present paper analyzes the application of the competency approach to the formation of digital intelligence using the tools of the moodle platform. In the e-learning course, digital learning content was correlated with a competencies that are defined according to digital intelligence hoards. The authors demonstrate the stages of formation, indicators for different levels of formation, content and examples of educational representation of material. The results of the pilot study for achieving all three levels of digital intelligence are also presented. A statistical analysis of the results of the experiment was carried out and their relevance proved.

1 INTRODUCTION

The modern economy requires the digitization of economic processes, which is the basis of innovative development of economic systems. Digital economy is creating new products, shaping new needs, and the speed and volume of information is increasing day by day. The development of digital intelligence among economic actors offers significant opportunities to create and conduct business based on new technological solutions or business models not previously applied. At the current stage of the development of the global economy, digital tools were accompanying all aspects of economic activity, and digital data technology and e-business were receiving increasing attention.

The use of digital technologies is transforming the relations between the participants of economic activity in its various sectors. That is why the formation and development of digital competences in economists, both general and professional, is an important task for modern universities in preparing future economists and improving their skills. "The public interest in sustainable and continuous development of the quality of labor resources and the increase of their value finds concrete expression in the rulemaking for modernization and achievement of effective structural changes in the education and qualification systems, herefore, the development of competency profiles and competency models in higher education is imperative. The realization of competence approach is meaningful, effective and supporting the future professional realization of the students and it should be prioritized. As a means of comparison with the rich theoretical experience and established practice, it is a real helper for the development of the higher education system as a responsibility not to the document, but to the result" (Nikolova Koleva, 2021). International and European institutions pay great attention to the development of standards of digital competence, in particular, the framework of digital intelligence provides the ability to adequately use digital technologies to work with data, management in-

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formation systems, economic risks, provide cybersecurity, digital communication and more. The development of such abilities among future economists needs to take place both during the training of information technology disciplines and in professionally oriented (vocational) academic disciplines. It is therefore necessary to develop the content, methods and forms for the formation and development of digital intelligence skills of future economists during university studies through appropriate educational programs.

The purpose of the present article is to define the notions, components, levels and characteristics of digital intelligence of the modern economist, to develop approaches to the formation and development of components of digital intelligence of future economists in higher education.

2 THE THEORETICAL BACKGROUND

Digital competences, computer skills, information literacy and related abilities represent a crucial element in ICT education (Information and Communication Technologies) (Stopar and Bartol, 2018). Digital competence is a basic skill for citizens and should be systematically assessed, taking into account characteristics such as knowledge, skills and attitudes (Hazar, 2018).

Digital skills are one of the most important conditions for the development of the digital market in any country, as they are directly or indirectly linked to all spheres of society and the economy. Significant work has been done by the European community to create the potential for digital transformation of education, in particular, to change the skills and competences requirements for citizens. The work was focused on developing a digital competency framework for citizens (DigComp), educators (DigCompEdu), educational organizations (DigCompOrg) and consumers (DigCompConsumers).

Digital competence is one of the key competences and is necessary for lifelong learning as it "involves the confident and critical use of electronic media for work, leisure and communication. It is related to logical and critical thinking, to skills for handling information at a high level". The DigComp conceptual reference model identifies 5 broad areas of digital competence, broken down into 21 competences (Park, 2019). The development of the entrepreneurial capacity of European citizens and organisations is one of the key policy objectives for the EU and Member States. European Commission identified sense of initiative and entrepreneurship as one of the 8 key competences necessary for a knowledge-based society. The EntreComp proposes a shared definition of entrepreneurship as a competence, with the aim to raise consensus among all stakeholders and to establish a bridge between the worlds of education and work (Bacigalupo et al., 2016). The European e-Competence Framework is not based on job profiles but rather on competences as this approach is more flexible. Its purpose is to provide general and comprehensive e-Competences specified at five proficiency levels that can then be adapted and customised into different contexts from ICT business and stakeholder application perspectives. The 41 competences of the framework are classified according to five main ICT business areas and relate to the European Qualifications Framework (Costa and Santos, 2017).

The level of digital competence of university students is determined in accordance with the DigCom 2.1 recommendations (González Calatayud et al., 2018; López-Meneses et al., 2020; Kuzminska et al., 2019), TPACK-21 (Schmidt et al., 2009; Valtonen et al., 2017; Miguel-Revilla et al., 2020).

Any framework of digital competence presented necessarily requires mastery of the components of digital intelligence. Park (Park, 2016) defines digital intelligence as a set of social, emotional and cognitive abilities that allow individuals to meet challenges and adapt to the requirements of digital life. By acknowledging conceptual dyad, digital intelligence could be a result of the process of digital learning (Kineshanko and Jugdev, 2017). Since digital technologies support the learning process and have become an educational subject as well as teaching content, the development of digital intelligence is encouraged in contemporary students (Škoda and Luić, 2019).

Today's education is best met by the concept of digital intelligence development that includes eight interconnected areas: digital identity, digital use, digital safety, digital security, digital emotional intelligence, digital communication, digital literacy, and digital rights (Dostál et al., 2017). Cismaru et al. (Cismaru et al., 2018) explores the development of four categories of skills (operational, informational, strategic and digital fluency) as dimensions of the digital intelligence.

Entrepreneurs are often pressed to create and launch products and services as quickly as possible to achieve a first-mover advantage in the market. In doing so, they tend to overlook cybersecurity threats and risks due to a lack of awareness and insufficient funding. This can lead to theft of intellectual property, project failure, and inaccurate risk assessment (Plachkinova and Pittz, 2021).

3 IMPLEMENTATION

Digital economy is based on information and communication and digital technologies, the rapid development and spread of which are already affecting the traditional (physical-analogue) economy, transforming it from a resource-consuming economy to a resource-creating economy. Data are the key resource of the digital economy, generated and enabled by electronic communications through the operation of digital devices, tools and systems. In order to achieve digital competitiveness in the digital economy, it is necessary to develop the digital intelligence skills in a future economist.

Similar to IQ and EQ, which are used to measure general and emotional intelligence, digital skills are DQ (Digital Quotient), which is digital intelligence. The DQ framework contains 3 levels of digital intelligence (Deepak, 2017):

- "digital citizenship" is the use of digital technologies in everyday life, for interaction with each other, communication, viewing of digital content, etc.;
- "digital creativity" is the use of digital technologies to create content, media, applications, etc.;
- "digital entrepreneurship" is the use of digital technologies for business, professional activity, etc.

The defined levels are applied to such components of digital intelligence as: Digital Changemaker Identity, Digital Use, Digital Safety, Digital Security, Digital Emotional Intelligence, Digital Communication, Digital Literacy, Digital Rights. In order to determine indicators for all components of the future economist's digital intelligence, it is necessary not only to analyze the DQ framework, but also the labor market requirements to the competences of a modern digital economist. The description of the components of digital intelligence is presented in figure 1. Thus, two basic academic disciplines – "Information Technology in Economics" and "Database Management Systems", in the program of training of specialists in the economy are responsible for the formation of digital skills.

According to the data of DQ Institute, a person possesses **Digital Changemaker Identity** if he/she knows the general and emerging trends in the digital environment, identifies and evaluates innovative opportunities for business or social impact, provided by the improvement of new technologies, development of higher-order thinking skills, expansion of thinking beyond the individual scale to integrate digital networks and tools in response to broader social and economic challenges. Such people demonstrate professionalism and value, an interest in understanding the existing gaps in their digital competence and technology, using them for self-development and further business growth (Park, 2019). At The Future of Jobs Report forum, it was stated that the more work on soft skills in addition to hard skills, the more navigate easily tomorrow's job market (The Future of Jobs Report, 2020). Soft skills are crucial for the complex and dynamic process of career management and development for an economist mostly within the knowledge-based society context (Suciu and Lacatus, 2014). Teaching detailed and nuanced industry knowledge is arguably beyond the scope of entrepreneurship education systems, but to an extent, it is of paramount importance that students are exposed to the organic industry knowledge through interaction and experiential experiences. Within such interaction, the development of convergent 21st century skills such as social elationships, leadership, creativity and critical thinking further nurture entrepreneurial intents among students (Ghafar, 2020). The indicator of the **Digital Changemaker Identity** is the ability to identify and develop yourself as a competent digital technology user in Economics. To reach the Digital Citizen level, it is enough for a modern economist to understand the possibilities of using digital technologies to build your own image and the impact of knowledge and technology on professional development; use technologies to control and form your own digital identity; to demonstrate honesty in technology use and self-efficacy by finding ways to take advantage of the opportunities available to you in the digital environment. The level of "Digital Creator" presupposes the future economist's understanding of how to be aware of the progress of ICT, as well as the ability to integrate digital technologies in professional life; having a healthy identity as the co-creator of the digital ecosystem, able to explore and identify contemporary problems, jointly develop new ideas for their solution through technology. To reach the Digital Entrepreneur level, it is necessary to be able to identify and evaluate innovative business or social impact opportunities that are enhanced by new technologies; monitor and integrate emerging trends and technologies, structure data collection to identify new technology products / services that determine the potential added value of the business for sustainability and profitability of the business. Within the framework of both academic disciplines, namely "Information Systems and Technology in Economics" and "Database Management Systems" the **Digital Changemaker Identity** skills can be developed through the use of project-based, case-based, and practice-oriented training.

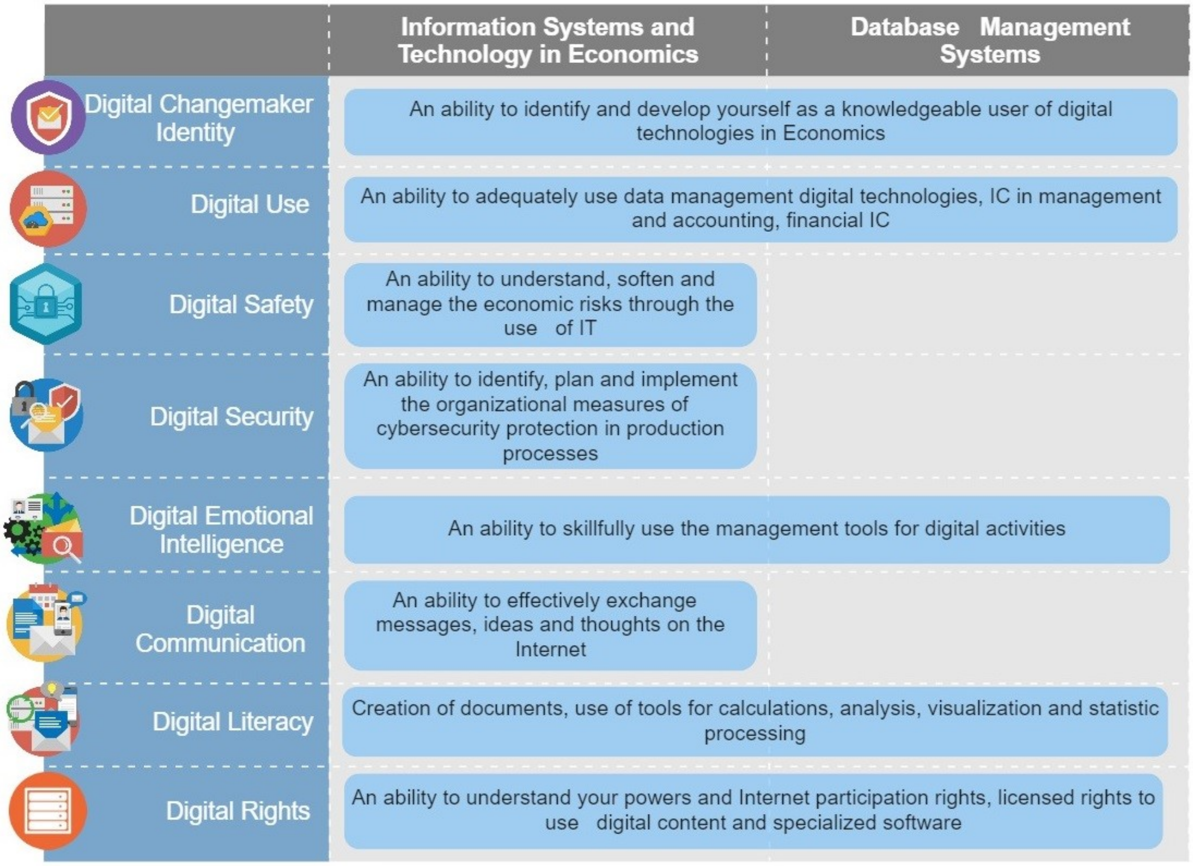

Figure 1: Components of digital intelligence.

Digital data technology, information systems in management, accounting and finance are increasingly playing a key role in managing business processes, including all areas of economic activity, and future economists therefore need **Digital Use** skills. In (Wong et al., 2016) several considerations and suggestions are drawn in terms of rethinking and pursuing usability in training when applied to Enterprise Resource Planning (ERP), and other business process management software systems, SAP, which comes as an integrated solution that incorporates the key business functions and processes of an organization. The rapid growth through the use of Enterprise Resource Planning (ERP) systems by Indonesian companies has been responded by ERP vendors in providing skilled human resources in ERP environment by cooperating with universities, particularly for training accounting students. Satisfaction with class and instructor influence perceived ease of use, students feel satisfied with ERP training and this affects their intentions in using ERP in the future (Imbiri, 2019). Chen and Zhou (Chen and Zhou, 2013) presents the enterprise resource planning (ERP) course layout aiming at the current problems from six aspects of the curriculum, teaching content, teaching resource, teaching method, teaching evaluation, teacher training. Shraideh et al. (Shraideh et al., 2018) conducted a practical course for teaching topics of SAP Leonardo and SAP HANA by suggesting model for conducting a capstone course consisting of eight phases. The model is geared to teaching new and innovative industry-related topics by using a project-based learning approach including elements of experiential learning and role-play teaching. The **Digital Citizen** level assumes the modern economist's understanding of the impact of the use of digital technologies on health, productivity of work, welfare and lifestyle, the possession of the relevant knowledge to solve these consequences; the use of technology in a targeted manner to achieve better objectives, effective use of digital content and tools for their own benefit. At the same time, a modern economist with a **Digital creativity** level has to be able to develop new ideas for solving the given tasks; to use self-motivation and ingenuity in using technologies in professional activity, for allocating available resources; to select and use digital technologies and information systems to plan and execute business processes. To attain the **Digital entrepreneur** level a student must use digital technologies to improve organizations, achieve business goals, work with economic indicators, information systems covering all spheres of economic activity, use systems to manage enterprise resources; to create, implement and use information systems and technology in different spheres of economic activity. The formation and development of such skills is ensured in the course of studying "Information Systems and Technology in Economics" and "Database management systems" academic disciplines, as well as professionally oriented disciplines in economics, accounting, analysis, modeling, management.

Organizations are faced with increasing complexity, uncertainty and enhanced threats from a wide range of forces. Depending on how this situation is handled, it can become risk or opportunity to erode or enhance business value. In addition, organizations have to meet most different stakeholders', legal and regulatory risk management requirements, comprehensive enterprise risk management are challenge and core competence for organizations' sustainable success (Stoll, 2015). Raanan (Raanan, 2009) research which applications of risk management to many aspects of modern life, from insurance, banking, health issues, business ventures, to project management and more. The **Digital Safety** indicator is the ability to understand, mitigate and manage economic risks using IT. To reach the level of a Digital Citizen the future economist needs: to understand the different types of behavioral cyber risks, how he/she can face these risks, how these risks can affect him/her; to develop the necessary technical, socio-cognitive, communicative and decision-making skills to deal with cyber risk situations when they occur, and know the tools to overcome these negative outcomes on the Internet. The Digital Creator level involves understanding the cyber risks of content they face on the Internet and the strategies associated with appropriate behavior, and the skills needed to develop and use conflict management techniques to reduce these risks. In order to reach the level of Digital Entrepreneur it is necessary to understand different types of cyber risks of commercial organizations, which can cause cessation or slowdown of business processes, loss of competitive advantage, loss of customers or profit, reduction of the business value and so forth. In addition, in order to encourage the use of digital entrepreneurship, it is necessary to be able to identify such risks and to develop creative strategies using digital tools to address and prevent the threats associated with those risks.

Integration of digital security skills as an independent variable is critical to the understanding of the use of online protective measures. Having the necessary skills and knowledge to engage in a cyber-safety behavior can help users avoid cyber-victimization, reducing the odds of negative outcomes such as the theft of data, money or personal information (Dodel and Mesch, 2018). Knowledge and skills in the areas of information security, information privacy, and copyright/intellectual property rights and protection are of key importance for organizational and individual success in an evolving society and labour market in which information is a core resource (Burkell et al., 2015). The indicators Digital Security are the ability to recognize, plan and deploy organizational cybersecurity tools in manufacturing processes. At the same time, it is sufficient for an economist possessing the Digital Citizen level to recognize and eliminate technical and software cyber threats at the level of the operating system, work in the network, work with personal data and copyrighted content, to know the types of threats in the digital environment, identify strategies and tools to be used to avoid such threats, use digital technologies without compromising their data and devices. The Digital Creativity level implies the ability to plan and implement cybersecurity protection in the creation of digital content, organization of data security and working information systems, identify vulnerabilities, quantify associated risks (e.g., income deficiency or business losses), use tools, strategies and protocols to ensure and improve data privacy and security. To reach the Digital Entrepreneur level, one needs to be able to organize a secure information environment for the business organization, to actively support cyber security in the organization, providing advice and guidance on potential risks and strategies for addressing them by developing and adhering to already developed communication strategies for organizations to ensure adoption and compliance of security policies and standards that ensure a viable environment for the enterprise. The formation of students' Digital Security level is carried out in the process of mastering the content-rich Module "Digital Security: Protection in the Digital Environment" within the framework of Information Systems and Technology in Economics course.

It is widely acknowledged that emotional intelligence is a crucial component in organizations. It has been proved that leaders and employees who are emotionally intelligent are more efficient, creative, and make better decisions (Bonesso et al., 2020). In today's digital and technical environment, employers are looking for personnel that can contribute to the organization not only with the use of technical skills but can also express their expertise with the use of positive emotional intelligence and communication effectiveness (Hendon et al., 2017). The indicator of Digital Emotional Intelligence is the possibility to skillfully use digital tools for management. To master the Digital Citizen level the future economists should possess social and emotional skills in digital interaction of people, connected with both psychological interaction and practical, physical actions in confirmation of socially determined socially significant things. In order to reach the level of Digital Creator it is necessary to identify, understand and use your own emotional states, to be able to direct them, promote cooperation and positive interaction between internal and external interested parties in order to achieve the set goal; to understand and use your own emotional states, which are derivative and primary to digital media and personal value systems. The Digital Entrepreneur level implies the ability to develop interpersonal skills, the ability to manage one's emotions, understand emotional responses and behaviors depending on the context and digital environment, the ability to build partnerships at personal, local, social and global levels to achieve organizational goals. The formation and development of such skills are ensured in the process of studying basic academic disciplines in information technologies – namely, Database Management Systems and Information Systems and Technology in Economics, as well as professionally oriented academic disciplines in management, project management and business modeling.

The importance of **Digital Communication** for economists is beyond question, as information and communication technologies are a driver of the digital economy (Domazet and Lazić, 2017). Digital communication and collaboration use features of digital technologies with confidence for communication, cooperation and collaboration; effectively search, find, retrieve, process and communicate information from a variety of digital sources and in a variety of formats (Gekara et al., 2019). The ability for an undergraduate economist to apply analytical skills to economic issues of contemporary relevance is an integral part of their tertiary training. In order to encourage students O'Brien and Freund (O'Brien and Freund, 2018) explored the potential for future economists to exploit their social media communication skills with reflective blogging. The indicator of Digital Communication is an ability to effectively exchange messages, ideas and thoughts on the Internet. Herein, it is enough for an economist with the Digital Citizen level to know and to be able to use various communication tools for effective messaging. The level of Digital Creativity implies the ability to create and transmit digital content, independently organize communication channels for communications (for a large number of users inclusive); to store message histories, to resume task on the needed Internet page, the ability to use multiple communication tools without disrupting the workflow; as well as the ability to create and organize videoconferencing; etc. Digital Communication for an economist on the third level implies the ability to create and establish different communication environments to discuss and formulate business strategies and tactics in order to achieve the organization's goals. This level partly overlaps with Entrepreneurial competence and is one of the main components of Digital Competence. The formation of appropriate skills of Digital Communication in future economists can be carried out within Information Systems and Technology in Economics academic discipline while studying the informative module "Digital Communications in Global Space". Therefore, Digital Communication for the modern economist is both the ability to use the tools of gathering and disseminating professional economic information and data, assessible through digital means.

Information technologies are rapidly evolving and changing, along with that the term Digital Literacy is constantly acquiring new interpretations. This means that the role of information technologies in training specialists in different areas is undergoing constant change as well (Pangrazio, 2014; Santos and Serpa, 2017; Spante et al., 2018). As stressed by Murray and Pérez (Murray and Pérez, 2014), many students entering the university today have a high level of exposure to digital technologies and media. However, they are not prepared to cross the bridge between personal and academic use of technology. As academic knowhow is gained through formal education, so too must technological prowess be gained through structured learning experiences. Chan et al. (Chan et al., 2017) define digital literacy as "the ability to understand and use information in multiple formats with emphasis on critical thinking". The indicator of Digital Literacy of a future economist the creation of documents, use of tools for calculations, analysis, visualization and statistic processing. The Digital Citizen level implies the ability to find, process, organize, visualize and store economic data. To reach the Digital Creator level, it is necessary to be able to work with software environments for automation of processes of economic data processing (statistical, analytical); to create and use database management systems, data warehouses; to create and use economic and mathematical methods and models, diagnostic methods of control and estimation of the level of economic growth by means of automation using digital tools; to model and forecast economic processes using modern digital technologies. At the highest level of Digital Literacy the Digital Entrepreneur implies the ability of a student to design databases, information systems, algorithms and data collection tools, to develop decision-making models. Economists may achieve such a level of Digital Literacy if they possess experience of using different technologies gained not only within the framework of studying such academic disciplines as Information Systems and Technology in Economics and Database Management Systems at the university, but also in the process of professional activity.

Organizations require skilled and knowledgeable professionals who understand risks and responsibilities related to the management of information privacy, information security, and copyright/intellectual property (Burkell et al., 2015). New digital networked technologies enable users to participate in the consumption, distribution, and creation of content in ways that are revolutionary for both culture and industry. Young people operate in the digital realm overwhelmingly ignorant of the rights, and to a lesser degree the restrictions, established in copyright law (Palfrey et al., 2009). Software publishers use digital rights management, specifically copy-protection techniques, to prevent unauthorized and illegal copying of their software products (Djekic and Loebbecke, 2005). The indicators of Digital Rights are the ability to understand your powers and Internet participation rights, licensed rights to use digital content and specialized software. Thus, to reach the level of a Digital Citizen, it is sufficient to understand the concept of confidentiality as a human right, what personal information is and how it can be used, stored, processed and shared on digital platforms along with strategies and tools that help keep personal information private and secure, is aware of copyright licenses and Creative Commons tools, licensing choices for licensors. The Digital Creator level implies the knowledge of the law and rights regarding the ownership of information and content hosted in a digital environment, the ability to distinguish between creative use and appropriation of someone else's work; the ability to track and manage changes to your digital content to protect your/organizational assets from unauthorized changes or unauthorized use; to design and use patents, trademarks, copyrights to protect your digital works through a variety of tools and applicable legislation. In order to reach the level of a Digital Entrepreneur, it is necessary to effectively integrate legislation with one's own practice to ensure the support and enforcement of digital rights in the digital environment as part of the entrepreneurial activity.

Competency indicators have been developed for each component of digital intelligence.

Indicators of digital intelligence skills at the level of "Digital Citizen":

- **DI1. Digital Changemaker Identity** (using digital technologies to build your own image and the impact of knowledge and technology on professional development; using technologies to control and form your own digital identity; demonstrating honesty in technology use and self-efficacy by finding ways to take advantage of the opportunities available to you in the digital environment);
- **DI2. Digital Use** (understanding of the impact of the use of digital technologies on health, productivity of work, welfare and lifestyle, the possession of the relevant knowledge to solve these consequences; the use of technology in a targeted manner to achieve better objectives, effective use of digital content and tools for their own benefit);
- **DI3. Digital Safety** (understand the different types of behavioural cyber risks, how he/she can face these risks, how these risks can affect him/her; develop the necessary technical, socio-cognitive, communicative and decision-making skills to deal with cyber risk situations when they occur; know the tools to overcome these negative outcomes on the Internet);
- **DI4. Digital Security** (ability to recognizing and eliminate technical and software cyber threats at the level of the operating system; work in the network, with personal data and copyrighted content; know the types of threats in the digital environment, identify strategies and tools to be used to avoid such threats; use digital technologies without compromising their data and devices);
- **DI5. Digital Emotional Intelligence** (possess social and emotional skills in digital interaction of people, connected with both psychological interaction and practical, physical actions in confirmation of socially determined socially significant things);
- **DI6. Digital Communication** (level to know and to be able to use various communication tools for effective messaging);
- **DI7. Digital Literacy** (ability to find, process, organize, visualize and store economic data);
- **DI8. Digital Rights** (understand the concept of confidentiality as a human right, what personal information is and how it can be used, stored, processed and shared on digital platforms along with strategies and tools that help keep personal information private and secure; is aware of copyright

licenses and Creative Commons tools, licensing choices for licensors).

Indicators of digital intelligence skills at the level of "Digital Creator":

- **DI1. Digital Changemaker Identity** (future economist's understanding of how to be aware of the progress of ICT; ability to integrate digital technologies in professional life; ability to explore and identify contemporary problems, jointly develop new ideas for their solution through technology);
- **DI2. Digital Use** (ability to develop new ideas for solving the given tasks; to use self-motivation and ingenuity in using technologies in professional activity, for allocating available resources; select and use digital technologies and information systems to plan and execute business processes);
- **DI3. Digital Safety** (understanding the cyber risks of content they face on the Internet; understanding the strategies associated with appropriate behavior, and the skills needed to develop; using conflict management techniques to reduce cyber risks);
- **DI4. Digital Security** (ability to plan and implement cybersecurity protection in the creation of digital content, organization of data security and working information systems; identify vulnerabilities, quantify associated risks (e.g., income deficiency or business losses); use tools, strategies and protocols to ensure and improve data privacy and security);
- **DI5. Digital Emotional Intelligence** (identify, understand and use your own emotional states, to be able to direct them; promote cooperation and positive interaction between internal and external interested parties in order to achieve the set goal; understand and use your own emotional states, which are derivative and primary to digital media and personal value systems);
- **DI6. Digital Communication** (create and transmit digital content, independently organize communication channels for communications (for a large number of users inclusive); store message histories, to resume task on the needed Internet page, the ability to use multiple communication tools without disrupting the workflow; ability to creating and organize videoconferencing);
- **DI7. Digital Literacy** (ability to work with software environments for automation of processes of economic data processing (statistical, analytical); ability to create and use database management systems, data warehouses; ability to create and use economic and mathematical methods and models, diagnostic methods of control and estimation of the level of economic growth by means of automation using digital tools; ability to model and forecast economic processes using modern digital technologies);
- **DI8. Digital Rights** (knowledge of the law and rights regarding the ownership of information and content hosted in a digital environment; ability to distinguish between creative use and appropriation of someone else's work; ability to track and manage changes to your digital content to protect your/organizational assets from unauthorized changes or unauthorized use; ability to design and use patents, trademarks, copyrights to protect your digital works through a variety of tools and applicable legislation).

Indicators of digital intelligence skills at the level of "Digital Entrepreneur":

- **DI1. Digital Changemaker Identity** (ability to identify and evaluate innovative business or social impact opportunities that are enhanced by new technologies; ability to monitor and integrate emerging trends and technologies; ability to structure data collection to identify new technology products / services that determine the potential added value of the business for sustainability and profitability of the business);
- **DI2. Digital Use** (use digital technologies to improve organizations, achieve business goals, work with economic indicators, information systems covering all spheres of economic activity, use systems to manage enterprise resources; create, implement and use information systems and technology in different spheres of economic activity);
- **DI3. Digital Safety** (understand different types of cyber risks of commercial organizations, which can cause cessation or slowdown of business processes, loss of competitive advantage, loss of customers or profit, reduction of the business value and so forth; ability to identify risks and to develop creative strategies using digital tools to address and prevent the threats associated with those risks);
- **DI4. Digital Security** (ability to organize a secure information environment for the business organization; ability to support cyber security in the organization, providing advice and guidance on potential risks and strategies for addressing them by developing and adhering to already developed communication strategies for organizations to ensure adoption and compliance of security policies

and standards that ensure a viable environment for the enterprise);

- **DI5. Digital Emotional Intelligence** (ability to develop interpersonal skills; ability to manage one's emotions, understand emotional responses and behaviors depending on the context and digital environment; ability to build partnerships at personal, local, social and global levels to achieve organizational goals);
- **DI6. Digital Communication** (ability to create and establish different communication environments to discuss; ability to formulate business strategies and tactics in order to achieve the organization's goals);
- **DI7. Digital Literacy** (ability of a student to design databases, information systems, algorithms and data collection tools; develop decision-making models);
- **DI8.Digital Rights** (ability to effectively integrate legislation with one's own practice to ensure the support and enforcement of digital rights in the digital environment as part of the entrepreneurial activity).

4 THE RESULTS OF EXPERIMENTAL WORK

The pedagogical experiment on the development of digital intelligence competences for future economists lasted for 3 years and involved the first year students majoring in Economic (the total of 142 students). The formation and development of digital intelligence skills of future economists was carried out within the framework of studying the Information Systems and Technology in Economics academic discipline. The formation of DQ was carried out in 3 stages: (1) Digital Citizenship through two content modules in the Information Systems and Technology course; (2) Digital Creativity through a competency-based project; (3) Digital Entrepreneurship through practical training using real-life work situations. The course of experimental research included measuring students' digital intelligence skills before the start of the discipline and at the end of each stage.

The course content modules on Information Systems and Technology in Economics included: Digital Identity and Rights of the Modern Economist, Digital Security: Protection in the Digital Environment, Cyber Risks in the Public Digital Domain, Digital Communications in the Information Environment, Economic Data Tools, Visualisation of Economic Information, Digital Tools for Economist Management, Information Systems for Economic Activity. The process of forming appropriate skills in accordance with the components of digital intelligence level "Digital Citizen" was provided by a set of educational resources and services, tasks for laboratory work.

The e-learning course (ETC), based on the Moodle platform, was used as an internal resource for the university's e-learning environment to learn theoretical educational material to organize the educational process of future economists.

To determine the acquisition by students of the necessary competencies by the means available in the moodle system, the following was created:

- Technical representation of the competency framework within the system competencies repository.
- Assignment of relevant competencies to the training course.
- Assignment of appropriate competencies to individual elements of the e-learning course.

The digital competence framework includes (figure 2):

- indicator
  - level
    - exponent

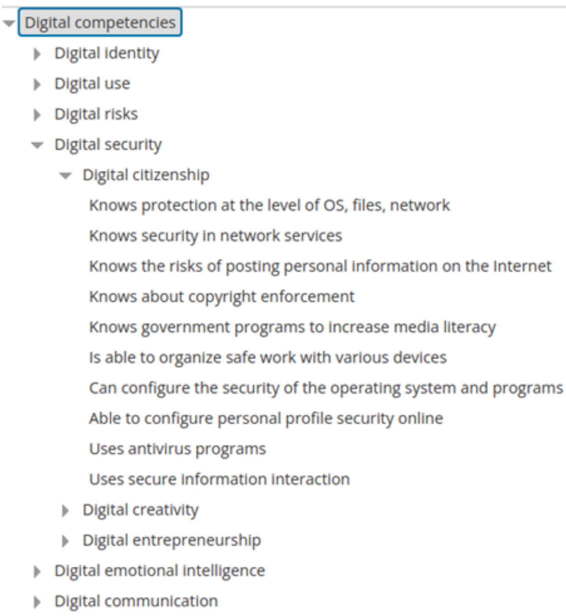

Figure 2: Digital competence framework in the Moodle system.

The content of the competency framework corresponds to the components of digital intelligence skills with have been added to the relevant e-learning course.

But simply the technical definition of the course in which the relevant competencies will be formed is not enough to recognize that the student has acquired these competencies. A prerequisite is the presence of educational elements, the successful development of which will symbolize that the student has acquired the competencies that these elements are designed to develop in him.

At the same time, different approaches to determine the acquisition of competencies were identified for different indicators.

To obtain the competencies "knows..." the student must review the theoretical material (read the text, watch the study video, presentation, etc.) and successfully pass the training test. The Moodle system allows you to track the successful completion of educational elements by students both automatically (fulfillment of requirements) and by students themselves (personal determination of the state of understanding of the material received). Therefore, the student can independently determine the theoretical material as performed, and the test is marked as completed when receiving a grade above 60% of the maximum. Only when all these conditions are met is the indicator of competence considered achieved.

To obtain competencies "able..." students were asked to perform a set of tasks in laboratory work. The conditions for determining these tasks as performed (and, consequently, obtaining the relevant indicators of competence, which are tied to these tasks) are to provide for the verification of work performed and receive an assessment of at least 60% of the maximum (figure 3).

When using the option of students gaining knowledge through non-formal education, to confirm the acquired competence, it was proposed to provide evidence of successful completion of third-party courses by uploading a certificate in the e-learning course. After verification of the certificate, the teacher confirmed the acquisition of competence.

Determining the achievement of competency indicators "uses..." can no longer be done automatically. In this case, the educational elements of the e-course require the student to request confirmation of the acquisition of appropriate competence from the teacher. According to the results of research conducted by the student, completed project task or completed practice, the teacher marks the acquisition of competence.

Thus, we obtained a list of activities aimed at forming the appropriate capabilities for each component of digital intelligence of the future economist (figure 4)

Also, control tasks and tests were formed according to certain indicators. Each student gained access

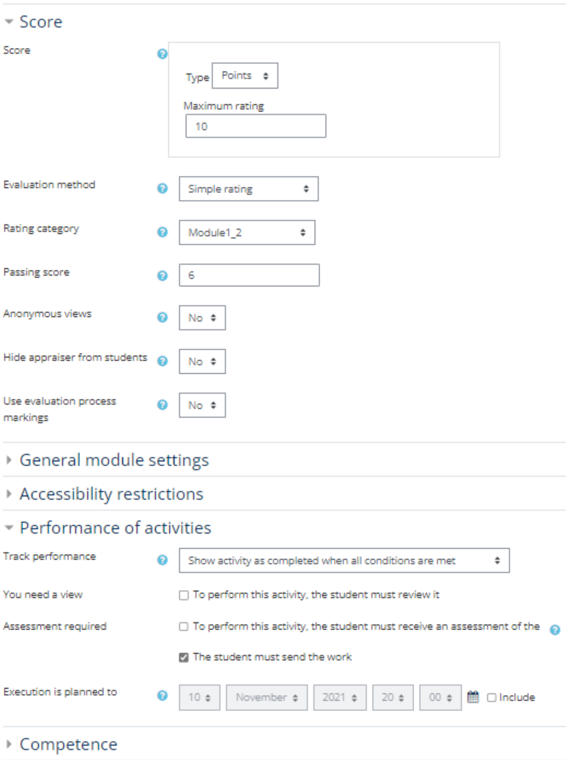

Figure 3: Adjustment of the passing score and conditions of the performance.

to the structure of digital competence and the corresponding activities that must be performed for the successful formation of digital competence. The figure 5 shows a screen with the activities that the student sees. After completing tasks for laboratory and independent work, the student undergoes control activities, the results of which determine the level of formation of digital competence (for each component). The results of the formed components of digital competence the student can see after his teacher evaluates the relevant activities in the e-learning course or after presenting a certificate of mastery of the relevant mass online courses, which certifies the formation of relevant competencies.

After completing the two modules of the discipline, students were offered a project assignment to achieve the Digital Creativity level. During the project work, students learned how to apply a set of services and tools developed during theoretical training to solve different types of tasks related to economic activity of an enterprise. Before starting the tasks of this project, the students had to split into small groups, plan the teamwork, choose a service to manage the project, assign roles to the participants, set areas of responsibility and deadlines for the tasks. In the course of the project assignment, the students were asked to develop the information structure of

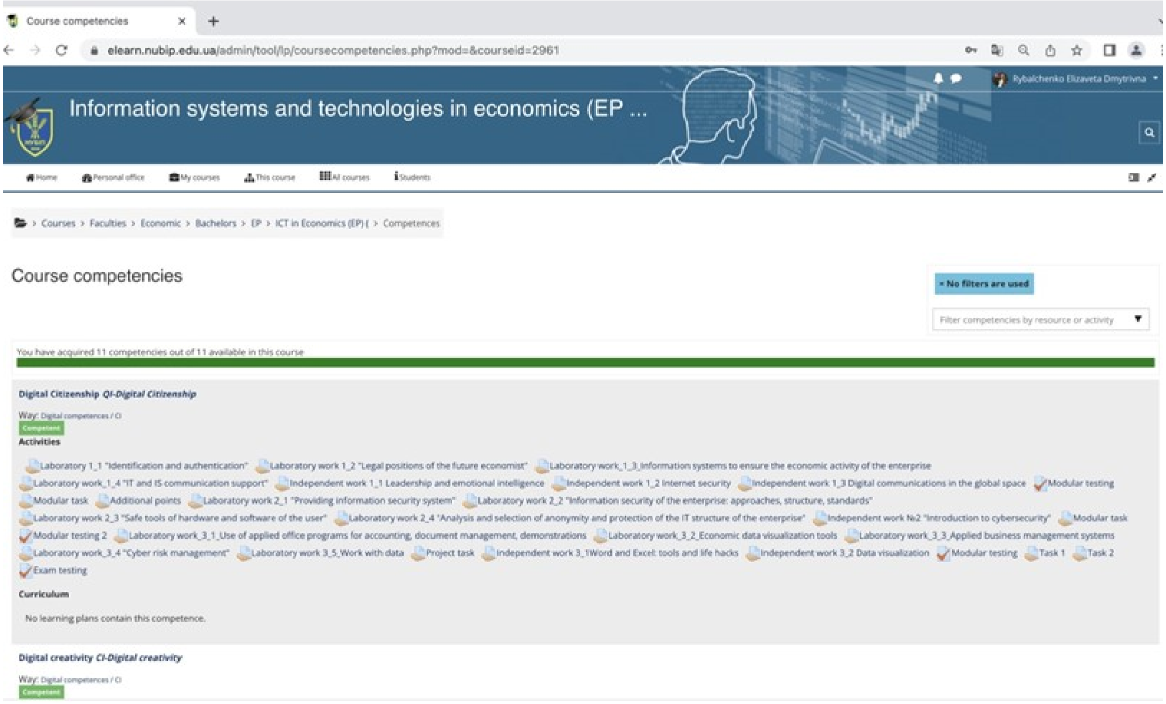

Figure 4: Correspondence of competencies and activities within one of the components of digital competence.

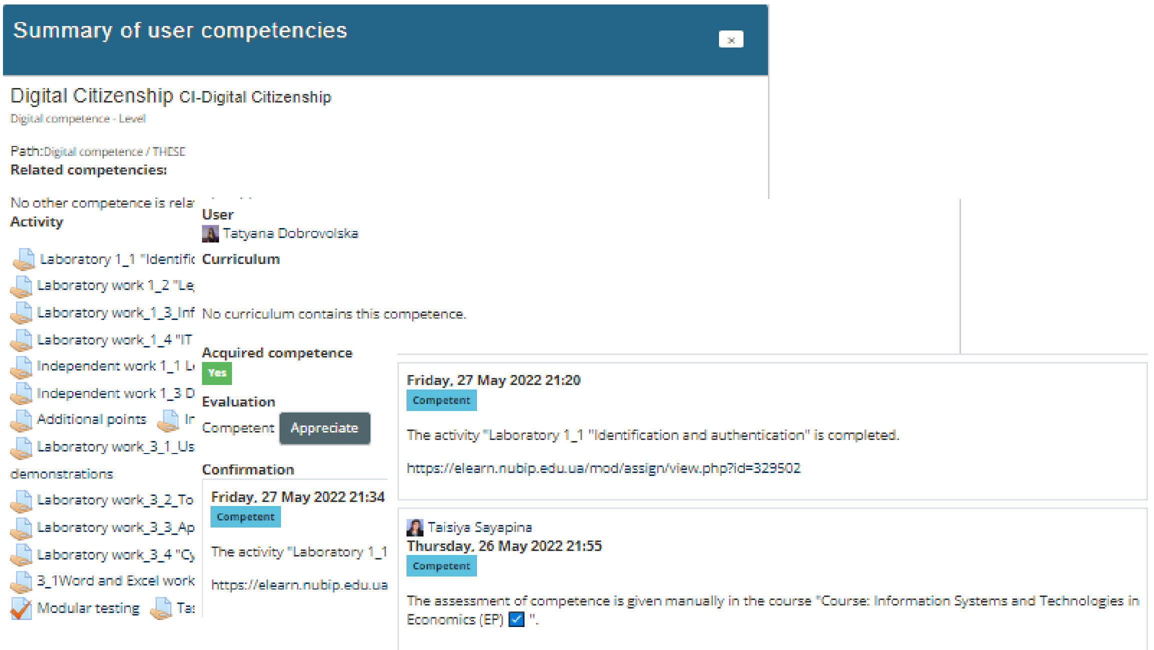

Figure 5: The final page of the student's competence.

the virtual business activity based on the analysed organisational and functional structure of the enterprise; to select the software for economic activity (processing, systematisation, visualisation and storage of economic data), tools for confidentiality and data security using appropriate cloud services.

In order to achieve the "Digital Entrepreneurship" level of the learning experience, the students were asked to solve a case study based on the production situation described. An example of such a task is given below. "A retail chain is planning to expand its branches. Given the number of employees, customers and counterparties of the company planned after the expansion, to analyse the technical and functional characteristics of the existing systems in the market and to select the optimal in terms of purchase and maintenance costs: CRM-system; tool for checking the activities of counterparties; tool for assessing the financial performance of the company. Evaluate the cost of implementing such systems in the company. Set up user authorisation rules in the selected systems to ensure the security of company data". The result of the completed task is a presentation of the completed work in the form of a joint document, which is generated by all participants of the project.

As a result, after graduation each student received the following results of the formation of digital competence (figure 6).

The leading idea of the research concept is reflected in the hypothesis based on the assumption: if the training of modern economists is carried out according to the proposed phased formation of digital intelligence skills, it will increase the levels of digital intelligence: "digital citizen", "digital entrepreneur" and "digital creator".

At the beginning of the pedagogical experiment, each student assessed their own level of competence in the components of digital intelligence in accordance with the developed indicators on a scale from 0 to 10 for the levels of "Digital Citizen", "Digital Creator", "Digital Entrepreneur". For each level, the average value of the formation of the corresponding component of digital intelligence was determined. After completing the training, in which students were offered resources, tasks, training practices for the formation of digital intelligence skills at different levels during three stages, students were asked to re-evaluate the level of formation of digital intelligence competencies. The results of the experiment for 3 academic years on the formation of competencies in digital intelligence at the levels of "Digital Citizen", "Digital Creator", "Digital Entrepreneur" are presented in tables 1-3.

To confirm the hypothesis of the study, a null hypothesis was put forward: the average value of the level of formation of digital intelligence before and after the experiment for each level does not differ. Deviation of this hypothesis for each level will confirm the effectiveness of the technologies used. The sample data have a normal distribution and form a pair of correlating values, whereas the paired Student t-test was chosen to evaluate the results.

Assessment of digital intelligence skills at the level of "Digital Citizen" is presented in table 1.

The sample data have a normal distribution and form a pair of correlating values, whereas the paired

Table 1: Assessment of digital intelligence skills at the level of "Digital Citizen".

Components of digital intelligence	Sampling		Deviation from the average	
	To	After	To	After
DI1	4.78	7.94	0.26	1.14
DI2	3.95	6.33	-0.57	-0.47
DI3	3.70	5.67	-0.82	-1.13
DI4	5.69	7.27	1.17	0.47
DI5	4.26	7.41	-0.26	0.61
DI6	3.81	5.27	-0.71	-1.53
DI7	4.86	7.84	0.34	1.04
DI8	5.13	6.67	0.61	-0.13
Σ	36.18	54.40	0.02	0.00
Average value	4.52	6.80		

Table 2: Assessment of digital intelligence skills at the level of "Digital Creator".

Components of digital intelligence	Sampling		Deviation from the average	
	To	After	To	After
DI1	2.91	5.35	-0.07	-0.36
DI2	2.85	5.53	-0.13	-0.18
DI3	1.78	5.33	-1.20	-0.38
DI4	2.98	5.58	0.00	-0.13
DI5	1.97	5.50	-1.01	-0.21
DI6	3.98	5.92	1.00	0.21
DI7	3.47	6.29	0.49	0.58
DI8	3.86	6.18	0.88	0.47
Σ	23.80	45.68	-0.04	0.00
Average value	2.98	5.71		

Student t-test was chosen to evaluate the results. The t-criterion was calculated by the formula $t = \frac{|M_d|}{\frac{S_d}{\sqrt{N}}}$, where M_d – is the mean difference of the values, S_d – standard deviation, N – the number of parameters. The estimated t-criterion is 8.7, the critical value of the Student's t-criterion for the number of degrees of freedom 7 is 2.365. Since t-estimated > t-critical, we can reject the null hypothesis and conclude that the difference in average values before and after the experiment is statistically significant ($p = 0.05$).

As can be seen from table 1, students have increased the level of skills "Digital Citizen" as a result of studying the proposed courses by an average on 22.8%. Graphical interpretation of the results of the experiment for the level of "Digital Citizen" are given in figure 7.

Assessment of digital intelligence skills at the level of "Digital Creator" is presented in table 2.

The estimated t-criterion is 2.534 and exceeds the

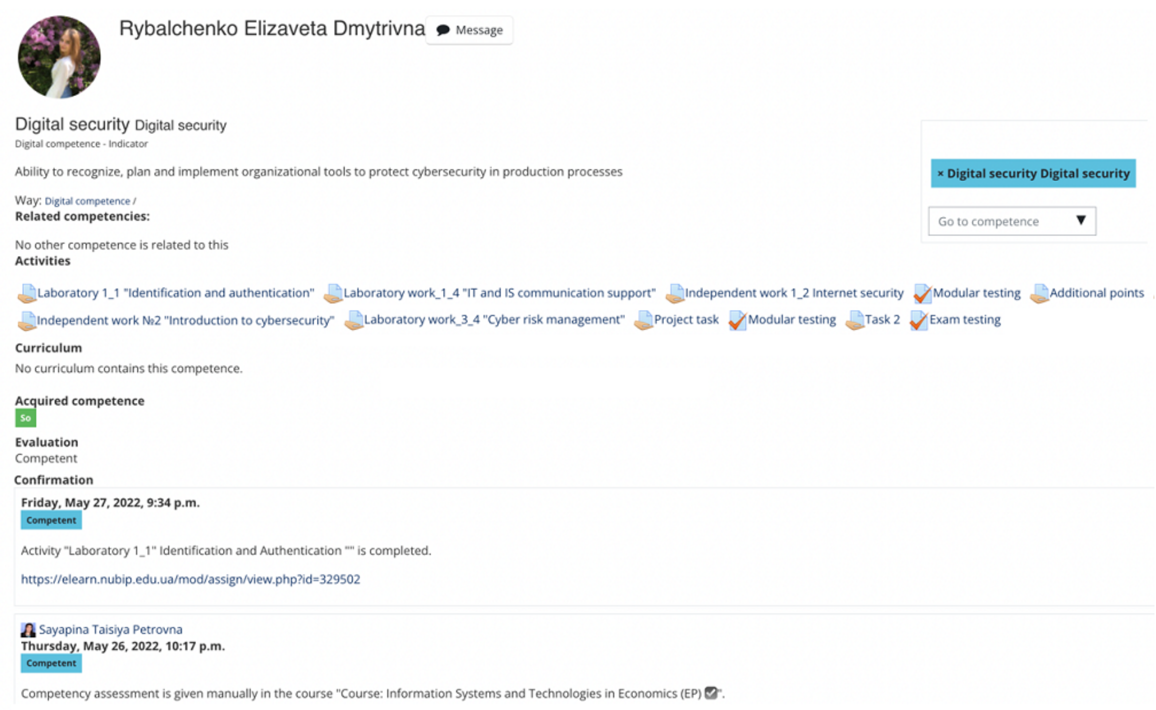

Figure 6: Distribution of competencies by student.

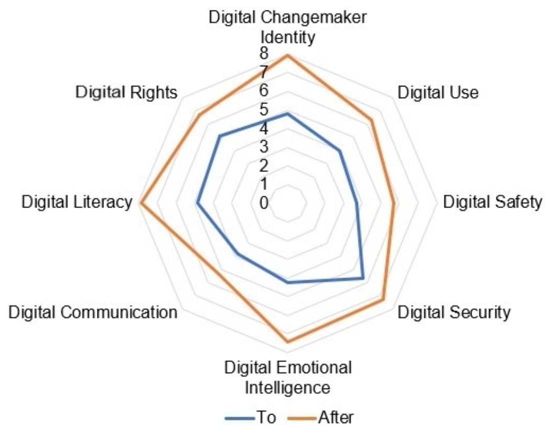

Figure 7: Graphical interpretation of digital intelligence skills at the level of "Digital Citizen".

t-critical, we can reject the null hypothesis and conclude that the difference in average values before and after the experiment is statistically significant ($p = 0.05$).

As can be seen from table 2, students increased the level of skills of "Digital Creator" as a result of project tasks by an average of 27.3%. Graphical interpretation of the results of the experiment for the level of "Digital Creator" are given in figure 8.

Assessment of digital intelligence skills at the level of "Digital Entrepreneur" is presented in table 3.

The estimated t-criterion is 7.22 and exceeds the

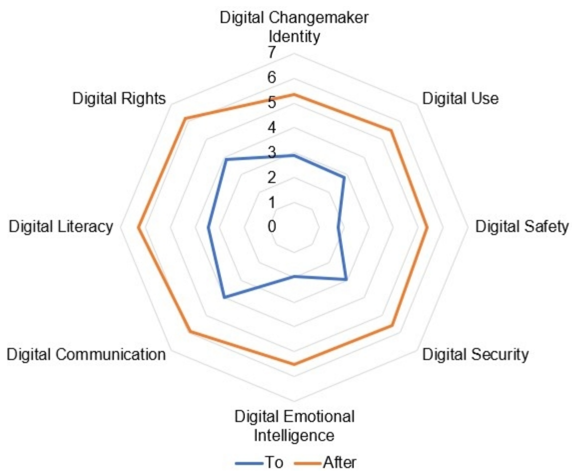

Figure 8: Graphical interpretation of digital intelligence skills at the level of "Digital Creator".

t-critical, we can reject the null hypothesis and conclude that the difference in average values before and after the experiment is statistically significant ($p = 0.05$). As can be seen from table 3, students have increased the level of skills "Digital Entrepreneur" as a result of internships by an average of 23.6%. Graphical interpretation of the results of the experiment for the level of "Digital Entrepreneur" are given in figure 9.

In the results of the experiment in the first, sec-

Table 3: Assessment of digital intelligence skills at the level of “Digital Entrepreneur”.

Components of digital intelligence	Sampling		Deviation from the average	
	To	After	To	After
DI1	3.44	6.37	-0.13	0.46
DI2	2.88	6.16	-0.69	0.25
DI3	3.65	5.45	0.08	-0.46
DI4	3.64	5.96	0.07	0.05
DI5	2.98	5.91	-0.59	0.00
DI6	4.16	5.30	0.59	-0.61
DI7	2.55	5.85	-1.02	-0.06
DI8	5.26	6.31	1.69	0.40
∑	28.56	47.31	0.00	0.03
Average value	3.57	5,91		

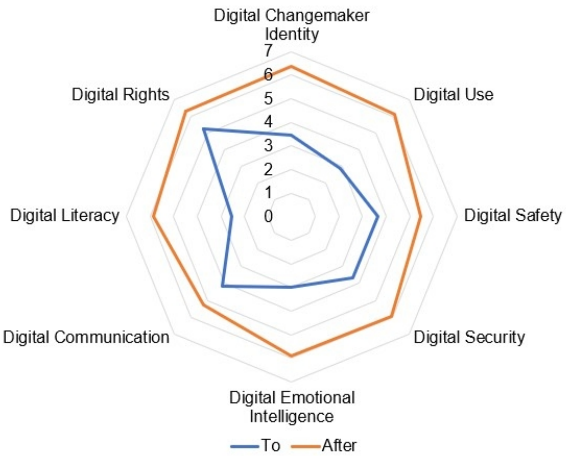

Figure 9: Graphical interpretation of the results for the level of “Digital Entrepreneur”.

ond and third stages, presented in figures 7-9, and in tables 1-3, we observe the heterogeneity of the indicators of the formation of digital intelligence skills for different components. After the first stage, the highest level of DI is observed for the components of digital identity, security, emotional intelligence, and digital literacy, which we explain by additional thematic MOOCs and by the using of appropriately selected resources and services for training skills, matched the specified DI components. For the development of other DI components for the level of Citizen, other professionally-oriented courses are provided, during which these skills will be developed, for example, the discipline “DBMS”. For the levels Creator and Entrepreneur levels, the level of skills formation with different elements is connatural, which is explained by the formation of competency and practice-oriented tasks considering the development of all components of DE, applying blended learning technology, which included project work methods, case method, individual and teamwork. Achieving the maximum values of the corresponding indicators of the digital intelligence is expected during the study of other professionally-oriented disciplines.

5 CONCLUSIONS

The analytical study made it possible to identify and describe the following components of the digital intelligence of the economist: Digital Changemaker Identity, Digital Use, Digital Safety, Digital Security, Digital Emotional Intelligence, Digital Communication, Digital Literacy, Digital Rights. The content of the Information Systems and Technologies academic discipline for training future economists at universities, in which digital intelligence skills can be developed, is proposed.

The developed approach gives the possibility to formulate digital intelligence skills of the digital citizen, digital creator and digital entrepreneur levels. The essence of the approach lies in the step-by-step formation of skills that correspond to each successive level. The initial stage involves studying the educational material and performing a series of hands-on classes within the disciplines. In this way, digital citizen skills can be formed. The second stage is to carry out a project work that requires creativity to solve the project task, and as a result, future economists will develop the skills of the Digital creator level. The third stage involves the fulfillment of a real production situation, which requires the student not only to have previously acquired knowledge, skills and their application in practice, but also to gain new experience in solving typical production situations and responding to appropriate challenges. This stage is designed to build students’ Digital entrepreneur skills.

A formalized approach to the formation of tasks in the elearning course in accordance with the components of digital intelligence (DQ) using the built-in tools of the moodle platform, provides an opportunity to improve the learning process of students in accordance with the objectives of competencies.

Three-stage approach of forming skills of digital intelligence was tested for three years to train students in “Economics”. As a result of pedagogical experiment, the level of digital intelligence skills has been increased, in particular, the level of “digital citizen” increases by 22.8%, the level of “digital creator” by 27.3% and the level of “digital entrepreneur” by 23.6%. The obtained results show that under the given conditions of the organization of training during studying of educational course Information Systems and Technology in Economics at students of economic specialties the level of digital intelligence increases on the average by 24.4%. But the development of digital intelligence of future economists is carried out in the future during the study of vocational courses, internships, diploma design, as well as through non-formal education.

Among the perspective areas of research, we see the definition of conditions and construction of models of individual educational trajectory for students of economic specialties in order to effectively develop their digital intelligence.

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Using GitHub Cloud Service in Training Future IT Professionals: Local Study

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Keywords: GitHub, Future IT Professionals, Collective Development.

Abstract: In today's IT industry, it is important to develop the ability of IT students to collaboratively develop software, professional and personal skills. An effective method for developing such skills in future IT specialists is to organize different types of educational projects related to different programming technologies during the execution of mini projects, group and individual project assignments, term papers, academic training within the academic disciplines. The paper summarizes the results of a pedagogical study involving 29 expert students who study Computer Science and Software Engineering and used cloud service for GitHub collaborative IT development projects. The research findings testify, the most effective characteristics of this service, according to experts, identified the possibility of collaborative development of software (i1), the convenience of bug tracking (i3) and the convenience of the code editor (i7). It offers examples and results of using GitHub cloud service in the process of executing educational projects by future IT specialists.

1 INTRODUCTION

With the development of information technology (IT), the approach to the organization of collaborative development of software products is changing. Hence, it is necessary to take into account the fact that future IT specialists should be able to adapt instantly to new situations, make appropriate decisions and quickly solve their tasks not only personally, but also while working as a team. In order for students of IT profession to continue to hold leading positions in IT industry in their professional activity, to meet the requirements of customers and employers, it is necessary to develop in them the ability to design and manage projects, to work in a team, to develop skills to use cloud services for project management and team development of software products in the process of their academic training at the university.

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2 THEORETICAL BACKGROUND

Cloud software for team development of software products allows users to collaborate on code, manage their versions, and more. Cloud services such as GitHub, Bitbucked, GitLab, Phabricator, Beanstalk, which were researched and described in the paper (Korolchuk, 2019). become part of the cloud-oriented scientific and educational environment of the university if used on a regular basis (Glazunova and Shyshkina, 2018). GitHub is the most popular code management platform for software development, as it enables future IT professionals to manage and collaborate on their software development training projects.

GitHub is an online Git service that hosts Git repositories and provides other features such as issue tracking. GitHub has become the prominent platform for hosting open source projects (Metz, 2015). GitHub has been embraced by the software development community as an important social platform for managing software projects and to support collaborative development (Feliciano et al., 2016). The most important benefit of using GitHub is not to support the short-term priorities of a semester-long course, but, rather, to encourage sustainable and well-documented digital development, both of student projects and the course itself (Beshero-Bondar and Parker, 2017).

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When using GitHub in education, one has to think about the purpose, what the goal is and then how the features in GitHub can be used to reach this goal. GitHub can be used in many different ways, but it might not be applicable in all types of courses because a certain amount of knowledge about Git is required to be able to use the features (Gunnarsson et al., 2017). Git and GitHub into data science workflows is considered best practice, and provides thoughtful advice on how to conceptualize the GitHub workflow (Fiksel et al., 2019). Other work describes a GitHub Education study that shows that using GitHub in the classroom can lead to a much improved understanding of students' project management (GitHub Education, 2020).

The most important skills employers seek in engineering are creativity, teamwork and critical thinking. Kertész (Kertész, 2015) presents the results of a collaborative learning experiment using GitHub in lab work, where the focus was on students' direct interaction with each other's learning process. Depending on how GitHub is implemented in learning programming, students may rely on GitHub for activities such as, submitting assignments, collaborating on group projects, and receiving feedback (Hsing and Gennarelli, 2019). An immediate advantage is for classes that have group projects. With GitHub Classroom, instructors can easily assign groups of students to teams and give each team their own GitHub repository within a GitHub Classroom. Students can then use Git and GitHub to collaborate on a project, just as they would in an academic or industry research project. Because teachers can see each student's commit history, it is easy to see how each student contributed to the project (Fiksel et al., 2019). A collaborative tutorial assignment on the GitHub platform was embedded in an undergraduate cybersecurity course. Students were asked to create a tutorial that would be combined with their peers' tutorials to create a course eBook. The tutorial topics were required to be in the general domain of network security. With regards to tutorial difficulty, students were told to target an audience that had completed an introductory computer networking course (Marquardson and Schuetzler, 2019).

Instead, this study was aimed at answering the following research questions: a) how to use the cloud service to collectively develop GitHub for programming training projects; b) which function-based assessment indicators affect the effectiveness of the cloud service for collective GitHub development; c) how collective GitHub development influences the formation of professional programming competence of future information technology specialists. The motivation for this study was to demonstrate the effectiveness of using the GitHub cloud service for student programming projects.

The problem of the research stems from the need to find effective information and communication technologies for the organization and implementation of various types of collaborative projects by future IT specialists. Therefore, this study was conducted to determine the characteristics of the GitHub cloud service, which affect the effectiveness of the execution of educational projects on programming in the process of training IT students and in order to form professional programming competence.

3 RESEARCH METHODOLOGY

3.1 General Background

In order to determine how effectively GitHub's cloud service enables students to carry out programmatic learning projects, such as interacting with team members, collectively working on code, sharing ideas, and reviewing each other's work during research, students' thoughts and impressions about using this cloud service were gathered. A descriptive study utilizing survey methodology was used as appropriate to achieve the objectives of the study. This allowed the researchers to gain a more detailed view of the students regarding the use of the GitHub cloud service in the execution of educational programming projects using pedagogical observation and peer review methods. The study was conducted in two stages. At the first stage, the role of experts was performed by students who evaluated the effectiveness of the GitHub cloud service for the implementation of programming training projects. The study of the first stage was conducted among the 3-rd year students of the Faculty of Information Technologies of the National University of Life and Environmental Sciences of Ukraine (NULES of Ukraine) during the second academic term of 2019 (29 students).

Twenty-nine students of IT specialities performed a collective mini-project in the process of studying one informative module in the discipline "Object Oriented programming". The study of this academic discipline was preceded by the study of "Database Organization" discipline; "Development of a program system for working with IT company management computer systems databases" was selected as the project theme. After completion of the technological practical training, an expert evaluation of the GitHub cloud service was conducted by the students in the second phase. To understand the attitude of students to the service for collaborative development, the following indicators of their evaluation from the point of view of functionality were determined: (i1) possibility of collaborative development of software; (i2) ability to manage code versions; (i3) convenience of bug tracking; (i4) ability to organize and plan teamwork; (i5) communication capability; (i6) the ability to support platforms; (i7) the convenience of the code editor; (i8) security and privacy; (i9) availability of wiki pages. In order to evaluate the GitHub collaborative development cloud service by specific indicators, a survey was developed, which consisted of 9 questions, in which the experts evaluated the importance of the indicators by assigning a ranking number.

In 2020, the second phase of the study was conducted, during which the effectiveness of the use of the GitHub cloud service was evaluated in the training of future IT professionals for the formation of professional competence. During experimental research among 3rd year students of the faculty there were two samples of students: control (96 students) and experimental groups (99 students). Student assessment was conducted during the study of the subject "Object-Oriented Programming" for two semesters and technological practice (internship).

In the experimental study, students performed two mini-projects in academic disciplines and one group project during technological practical training. The first part of the study was to carry out the students' programming project using the resources of the e-learning course (ELC) of the academic discipline combined with the cloud service for the collective development of GitHub.

3.2 Data Analysis

The experts evaluated the significance of the developed indicators by assigning them a ranking number. The highest rated factor was assigned a rank of 1. The level of agreement of experts' opinions was determined by the coefficient of concordance. The concordance coefficient was applied to assess the degree of consistency among experts, which was calculated by the formula:

$$W = \frac{12S}{m^2(n^3 - n)},$$

where

$$S = (\sum x_{ij} - \frac{\sum\sum x_{ij}}{n})^2,$$

x_{ij} – evaluations of the ranks of each object of examination, n – number of criteria evaluated, m – number of experts who evaluated the service. To calculate it, the sum of the assigned ranks and deviation squares of the rank sums from the average sum for each indicator were determined. The statistical significance of the coefficient of concordance was checked against the Pearson correlation criterion $\chi^2 = m(n-1)W$. Based on the sums obtained, the sum of the converted ranks was determined and the weight of each indicator was calculated to the formula, where $s_{ij} = x_{max} - x_{ij}$.

Student's t-test and analysis of variance were used to test the effectiveness of using the GitHub cloud service to develop professional competence. One-factor and two-factor analysis of variance with inter-group and intragroup factors – mixed-model analysis of variance (mixed-model ANOVA). Student's T-test allows to check the equality of mean values in two samples and is calculated by the formula:

$$t = \frac{|M_1 - M_2|}{\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}},$$

where M_1 and M_2 – mean value in control and experimental groups; σ_1 and σ_2 – standard deviation; N_1 and N_2 – sample sizes.

The variance two-factor analysis allowed to estimate the effect of two factors on different samples of objects, and the one-factor one on the influence depending on the evaluation stage.

The following conditions were considered to obtain reliable results of analysis of variance:

1. In the analyzed groups, the values of the dependent variable should be normally distributed. In this case, it is assumed that the value of the dependent variable has a normal distribution within each group, relative to the levels of factors. However, the response values do not have to have this distribution. Another weakening of the normality requirements is the normality of the distribution of model residues.
2. Homogeneity (homoskedasticity) of group variances. That is, the values of the dependent variable in each group must be statistically equal.

4 IMPLEMENTATION

One of the important types of projects in the process of IT specialists training is the projects on the collaborative development of software products, and therefore it is important to prepare students for the implementation of such projects since college times, to develop in them the necessary professional and personal skills, in particular the skills of shared software developments. When choosing cloud services for collaborative development of software products, the following issues should be taken into account: interoperability on the code, bug tracking, discussion of the code with other team members, management of versions of code and integration of additional services, availability of a repository, wiki and code editor, etc. There arises a need to integrate additional services so that the cloud services of software products collaborative development could enable us to manage projects. While implementing software development projects, the students cannot be restricted by cloud services only while organizing the teamwork; the future IT specialists also need the services, which will allow them to work together on the product code they plan to develop.

Given the rate of change in the field of IT, the number of cloud services for teamwork is constantly increasing, but assessing the functionality of such services, they can be subdivided into two categories: cloud services for project management (1) and team development of the software product (2).

Recently, educators also started using GitHub as a teaching tool for programming courses by hosting code samples and managing student tasks, and organizing teamwork (Angulo and Aktunc, 2019). The ability to use version control is a valuable skill for computer science graduates to possess. Git is a well-established, well received source version control system for the software development community and beyond (Bonakdarian, 2017; Kelleher, 2014; Haaranen and Lehtinen, 2015).

To complete the programming projects, experimental group students were asked to combine ETC resources in different academic disciplines with the GitHub service. In to complete the programming projects, students' experimental group were asked to combine ETC resources in different academic disciplines with the GitHub service. Morze and Glazunova (Morze and Glazunova, 2013) proposed the structural features, the ratio of form and content of the smart course elements and its properties: individual learning paths, content personification, the use of training elements with links to public information resources, interactive training elements, multimedia, communication and cooperation elements are substantiated. Teachers of relevant disciplines and technological practical training placed tasks of collective projects in the ELC. The ETC, posted by the teacher, contained the theoretical material (Book, Lesson resources) and course terminology (Glossary resource), lab sessions assignments (Assignment resource), and the exchange of useful resources and files (Database resource). At GitHub, student teams create their own projects, in which they can further collaborate on code writing, use the repository, perform branches, issue releases, and communicate with each other while completing study project tasks. The scheme of combining Moodle resources with the GitHub cloud service is presented in figure 1.

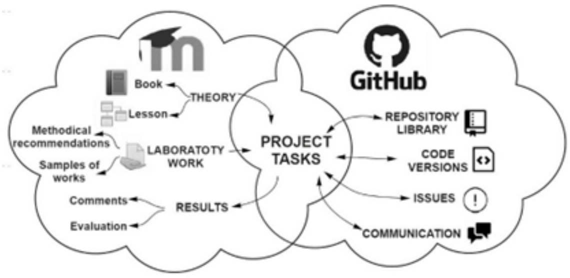


Figure 1: The scheme of combining Moodle resources with the GitHub cloud service.

For project or lab assignments, student groups can work on a public repository sharing code and ideas. It also allows cross-team communication with multiple teams working on a larger project as it happens in industry settings or teams exchanging ideas and reviewing each other's works. GitHub's cloud service provides users with a user-friendly web interface to the repository, user profile tools, change tracking, messaging, comments and online access, allowing the instructor and students to track the contributions of each team member so that students can be held accountable for their work. Thus, we can single out the following features of the GitHub cloud service (figure 2), which are important in the course of the implementation of educational projects on programming:

- programming: code editor; code versions management; bug tracking; platform support; availability of wiki pages;
- collaborative development: joint software development; teamwork planning and organization; establishing communication; security and privacy.

Precisely these features, inherent in GitHub tools, make it possible to apply different types of educational projects related to different programming technologies. This cloud service was offered to students for completing mini projects, for group and individual project assignments, term papers within academic disciplines.

In order to determine the effectiveness of the cloud service for GitHub collaborative development, 29 students were surveyed on the above-mentioned evaluation indicators after the implementation of the programming educational projects. A questionnaire was developed to ask students to assess the importance of each of the indicators:

- i1. Possibility of collaborative development of software;
- i2. Ability to manage code versions;

Figure 2: Classification of GitHub cloud service features.

- i3. Convenience of bug tracking;
- i4. Ability to organize and plan teamwork;
- i5. Communication capability;
- i6. Ability to support platforms;
- i7. Convenience of the code editor;
- i8. Security and privacy;
- i9. Availability of wiki pages.

Table 1 provides an assessment of the results of determining the effectiveness of cloud service for GitHub team development in the course of executing educational projects on programming by future IT specialists. The highest-rated indicator was assigned a rank of 1.

The concordance coefficient $W = 0.85$ indicates a high degree of convergence among experts. Pearson correlation criterion was calculated to assess the significance of the concordance coefficient $\chi^2 = m(n-1)W$. As the calculated one χ^2 (197.2) is higher than the table value (15.5) for the number of degrees of freedom $K = n-1 = 9-1 = 8$ and at a given level of importance $\alpha = 0.05$, we may conclude that the obtained coefficient of concordance of 0.85 is not accidental, and therefore the results obtained are statistically significant.

Based on the obtained rank sum the weights of the indicators considered were calculated. The survey matrix was transformed into a matrix of transformed ranks according to the formula, where $s_{ij} = x_{max} - x_{ij}$, in which $x_{max} = 9$ and the weight of each indicator was calculated.

The analysis of the significance of the factors studied revealed that the following indicators were noted by the students as being the most significant ones: the possibility of collaborative development of software, the convenience of bug tracking, the convenience of the code editor, and the ability to manage code versions when completing educational projects on programming.

In the second stage of the study, students worked on tasks of various projects using the cloud service GitHub. It was proposed to carry out collective mono-projects during the study of professional disciplines or course work within such disciplines, which will allow the formation of future IT professionals professional competencies and soft skills using services for collective IT development for inverted learning (Glazunova et al., 2022).

While studying “Object Oriented Programming” academic disciplines students were asked to complete mini projects using a cloud service to collaboratively develop GitHub software. The purpose of such projects was to develop professional competencies and personal effectiveness skills in future IT specialists Students worked in teams of 4-5 people. In each team a leader was identified, he distributed the tasks among the participants of the collective project. The task of “Database Organization” organization mini projects was to design a relational model of databases for the future automated system (according to the topic chosen by students); constructing class diagrams and developing a system using a class composition.

Table 1: Assessment of the results of determining the effectiveness of cloud service for GitHub team development in the course of executing educational projects on programming by future IT specialists.

Indicator	Rank sum	S	Concordance coefficient	Pearson criterion		Sum of converted ranks	Indicator weight
				predictive	table		
i1	35	12100	0.85	197.2	15.5	226	0.22
i2	121	576				140	0.13
i3	62	6889				199	0.19
i4	147	4				114	0.11
i5	173	784				88	0.08
i6	248	10609				13	0.01
i7	96	2401				165	0.16
i8	227	6724				34	0.03
i9	196	2601				65	0.06
∑	1305	42688				1044	1

Within the framework of mastering the ”Object Oriented Programming” academic discipline, the students were offered to implement an educational project entitled “Development of a program system for working with IT company management computer systems databases”, the objective of which was to review and analyze modern design technologies; to develop and use software standards for common computer-driven control systems; to develop software structures for the computerized management system and UML diagrams of design entities; to develop a graphical interface for computer control system software; programming and debugging using object-oriented programming techniques; testing and analysis of the performance of the developed computer management software; reporting on the performance of computer-based management systems; development of a set of standard documents to support the developed computer management software.

Within the framework of the project and technological practical training, students performed a collaborative project using the GitHub cloud service aimed at the development of their professional and personal competencies, namely: improvement of practical skills in software development and design using modern approaches and tools for flexible software development, development of teamwork skills in students, which are in demand on the modern IT labor market. The task of the team project was to develop software with web interface and relational database using HTML, CSS, JavaScript, MySQL, PHP technologies. Work on the educational project was carried out in line with the principles of Agile flexible development and Scrum methodology, which provides an incremental and iterative approach and specific roles of the participants in the development of the collaborative project. In the course of collaborative IT development using GitHub, future IT specialists kept the educational project code and necessary documentation in the public domain. In addition, a version control system was used to provide integrity and multiuser access.

5 EXPERIMENTAL RESULTS

To assess the effectiveness of the use of GitHub, two samples of students were selected: a control group (Control) without the use of a joint development service in the educational process and an experimental one using GitHub (Experiment). The comparison will be made in three stages of studying the discipline ”Programming”. Assessments were conducted in the following sequence: exam for the first semester (Examen1), results for the second semester (Examen2) and internship (EducPractic). Accordingly, the study put forward the following null hypotheses, the deviation of which will confirm the effectiveness of the use of the cloud service GitHub for the formation of professional competence: 1) the average score in the control and experimental groups does not differ; 2) the difference in the average score at different stages of evaluation is statistically insignificant; 3) the difference in the average score by groups (samples) at different stages of evaluation is statistically insignificant.

To test the first hypothesis, Student’s t-test or its non-parametric analogue, the Mann-Whitney-Wilcoxon test, will be used. To check others – analysis of variance. In particular, for the second hypothesis, one-factor analysis of variance (if necessary, non-parametric Kruskal-Wallis test) and for the third, two-way analysis of variance with intergroup and intragroup factors – mixed-model analysis of variance (mixed-model ANOVA).

Before starting the statistical verification, the power analysis should be used to determine the level of effect for the given methods that provide sample sizes. Table 2 shows the sample sizes in different sections. A significance level of 0.05 and a power of 80% were also selected for power analysis.

Table 2: The size of student samples at each stage of the study.

Evaluation stage	Group		Sum
	Control	Experimental	
Examen1	96	99	195
Examen2	96	99	195
EducPractic	96	99	195
Sum	288	297	-

To assess the possibility of neglecting the normality requirement, the effect level for Student's t-test was determined by the first hypothesis for samples of experimental and control groups, which are 288 and 297, respectively. The results of the calculations are presented in listing (figure 3).

```
pwr.t2n.test(n1=288, n2=297, sig.level=0.05,
             power=0.80)
t test power calculation
             n1 = 288
             n2 = 297
              d = 0.232
      sig.level = 0.05
          power = 0.8
```

Figure 3: Evaluation of the effect for the Student's t-test.

As figure 3 of the power analysis shows, the effect level is 0.232 (d value), which indicates the possibility of determining small effects (Cohen, 1988), accordingly, the requirement for data distribution according to the normal distribution law can be neglected.

To analyze the capacities for small groups, a calculation was made for pairwise comparisons of the obtained scores in terms of individual types of evaluation (sizes of groups 96 and 99), which is presented in listing (figure 4).

```
pwr.t2n.test(n1=96, n2=99 , sig.level=0.05,
             power=0.80)
t test power calculation
             n1 = 96
             n2 = 99
              d = 0.403
      sig.level = 0.05
          power = 0.8
    alternative = two.sided
```

Figure 4: Evaluation of the effect for pairwise comparisons of scores in terms of individual types of evaluation.

The obtained value of the effect (0.403) corresponds to the average theoretical level of the effect, therefore, when choosing a statistical procedure, it is advisable to consider the law of data distribution in the samples.

For the second hypothesis, where the test method should be a one-way analysis of variance with a group size of 195, the calculated effect is shown in listing (figure 5).

```
pwr.anova.test(k=3, n=195, sig.level=0.05,
               power=0.80)
Balanced one-way analysis of variance power
calculation
              k = 3
              n = 195
              f = 0.129
      sig.level = 0.05
          power = 0.8
```

Figure 5: Effect evaluation for analysis of variance.

The obtained value (0.129) is close to the theoretical value of the small effect (0.1) but slightly exceeds it. Therefore, when establishing the inconsistency of the distribution with the normal law, we additionally use nonparametric methods.

Since there is no statistical procedure for determining the level of effect in the power analysis for two-factor analysis with an unbalanced design (groups of different sizes), this analysis was not performed. The obtained average scores in the sections of the groups and evaluation by the results of the second stage of the experiment are presented in table 3 and in figure 6.

Table 3: The average performance of students in the control and experimental groups in terms of stages of assessment.

Evaluation stage	Group		By types of evaluation
	Control	Experimental	
Examen1	73.1	75.9	74.5
Examen2	76.2	79.9	78
EducPractic	74.3	82.2	78.2
By groups	74.6	79.3	-

According to the summary data, the difference between the overall scores in the groups is 4.7 points. At the same time, if we evaluate the pairwise differences in grades for different types of assessment, the biggest difference was in the success of students in the results of internship – 7.9 points.

Analyzing the data presented in figure 3, we see the difference in the medians, as well as the distribution of scores – the experimental group shows the best results for both general and stages (figure 7).

In this case, if the experimental group is characterized by an increase in scores in stages: Examen1 $\rightarrow$ Examen2 $\rightarrow$ EducPractic; then in the control group after the growth of average scores, the average scores of internship results are lower than for the exam in the

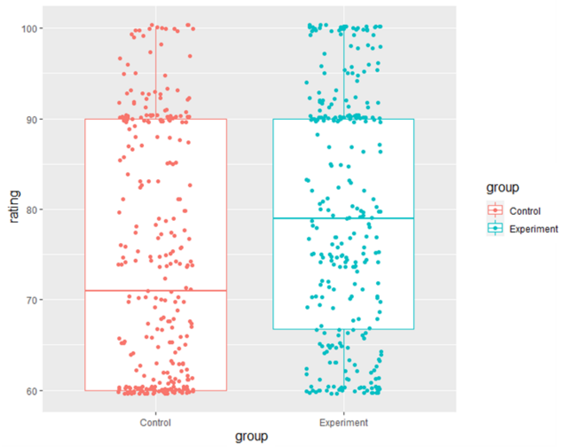


Figure 6: Average student performance based on the results of three stages of assessment.

Figure 7: The success of students of control group and experimental group in terms of assessment stages.

2nd semester.

Comparing estimates by type of control, there is an increase in scores by stages (figure 8). At the same time, a significant change occurred between exams in different semesters (3.5 points).

The difference between such related stages as the exam in the 2nd semester and internship is insignificant (0.2 points), which is caused as noted above by the deterioration of grades for internship in the control group.

For the final choice of methods for estimating statistical hypotheses, the samples were tested for distribution normality using the Shapiro-Wilk test. The obtained results are presented in figure 9.

According to the data obtained from the Shapiro-Wilk tests, the null hypothesis about the normality of the distribution laws of the control (p-value $= 1.382 \cdot 10^{-15}$) and experimental groups (p-value $=$

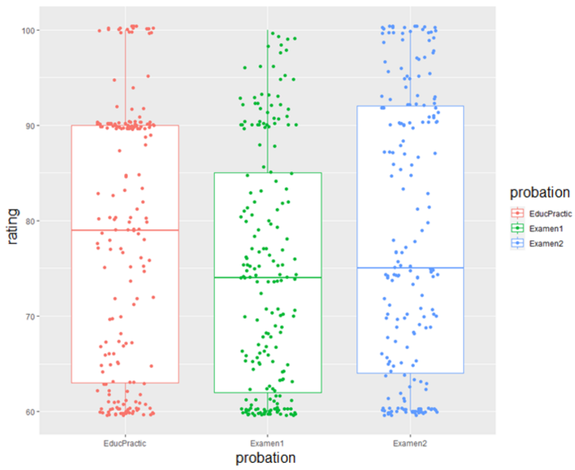


Figure 8: Student performance in terms of assessment stages.

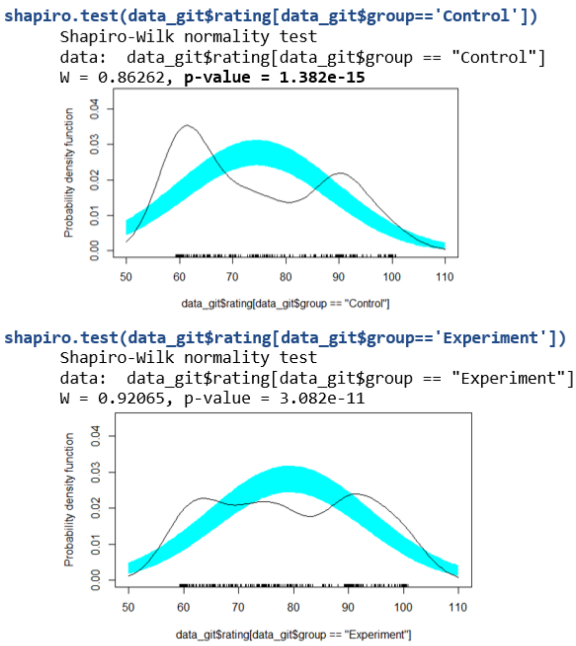


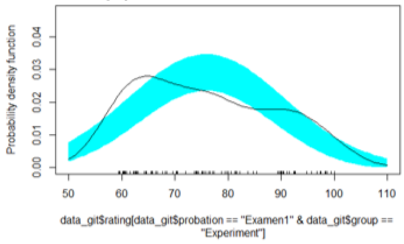
Figure 9: The results of checking the samples (control group and experimental group) for the normality of the distribution.

$3.082 \cdot 10^{-11}$) was rejected, which also illustrated the graphs of the empirical and the theoretical distribution density function.

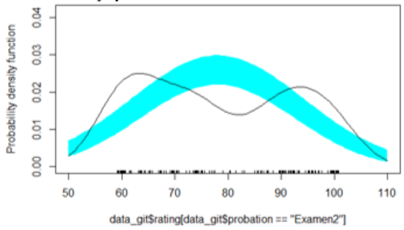
Similarly, the verification of the obtained data was carried out by types of evaluation, which is presented in figure 10.

The obtained results (p-values: $3.536 \cdot 10^{-10}$, $7.687e \cdot 10^{-11}$ and $1.741 \cdot 10^{-11}$) indicate that these samples are not subject to the normal distribution law. Because analysis of variance is used to assess the statistical significance of differences, a group variance test (Barlett test) and an emission test (Bonferroni

```
shapiro.test(data_git$rating[data_git$probation=='Examen1']
        Shapiro-Wilk normality test
     data:  data_git$rating[data_git$probation == "Examen1"]
     W = 0.89979, p-value = 3.536e-10
```




```
shapiro.test(data_git$rating[data_git$probation=='Examen2'])
        Shapiro-Wilk normality test
     data:  data_git$rating[data_git$probation == "Examen2"]
     W = 0.8889, p-value = 7.687e-11
```




```
shapiro.test(data_git$rating[data_git$
                              probation=='EducPractic'])
     Shapiro-Wilk normality test
     data:  data_git$rating[data_git$
                              probation == "EducPractic"]
     W = 0.87758, p-value = 1.741e-11
```

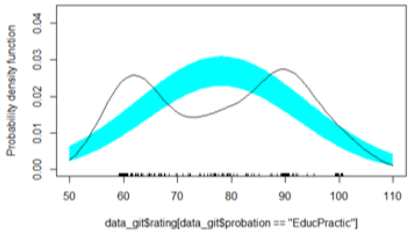


Figure 10: The results of checking the data on the normality of the distribution by type of assessment.

test) were performed.

To conduct the Barlett test, the null hypothesis was put forward that the variances between the groups are equal. The estimate of the variance homogeneity in the groups for different types of estimation is shown in listing (figure 11).

```
bartlett.test(rating ~ probation, data=data_git)
     Bartlett test of homogeneity of variances
     data:  rating by probation
     Bartlett's K-squared = 3.9919, df = 2,
                                p-value = 0.1359
```

Figure 11: Estimation of variance homogeneity for different types of estimation.

The obtained value of p-value = 0.1359 is greater than the significance level – 0.05, so there is no reason to reject the null hypothesis of the test on the equality of variances in groups. The data obtained in this way indicate that the variance data are statistically different. Similarly, the statistical equality of variances for the control and experimental groups of the third hypothesis, which is presented in listing (figure 12), was estimated.

```
bartlett.test(rating ~ interaction(group, probation),
                                     data=data_git)
     Bartlett test of homogeneity of variances
     data:  rating by interaction(group, probation)
     Bartlett's K-squared = 4.1934, df = 5,
                                     p-value = 0.5219
```

Figure 12: Estimation of dispersion homogeneity for control group and experimental group.

As in the previous case, we decide to reject the null hypothesis of equality of variances.

The Bonferroni test listings (figure 13) show no emissions for both types of analysis of variance. Accordingly, the original data meet these two requirements for analysis of variance.

```
outlierTest(aov(rating ~ probation, data = data_git))
     No Studentized residuals with Bonferroni p < 0.05
     Largest |rstudent|:
         rstudent unadjusted p-value Bonferroni p
     309 1.875526           0.061222           NA
outlierTest(aov(rating ~ group*probation,
                                   data = data_git))
     No Studentized residuals with Bonferroni p < 0.05
     Largest |rstudent|:
        rstudent unadjusted p-value Bonferroni p
     17 1.938724           0.053021           NA
```

Figure 13: Bonferroni test.

Therefore, considering the obtained estimates of the normality of the data distribution and the results of power analysis, we choose the following methods for testing hypotheses:

- Hypothesis 1: to check the equality of the average overall scores – Student's t-test; for comparisons of average scores in groups for individual types of evaluation – Mann-Whitney test, as in contrast to the overall estimates, the size of the effect is estimated as average, which does not allow to ignore the normality of the distribution.
- Hypothesis 2: despite the fact that the size of the effect is close to small, in addition to one-way analysis of variance, the results were verified through the Kruskal-Wallis test.
- Hypothesis 3: since it is impossible to perform a power analysis for two-factor analysis of variance with an unbalanced design, the requirement of normality was neglected due to the large samples in each group (Zar, 1996). Moreover, tests for the homogeneity of variances and emissions indicated the possibility of analysis of variance.

After analysis and selection of the above methods, the hypotheses put forward in the study were tested.

According to a preliminary analysis, the difference between the overall scores in the groups is 4.7 points. To assess whether this difference in scores is statistically significant (Hypothesis 1), we chose in the previous stages we chose Student's t-test. Prior to the test, a check was made for the Welch amendment to be considered for samples with different variances (figure 14).

```
var.test(rating~group,data=data_git)
F test to compare two variances
data:  rating by group
F = 1.0324, num df = 296, denom df = 287,
                          p-value = 0.7859
alternative hypothesis: true ratio of
             variances is not equal to 1
             95 percent confidence interval:
 0.8200786 1.2992479
sample estimates:
ratio of variances
           1.032437
```

Figure 14: Test for equality of variances in samples.

As you can see from the data presented in figure 14, the probability of obtaining an error of the first kind is 78.6% with a permissible 5%, to reject the null hypothesis. Therefore, the variances are statistically equal and the Welch correction is not required. The evaluation of the t-test for the overall averages in the two groups is presented in listing (figure 15).

```
t.test(rating~group,data=data_git, var.equal = TRUE)
Two Sample t-test
data:  rating by group
t = -4.2478, df = 583, p-value = 2.512e-05
alternative hypothesis: true difference in means
between group Control and group
Experiment is not equal to 0
95 percent confidence interval:
 -6.961609 -2.559435
sample estimates:
   mean in group Control mean in group Experiment
                74.55892                 79.31944
```

Figure 15: Checking the equality of average overall scores.

According to the obtained results, the actual value of the criterion $-t_f = 4.25$ exceeds the critical $-t_cr = 1.967$ for a given level of significance (0.05), which is necessary to reject the null hypothesis of equality of the two averages. Therefore, we can conclude that the difference between the mean scores between the control and experimental groups (4.7 points) is statistically significant. In this case, with a probability of 95%, this difference will be from 2.6 to 7.0 points. Accordingly, the null hypothesis is rejected.

As noted earlier, a nonparametric Mann-Whitney-Wilcoxon test, which is used for samples without a normal distribution, was calculated to confirm the difference in scores between samples at different stages of the assessment (figure 16).

```
wilcox.test(rating~group,data=data_git
[data_git$probation=='Examen1',], paired = FALSE)
Wilcoxon rank sum test with continuity correction
data:  rating by group
W = 4059.5, p-value = 0.07764
alternative hypothesis: true location
                    shift is not equal to 0

wilcox.test(rating~group,data=data_git
[data_git$probation=='Examen2',], paired = FALSE)
Wilcoxon rank sum test with continuity correction
data:  rating by group
W = 4035, p-value = 0.05729
alternative hypothesis: true location
                    shift is not equal to 0

wilcox.test(rating~group,data=data_git
[data_git$probation=='EducPractic',], paired = FALSE)
Wilcoxon rank sum test with continuity correction
data:  rating by group
W = 3206.5, p-value = 7.217e-05
alternative hypothesis: true location
                    shift is not equal to 0
```

Figure 16: Calculation of the nonparametric Mann-Whitney-Wilcoxon test.

The obtained test results indicate that a statistically significant difference between the averages in the groups is observed only for internship (7.9 points), which is indicated by the value of p-value which is less than the level of significance.

However, it should be noted that in addition to the fact that this test, like all non-parametric has less accuracy, the use of pairwise comparisons with the possibility of analysis of variance is not statistically effective. Therefore, this analysis can be considered as additional in a more efficient analysis of variance.

As noted in the previous analysis, the difference between the exams was significant in contrast to the exam (2 semester) and internship. To test the statistical significance of the differences in the mean score at different stages (Hypothesis 2), the significance of the differences was estimated (figure 17).

```
fit_probation <- aov(rating ~ probation,
                               data = data_git)
             Df Sum Sq Mean Sq F value Pr(>F)
probation     2   1701   850.6   4.555 0.0109 *
Residuals   582 108674   186.7
     ---
Signif. codes: 0 '***'0.001'**'0.01'*'0.05'.'0.1' '1
```

Figure 17: Assessing the significance of differences.

The F-test indicates that there are differences between the groups ($p < 0.05$). As noted at the stage of selection of research methods, an additional analysis was performed according to the non-parametric Kruskal-Wallis test (figure 18).

The results of the Kruskal-Wallis test confirmed the results of one-way analysis of variance.

```
fit_kruskal <- kruskal.test(rating ~ probation,
                            data = data_git)
          Kruskal-Wallis rank sum test
     data:  rating by probation
     Kruskal-Wallis chi-squared = 6.9486, df = 2,
                            p-value = 0.03098
```

Figure 18: Analysis by the nonparametric Kruskal-Wallis test.

Pairwise comparisons using the Tukey test (figure 19) and graphical data (figure 20) concluded that the difference between the exams (Examen2-Examen1 – p-value = 0.029) and the exam for 1 semester was statistically significant. Internship (Examen1-EducPractic – p-value = 0.022) and is -3.7 and 3.5, respectively. The difference between the second semester and the internship is not statistically significant (p-value = 0.994 and intersects on the graph with a vertical January) and is within the statistical error.

```
TukeyHSD(fit_probation)
Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = rating ~ probation, data = data_git)
$probation
                          diff        lwr        upr     p adj
Examen1-EducPractic -3.6871795 -6.9389205 -0.4354385 0.0215893
Examen2-EducPractic -0.1435897 -3.3953308  3.1081513 0.9940823
Examen2-Examen1      3.5435897  0.2918487  6.7953308 0.0287904
```

Figure 19: Conducting pairwise comparisons using the Tukey test.

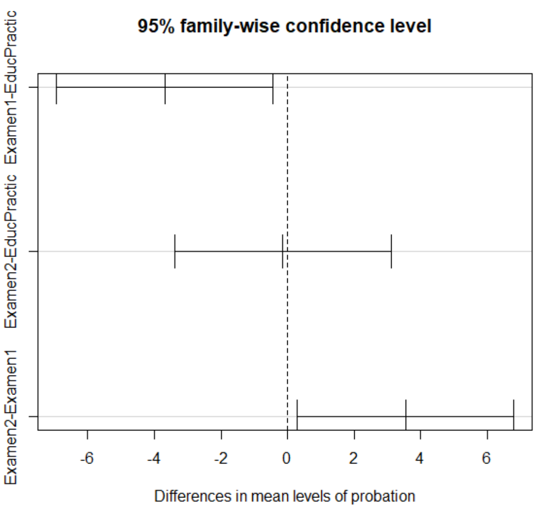


Figure 20: Graphical display of pairwise comparisons.

To check the statistical significance of the difference in the mean score by groups (figure 21) at different stages of the assessment (Hypothesis 3) was used two-factor analysis of variance with intergroup and intragroup factors – mixed analysis model (ANOVA). In our study, the intergroup factor was the distribution of groups of students relative to the control and experimental, and intragroup – the stages of evaluation.

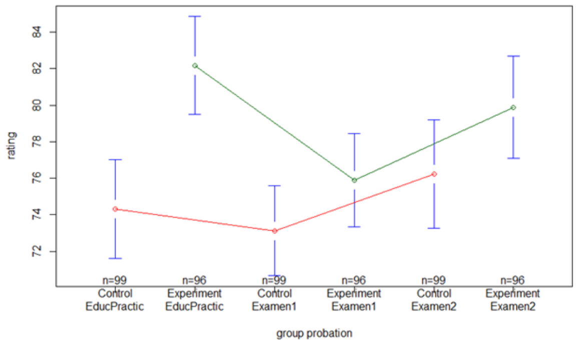


Figure 21: Plot group means and confidence intervals.

The constructed variance model for two-factor analysis of variance is presented in listing (figure 22).

```
fit <- aov(rating ~ group*probation +
       Error(id/probation), data=data_git)
       summary(fit)
Error: id
          Df Sum Sq Mean Sq F value  Pr(>F)
 group      1  3314    3314   9.247 0.00269 **
 Residuals 193 69162    358
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Error: id:probation
          Df Sum Sq Mean Sq F value   Pr(>F)
 probation       2  1701   850.6   9.257 0.000118 ***
 group:probation  2   728   363.8   3.959 0.019871 *
 Residuals      386 35471    91.9
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 22: Estimation of a two-factor variance model.

The calculated value of the Fisher criterion, based on the mean squares of the deviations within and between groups and the corresponding degrees of freedom for each of the factors is:

- For groups:

  $\nu BG = m \; --1 = 2-1 = 1$

  $\nu WG = n \; --m = 288 \; --2 = 286$

  where m is the number of factor levels (groups), n is the number of observations (students)

  Accordingly, according to tables F of Fisher's test at a significance level of 0.05, the empirical (theoretical, critical) value is F{0.05; 1; 286} = 3.847.

- For types of assessment:

  $\nu BG = m \; --1 = 3-1 = 2$

  $\nu WG = n \; --m = 195 \; --3 = 192$

Accordingly, according to tables F of Fisher's test at a significance level of 0.05, the empirical (theoretical, critical) value is F{0.05; 2; 192} = 3.042.

- For stages and interaction of groups and stages

  $\nu BG = (m_1 - 1) * (m_2 - 1) = (2-1) * (3-1) = 2$

  $\nu WG = (m_1 + m_2 - 1) * (n-1) = (2+3-1) + (\frac{99+96}{2} - 1) = 386,$

  where m_1, m_2 is the number of levels for intergroup (group) and intragroup (stages) factors, n is the number of observations (students) in each sample divided into groups and stages – F{0.05; 2; 386} = 3.847.

According to the results of the study, the dependence of the averages for groups and types of assessment is statistically significant, as indicated by the value of the actual F statistics, exceeding the critical values found: 9.247>3.890 and 9.257>3.042 (or according to p-value – 0.0026 and 0.00011, respectively, which is much less than the significance level of 0.05). That is, two-factor analysis of variance proved the preliminary results on the deviation of 1 and the second null hypotheses.

As for the interaction of groups and stages, is the question in assessing the statistical significance of differences by groups at different stages, the value of the obtained Fisher statistics is more than critical – 3.959>3,847 (p-value = 0.019871) indicates the presence of an additional effect from the interaction. That is, there is a significant difference in the average of individual groups by type of assessment. For the obtained model we will make multiple comparisons according to the Tukey test:

- The group comparison (figure 23) confirmed the t-test data on the statistical significance of the difference in the rating score for the control and experimental groups, which is 4.7 points.

```
emmG <- emmeans(fit, ~ group)
pairs(emmG)
contrast              estimate   SE  df t.ratio p.value
Control - Experiment     -4.76 1.57 193  -3.041  0.0027
```

Figure 23: Multiple group comparisons.

- From the obtained comparisons (figure 24) of the averages by stages (types of evaluation) for all groups, we see that the significant difference in the average evaluations corresponds to the data of one-factor analysis for the second hypothesis.

- Pairwise comparisons of the difference between the mean scores for the groups divided by both factors are significant for most comparisons (figure 25).

```
emmG <- emmeans(fit, ~ group)
pairs(emmG)
contrast              estimate    SE  df t.ratio p.value
EducPractic - Examen1    3.726 0.971 386   3.838  0.0004
EducPractic - Examen2    0.176 0.971 386   0.181  0.9820
Examen1 - Examen2       -3.550 0.971 386  -3.657  0.0008
```

Figure 24: Multiple comparisons by type of assessment.

```
emm <- emmeans(fit, ~ group*probation)
pairs(emm)
contrast                                      estimate   SE  df t.ratio p.value
Control EducPractic - Experiment EducPractic    -7.874 1.93 390  -4.089  0.0007
Control EducPractic - Control Examen1            1.172 1.36 386   0.860  0.9556
Control EducPractic - Experiment Examen1        -1.593 1.93 390  -0.827  0.9624
Control EducPractic - Control Examen2           -1.939 1.36 386  -1.423  0.7128
Control EducPractic - Experiment Examen2        -5.582 1.93 390  -2.899  0.0453
Experiment EducPractic - Control Examen1         9.046 1.93 390   4.698  0.0001
Experiment EducPractic - Experiment Examen1      6.281 1.38 386   4.540  0.0001
Experiment EducPractic - Control Examen2         5.935 1.93 390   3.082  0.0266
Experiment EducPractic - Experiment Examen2      2.292 1.38 386   1.656  0.5617
Control Examen1 - Experiment Examen1            -2.765 1.93 390  -1.436  0.7052
Control Examen1 - Control Examen2               -3.111 1.36 386  -2.283  0.2034
Control Examen1 - Experiment Examen2            -6.754 1.93 390  -3.508  0.0067
Experiment Examen1 - Control Examen2            -0.347 1.93 390  -0.180  1.0000
Experiment Examen1 - Experiment Examen2         -3.990 1.38 386  -2.883  0.0474
Control Examen2 - Experiment Examen2            -3.643 1.93 390  -1.892  0.4087

P value adjustment: tukey method for comparing a family of 6 estimates
```

Figure 25: Multiple comparisons by groups and types of assessment.

Comparisons between the same types of evaluations between the control and experimental groups showed:

- The difference in the average scores on the exam for the first semester (Control Examen1 – Experimental Examen1) is statistically insignificant (p-value = 0.7052>0.05);
- The difference in the average scores on the exam for the second semester (Control Examen2 – Experimental Examen2) is statistically insignificant (p-value = 0.4087>0.05);
- The difference in the average scores on internship (Control EducPractic – Experimental EducPractic) is statistically significant (p-value = 0.0007<0.05) and is 7.8 points.

These results confirmed the results of the Mann-Whitney-Wilcoxon test that the effectiveness of the implementation of experimental methods affected the results of internship, during which students actively used the cloud service GitHub to implement collective projects.

Assessing separately the dynamics of differences in each of the groups by stages, we see that in the control group, each change in the average score between different types of assessment is insignificant, which indicates the absence of any dynamics in traditional learning: "Control Examen1 – Control Examen2" – p-value = 0.2034, "Control EducPractic – Control Examen2" – p-value = 0.7128, "Control EducPractic – Control Examen1" – p-value = 0.9556. In contrast, for the experimental group where such changes were statistically significant.

6 CONCLUSIONS

The educational projects on programming are an effective method for shaping the professional and personal competencies of future IT specialists. To work on educational projects, you should use modern cloud services for collaborative IT development, such as GitHub. The most effective features of this service are the possibility of collaborative development of software (i1), the convenience of bug tracking (i3), and the convenience of the code editor (i7), which are determined by the statistical processing of student peer review. Other features of this service that have also been explored include the ability to manage code versions (i2), the ability to organize and plan teamwork (i4), the ability to communicate (i5), the ability to support platforms (i6), security and privacy (i8), availability of wiki pages (i9).

The GitHub cloud service can be applied to complete mini projects, group or individual work, term papers, or during the academic training of the students. The examples of using GitHub discussed in the paper show that the specific features of this service completely satisfy the needs of students of IT profession in the implementation of the tasks of educational projects on programming. And affects the formation of professional competence of future specialists in information technology, as evidenced by the results of the study. The obtained results of the experimental group are higher by 5.93% than in the control group. Crucial to the formation of professional competence are the use of cloud service in the implementation of collective projects for software development during training.

Further research can be aimed at theoretical substantiation and development of methods of flexible training of future information technology specialists using services for joint software development in the implementation of educational projects, as the technology of agile learning is closest to real conditions in software development.

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Features and Results of Learning Cloud Technologies by the Teachers for the Organization of the Educational Process in Quarantine

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Abstract: The article substantiates the need to develop and implement a distance course "Cloud technologies in the educational process in quarantine". It is noted that the purpose of the course was to acquaint teachers of general secondary education institutions, college teachers, vocational and higher education institutions with the basic possibilities of using cloud technologies to ensure the educational process in distance learning. The list of topics with which the students get acquainted is given: basic concepts, models of cloud services, architecture and proposals from leading cloud services companies; cloud services in the work of the teacher, the peculiarities of working with mail; cloud storage as an alternative to replacing conventional drives; opportunities to create documents with the provision of sharing rights to multiple users; opportunities to create Internet surveys using cloud technologies; opportunities to create presentations using cloud technologies; cloud-based means of creating mind maps; means of creating sites; cloud-based learning management systems (for example, Google Classroom). In this article, students are understood as teachers who have taken courses. The peculiarities of the proposed distance course and the difficulties that the students had in performing certain tasks are identified and described. The statistical results of the course are given. The article also presents the results of two waves of face-to-face courses for teachers of Zhytomyr schools. However, the results of a survey of students on distance learning in schools over the past two years are presented. Organizers of such courses must take into account the following features: 1) take into account the number of participants; 2) in the registration questionnaire to focus on the correct completion of all fields, especially when filling in the field "e-mail"; 3) when connecting students to the course, not only provide materials to familiarize with the organization of courses, Google Classroom, the purpose of the courses but also conduct introductory testing to determine the level of awareness of students with the necessary materials; 4) focus on the timely completion of tasks so as not to create inconvenience to other participants.

1 INTRODUCTION

During the global pandemic, the question of the readiness of teachers of general secondary education institutions, college teachers, vocational, and higher education institutions to carry out distance learning qualitatively became acute. Teachers had to adapt to the new challenges of today quite quickly, in a few days. In particular, teachers had to prepare in a short time to organize the educational process for the period of quarantine, which also provided for the organization of distance learning, which in turn, qualitatively possible to perform using cloud technologies.

Also, following the "Procedure for the professional development of pedagogical and scientific-

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pedagogical workers", one of the approved forms of professional development is remote (Cabinet of Ministers of Ukraine, 2019). Also, by the same procedure, one of the main areas of professional development is: "the use of information and communication and digital technologies in the educational process, including e-learning", as well as the development of digital competence (Cabinet of Ministers of Ukraine, 2019).

Therefore, it was decided to modify the developed course (Vakaliuk et al., 2021) for new challenges and offer teachers to take it remotely to develop their digital competence.

For this purpose, a certificate educational program "Information systems and cloud technologies in the educational process" was developed (Vakaliuk, 2022) within the specialty 126 "Information systems and technologies" at the Zhytomyr Polytechnic State University. Within the framework of this certified educational program the course "Cloud technologies in the educational process in the conditions of quarantine" was developed.

The purpose of the course was to acquaint pedagogical and scientific-pedagogical workers with the main possibilities of using cloud technologies to ensure the educational process in terms of distance learning.

2 THEORETICAL BACKGROUND

The issue of informatization of the educational process at present the subject of many works. In particular, Mintiy et al. (Mintiy et al., 2017) considered the problem of development of information and communication competencies of teachers of pedagogical institutions of higher education according to the program of advanced training courses "Information and communication technologies in full-time and distance (combined) training". Osadchyi and Osadcha (Osadchyi and Osadcha, 2017) investigated the possibilities of distance learning in the study of technical disciplines. Bogachkov et al. (Bogachkov et al., 2020) proposed a comprehensive application of Google Classroom to create variable courses. They proposed a prototype of the Classroom X application, which provides the ability to automatically plan a specific sequence of tasks, automate the verification of tasks, the organization of repetition of a certain material, etc.

Britto (Britto, 2012) considered cloud computing in higher education, Dzikite et al. (Dzikite et al., 2017) studied lecturers' competencies in information and communication technology for effective implementation of ICT-integrated teaching and learning in textiles and clothing degree programs, Hanson-Baldauf and Hughes (Hanson-Baldauf and Hughes, 2009) studied the problem of the information and communication technology competencies of students enrolled in school library media certification programs, Jalgaonkar and Kanojia (Jalgaonkar and Kanojia, 2013) analyzed the possibilities of adoption of cloud computing in distance learning, Simonson et al. (Simonson et al., 2015) studied the problem of teaching and learning at a distance.

Also, some scientists considered the problem of distance learning at school both during the quarantine period and in general (Lytvynova and Demeshkant, 2021; Zhenchenko et al., 2021; Ovcharuk and Ivaniuk, 2021; Zhorova et al., 2022; Sych et al., 2021; Trubavina et al., 2021). In particular, Lytvynova and Demeshkant (Lytvynova and Demeshkant, 2021) reviewed the results of the "SMART KIDS" experiment in the context of distance learning in primary school during the COVID 19 pandemic, Zhenchenko et al. (Zhenchenko et al., 2021) investigated the professional approach to the use of electronic educational resources on Ukrainian techniques in remote preparation for the COVID-19 pandemic, Ovcharuk and Ivaniuk (Ovcharuk and Ivaniuk, 2021) reviewed the results of a survey regarding the level of digital competence of Ukrainian teachers in the context of lifelong learning using a self-assessment tool. But the researchers ignored the question of the effectiveness of organizing such courses in a remote form.

Therefore, the purpose of the article is to identify and describe the features of distance learning of cloud technologies for teachers of general secondary education, college teachers, vocational and higher education institutions for use in the educational process in quarantine.

3 RESULTS

To provide distance learning for teachers of general secondary education, college teachers, vocational, and higher education institutions, we develop the course "Cloud technologies in the educational process in quarantine" (Vakaliuk, 2020). This course has been modified by improving the course "Cloud Technologies in Education" taking into account the new challenges currently facing pedagogical and scientific-pedagogical staff of educational institutions.

The main challenges include the organization of distance learning using cloud technologies, the organization of the educational process in quarantine, time constraints, and more.

The previous course "Cloud technologies in education" was changed by reducing the amount of educational material, tightening the deadlines, and the feature was not traditional learning in the classroom, and distance learning.

The course was limited for 5 days, so that course participant could quickly get acquainted with the necessary cloud technologies that would allow them to organize the educational process in their educational institution.

During the course, teachers had the opportunity to get acquainted with:

- basic concepts, models of cloud services, architecture and proposals from leading cloud services companies (Markova et al., 2019);
- Google services in the work of the teacher, the peculiarities of working with mail;
- cloud storage as an alternative to replacing conventional drives;
- the ability to create documents with the provision of sharing rights to multiple users;
- opportunities to create Internet surveys by cloud-based tools;
- opportunities to create presentations by cloud-based tools;
- cloud-based mind maps (Ivanova et al., 2020);
- tools for creating sites (Pirohov et al., 2018);
- cloud-based learning management systems (for example, Google Classroom (Bondarenko et al., 2018)).

Here is an example of a training session.

Topic: **Creating a mind map.**

Objective: To learn how to create mind maps using cloud technologies.

1. Select one of the suggested services for creating mind maps.
2. Log in to your account.
3. Create a new mind map on a topic related to the subject you teach.
4. Give access to the 2 people after you in the list and the teacher.
5. Take a screenshot of the created mind map. Go to the Classroom, select the appropriate task, go to it by clicking "View Tasks", create a picture, and paste a copied screenshot.
6. After completing all tasks and inserting a picture, click "Submit".

Note that for each task there are theoretical materials, where the teacher step by step described the work with each service and supplemented the material with screenshots. Each topic was fully disclosed in the theoretical information and the listeners only had to open the materials and get acquainted with it.

Besides, the theoretical materials also gave examples of the use of a cloud service in the educational process of an educational institution.

We will point out the peculiarities of this course and the difficulties that students have in performing certain tasks. At this stage, we apply the method of mathematical statistics – the method of registration, which involves the detection of a particular phenomenon and its quantitative calculation.

The first is that *when registering for the course, a significant number of potential students (113 people) indicated e-mails either with errors or non-existent*. As a result, some of them were unable to join the course at the time it began. In this article, students are understood as teachers who have taken courses.

Second. *Listeners do not read the instructions and messages carefully*. As a result, the teacher had to spend a significant amount of time answering the questions that are fully listed in the instructions.

Third. Some students (353 people) *did not complete the tasks in the scheduled time* specified at the beginning of the course, which led to inconvenience to other participants, as all participants interacted not only with the teacher but also with each other.

Fourth. One of the forms of reporting turned out to be quite *complicated – inserting a picture in the form of screen capture* to confirm the performance of certain tasks. Everyone who encountered this problem did not even read the instructions, which again described all the steps step by step. Moreover, if one participant asked this question, and the teacher gave a meaningful answer, the other participants pretended not to see these comments, and just asked the question again. Again, all this reduced productivity and, accordingly, the effectiveness of the teacher's work on checking tasks, advising students on more important issues.

Fifth. *The implementation of project activities, which consisted of joint work on documents of different types, proved to be problematic*. For example, there were difficulties in studying the topic "Creating documents with sharing rights to multiple users". One of the tasks of this topic was:

1. Create an essay on "Cloud technologies in education".
2. Give access to 3 people on the list after you and the teacher.
3. Edit the document you have been granted access to.

4. In each document in which you are granted access, write a comment.

The task “Edit the document you have been granted access to” caused negative emotions in most students because they perceived this task as having another participant in the course have to make changes to show that the person is making many mistakes. Although in fact, the teacher in the organizational moments and the comments to the tasks drew attention to the fact that the purpose of the courses is to learn to work together on the project, and not another.

Significant difficulties also arose in working on a joint presentation. As in all tasks, users worked with 6-7 persons (under the conditions of tasks), and in this task, it was necessary to work at once with all groups, it led to more serious problems. In particular, the task was to create a business card about yourself on a separate slide. But some course participants already created their business cards on the created slides, or deleted already filled business cards, which led to misunderstandings and confusion when checking such a task.

There were also tasks that the students liked more, and they could express themselves creatively. In particular, one of the topics proposed for the study was cloud-based tools for creating mind maps. Course participants were offered 4 different cloud services that can be used for this type of activity, although some teachers used others not listed in the instructions.

As a result, course participants proposed their vision of using cloud-based tools to create mind maps, and created mental maps on a variety of topics: Mathematics, Biology, Polish, English (grammar, words – figure 1 and figure 2), Higher Mathematics, Computer Science, etc.

Note that an interesting and creative task was to create your presentation using cloud technologies. Each teacher, taking into account the specifics of teaching their subject, created a presentation using cloud technologies (figures 3 and 4). Several cloud services were offered to the course participants.

Upon completion of this course, students who have completed all planned tasks and worked on all assigned topics, receive a certificate of completion of the course “Cloud technologies in distance learning in quarantine”.

The distance course “Cloud technologies in distance learning in quarantine” was conducted in three waves: the first wave took place from 30.03.2020 to 03.04.2020, the second – from 06.04.2020 to 10.04.2020, and the third – from 13.04.2020 to 17.04.2020. Similarly, we apply the method of mathematical statistics – the method of registration, which is described above.

A total of 1,500 participants were registered, of whom 1029 took on the tasks, and only 816 completed the entire course. The statistics of participants by waves are presented in table 1 and visualized in figure 5 and figure 6 in the form of diagrams.

Table 1: Statistics of participants on waves.

	Waves			Together
	1st	2nd	3rd	
A total of registered	500	600	400	1500
Joined the course	367	381	281	1029
Completed the course	296	274	246	816

Negative dynamics between registered participants and those who started the tasks is because some registered participants did not specify their e-mail when registering, some participants did not take into account external factors that hindered them in performing tasks, and some participants did not check the mail. The situation is the same with those participants who joined the course and those who completed it. This is because some of the participants did not understand that they would need to complete the task, but decided that to obtain a certificate they only need to register. Some of the participants simply could not complete the proposed tasks.

During the whole period of the courses were involved:

- teachers of general secondary education – 499,
- educators of preschool educational institutions – 16,
- pupils and students – 5,
- teachers of higher education institutions – 70,
- teachers of colleges and vocational schools – 82,
- managers of educational institutions – 94,
- employees of education departments – 5,
- other employees at school – 34,
- researchers – 3,
- managers of other institutions – 8.

Detailed statistics are visualized in figure 7.

Employees of 40 higher education institutions became students of the developed distance course. The most active were the employees of the following higher educational institutions:

- Zhytomyr Polytechnic State University,
- Pavlo Tychyna Uman State Pedagogical University,

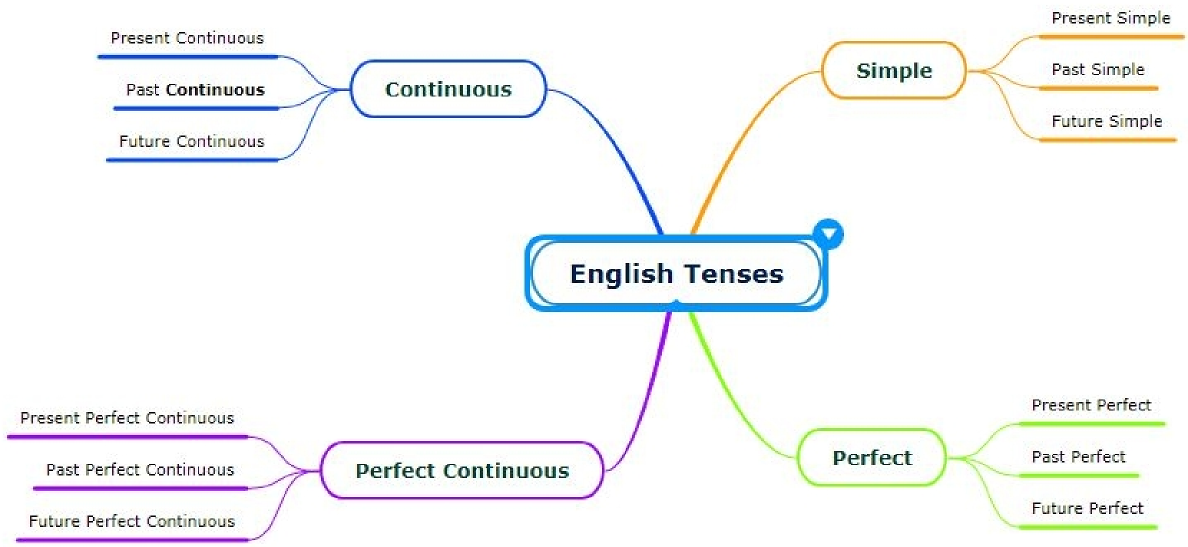

Figure 1: An example of a mind map for learning foreign languages, created by students during a distance learning course.

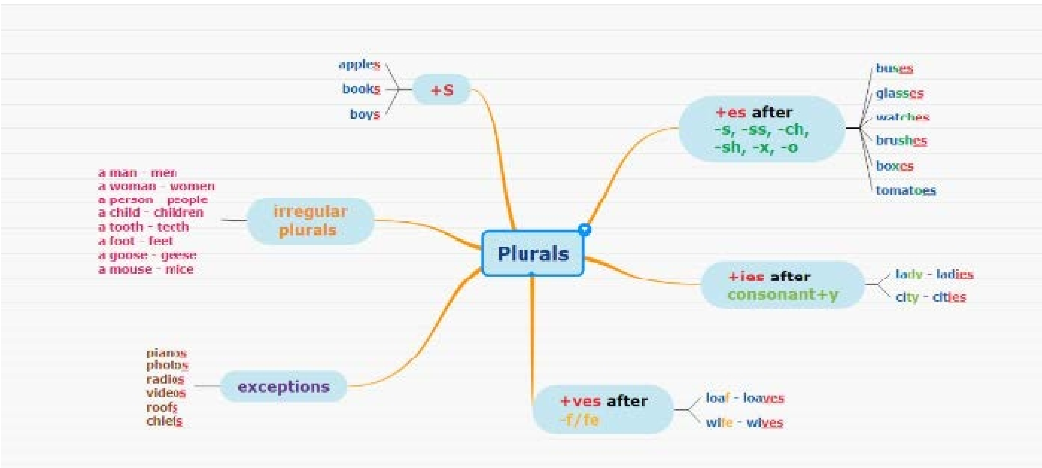

Figure 2: An example of an intellectual map for learning foreign languages, created by students during a distance learning course.

- National University of Life and Environmental Sciences of Ukraine,
- National Pedagogical Dragomanov University,
- Uzhhorod National University.

If we consider the statistics of participants about the regions of Ukraine, there were representatives of all regions of Ukraine (figure 8).

The developed course is aimed at developing information and communication competence of teachers of general secondary education, college teachers, vocational and higher education institutions by acquainting students with the basic possibilities of using cloud technologies to ensure the educational process in distance learning.

During the final survey of the course participants, it was found that the tasks took a lot of time and effort from the participants, but they were all satisfied after the courses. Students noted that the advantage of these courses for them was that there were more practical tasks than theory, the advantages of the students included the distribution of the submitted theoretical material and material for self-study and practical work.

Most of the students noted that they acquired new knowledge and skills in working with cloud services, as well as generalized and systematized them. As noted by students, the courses are modern, creative; lecture notes are clear; the clearly defined algorithm for performing tasks.

Participants also pointed out the advantage that the

Figure 3: Example of a presentation created by students during a distance learning course.

Figure 4: Example of a presentation created by students during a distance learning course.

courses were organized and conducted in a convenient format. All participants of the courses expressed a desire to take part in further similar events.

As a result of such courses, 2 waves of face-to-face courses were held for teachers of Zhytomyr secondary schools. The peculiarity of these courses was that the teachers were physically present in the auditoriums of the Zhytomyr Polytechnic State University.

Full-time courses were held from 25.08.2020-28.08.2020 and 14.09.2020-18.09.2020. In total, 91 employees of general secondary education institutions were involved, among them a number of teachers – 81, number of managers – 6, number of other employees – 4 (figure 9).

For example, here is an example of performing similar tasks in full-time courses (figures 10, 11, 12,

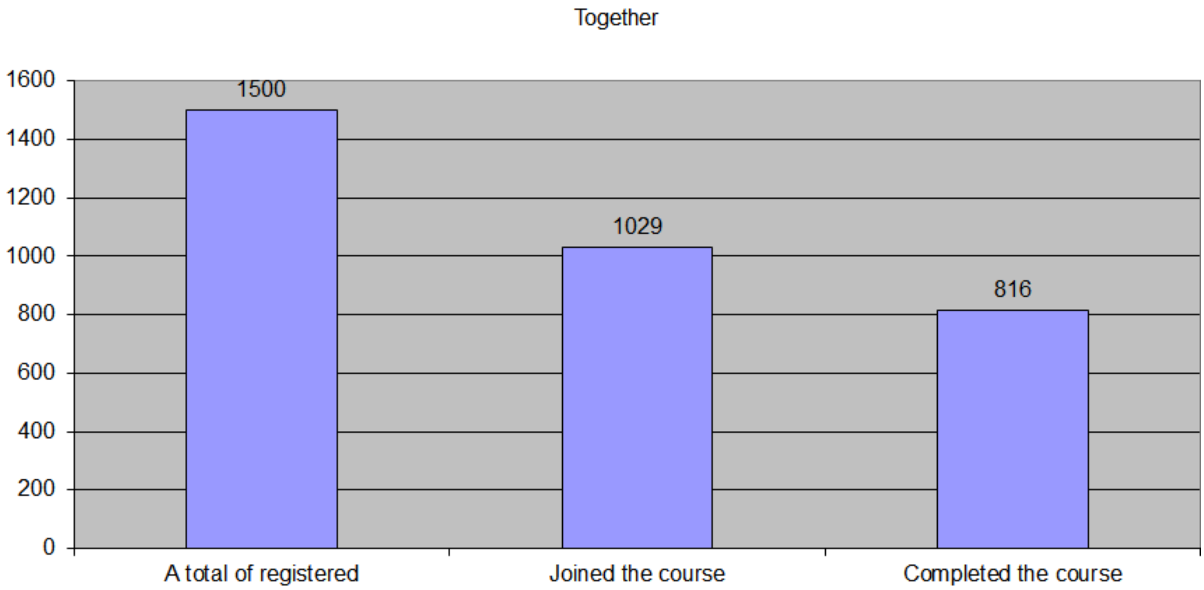

Figure 5: Statistics of course participants in general.

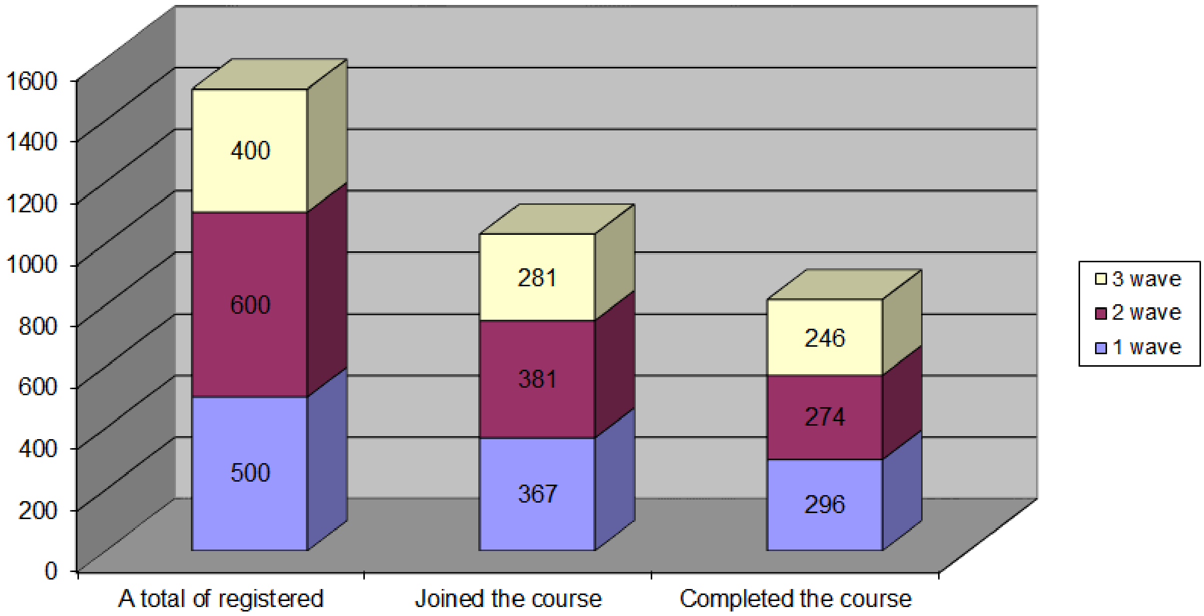

Figure 6: Data on the participants of the course on the waves.

13, 14).

This indicates that not only teachers are interested in improving their skills and improving their information and communication competence, but also managers (principals, deputy principals) and other categories of the school staff (including teacher assistants, social educators, secretaries, psychologists, etc.)).

We will point out the peculiarities of this course and the difficulties that students have in performing certain tasks in face-to-face format. At this stage, the method of mathematical statistics was used again – the method of registration, which involved the detection of a particular phenomenon and its quantitative calculation.

First and foremost. Listeners do not listen carefully to instructions and messages. As a result, the teacher had to spend a significant amount of time answering questions that are fully listed in the instructions and were voiced to students at the beginning of the lesson.

Second. Similar to distance learning courses, one-time reporting proved to be quite difficult in face-to-

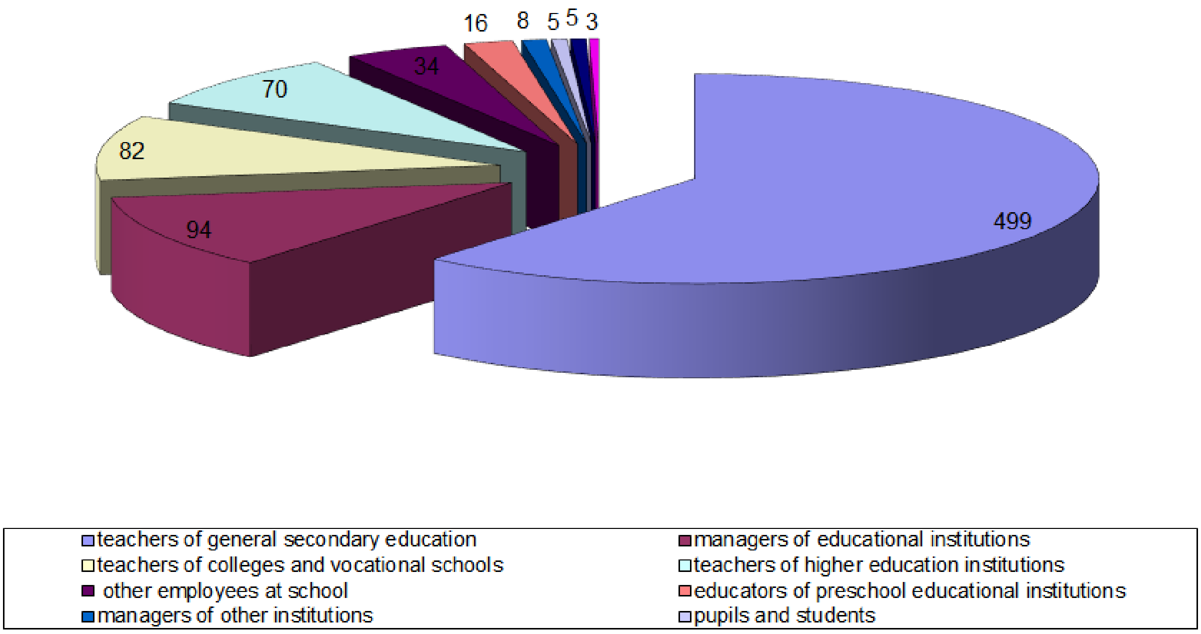

Figure 7: Percentage of participants at the place of work.

Figure 8: Statistics of course participants by regions of Ukraine.

face courses – inserting a picture in the form of a screen capture to confirm the completion of certain tasks. In addition to explaining how to do this at the beginning of each lesson, this was also described in the instructions. However, everyone who encountered this problem did not even read the instructions and did

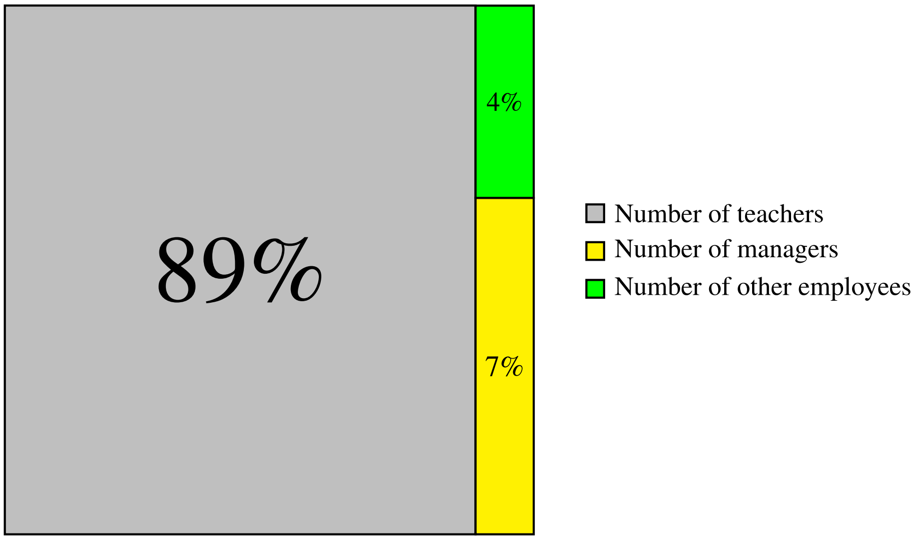

Figure 9: Distribution of course participants by position.

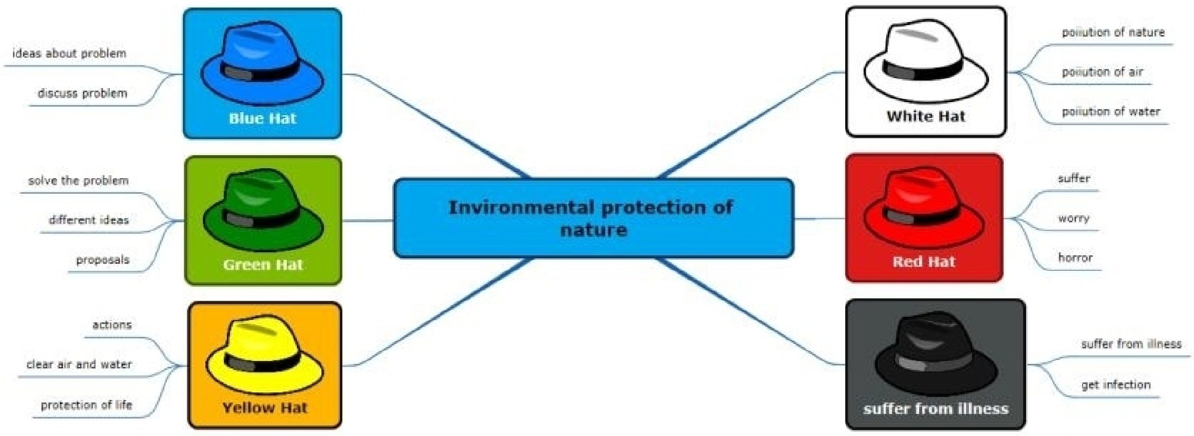

Figure 10: An example of a mind map with mistakes for learning foreign languages, created by students during a face-to-face learning course.

not listen carefully to the teacher.

As a result of the courses, we can conclude that the teachers themselves are not attentive and do not want to read the instructions carefully. This reduces the productivity of the teacher and the group as a whole.

Also for teachers, the pace of courses was fast, as the courses were condensed due to the presence of a large number of students in the audience for up to three and four days, respectively.

In addition, because the teachers again had different subjects, many teachers expressed a desire to continue courses for their special subject.

However, due to the spread of the COVID-19 pandemic and the beginning of the Russian aggression against Ukraine (Hamaniuk et al., 2020, 2021, 2022), this has not been continued so far. However, the wishes of all course participants (teachers) are sure to be reflected in our further activities and further research.

As a result, the authors were interested in the dynamics of the educational process in schools. Therefore, we conducted a survey of freshmen at the Zhytomyr Polytechnic State University in 2021 on the organization of the educational process in schools at the beginning of quarantine and after such courses. A total of 263 students took part in the survey. These were first-year students of the Faculty of Information and Computer Technologies of Zhytomyr Polytechnic State University.

As a result, it was found that during the beginning of the COVID-19 pandemic (March-April 2020) training was organized as follows (figure 15):

- 11.8% of respondents answered that they performed tasks independently and dealt with the ma-

Figure 11: An example of a mind map for learning foreign languages, created by students during a face-to-face learning course.

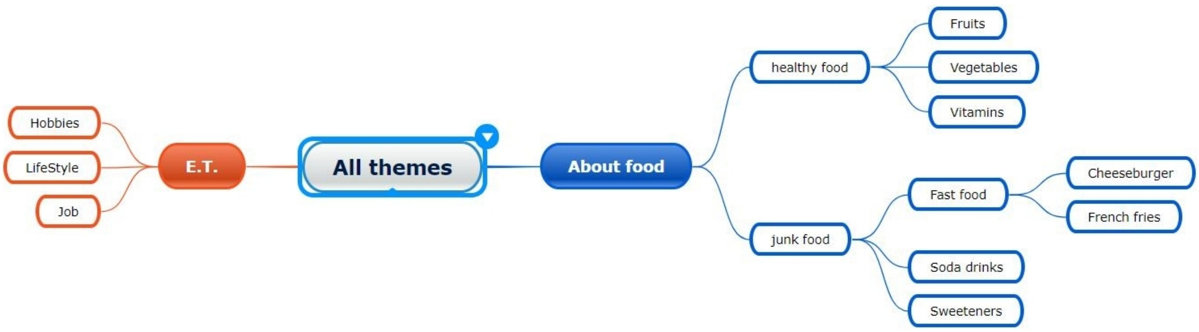

Figure 12: An example of a mind map for learning foreign languages, created by students during a face-to-face learning course.

terial;

- 35.7% indicated that teachers sent theoretical materials and assignments in Viber,
- 52.5% indicated that teachers conducted online ICT classes (Zoom, Google Meet, etc.).

During the extension of the quarantine COVID-19 (September 2020-May 2021) (after the mass courses) training was organized as follows (figure 16):

- 3.8% of respondents answered that they performed tasks independently and dealt with the material;
- 13.7% indicated that teachers sent theoretical materials and assignments in Viber;
- 82.5% indicated that teachers conducted online lessons in ICT (Zoom, Google Meet, etc.).

The comparison before and after is shown in figure 17.

As we can see, the dynamics of the use of cloud services after the courses was positive, and most teachers used cloud services to organize distance learning in the educational process.

Also during the survey, it was found that 56.7% of

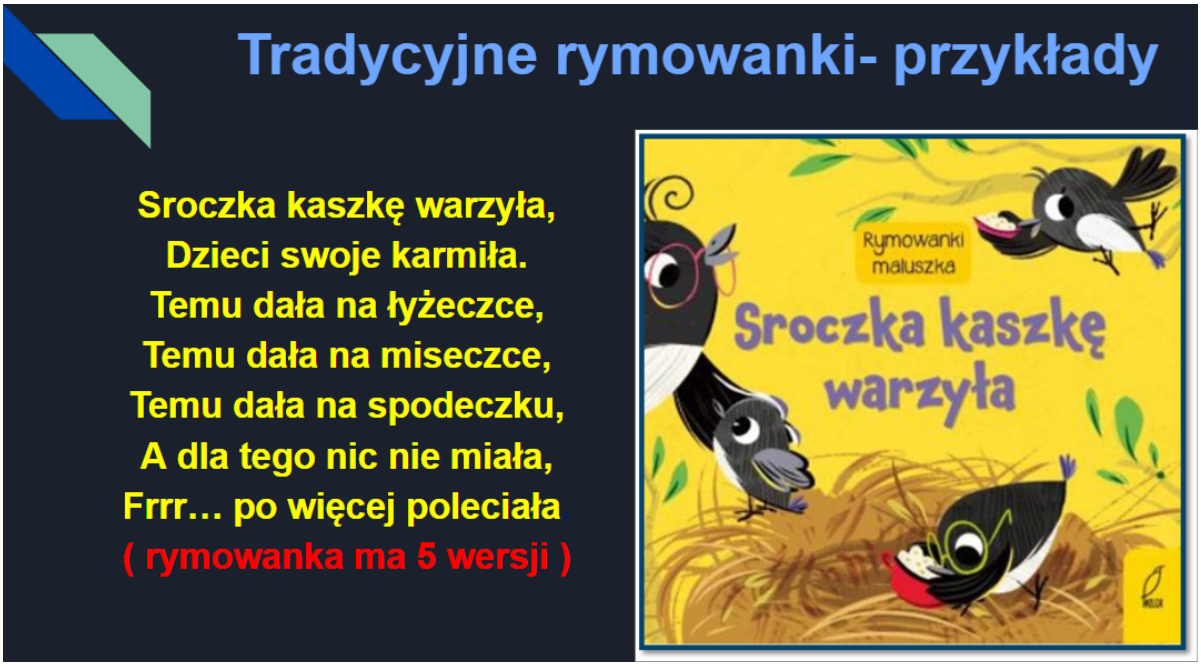

Figure 13: Example of a presentation created by students during a face-to-face learning course.

Figure 14: Example of a presentation created by students during a face-to-face learning course.

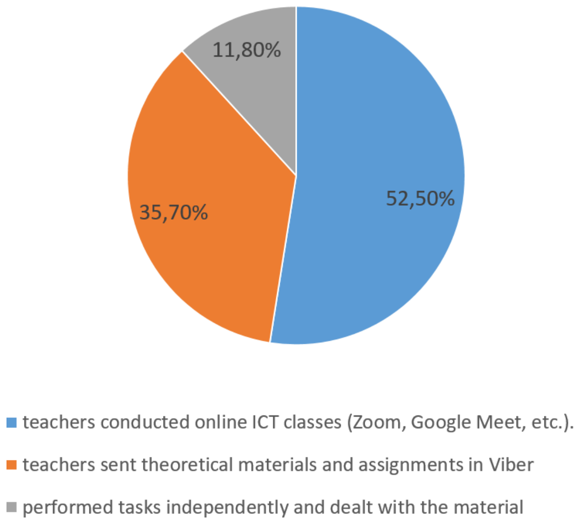

Figure 15: Survey results for March-April 2020.

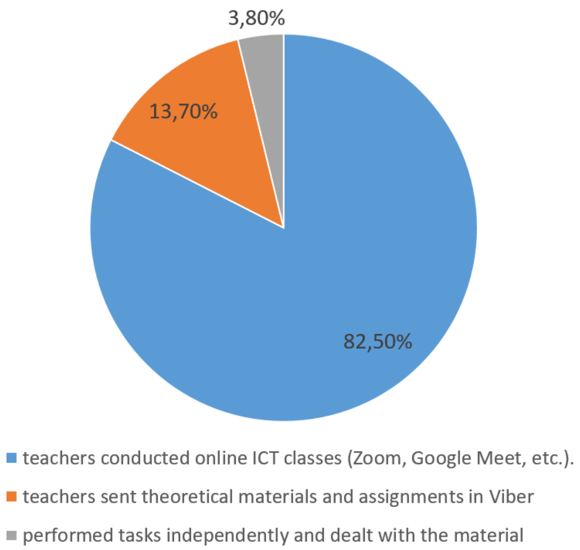

Figure 16: Survey results for September 2020 – May 2021.

teachers used in 2020-2021 academic year ICT learning tools that have not been used before. At the same time, students cited various tools that were covered by teachers in the above courses.

In addition, the authors found that 13.3% of respondents prefer distance learning (due to the use of different cloud services), 29.7% prefer blended learning and 57% of students chose the traditional form of learning.

It was also found that distance learning was comfortable for 44.5% of respondents, for 16.3% – was not comfortable, 36.1% said they found it difficult to answer this question, there were isolated cases where students answered 50/50; no, it is difficult to force yourself to work on the material when there are many distractions, no more than that; for some time it was convenient, but it is quite a heavy load; it all depends on the education of the teacher; has its advantages and disadvantages; different items are given differently, etc.

As we can see, in the educational process of general secondary education an important role is played by the teacher's awareness of modern means of information and communication technologies, which should be used in distance learning. Modern realities (pandemic caused by the COVID-19 virus, Russia's war against Ukraine) suggest that distance learning will still be relevant for some time, so higher education and general secondary education should pay attention to retraining professionals to improve their competencies in the field of information and communication technologies.

4 CONCLUSIONS

Organizers of such courses must take into account the following features: 1) take into account the number of participants; 2) in the registration questionnaire to focus on the correct completion of all fields, especially when filling in the field "e-mail"; 3) when connecting students to the course, not only provide materials to familiarize with the organization of courses, Google Classroom, the purpose of the courses but also conduct introductory testing to determine the level of awareness of students with the necessary materials; 4) focus on the timely completion of tasks so as not to create inconvenience to other participants.

As practice has shown, teachers who have taken courses are more adapted to distance learning and can provide students with the necessary knowledge online using cloud services. The students themselves (former students) believe that everything depends on the competence of the teacher who teaches the lesson. At the same time, each student, as well as each teacher (student of the courses) is an individual, and he perceives the material differently. However, demanding attention from students, not every teacher is like that. Therefore, teachers should also start with themselves, developing their attentiveness, ability to listen and memorize the necessary actions from the first time, and not return to the initial actions with each new task.

It is also worth noting that students who actively used cloud services in distance learning at school, easily switched to distance learning at the university when the need arose. This indicates the usefulness of such courses for both teachers and pupils, prospective students.

It should also be noted that most of the persons

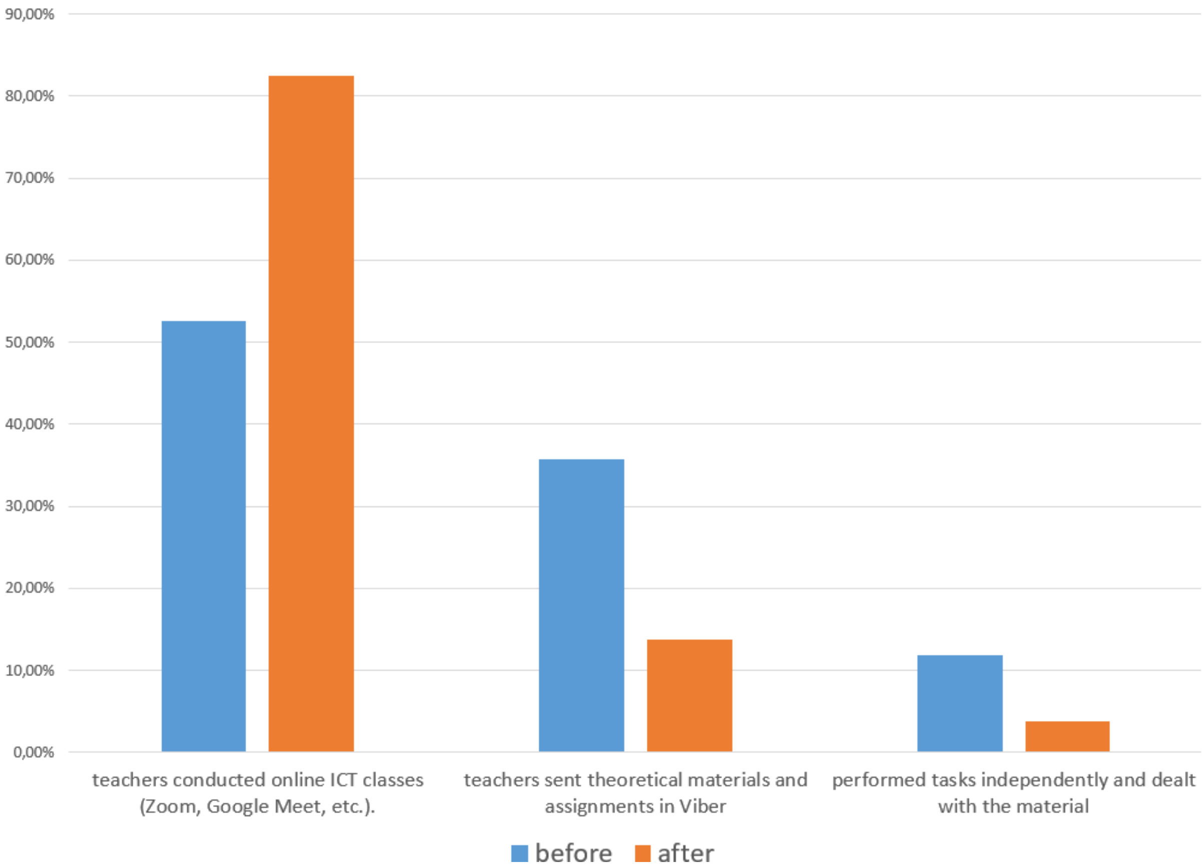

Figure 17: Survey results comparison.

who took courses in one form or another, from time to time ask the author of the course about the possibility of continuing courses on the specifics of individual subjects, and there were some requests to repeat these courses. This indicates the relevance, demand for such courses for different categories of educators.

Prospects for further research see the expansion of courses for individual groups of subjects, focusing on the specifics of each subject individually and, accordingly, to verify the feasibility of such courses, as well as interviewing not only teachers but also students.

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Stages of Adaptive Learning Implementation by Means of Moodle LMS

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Keywords: Adaptive Learning, E-Learning, Microlearning, Students' Needs, Moodle.

Abstract: Adaptive learning is a methodology that allows to identify the level of students' knowledge and their learning styles and transform materials, tasks and ways of their delivery according to the needs of learning process participants. The interest of higher education institutions (HEI) to use adaptive learning as an innovative data-driven approach to the educational process is increasingly growing. However, the level of its actual use in HEIs is not high. The main reason is that a university has to overcome a lot of challenges in the process of adaptive learning implementation including technological, pedagogical and management-related ones. The authors address the problem of the possibility of adaptive learning integration into existing learning management systems (LMS) on the basis of Moodle as one of the most popular LMS for e-learning arrangement. The research is focused on the study of activities and resources that can be used as solutions at different stages of adaptive learning development in an e-learning course (ELC). This is an up-to-date question as it allows to cut the costs on innovation implementation and at the same time simplifies its introduction for teachers as they have already got experience in the system. Although Moodle LMS is not an adaptive learning system, it can be used as a compromise for adaptive learning implementation at higher education institutions, claim the authors. It provides administrators and teachers with tools to vary all stages of a learning process starting with delivery of information and ending with assessment. Learning materials can be adopted through choosing different types of delivery of the same information as well as through the choice of the level at which students are able to gain the knowledge. The sequence of information delivery also can be adjusted to the students' needs through using settings in lectures and other types of materials. Adaptive assessment can be achieved through adaptive quizzes tools. In the paper it is offered to look at the perspective of adaptive learning implementation through the stages of its development in an electronic learning course (ELC), activities and resources that can be used to provide those stages. Microlearning is highlighted as a means of adaptive learning implementation.

1 INTRODUCTION

Modern e-learning platforms are able to support the creation and sharing of educational content and building collective intelligence. Students can look for such content online and decide whether it is suitable for achieving their learning objectives. However, searching and organising suitable content can easily make learners lose their focus on learning (Huang and Shiu, 2012). Therefore, open and flexible approaches and the establishment of adaptive systems are required to ensure better delivery of educational content and provision of high quality education for a large number of higher education institutions (HEI) students (Pelletier et al., 2021). The interest of higher education institutions to use adaptive learning as an innovative data-driven approach to the educational process is increasingly growing. However, the actual use of adaptive learning by HEIs remains rather limited in spite of promising results of recent studies on its effectiveness (Mirata et al., 2020). The main types of challenges faced by HEIs in the process of adaptive learning implementation include technology, pedagogy, and management-related issues (Mirata et al., 2020). Among them there are dealing with real time data, difficulties in integrating adaptive learning solutions into existing learning management systems (LMS), the need to change e-learning courses design and content etc. In particular, in the process of adaptive learning implementation teachers often struggle with modifying learning content, because they have lack of experience with adaptive technologies. Most higher education institutions still have unified learning materials which do not consider students' learn-

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ing styles, knowledge level difference, needed depth of study, time frameworks for the course completion etc.

In the process of knowledge consumption students tend to divide knowledge arrays into small parts, and then put them in order and format that is easy to process for them. This is also proven by the results of the survey conducted at Borys Grinchenko Kyiv University. Learners then develop links between these pieces until they fully grasp the knowledge (Huang and Shiu, 2012). This corresponds to one of the recent educational trends – microlearning. It is a learner-centred teaching and learning approach which is result oriented and provides division of the material into segments that are easy to be consumed at a time (Grevtseva et al., 2017). Microlearning components often remove any inconsequential and unrelated content and focus only on what a student needs to know. This reduces learners' cognitive load and increases retention since they are able to process information more effectively (Giurgiu, 2017). When material is split into smaller sections it is much easier to be adapted to students' needs. Thus, the authors claim that microlearning can be used as a means to implement adaptive learning in HEIs.

The aim of the research is to determine whether learning management systems (LMS) can be used as a platform for implementing adaptive learning as they are already used for e-learning arrangement in HEIs. For this purpose activities and resources in e-learning courses (ELC), that allow the adaptation and personalisation of materials in a way which is relevant to students' individual needs, are studied. The authors offer to look at the perspective of adaptive learning implementation through the stages of its development in an ELC (initial stage, pre-test stage, path generation stage, learning stage, post-test stage), activities and resources that can be used to provide those stages. The e-learning system of Borys Grinchenko Kyiv University based on Moodle LMS is taken as a background for testing adaptive learning implementation in ELC.

2 ANALYSIS OF RESEARCH AND PUBLICATIONS

Skinner (Skinner, 1968), who is considered to be a founder of personalised (adaptive) learning, stated in his book "The Technology of Teaching" that one of effective ways of teaching is dividing material into small parts and adapting learning tasks to current level of students' knowledge. Elements of adaptive learning were reflected in (Bloom, 1994; Pashler, 1998; Cronbach, 1967; Bondar and Shaposhnikova, 2013; Fedoruk, 2010; Osadcha et al., 2021).

The definition of adaptive learning by Skinner (Skinner, 1968) led us to considering microlearning as a means of adaptive learning implementation. Microlearning has got a lot of attention from scientists recently. According to Leong et al. (Leong et al., 2020) 476 relevant publications have been identified during 2006–2019. Hug (Hug, 2007) in his book "Didactics of Microlearning" is covering a vast variety of questions on the topic, including those considering adaptive learning cycles. In particular, the question of adaptive microlearning is addressed by Gherman et al. (Gherman et al., 2021), Sun et al. (Sun et al., 2016).

Among the tools for implementation of adaptive learning in HEIs learning management system is noted. One of such systems that gained popularity in universities due to its flexibility and free distribution is Moodle LMS. That makes the question of implementation of adaptivity elements in Moodle relevant and many researchers have paid attention to this topic in recent decade among whom there are Surjono (Surjono, 2011), Caputi and Garrido (Caputi and Garrido, 2015), Kukhartsev et al. (Kukhartsev et al., 2018), Gaviria et al. (Gaviria et al., 2009), Akçapınar (Akçapınar, 2015), Nikitopoulou et al. (Nikitopoulou et al., 2017), Jurenoks (Jurenoks, 2017), Rollins (Rollins, 2017).

3 THEORETICAL BACKGROUND AND PRACTICAL IMPLEMENTATION

One of promising educational technologies according to NMC Horizon Report 2018 is adaptive learning – adaptation of content and choice of means for its implementation according to the needs of educational process participants to increase the effectiveness of activities. Personalization of the approach to learning cannot be made without understanding educational technologies implemented in HEIs. Many HEIs use e-learning systems for provision of distant learning, blended learning and independent study. Moodle LMS is a widely used e-learning system as it is open source and can be adapted to HEIs' needs. Moodle LMS is used at Borys Grinchenko Kyiv University, therefore it is chosen by the authors as a platform for innovation implementation.

Adaptive learning is a technique that involves periodically gathering information about students' level of knowledge and learning styles, and configuring learning resources, tasks, and assessment accordingly (Edmonds, 1987). Thus, e-learning developers are challenged to take into account the needs of users to ensure better learning outcomes. The main factors that influence the quality of ELCs according to the survey are the choice of the diversity of presentation formats, the tasks and tests complexity, the level of complexity of the course and the sequence of study of the material (figure 1). Implementing adaptive learning can ensure that these needs are met.

Adaptive design of the e-learning platform also plays an important role under the current conditions as students use various devices among which are PC, tablets and smartphones. Moodle LMS is able to provide required adaptivity of the design.

According to the the Deming or Plan-Do-Check-Act (PDCA) cycle for higher education (Gueorguiev, 2006) (figure 2) it is vital to analyse the factors that influence the effectiveness of the educational process, current situation in a HEI and tendencies in educational technologies on the international level prior to integration of any innovative tools and methodologies into the educational process.

All adaptive learning systems follow a similar PDCA architecture (figure 2) that gathers data from the learner and then uses that data to estimate the learner's progress, recommend learning activities, and provide tailored feedback. The adaptive learning algorithm is designed to make such decisions by referring to a learning plan (the knowledge to be learned), a student model of learners' background characteristics (knowledge level, learning style, individual needs, etc.), and a task model that specifies features of the learning activities (such as questions, tasks, quizzes, dynamic hints, feedback, prompts, and recommendations) (Lee and Park, 2008).

The goal of responsive e-learning is to provide students with the tools they need to absorb the material they need to the best of their ability. Requirements for tailored educational materials are tailored to the goals of the educational process (van Velsen et al., 2008). Consideration should be given to students' prior knowledge as well as differences in learning styles and individual needs. Among the objectives of the appropriate learning system is to ensure the same efficiency of the educational process for students who are not familiar with the field of knowledge as those who have previous academic experience.

Adaptive learning tools are technologies that can be synchronised with the learning process and, based on machine learning technologies, can adapt to the progress of each student and independently adjust the learning content in real time. Adaptability can be manifested in one or more elements of technology: content, evaluation, consistency.

Content adaptation is the presentation of educational materials in a form that will allow the student to navigate his own educational trajectory. Content adaptation includes contextual clues, content branching, material partitioning, volume selection and material format. For example, when giving a lecture online, you can use the question system to assess whether a student has mastered the relevant material at a sufficient level, and if necessary, return it to certain information again, or allow them to skip some of the material as previously learned.

Sequence adaptation involves the automatic selection of relevant content, the level of complexity and the order of study of the material based on the analysis of the results of its educational activities. Adaptive-sequence tools are the most complex, because they analyse the data and compile and adjust the student's individual trajectory in real time.

Data collection is not limited to accumulating information about correct and incorrect answers. Adaptive programs take into account many different indicators to make a personal learning trajectory:

- correct answer;
- number of attempts;
- use of additional tools or resources;
- interests of the student (for example, what resources the student prefers).

The adaptive sequence is implemented in three stages: to collect the data, to analyse it and to adapt the sequence of the material submission to the needs of the particular student. The main advantage of a learning tool with adaptive consistency is to fill knowledge gaps. If a student has missed a class or has not yet mastered the topic and now this impedes the learning of new material, the sequence of tasks and topics changes. So the student first fills in the knowledge gap and then moves on to the current topic.

The adaptation of the assessment assumes that each subsequent question depends on the answer given by the student to the previous one. The better it is, the more difficult the tasks are, and vice versa – if it is too difficult for the student, the questions will be easier until the material is mastered. Adaptive assessment tools are commonly used for periodic monitoring every few months. Students receive a relatively voluminous test assignment, the purpose of which is to test how well they have mastered the material per module, semester, etc. After monitoring, data is analysed, and the results are used to further adjust the program and the individual learning trajectory of each student. Therefore, one of the advantages of adaptive tests is detailed statistics.

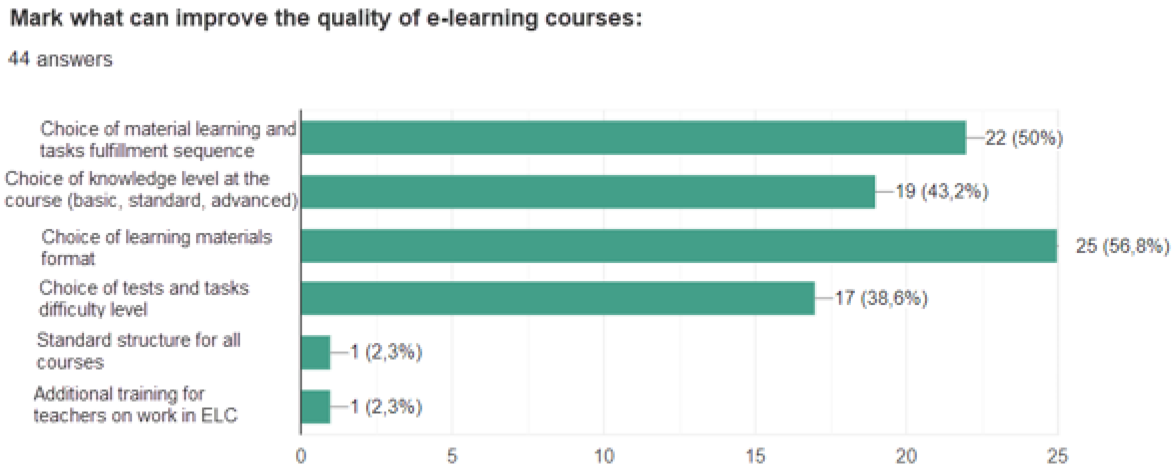

Figure 1: Factors influencing the quality of ELC (survey results).

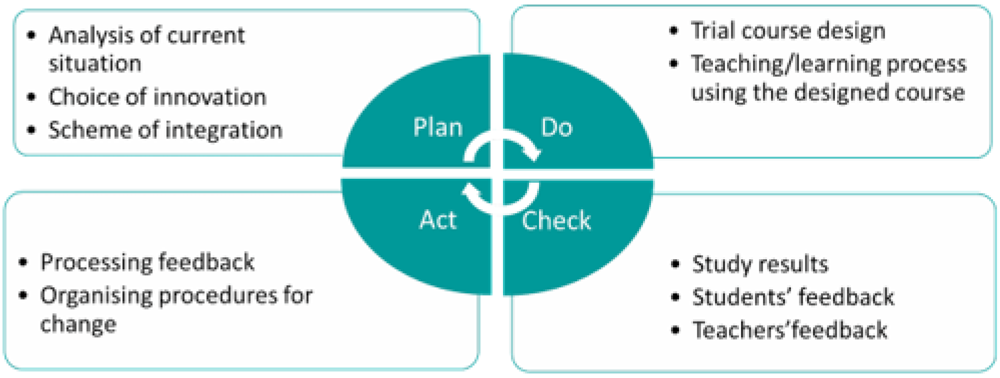

Figure 2: PCDA cycle for innovation implementation in HEI.

The adaptive learning implementation process can be classified into the following stages: initial stage, pre-test stage, path generation stage, learning stage, post-test stage (Huang and Shiu, 2012).

Initial stage. Learners login to the e-learning system and select a course to study. In Borys Grinchenko Kyiv University this stage is organised by integration of educational programmes in the e-learning system. Every student is enrolled in all the courses of their educational program and each course is bound to a specific semester(s). For this stage such activities as Subcourse, Assignment and Page are used to provide students with information on all ELCs (disciplines), their forms of control in each semester and students' progress in each discipline and in general (figure 3).

Pre-test stage. Learners are provided with a pre-test and/or a survey to determine their level of knowledge, learning styles, intended learning outcomes. The testing results become the basis for learning path generation. At this stage gaps in students' knowledge are identified as well. In Moodle the stage can be implemented by such activities as Quiz, Survey, Questionnaire. The choice of the activity depends on its aim.

Thus, the activity Survey is pre-populated with questions and a teacher cannot create own questions there. The Attitudes to Thinking and Learning Survey (ALLTS) Survey resource allows you to assess the level of collaboration of a learning community (group). This will help determine the optimum balance of individual and group work in the course.

The Questionnaire module is aimed at collecting data from users. Unlike the Survey activity, it allows teachers to create a wide range of questions and modify them to the needs of the course. However, the purpose of these two modules is similar – to gather information and not to test or assess students. It can be used to determine learning styles for further selection and gradation of materials.

The Quiz resource lets you rank students' level of knowledge through standard testing. With the Overall feedback setting (figure 4), boundaries are set for each level of knowledge and the student receives a corresponding feedback. For example, students with a score of 80% and above may be offered an advanced course, with results of 60-80% a standard course, and

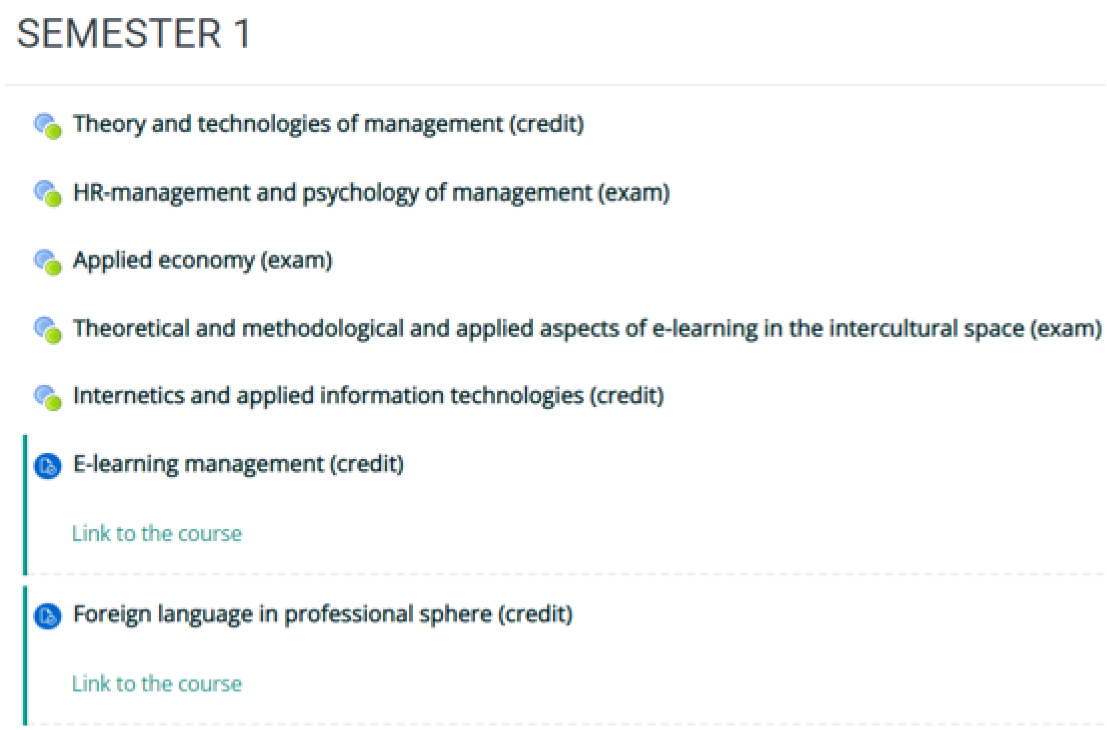

Figure 3: Example of disciplines arrangement in the educational program “E-learning management in the intercultural space”.

a basic course for those who scored less than 60%

Path generation stage. At this stage a student has to receive an individual learning path based on the results of the pre-test stage. Moodle LMS does not contain automated mechanisms to provide this stage being a learning management system, but not an adaptive learning platform. Therefore, alternative ways of the stage implementation must be found to provide students with their own learning trajectory.

Topics can be used to separate materials for students with different knowledge levels. By changing course layout to the section per page format and placing all materials of the corresponding level into the relevant section (figure 5) we simplify navigation in the course.

Another option is to use the Checklist module to form lists of themes or tasks that have to be fulfilled to finish the course. The items can be added to the list from the current section, from the whole course or manually created. The status of the items in the list is updated automatically as students complete the related activity. A checklist can be edited so that only activities or resources that contain tasks were listed as obligatory ones. Thus, a teacher can customise checklists to the needs of a group and create them either for the whole course or for each module/theme separately. If different items can be completed by students with different levels of knowledge or learning styles, a teacher can set up an amount of items to be checked off to complete the Checklist (figure 6).

An individual learning path in Moodle LMS can be provided to a student as a list of to-do items to complete the course based on the pre-test results. It might require individual teachers recommendations or be partly unified for a specified level of knowledge.

Learning stage. At this stage recommended material is identified and a student deals with the learning content of a course. To provide flexibility of the content microlearning is used. The material separated into small logically complete parts can be easily used in any activity or resource used at the learning stage. Microlearning has a variety of advantages including better implementation of students’ needs, wider diversity of materials for different knowledge levels, lower time expenses for material consumption, a possibility for knowledge gaps filling, increased motivation etc. (Varchenko-Trotsenko et al., 2019). Such materials are also easier renewable when needed as a teacher is able to change it by small pieces. According to the results of the survey they also correspond better to students’ needs who indicated materials divided into micro modules, short videos, visual materials and presentations as the most effective formats for theoretical materials (figure 7).

Among the activities used at the learning stage the most popular are Assignment, Book, Chat, File, Forum, Glossary, Lesson, Page, Quiz, Wiki and Workshop. In our work we are going to pay attention to

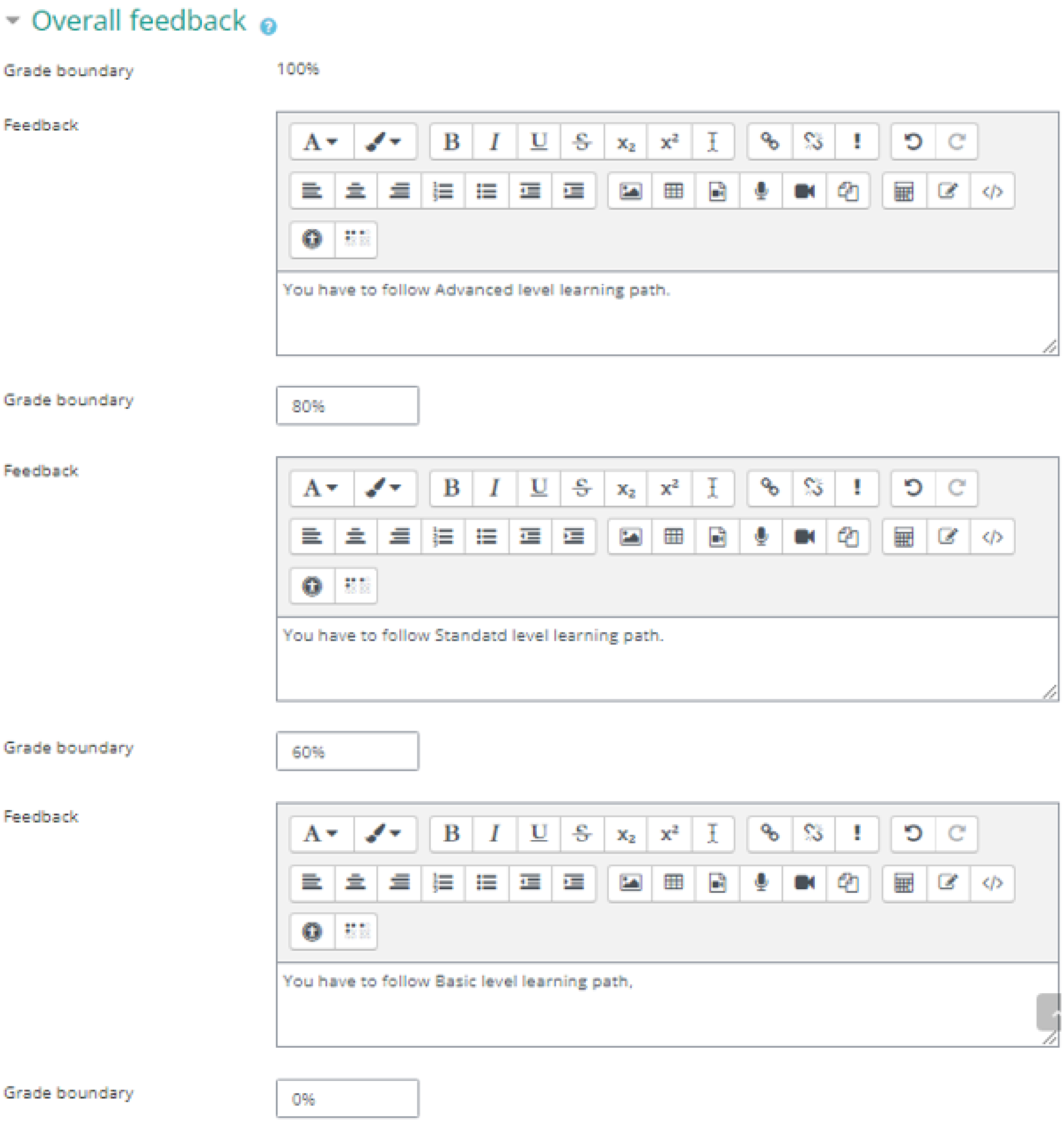

Figure 4: Overall feedback setting for introductory testing in ELC.

the activities which are the most beneficial from the perspective of adaptivity implementation, i.e. Lesson and Quiz modules.

A teacher can use Lesson activity to provide consequent theoretical materials (that is a set of pages with lecture materials) or to organise learning activities where different trajectories of a lesson are offered using transactions between pages, adding extra clusters and pages with questions (multichoice, matching, short answer questions, etc.) (figure 8). Depending on the given answer and the way a teacher uses Lesson activity, a student can either go to the next page or return to the previous page or be directed in another way that corresponds to the student's needs.

If it is required, a Lesson can be assessed, designed in different difficulty levels, and can be a part of adaptive assessment.

A type of the lesson can be chosen by a lecturer depending on the educational needs and the way it will be used – for support of in-class activities or for self study.

One of the activities through which an assessment

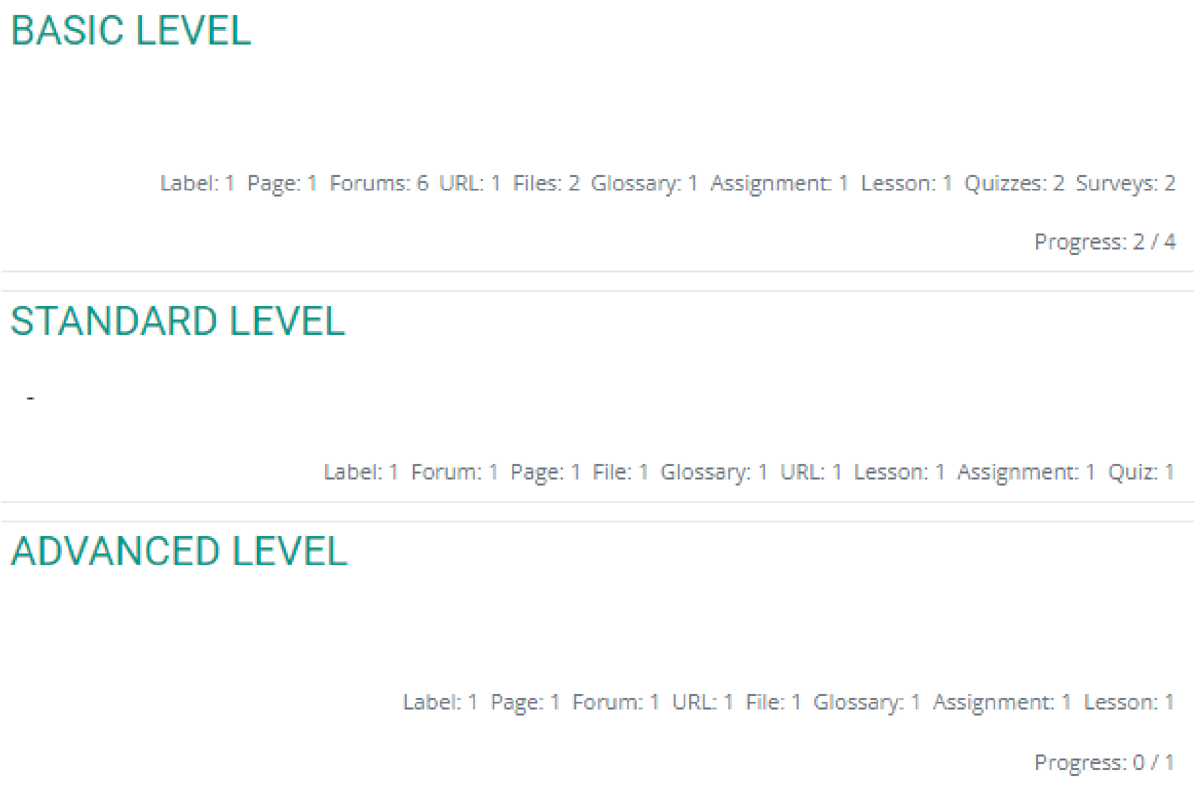

Figure 5: Arrangement of learning materials according to the level with the help of the topic sections.

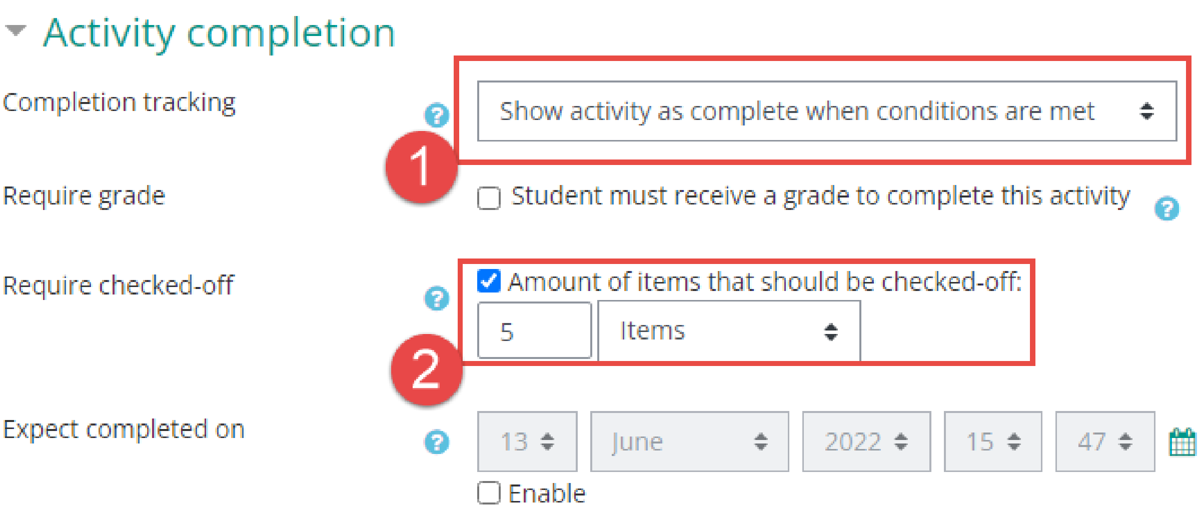

Figure 6: Activity completion settings in Checklist module.

can be organised is Quiz, its filling and display for students depends on the setting of different parameters. We can change the Question behaviour parameter to select the best student passing test mode. Selecting Adaptive mode and Adaptive mode (no penalties) allows students to make multiple attempts before moving on to the next question. That is, if students are unsure of their answers, they can check it directly during the attempt and change their answers, but the repeated answer is indicated by taking into account the appropriate penalty indicated by the teacher in the parameters of the question (Fig. 9).

Penalties are established for each question separately in the Multiple tries section of editing a question. Hints are added in the same section. Both options are used only in the correspondent modes which

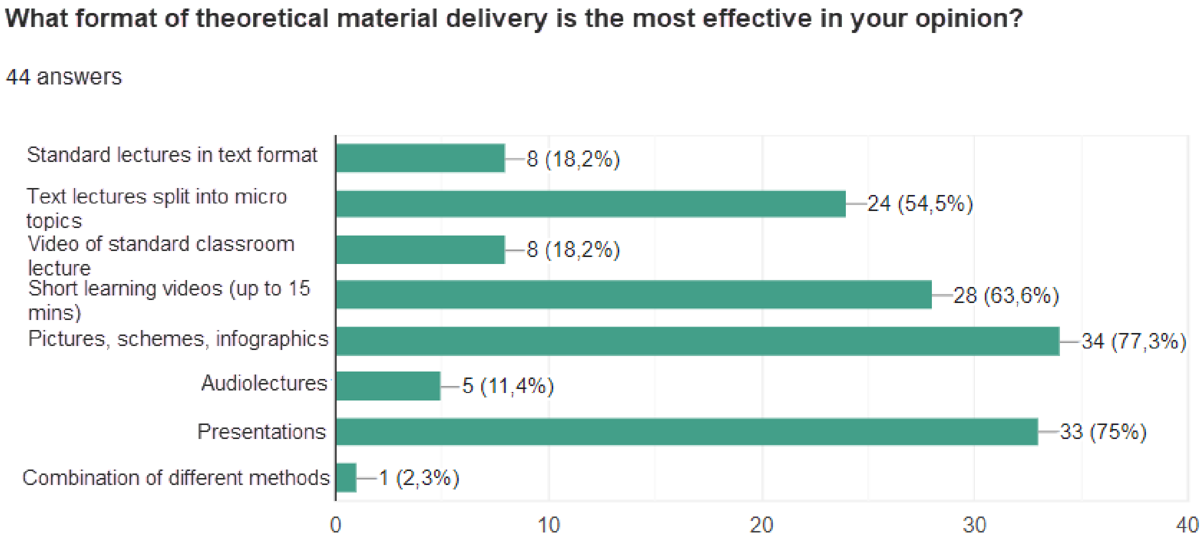

Figure 7: Effective ways of theoretical material delivery (survey results).

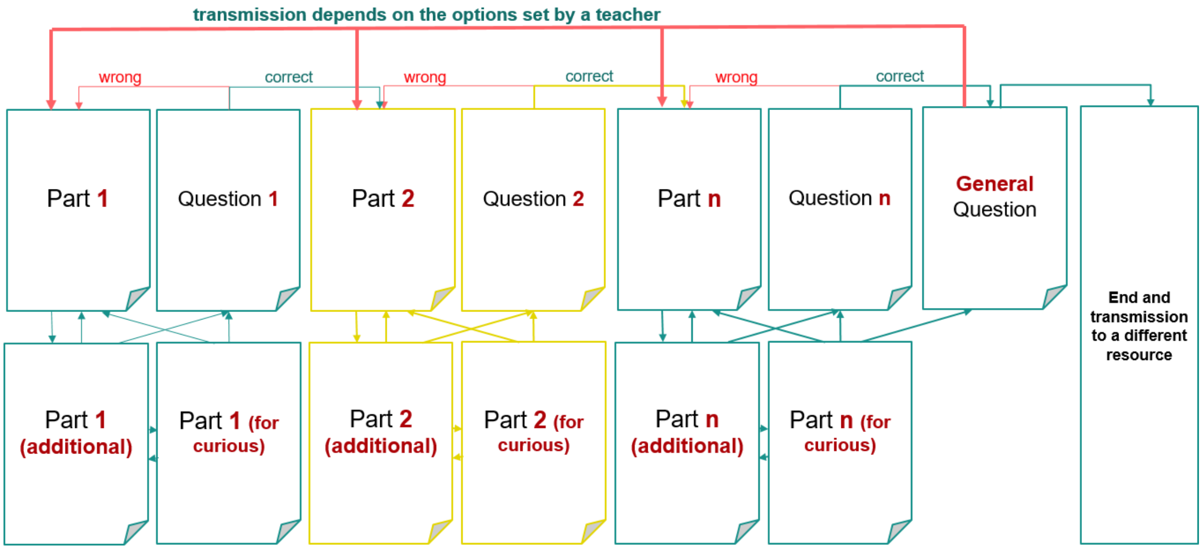

Figure 8: Logical scheme of an adaptive lesson.

allows teachers to use the same question in tests with different modes. For example, a test for formative assessment might have multiple tries and hints, whereas for a summative assessment test Deferred feedback mode can be chosen.

In Interactive with multiple tries mode after submitting one answer and reading the feedback, the student must click the "Try Again" button before attempting a new answer.

The teacher can provide students with tips to help answer questions. Once a student has correctly answered the question, he can no longer change his answer. After a student has made too many mistakes with the question, the answer is evaluated as incorrect (or partially correct) and receives feedback. A student may have different feedback after each attempt. The number of attempts a student receives is the number of tips in determining the question plus one. The use of this mode gives a student an opportunity to determine whether to use the tips or not and adjust their assessment.

Deferred feedback or Immediate feedback mode with Certainty-based marking (CBM) are the modes where a student not only answers the question but also indicates how confident they are: not very sure (less than 67%); average confidence (between 67% and 80%) or very confident (more than 80%).

When the answer is assessed, both accuracy and the level of certainty are considered by the system. For example, if the answer is correct, but only

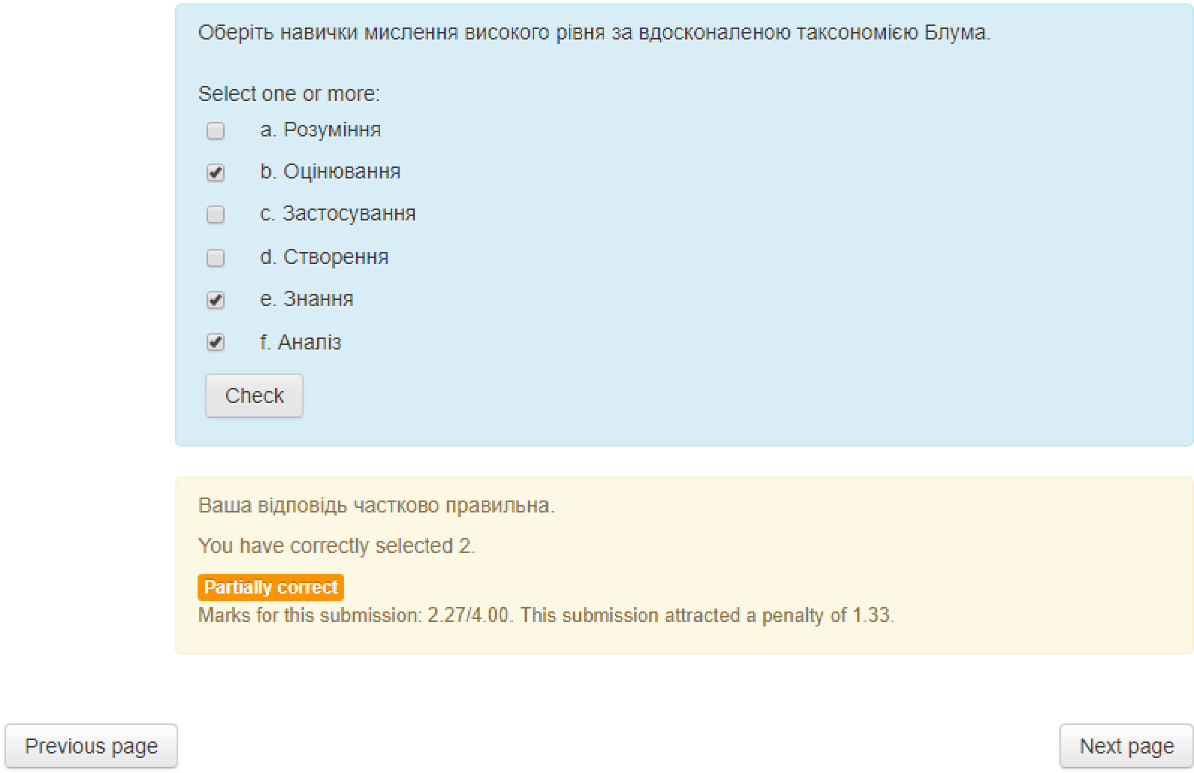

Figure 9: A test with penalties in the Interactive with multiple tries or Adaptive mode.

guessed, the score is adjusted from 1 to 0.33. If the answer is incorrect and high level of confidence was indicated, the score can be from 0 to -2 points (figure 10).

Using this mode provides the following benefits for students:

- they have to evaluate the correctness of our own answer;
- encouraging a solution to a problem, as opposed to answering questions immediately;
- adds confidence in your own knowledge;
- get a more objective rating.

To encourage students to fill the gaps in their knowledge, Combined feedback option can be used in questions for Quiz. For each incorrect or partly correct answer a teacher can indicate a related topic to study or/and give links to the corresponding activities and resources in the course.

Post-test stage. After the learner has finished the entire learning path, it has to be checked whether the learning process was successful or not and needs some changes to be made. The summative assessment can be arranged in the form of a test, a project (individual or group), a speech etc. Thus, such activities as Quiz, Workshop, Wiki or Assignment are prevailing at this stage. The results of summative assessment must be analysed to find out strengths and weaknesses of the e-learning course and plan improvements for its next PDCA cycle. It is also essential to get feedback from students on the course to see whether there was enough material on each topic and whether it was understandable, diverse and easy to use. The feedback collection can be arranged with activities Questionnaire, Feedback, Forum.

Feedback lets you create surveys with different types of questions, including multiple choice, yes / no, or text input to determine the level of satisfaction in the learning process, gaps in the course arrangement, etc. This resource allows you to view statistics in the form of diagrams, tables, and download them for further processing.

4 CONCLUSION

The survey of students carried out at Borys Grinchenko Kyiv University indicated that there is a need for personalisation of the learning environment and individual learning path arrangement. Adaptive learning is an educational approach that can meet the needs.

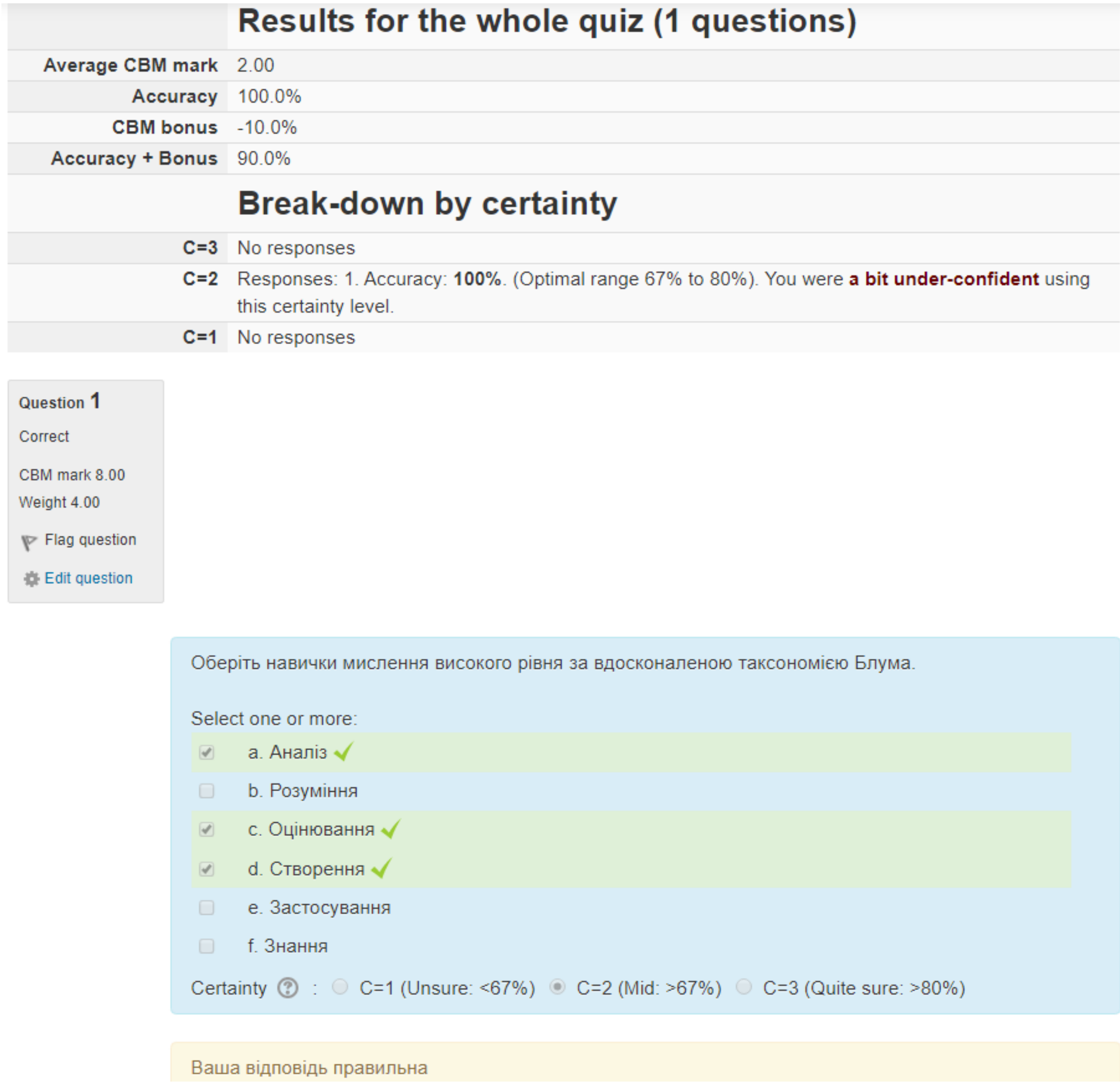

Figure 10: An example of answered question in a mode with CBM.

Analysis of Moodle LMS activities and resources presented in the research paper has shown that adaptive learning can be implemented in HEIs with the help of already used learning management systems. Each stage of adaptive learning implementation (initial stage, pre-test stage, path generation stage, learning stage and post-test stage) is possible to be arranged by means of Moodle LMS. Microlearning plays an essential role in adaptive learning implementation as learning materials divided into small parts are easier to meet individual educational needs of a learner, to navigate in an ELC and to update when required.

The paper is dedicated mostly to technological challenges of adaptive learning implementation. Further research of the topic might include pedagogical and management-related issues such as learning materials modification, teacher training, adaptive e-learning courses and educational programs correlation, etc.

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System-Forming Aspects of the Computer Science and Mathematics Teachers' Readiness to Develop and Use Computer Didactic Games in Educational Process

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Keywords: Readiness, Visual-Spatial Aspects, Computer Science Teacher, Mathematics Teacher, Computer Didactic Games, Educational Process, Professional Activity, Life-Long Learning.

Abstract: The research, based on the actualization of the innovative paradigm, the ideas of child-centrism, and the analysis of system-formal aspects, presents the conceptualization of readiness of computer science and mathematics teachers to develop and use CDGs in the educational process. The results of a practically oriented research state of this readiness are presented, which is considered as an integrated professional and personal ability of the teacher, consisting of motivational-value, cognitive-active and personal-reflective components and is aimed at using CDGs in the educational process as a relevant innovative technology. In the system of the cognitive-activity component, the spatial aspect is analyzed. Actualization of the spatial aspect is considered as a way of revealing the phenomenology of real and virtual spaces, presented as significant pedagogical environments of cognitive-semantic and spatial-value contexts. Based on the generalization of the results of the study of motivational-value, cognitive-active and personal-reflective criteria of the readiness of computer science and mathematics teachers to develop and use CDGs, the average level of its formation was determined. The main educational strategies aimed at improving this readiness are determined, among which the addition of educational programs with topics that reflect the ways and practices of applying CDGs in the preparation of future computer science and mathematics teachers, their retraining and advanced training are relevant; the use of innovative pedagogical technologies for the formation of computer science and mathematics teachers to develop and use CDGs in the educational process, etc.

1 INTRODUCTION

The current direction of today's education is creating conditions for shaping an individual who is at the same time professionally competent, socially engaged and creative. The content of the knowledge to be acquired by modern specialists, its volume, the set of skills necessary for professional activities are constantly changing and increasing. All spheres of education are searching for ways to intensify and quickly modernize the training system, improve education quality by using digital technologies as an instrument for human activities and a new and fundamentally different way of education. This led to the development of new methods and forms for the provision of education (Yevtuch et al., 2021; Semerikov et al., 2021a,b; Klochko et al., 2020; Mayer, 2019; Bollin et al., 2021; Rocha and Barroso, 2021; Picka et al., 2022; Vakaliuk et al., 2023).

One of the most important tasks of the educational system today is to introduce educational technologies that could facilitate the formation of a creative and active personality, able to meet the challenges and to achieve the desired goals. The above highlights the importance of the development and implementation of different approaches to the realization of educational tasks, aimed at the development of students' creative activities.

A computer science and mathematics teacher today has to understand the efficient pedagogical tech-

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nologies and effectively use digital technologies in teaching informatics. The use of gaming technologies and computer didactic games (CDGs), in particular, is one of such approaches.

The games accompany people throughout life and this phenomenon greatly attracts the interest of researchers. In the current situation, they may be a great motivation for students to learn specific subjects on the one hand and a way to facilitate teachers' work on the other.

Let's consider the pedagogical and value understanding of the phenomenon of computer games. Accordingly, we will reveal the debatable understanding of computer games as an innovative educational direction and a system of modern digital technologies that can bring qualitative changes to the educational process.

Today's teachers' succeed in mastering educational electronic resources that they use in the class (Klochko et al., 2020, 2022b; Rybka, 2018; Picka et al., 2022). CDGs as a system of education may be an integral part of electronic educational resources. Computer didactic games present a type of electronic educational resource that targets students and functions on the basis of digital technologies, presenting a chain of tasks built on the basis of the development education. CDGs do not change but complement traditional game forms and classes, and present a natural way to attract students to the latest information technologies (Bollin et al., 2021; Klochko et al., 2020, 2022b). The practical application of such games demonstrates that they remain valuable educational tools as they have the following advantages (Mayer, 2019): a new way of working provokes students' interest in education; practical manipulation assists the processes of learning,memorization, increases cognitive abilities, enables the realization of individual learning strategies and stimulates students' capacity for research and talent; attractive sounds, actions and colors make games interesting and help students to obtain information in a user-friendly form.

CDGs may be divided into three groups (Tobias and Fletcher, 2012):

1. *Educational*. They contribute to students' education: develop basic mathematical and computer science skills, familiarize the child with the alphabet, to obtain and improve knowledge of chemistry, physics, geography etc. (figure 1).

2. *Developing*. They contribute to students' cognitive development, encourage activities and independent creative work, develop memory, logical thinking, develop reading skills, etc. (figure 2).

Figure 1: Bristar: Heroes of Math and Magic (Bristar, 2021).

Figure 2: Scratch: About Scratch (Scratch, 2022).

2. *Diagnostic*. They determine the level of development of students' skills (figure 1).

The studies carried out up to now demonstrate that important skills may be acquired, developed or supported by CDGs. The spatial visualization (rotation and mental manipulation by two- and three-dimension objects), for example, improves during the reproduction of the video game (Subrahmanyam and Greenfield, 1994; Klochko et al., 2020). CDGs are a perfect environment for promoting authentic educational processes: advancing a process of learning-by-doing and thus enabling a student to control his/her own training experience; provide an experience in simulating interactive scenarios that students deal with in the real world; the use as an environment for active learning and improving task solving skills.

Conducting an overview of this problematic, we will present current directions and important results and ideas of introducing computer didactic games into the educational process.

Oliveira et al. (Oliveira et al., 2023) analyzed a large volume of literature (2108 studies) and presented a panoramic view of the problem, – they identified a spectrum of rather contradictory trends and educational phenomena of the use of computer games. According to the results indicated by the authors, gamification in education is studied in the following areas (Oliveira et al., 2023): definition of the phenomenon of different perception of gamification design by people; increasing the involvement in activities and the effectiveness of students' activities; actualization of the variability and diversity of the implementation of educational activities; increasing interest and motivation to study; promoting the consideration of the individuality of students and their personal preferences in the learning process; actualization of the use of different learning styles; taking into account the perception and effectiveness of various pedagogical methods, orientation towards the transformation and variability of the structure of knowledge. At the same time, the authors note that gamification can produce contradictory educational results, which relate to both increasing the effectiveness of learning and motivation for it and interest in it. Important is their observation that in studies (Oliveira et al., 2023): for the adaptation of educational systems, students are mainly involved only as users; there is no sufficient comparison of adapted gamification with non-personalized gamification in the works; there is insufficient evidence of the impact of adapted gamification on student experiences; cultural and gender aspects of gamification are not studied; research does not reveal the role of an adapted gamified educational environment in relation to its design. The researchers' ideas that the actualization of cultural, gender, demographic, characterological, and design aspects can affect the effectiveness of gamification are relevant. Significant in this context is the problem of personalization and design.

The effectiveness of education with electronic educational game resources in mathematics, conducted during the study "Rozumnyky" (Smart kids) is described in (Bykov et al., 2017). Researches argue that using electronic educational game resources in the educational process contributes to the improvement of students' motivation, thinking, and memory and actualizes integrative learning and the development of key and subject competencies (Bykov et al., 2017).

The research publications gave consideration to the question of development and efficient implementation of CDGs or their elements into the educational process on different levels of education. Relevant in this aspect is the research of Zhaldak (Zhaldak, 2012) devoted to the problem of providing educational institutions with educational software. This problem is revealed by the authors in the context of humane ideas of a harmonious combination of computer-oriented learning technologies and information culture with existing pedagogical traditions. Information technologies are also represented as one of the effective ways of humanizing the educational process and expanding the communication of its participants. Pedagogical, health-preserving and spatial aspects of the use of digital technologies, in particular, work with an interactive whiteboard, are revealed in the mentioned research.

System-organizing methodological aspects of the formation of educational technologies were considered in the research of Semerikov et al. (Semerikov et al., 2021b) by rethinking the concepts of "methodical" and "methodologic/methodical system" and determining ways to develop a "new class of teaching methods – computer-based training systems". In particular, they built a model of a computer-oriented method of teaching informatics for future mathematics teachers, aimed at forming their informatics competence, a component of which is a method of training competences in programming and computer games development (Semerikov et al., 2021b).

Hakak et al. (Hakak et al., 2019) explore the issue of gamification based on cloud technologies. They point to the need to create a gamified learning environment and present an option for a gamified curriculum, within which different educational subjects can be integrated. From a spatial point of view, this study demonstrates an attempt to create a digital educational quasi-space as "smart", interactive and integrating different subject areas.

Based on the application of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) methodology in three multidisciplinary databases of educational centers. Manzano-León et al. (Manzano-León et al., 2021) conducted research on gamification. The authors indicate that gamification is an effective means of influencing the academic performance and motivation of students.

The majority of the studies in this sphere concern primary education. To a lesser extent, attention is paid to secondary and higher education. The studies have mostly been carried out based on the examples of using CDGs to learn mathematics and languages. Game is a priority activity for pre-school children and remains an active way of discovering the world for primary school children (Varina et al., 2022). Using games in the educational process for young pupils and seniors remains less researched, since children of this age group are educated on the basis of the activities-oriented approach with the use of more formal ways of learning.

Michala et al. (Michala et al., 2018) present the benefits of using CDGs in secondary school for the development of cognitive and emotion management skills. The authors' use of Greek art and culture when using CDGs is interesting. The use of CDGs and Greek art actualizes the expressive visual-spatial aspect of learning. This reveals the significance and educational effectiveness of interconnected spatial, visual-spatial and visual-cognitive aspects.

Rybka (Rybka, 2018) undertook a study in which she examined the phenomenon of gamification based on the example of using computer games for teaching philosophy in engineering higher educational institutions. The author identified destructive and negative phenomena in the process of using game forms, suggested ways to overcome them. She emphasizes that game practices, as those that activate and nurture emotional intelligence, are especially necessary and valuable for students studying at engineering higher educational institutions.

Research by Rocha and Barroso (Rocha and Barroso, 2021) is inclusively focused on the design and implementation of a game application for cognitive rehabilitation of children with special educational needs and the elderly. Preliminary results showed that their computer didactic game can be used as an auxiliary tool in special education and in rehabilitation.

Determining the innovative trend and the practical-technological significance of the implementation of computer didactic games in the educational process, we actualize the problem of forming a model of the computer science and mathematics teachers' readiness to develop and use CDGs on the selection of system-forming aspects. The specified system-forming aspects are understood as methodological and conceptual prerequisites that constitute the specified readiness not only axiomatically, but through the disclosure of the multidimensional nature of the problem. We highlight the following system-forming aspects of the computer science and mathematics teachers' readiness to develop and use CDGs: innovative, cognitive-activity, personal-reflective, motivational-valuable, valuable, spatial which is considered as spatial-cognitive and visual-spatial, temporal, cultural and educational, creative, communicative. In this study, we consider the first six system-forming aspects.

The innovative aspect was considered above in the pedagogical and value understanding of the implementation of gamification in the educational process. Accordingly, this aspect represents the significance, features and direction of the introduction of CDGs into the educational process as an innovative trend. The innovative orientation of computer didactic games is realized in relation to the concept of the triangle of knowledge (Unger et al., 2020), which includes a close interaction of education, science and innovation.

The following four aspects cognitive-active, personal-reflective, motivational-valuable, valuable are relatively traditional. They are used integratively or individually when forming models of readiness, skills, and competencies. Therefore, three of the specified aspects – cognitive-active, personal-reflective, motivational-valued – are considered as its components in our model. All other aspects to one degree or another take part in the constitution of readiness.

Special attention in the development of readiness is given to the spatial aspect, which we consider practically oriented as spatial-cognitive and visual-spatial. The use of the spatial aspect in the formation of readiness is determined by the understanding of the computer science and mathematics teachers' readiness to develop and use CDGs as a complex anthropological and cultural-educational phenomenon in which spatiality and visuality are expressive and significant.

As an example, we will present a study that is close in its orientation to our readiness development. Chen et al. (Chen et al., 2020) analyze five key components of game literacy – (1) basic game literacy, (2) high-level game literacy, (3) instructional design for game learning, (4) organization and management of game-based learning, and (5) evaluation of game-based learning needed by teachers to implement game-based learning. The authors emphasize the importance of educational design when implementing game-based learning. The result of the research by Mathe et al. (Mathe et al., 2018) is the conclusion that the effectiveness of the use of digital games by Swedish teachers depends on the competence and motivation of teachers for professional development, on the availability of appropriate game resources. Nousiainen et al. (Nousiainen et al., 2018) present four basic competencies – pedagogical, technological, collaborative and creative, which are necessary for teachers to effectively implement game pedagogy.

The use of didactic games, as well as game methods and technologies in general, contributes to a deeper methodological and value understanding of the environment in which they are implemented. First of all, it concerns virtual and real space. Traditionally, space is understood as a background where the educational process is implemented. In the system of modern postmodern scientific and methodological ideas, space is like time and the processes that are in them, or rather, with their help, are implemented integratively and holistically. Currently, visual-spatial approaches that have demonstrated their effectiveness in various fields of knowledge and life practices are relevant. One of such significant practices and technologies, which for their effective implementation require the active inclusion (or at least consideration) of the "visual-spatial" factor, are games. In addition to the indicated scientific and methodological trends and practical requests, we consider the issue of the development of the computer science and mathematics teachers' readiness to develop and use CDGs in the context of actualizing the spatial factor.

Accordingly, in this methodology, from a cognitive and axiological point of view, spatial phenomena, as well as real and virtual spaces, are considered significant for the technologicalization of education and for the professionalization of mathematics and computer science teachers. In the scientific pedagogical literature, the visual-spatial aspect of the development of the computer science and mathematics teachers' readiness to develop and use CDGs is not sufficiently disclosed. This, taking into account the above-mentioned trends of modern science and the socio-cultural sphere and requests for the effectiveness of the practical implementation of game-based learning methods, defines the researched problem as urgent.

For the methodological understanding of space, including virtual and spatial phenomena, the work of Avetysian (Avetysian, 2020), which reveals the meaning and nature of visuality, is relevant. In this study, the authors turn to the classical ideas of visuality by Merleau-Ponty (Merleau-Ponty, 2005) and Deleuze (Deleuze, 1989). At the same time, they emphasize ideas about: the semantic independence of the visual dimension of culture from language, the principle of the activity of a visual object, the peculiarities of the viewer's interaction with visual phenomena. Thanks to these ideas of visuality, we understand space not as a background against which certain events take place, but as a special spatial world with active spatial phenomena. From the cultural and educational point of view, the application of the presented ideas of visual theory for the development of the teacher's readiness to use didactic games is relevant. This is due to the fact that the visual-spatial aspect in the specified computer technology is one of the system-organizing factors.

In the theoretical and technological aspects of the application of the spatial approach and the idea of visuality, research by various authors is relevant.

Briantseva (Briantseva, 2016) reveals the peculiarities of designing digital didactic visual tools. Bäckman and Pilebro (Bäckman and Pilebro, 1999) present a study conducted within the framework of visual pedagogy, the results of which indicate improved cooperation during dental treatment in preschool children with autism. Du et al. (Du et al., 2022) present ways of helping children with autism spectrum disorder in teaching dental care based on the use of visual pedagogy tools. Drushliak (Drushliak, 2021) reveals the significance and features of visual information culture of future mathematics and computer science teachers and presents its model. Aiello and Parry (Aiello and Parry, 2019) reveal the features of visual communication. They emphasize the idea close to us, that visuality and visual means are a significant aspect of many disciplinary scientific and practical spheres. At the same time, the importance of visuality is not sufficiently realized. Goldfarb (Goldfarb, 2002) considers visual pedagogy, visual technology as relevant directly in the education and life of people, as it needs further purposeful development.

In scientific literature, the issue of developing the computer science and mathematics teachers' readiness to develop and use CDGs is insufficiently disclosed. Issues of actualization of spatial aspects in the system of the specified readiness, both during its development and during implementation, are not sufficiently disclosed. Taking into account the importance and innovativeness of the use of computer didactic games for the implementation of the processes of technologization, virtualization, digitalization, axiologisation, humanization of education, as well as for the development of the professionalization of the teacher and the formation of his innovative culture, the specified problem is presented as an actual.

The *purpose* purpose of the research is to study the value, cognitive-activity, personal-reflective and visual-spatial aspects of the computer science and mathematics teachers' readiness to develop and use computer didactic games.

2 SELECTION OF METHODS AND DIAGNOSTICS

Information on how CDGs are being developed and used in the educational process was generated following the results of the analysis of public educational standards (Cabinet of Ministers of Ukraine, 2011), typical educational programs, curricula, other normative documents, methodological works of teachers and literature sources. Analysis as for the computer science and mathematics teachers' readiness to develop and use CDGs in the educational process was carried out by using empirical research methods (observation of teaching activities, questionnaires, interviews), as well as verbal-communicative and psychodiagnostic research methods.

The research used a system of methods and approaches. Axiological, systemic, spatial, visual-spatial, cognitive-spatial, psychological, anthropological, and teleological (Milat, 2017) approaches were used. The methods of mathematical statistics, in particular, descriptive statistics, cluster analysis, were used to process the research results. To develop a model of the computer science and mathematics teachers' readiness to develop and use CDGs, the method of pedagogical modeling was used.

The readiness of computer science and mathematics teachers to develop and use computer didactic games was determined on the basis of three generalizing criteria. The names of the three criteria correspond to the three components of this readiness. Thus, we distinguish the following criteria: motivational-valuable, cognitive-active, personal-reflective. Accordingly, these criteria reflect the contents and meanings on the basis of which the components of readiness are formed. The criteria were determined as a result of the use of various diagnostic methods, including the author's, as well as by analyzing the educational achievements of teachers. Each criterion is characterized by three levels (low, medium, high) of the formation of a certain component of readiness. The results were summarized and interpreted based on the criteria. According to each criterion, we characterized the level of formation of its indicators. According to each criterion for evaluating the computer science and mathematics teachers' readiness to develop and use CDGs in the educational process, we characterized the level of formation of its indicators.

Motivational-value criterion:

- Low: there is no interest in the development of CDGs; there is a fragmented and limited interest in certain topics; lack of motivation and interest in using CDGs; the selection of CDGs is random; there is no interest in training in the use and development of CDGs.
- Medium: existing interest in the development of CDGs, related to the results; there is a responsible attitude to learning in the absence of creative activity; formal interest; motivation is due to the need to implement CDGs; existing interest in the application of CDGs in professional activity, related to its results; there is a responsible attitude to training in the development and use of CDGs; lack of understanding of the benefits of using CDGs in professional activities; episodic manifestation of creative activity.
- High: Internalization and awareness of the values of this activity, purposefulness in the implemented CDGs, formation of educational and cognitive motives, existing motivated and responsible attitude to the use of CDGs in the educational process, awareness of the educational and innovative significance of cognitive motives, systematic manifestation of creative activity, orientation towards achieving success, professional orientation for self-improvement; conscious choice of this didactic tool; training in the development and use of CDGs for the purpose of professional growth; motivated professional focus on the development and application of modern CDGs.

Cognitive-active criterion:

- Low: low level of knowledge on the development and use of CDGs, their low reproducibility, lack of systematicity; solving simple typical tasks with the help of others; the ability to use modern CDGs in professional activities is partially fragmentary in nature; fragmentary cognitive needs, interests, motives for developing and using CDGs.
- Medium: the average level of knowledge on the development and use of CDGs (partial system knowledge) and their fragmentary reproducibility; solving standard tasks on the development and use of CDGs with the help of others; the ability to independently solve the issue of choosing a CDGs is not inherent; the presence of cognitive needs, interests, motives for the development and use of CDGs.
- High: high level of knowledge (systemic, creative nature), knowledge of development and use of CDGs; the ability to independently solve typical problems, solving non-standard problems, full reproducibility, independent search for solution methods, the ability to generate new approaches in the development and application of CDGs; the ability to master modern knowledge, generating ideas, creativity in solving tasks, the ability to independently master the means of modern CDGs,

the search for and use of innovations, independent assessment of the appropriateness of the selection of modern CDGs; available cognitive activity, the desire to master modern knowledge, the availability of methods of scientific research activity, the professional orientation of cognitive activity in theoretical and practical activities; independent solving of problems of professional orientation of medium and high levels of complexity of development and use of modern CDGs tools; the presence of elements of creativity in solving problems, the ability to analyze, synthesize and establish relationships between socio-economic phenomena and processes; solving non-standard professional tasks, tasks of a high level of complexity; creative approach to solving; critical, contextual thinking; independence in assessing compliance and choosing tools of modern CDGs in solving professional problems; independent mastery of modern CDGs in order to solve professional problems, ability to work in a team.

personal-reflectiv criterion:

- Low: there is a fragmented ability to introspect; inability to plan activities in the process of developing and using CDGs; low capacity for self-control and self-regulation; there are inefficient methods and methods of organizing this activity, which are not purposefully formed; awareness of the content of the activity has a fragmentary spontaneous manifestation; in the vast majority of cases, the quality of performed tasks is inadequately assessed; fragmentary, random manifestation of the ability to self-educate; inability to independently master material on CDGs.
- Medium: the presence of self-analysis skills, which is mainly manifested under the influence of external factors; existing activity planning for the development and use of CDGs and the ability to self-monitor and self-regulate in individual cases, mainly under the influence of external factors; there is a fragmentary manifestation of one's own style of activity in the development and use of CDGs; separate manifestations of a conscious and purposeful own style of activity; awareness of the content of the activity and possessing the ability to evaluate and ensure the quality of the work performed on the development and use of CDGs; there is a non-systematic manifestation of the ability to independently master the material of individual topics on the development and use of CDGs.
- High: implementation of a conscious and adequate self-analysis, awareness and prediction of the results and consequences of the development and use of CDGs; existing planning of activities for the development and use of CDGs and the ability to self-monitor and self-regulate; cognitive abilities aimed at self-development; self-organizations that are managed and initiated by the individual himself; available skills to independently overcome obstacles; the characteristic deepness of the self-organization process in the system of activities for the development and use of CDGs; there are effective techniques and ways of organizing one's own style of activity for the development and use of CDGs, its conscious and purposeful formation with elements of creativity and innovation; awareness of the content of the development and use of CDGs and the ability to evaluate and ensure the quality of the work performed; the ability to determine promising directions for the development and use of the latest CDGs in professional activities, possessing the skills to choose and use modern CDGs tools; capable of self-education in this direction; the ability to implement knowledge, skills and abilities to achieve the goal of professional activity in the development and use of CDGs; the ability to self-realize, systematic, persistent manifestation, the ability to achieve success in this activity.

The following techniques were used in the research: "Diagnostics of motivation for success and fear of failures" (Rean et al., 2000); tests and questionnaires on determining levels of formation of motivational-value, cognitive-activity and personality-reflexive components; "Self-controlling Abilities" (Peisakhov, 1984); "Self-Efficacy Test" (Sherer et al., 1982); "Research of Strong-willed Self-regulation" (Zverkov and Eidman, 1990).

Questionnaires were used in the research: Questionnaire for determining the computer science and mathematics teachers' value orientations as for the development and implementation of CDGs in educational process (developed by Klochko (Klochko, 2018) on the basis of Rean et al. (Rean et al., 2000) method); Questionnaire for diagnostics of motivation for success and fear of failures (Rean et al., 2000); Questionnaire for determining the significance of readiness for the development and implementation of CDGs for successful professional activities (Greene et al., 1997; Volochkov, 2007); Questionnaire to determine the percentage distribution of computer science and mathematics teachers by levels of the ability to self-governance (Peisakhov, 1984; Sherer et al., 1982; Zverkov and Eidman, 1990); Questionnaire for determining the indicators of cognitive-activity criterion of evaluation of computer science and mathematics teachers' readiness to develop CDGs and implement them into the educational process (developed by Klochko (Klochko, 2018) based on Raven (Raven, 1989) methods); Questionnaire to determine the percentage distribution of computer science and mathematics teachers by levels of the ability to self-control (Peisakhov, 1984; Zverkov and Eidman, 1990); Questionnaire for determining the Indicators of personality-reflexive criterion for evaluation of computer science and mathematics teachers' readiness for CDGs development and implementation (developed by Klochko (Klochko, 2018) based on Rean et al. (Rean et al., 2000) methods); Fedorets-Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers.

The *"Questionnaire for determining the computer science and mathematics teachers' value orientations as for the development and implementation of CDGs in educational process"* contained the following questions (developed by Gurevych et al. (Gurevych et al., 2020) on the basis of Rean et al. (Rean et al., 2000) method):

1. Achieving professional success.
2. Developing personal strengths and abilities.
3. Acquiring professional and information competencies.
4. Providing material comfort.
5. Achieving recognition and respect in professional sphere.
6. Improvement of social status.
7. Striving to new achievements.
8. Self development and self improvement.
9. Recognition and respect of managers.
10. Achieving students' respect.
11. Developing students' interest to computer sciences.
12. Possibilities to show one's potential.
13. Possibility to improve pedagogical skills.
14. Possibilities to introduce new methods and forms of activities.

Respondents answered the questions of the questionnaire in accordance with two areas – development of CDGs and introduction of CDGs into the educational process.

The *"Questionnaire for determining the indicators of cognitive-activity criterion of evaluation of computer science and mathematics teachers' readiness to develop CDGs and implement them into the educational process"* contained the following questions (developed by Gurevych et al. (Gurevych et al., 2020) based on Raven (Raven, 1989) methods):

I. According to the development of CDGs:
   1. I am aware.
   2. I have knowledge.
   3. I have skills.
   4. Able to develop.
   5. Realize didactic peculiarities.
   6. Realize basic functional possibilities.
   7. Realize basic requirements to development.
   8. I know how to select topics.
   9. I can develop design.
   10. I know peculiarities of psychological influence on age groups of children.
   11. I know how to classify games.
   12. I know the basic classes of software.

II. According to the implementation CDGs into the educational process:
   1. I am aware.
   2. I have knowledge.
   3. I have skills.
   4. Able to use.
   5. Realize psychological peculiarities.
   6. Realize basic functional possibilities.
   7. Realize basic requirements to implementation.
   8. I know how to select games aimed at attaining lesson's goal.
   9. I know how to select games aimed at realization of person-centered approach.
   10. Implement with the aim to ensure cross curriculum connections.
   11. I know how to classify games.
   12. I know which software to use in this sphere.

The *"Questionnaire for determining the Indicators of personality-reflexive criterion for evaluation of computer science and mathematics teachers' readiness for CDGs development and implementation"* contained the following questions (developed by Klochko (Klochko, 2018) based on Rean et al. (Rean et al., 2000) methods (Gurevych et al., 2020)):

I. According to the development of CDGs:
   1. I am a qualified developer.
   2. I strictly determine a purpose of the development.
   3. I work much to improve competencies.
   4. I want to achieve high results.

5. I know my weaknesses and strive to improve them.
6. I constantly search for new methods, forms and ways for realization.
7. I know what to work with and what to learn in the nearest future.

II. According to the implementation CDGs into the educational process:

1. I am a qualified user.
2. I strictly determine a purpose of implementation.
3. I work much to improve competencies.
4. I want to achieve high results.
5. I know my weaknesses and strive to improve them.
6. I constantly search for new methods, forms and ways for realization.
7. I know how to use and look for necessary means.

The methodology is aimed at actualizing and revealing the spatial aspect of computer science and mathematics teachers' readiness for the development and use of computer didactic games. In this work, to reveal the phenomenology of CDGs, we turn to their understanding and application not only in the mental-semiotic and cognitive-operational planes, but as a spatial or, more precisely, "cognitive-spatial" phenomenon. The specified methodological insights correspond to the ideology of the "visual turn" and "spatial turn" in the methodology of science. A significant aspect of considering the indicated methodological trends, as significant, is that we can purposefully represent virtual reality, first of all, as a special informational and meaning-making space. It is important to understand the real physical space also as a special content-semantic or "cognitive-spatial" field, as a meaningful background or context actively included in the educational process. Accordingly, the use of digital technologies of virtual reality with the active participation of the teacher contributes to the "transformation" of physical space into the content-semantic or "cognitive-spatial" field of the educational process. In our opinion, the decisive factor in the specified "cognitive transformations" of virtual reality and real space is the use of game methods. In our opinion, this is due to the fact that in the semantics of the game in its semantic contexts, the spatial component is relevant but at the same time "hidden". The game, which first appears in childhood, is primarily aimed at the child's understanding of himself as a spatial phenomenon, as well as at revealing his ability to navigate in space, which, accordingly, are cognitive processes. Such a cognitive manifestation of life corresponds to the idea of autopoiesis of Maturana Romesín and Varela (Maturana Romesín and Varela, 2009). These authors interpret life as a cognitive autopoietic process. Accordingly, we expand and refine the specified understanding of Maturana Romesín and Varela (Maturana Romesín and Varela, 2009) to this educational context. We can note that for a person it is also a spatial and visual process. In this work, a "Fedorets-Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers" was developed to analyze the understanding of computer science and mathematics teachers about space as a special educational value, space as a possible tool for the intellectual development of a child, space as a background and a component of didactic games. An important methodological prerequisite for the development of this questionnaire was the idea of contextual learning, which can be interpreted as follows: a teacher who understands the surrounding environment, including space, as a way, as a condition or even as a "soft" teaching tool, will be more effective, competent and according to the nature of the child, use CDGs and other methods, in the implementation of which the spatial aspect is relevant.

The *"Fedorets-Klochko questionnaires for determining the value interpretation of space by a teacher of mathematics and computer science"* contained the following questions:

1. The purposeful use of space and spatial phenomena is an important pedagogical condition for effective disclosure of the content of educational material in mathematics and computer science.
2. The use of virtual space, augmented reality and digital technologies is a important pedagogical condition for the effective disclosure of the content of educational material in mathematics and computer science.
3. An integrative consideration of spatial phenomena and virtual space as meaning-forming and system-forming factors of the educational process is relevant for effective learning.
4. Virtual space, as well as real space, can be considered as a meaning-making matrix when implementing game-based learning methods.
5. The game-learning methods and actualization of phenomena of real space and virtual reality are presented as conceptualization tools that form a metaspace of meanings in the study of mathematics and computer science.
6. In order to improve the efficiency of professional activity, the teacher should apply the phenom-

ena of real space and virtual reality in order to present the educational material logically in an "expanded" and illustrative format.

7. Both real and virtual space have their own metalogic, which is revealed when using game methods.
8. Game learning methods and animation reveal the meaning-making aspect of real and virtual space, which can be purposefully applied in the study of mathematics and computer science.
9. The possibility of actualizing the phenomena of real space and virtual reality is considered as an instrumental value in the professional activity of a teacher of mathematics and computer science.
10. The actualization of the phenomena of real space and virtual and augmented reality corresponds to the spatial essence of human nature.

We will present the ideas and content-semantic aspects underlying the "Fedorets-Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers". This questionnaire is aimed not only at diagnosing the teacher's value interpretation of real and virtual space, but also at actualizing spatial issues as significant in the study of mathematics and computer science. The reflective aspect of this questionnaire is also important, which reveals to the teacher ways of understanding spatial phenomena as educational and life values (in particular, the value of harmonization).

Question № 1 – "The purposeful use of space and spatial phenomena is an important pedagogical condition for effective disclosure of the content of educational material in mathematics and computer science" – defines and actualizes the problems of real physical space represented as a "pedagogical tool" and a pedagogical condition for studying mathematics and computer science. It is clear that the real space becomes such a "pedagogical tool" by transforming into an educational semantic and meaning-forming context (space) by integrating the semiotic field of the lesson. This happens with the purposeful application of various educational methods (in particular, game ones) during the implementation of which spatial phenomena are actualized.

Question № 2 – "The use of virtual space, augmented reality and digital technologies is a important pedagogical condition for the effective disclosure of the content of educational material in mathematics and computer science" – purposefully defines and actualizes the problems of virtual space, represented as an established pedagogical environment and at the same time digital technology, which is used for learning mathematics and computer science. Virtual space by its very nature is an intellectual product and, accordingly, can be considered as an operational and educational environment and, accordingly, a field of knowledge and meanings. An important ant aspect of this virtual space is that it can largely model the real space one as it corresponds to human nature, including spatial thinking, the prerequisite for the formation of which is a developed human visual analyzer.

Question № 3 – "An integrative consideration of spatial phenomena and virtual space as meaning-forming and system-forming factors of the educational process is relevant for effective learning" – defines and actualizes the issue of the integrative application of virtual space and real space phenomena as a pedagogical condition and a "spatial" component of mathematics and computer science learning technologies. The methodological meaning of this question is the idea that the purposeful integrative application of technologies of both virtual space and phenomena of real space should give a synergistic and harmonizing educational effect. In children it is necessary to actualize mathematical thinking through visual perception and mathematical interpretations of the "world of things", "the world of geometric figures", "the world as a three-dimensional space" through the application of landscape pedagogy and through the visual disclosure of the phenomenology of the real world. As additional effects, it can be noted that this will also contribute to the preservation of physical and psychological health and aestheticization of the educational process. The specified "work" with real space in combination with the use of virtual space should form the student's understanding of virtual reality as a special tool and the world included in the real world. If the specified harmonization is not carried out, then the opposite effect is possible – the real three-dimensional space, as well as the world as a whole, will be considered by the student as a component of the virtual. This, in addition to the negative impact on the psyche, will not give the opportunity to fully reveal the student's cognitive potential. Therefore, in the educational process, according to the ancient Greek idea about the harmonious nature of man, between virtual reality and real space and the world, not competitive interactions should be formed, but synergistic, complementary and harmonious interactions.

Question № 4 – "Virtual space, as well as real space, can be considered as a meaning-making matrix when implementing game-based learning methods" – reveals the anthropobiological dimension of the teacher's understanding of spatial phenomena. Accordingly, within the semantic framework of this question, the space is simultaneously considered: in-actively as a neutral background or condition where the game is implemented, and also as an active learning tool – as a specific context filled with contents and meanings.

Question № 5 – "The game-learning methods and actualization of phenomena of real space and virtual reality are presented as conceptualization tools that form a metaspace of meanings in the study of mathematics and computer science" – presents game learning methods not only as activity-cognitive, but also as cognitive-spatial learning phenomena, which can form "quasi-spaces" (spaces of meanings) that participate in the development of informatic and mathematical meanings and concepts.

In question № 6 – "In order to increase the efficiency of professional activity, the teacher should apply the phenomena of real space and virtual reality in order to present the educational material logically in an "expanded" and illustrative format" – the physical characteristics of spatial reality (first of all, length) are reflected. Virtual reality is developed based on the transformation of the characteristics of real space. This can be represented as the "logic of space" and, accordingly, consider spatial phenomena in the format of "didactics of space", which real space determines due to its length (according to Descartes (Descartes, 2018)). From the standpoint of pedagogical psychophysiology, we interpret the concept of an expanded representation of educational material, first of all, as a demonstration of certain features, regularities, phenomena, both spatial structures and relationships between them. For example, the process of multiplication or addition can be depicted as subject operations in the spatial and subject fields. This will be an expanded format that clearly illustrates a certain arithmetic operation through "spatial logic". In this case, we demonstrate the indicated operations in detail. As the indicated operation is understood, it is "transferred" into the symbolic space. The specified aspect of "transfer" to the middle (interiorization into mental reality) leads to the phenomenon of "collapse" whose essence is that operations that were represented through the "logic of space" and the "logic of object actions" (for example, the close location of two groups of objects in "spatial semantics" of which was interpreted as addition) are transformed into a certain generalizing symbol in which the cognitive operation itself (for example, revealed during the demonstration of the operation with the help of objects) may no longer be displayed as spatial interactions (location). The specified features of the actualization of the subject field and the understanding of space as a meaning-making context are presented in the classical concept of the step-by-step formation of mental actions by Gal'perin (Gal'perin, 2012).

In question № 7 – "Both real and virtual space have their own metalogic, which is revealed when using game methods", game methods are represented as actualizing and revealing the "multidimensional" – semiotics, axiology and contextuality of space (real and virtual). These game methods essentially transform the real space into the quasi-space of the game by "filling" it with specific meanings. Real or virtual space becomes a semiotic-symbolic field in which and thanks to which the specified game is implemented, forming conceptualization skills in the child, which are transformed into components of mathematical thinking.

Question № 8 – "Game learning methods and animation reveal the meaning-making aspect of real and virtual space, which can be purposefully applied in the study of mathematics and computer science" – points out the importance of the purposeful use of real and virtual space for the representation of mathematical and informational phenomena. That is, consideration of the structure of space and the objects that fill it as environmental prerequisites for the development of mathematical thinking of rational-logical and multidimensional and systemic external and internal realities is actualized.

In question № 9 – "The possibility of actualizing the phenomena of real space and virtual reality is considered as an instrumental value in the professional activity of a teacher of mathematics and computer science" – space is revealed as a special instrumental value that can underlie the formation of meanings and goals of educational activities. In the specified question, ideas about space are presented as a valuable context of educational practices.

Question № 10 – "The actualization of the phenomena of real space and virtual and augmented reality corresponds to the spatial essence of human nature" – reflects the phenomenology of man as a spatial being. In this issue, human nature is considered multidimensionally and, accordingly, space is presented as a prerequisite and component of human physicality and its intelligence. This cognitive understanding of space and the corporeality associated with it corresponds to the ideas of Lakoff and Johnson (Lakoff and Johnson, 1980) on corporeal mind and corporeal cognitivism. This question is aimed at understanding a person in whom his integrity and physical and intellectual-spiritual essence has a significant and systemic spatial aspect, which accordingly forms an anthropic image of a person who is harmonized with the world. That is, human nature is related to nature as such. The idea of "anthropo-spatial" and "spatial-cognitive" intentionalities of a person, which must be revealed in the conditions of the educational process, is embedded in this general question.

The processing of the survey results was carried out using cluster analysis in order to identify groups of respondents and to determine ways of forming and improving the computer science and mathematics teachers' readiness to develop and use CDGs in the educational process. Cluster analysis was performed using the SimpleKMeans method and the Weka framework for data analysis and machine learning (WEKA, 2021). We described the SimpleKMeans algorithm in the research (Klochko et al., 2022a; Berry and Linoff, 2011). Dunn, DB, SD, CDbw and S_Dbw algorithms were used in the process of data preprocessing in order to determine the recommended number of clusters (Brito Da Silva et al., 2020; Moshtaghi et al., 2018) (table 1). The structure with the number of clusters 4 was chosen as the best in terms of compactness and resolution.

Table 1: Optimal number of clusters, calculated with the help of quality indices.

Index	Algorithms SimpleKMeans
Dunn	4
DB	4
SD	3
CDbw	3
S_Dbw	5

The study was conducted in two stages: Stage I – 2017-2020, 183 computer science and mathematics teachers from different regions of Ukraine participated in the study (Gurevych et al., 2020); Stage II – 2022, 123 computer science and mathematics teachers from different regions of Ukraine and Republic of Moldova participated in the study.

3 RESULTS AND DISCUSSION

The central theoretical result of this research is the formation of a model of the computer science and mathematics teachers' readiness to develop and use CDGs in educational process. In addition to the axiomatic and systematic approach, which includes the development of the field of problematization with the selection of the main aspects of the problem, the specified issue is solved by conducting research (presented below) (figure 3).

The development of this readiness model is based on teleological (target), anthropological and systemic approaches. Within the framework of the teleological approach, the harmonious, innovative development of the personality, which includes the formation of key and digital competencies, is considered as a prerequisite for the realization of the sustainable development goals and the innovative trend.

This model of readiness of the computer science and mathematics teachers' readiness to develop and use CDGs is based on the pedagogical value and teleological understanding of the main aspects. The specified aspects are considered as system-forming in the development of this readiness. We distinguish the following system-forming aspects – innovative, cognitive-active, personal-reflective, motivational-value, valuable, spatial, which is considered as spatial-cognitive and visual-spatial, temporal, cultural-educational, communicative aspects (figure 3). Let's consider these aspects in more detail.

Among the specified aspects, we consider cognitive-active, personal-reflective, motivational-value aspects as "internal" or anthropological, as such, which can be present in the mental reality of a professional personality. Based on the actualization and selection of the specified aspects as professionally significant, a structure of readiness is developed. The specified aspects correspond to the name of readiness components and reflect the corresponding professionally significant meanings and directions. The specified "internal" aspects are formed on the basis of activity-semantic and teleological integration of individual aspects: cognitive, activity, personal, reflective, motivational, value. Such integration of the specified aspects reflects deep professionally significant features, which we present below.

The integrated cognitive-activity aspect in the readiness model is transformed into its component of the same name. It reflects the cognitive and functional specifics of the professional activity of a teacher of mathematics and informatics and the peculiarities of the intellectualized process of studying these disciplines.

The personal-reflective aspect, which in the readiness model is transformed into the component of the same name. He characterizes reflection as a defining professional ability of a computer science and mathematics teachers, which is necessary when studying the specified educational disciplines. Reflexivity in this aspect is a professional ability that determines the personal and professional potential, in particular, for the implementation of control and verification of logical operations. Therefore, reflexivity, both as a cognitive and as a personal quality, is quite developed among specialists in mathematics and computer science. For its realization, reflexivity must be deeply included in the being of a professional, in his personality. Accordingly, the specified specialists should be capable of

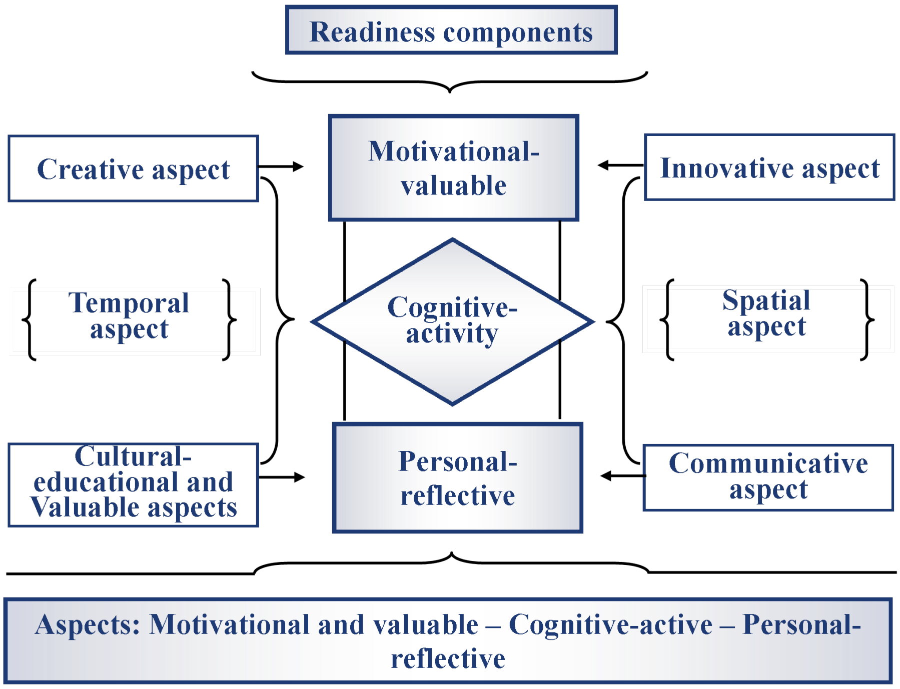

Figure 3: System-forming aspects of the model of the computer science and mathematics teachers' readiness to develop and use CDGs.

long-term, psychologically exhausting work on finding optimal solutions, which includes purposeful activities to correct possible errors.

The motivational-value aspect, which in the readiness model is transformed into the component of the same name, reflects the humanistic and human-oriented idea of professionalization of a specialist based on meaningful and internalized (that is, transferred to the inner mental reality) values, meanings, images, intentions, etc. That is, the actualization of the specified aspect and the component of readiness corresponding to it is a way of axiologising and a manifestation of humanistic, by its essence, pedagogy, which is based on values. In this aspect, the idea of "internal motivation" is implemented in accordance with the self-determination theory (Deci and Ryan, 2015).

In addition to those presented above, let's consider other relevant aspects, on the basis of which the readiness of the computer science and mathematics teacher to develop and use computer didactic games is formed – innovative, valuable, spatial (considered as spatial-cognitive and visual-spatial), temporal, cultural, educational, communicative.

Due to the actualization of the innovative aspect, the technological-innovative and socio-cultural significance of CDGs for the education of the future, which is the education of sustainable development, is problematized and revealed. CDGs are an innovative technology, the implementation of which in the educational process aims to move to a qualitatively new level of education. The innovative aspect is also a determining goal (telosom) in developing the computer science and mathematics teachers' readiness to develop and use CDGs. The innovative aspect, which is primarily explicit ("external") in relation to the personality-professional during its internalization (transfer into mental reality), is considered as part of the cognitive-activity component of readiness. Possession of the educational theory and practice of the application of CDGs largely reflects the innovativeness of the teacher as a professional quality and as his focus on self-development and creativity. It is significant that innovativeness is also considered as a value reference point in the process of implementing CDGs.

The value aspect is primarily an external factor of the cultural and educational space. When internalizing the value aspect, it is considered as part of the motivational-value component of readiness, and in the system of the cognitive-activity component in the format of value-oriented knowledge. The value aspect determines the meanings and orientations that are significant in the readiness system.

The cultural and educational aspect reflects the importance of professional and cultural contexts and professionally significant potentials of the educational environment in which readiness is developed and implemented. Guided by the anthropological ideas of Hall (Hall, 1959, p. 10-11) about the contextuality of cultures, we believe that the cultural and educational aspect is a defining professional context. The cultural and educational environment contains values, meanings, stereotypes of interaction, communication and behavior, ideas, directions, etc. in a contextual format. The development of readiness includes cultural-educational, value-semantic contexts and significant ideas that are present in them. Currently, there are ideas of direction of innovation, child-centeredness, humanization, technologization, non-violent communication, tolerance, freedom, democracy, professionalization, etc.

The communicative aspect contributes to the consideration of CDGs during their development and implementation as a special professional and communicative phenomenon, as a way of transferring knowledge, ideas and technologies. This is due to the fact that the game includes an expressive communicative aspect and can be interpreted as a way of communication. Therefore, communicability is primarily embedded in the structure of CDGs and the system of readiness itself and in all three of its components.

The creative aspect contributes to the consideration of CDGs and their implementation in the educational process as a creative phenomenon, which at the same time also contributes to the disclosure of the creative potential of an individual. Creativity, in turn, is impossible without spontaneity, a certain creative freedom, interpretability, social activity and, thus, it is a guide to the ideas of democracy and freedom as existential and educational values. Accordingly, the development of the implementation of CDGs in the educational process is a way of revealing creativity. We consider the creative aspect of readiness as part of the cognitive-activity component.

The temporal aspect actualizes the idea that CDG is a temporal phenomenon, which is important to take into consideration during their development and implementation. In turn, CDG, due to its temporal specificity, can contribute to the development of temporal competence, provided that the temporal aspect is purposefully actualized.

The spatial aspect is significant due to the fact that CDGs have a distinct spatial dimension, which must be taken into consideration during their development and implementation. We consider the spatial aspect as spatial-cognitive and visual-spatial. The spatial-cognitive aspect is aimed at developing the teachers' ability to use spatial phenomena in the educational process for the representation and illustration of educational material. The visual-spatial aspect is aimed at forming the ability to work with spatial phenomena, which includes their comprehension and interpretation. This aspect is also aimed at the development of visual-spatial intelligence. We consider the visual-spatial aspect of internalization into the mental reality of a professional personality within the framework of the cognitive-activity component of readiness.

Concluding the theoretical consideration of this problem, we will present the determination of the computer science and mathematics teachers' readiness to develop and use CDGs in educational process. By the computer science and mathematics teachers' readiness to develop and use CDGs, we understand the integrated cognitive-activity professional-personal ability of the teacher, which contains expressive value-motivational and reflective components and is aimed at implementation CDGs into the educational process, and is also implemented on the basis modern directions – innovative development, humanism, child-centrism, creativity, communicativeness, and taking into account spatial-temporal and cultural-educational specifics.

Let's proceed to consider the results of the study aimed at determining the state of the computer science and mathematics teachers' readiness to develop and use CDGs. The study was conducted to establish the presented readiness structure.

The authors analyzed the results of the evaluation of the components that constitute the readiness of computer science and mathematics teachers to develop and use CDGs into the educational process.

To evaluate and analyze the levels of components of the computer science and mathematics teachers' readiness to develop and use CDGs into the educational process, the following criteria were used: the motivational-value criterion, the cognitive-activity criterion, the personality-reflexive criterion.

The specified criteria integratively characterize the same name corresponding readiness components.

Motivational-value component of readiness. Accordingly, the motivational-value criterion characterizes a set of values, meanings, intentions, motives. The awareness of these motives, values and meanings is also important.

Interviewing, questioning and testing were used in the evaluation of the motivational-value criterion of computer science and mathematics teachers' readiness to develop and use CDGs in the educational process (Gurevych et al., 2020). During questioning, we were trying to realize to what extent the activities related to the development and implementation of CDGs are understandable, relevant, necessary and desirable (among the survey questions diagnostically significant were the following: “Do you agree that readiness for the development and implementation of CDGs is an important component of professional and information competencies of today’s computer science teachers?”, “Is it interesting for you to learn the way of developing and implementing CDGs in the educational process more deeply?”).

We also used the “Questionnaire for determining the significance of readiness for the development and implementation of CDGs for successful professional activities” (Greene et al., 1997; Volochkov, 2007). Teachers’ responses showed that teachers are aware of the importance of readiness for the development and implementation of CDGs for the successful professional activities (high level – 30,4 %, average – 50,1%, low – 19,5% of teachers) (Gurevych et al., 2020) (see figure 4).

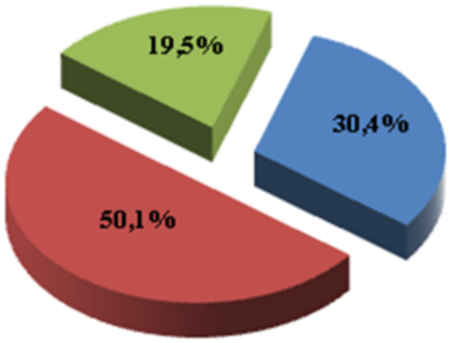

Figure 4: Significance of readiness for the development and implementation of CDGs for successful professional activities (high level – 30,4%, average – 50,1%, low – 19,5% of teachers) (Gurevych et al., 2020).

Value orientations, which had become a subject of study, also contribute to the achievement of professional success in teaching computer science and mathematics. For their diagnostics, the “Questionnaire for determining the computer science and mathematics teachers’ value orientations as for the development and implementation of CDGs in educational process was used” (developed by Klochko (Klochko, 2018) on the basis of Rean et al. (Rean et al., 2000) method) (table 2, figure 5).

Thus, understanding the importance of the development and implementation of CDGs into the educational process, the dominating values of teachers are the following: possibilities to introduce new methods and forms of works with students, develop students’interest to computer sciences, possibility to improve pedagogical skills in using CDGs, self-development, self-improvement as well as achieving professional success, development of personal strengths, talents, acquiring professional and information competencies in developing CDGs. The analysis of discrepancies showed that teachers give more priorities to using CDGs in the educational process ratherthan developing them. In addition, the sphere of CDGs development is of higher priority than their implementation for acquiring professional and information competencies.

Table 2: Hierarchy of computer science and mathematics teachers’ value orientations as for the development and implementation of CDGs in educational process. (The question number column is labeled “№”.)

№	Rating indicators of the development of CDGs	Rating indicators of the using of CDGs
1	4	6
2	4	5
3	4	9
4	13	13
5	10	11
6	14	14
7	9	7
8	2	4
9	12	12
10	11	10
11	2	1
12	7	7
13	8	3
14	1	1

Such results may mean that teachers do not fully realize the possibilities of professional growth in develop and using CDGs and do not comprehend all possibilities and ways for improving their teaching skills. It may be assumed that computer science and mathematics teachers are sufficiently oriented in the process of implementing new methods and forms of works in the classroom. They know how to develop students’ interest in computer science, to improve teaching skills and strive to self-development and self-improvement aimed at achieving professional success in the acquisition and development corresponding knowledge, abilities and skills in the sphere of CDGs. Additionally, there is a lack of care for material comfort, improvement in social status, recognition in the professional sphere, and achievement of respect. However, computer science and mathematics teachers were also observed to be more oriented towards professional realization and improvement, which dominated their requirement for recognition and respect, improve social status, ensuring material comfort.

The motivation for achievement favours an increase in persistence, self-esteem, regulation of activities, the formation of readiness for the development of

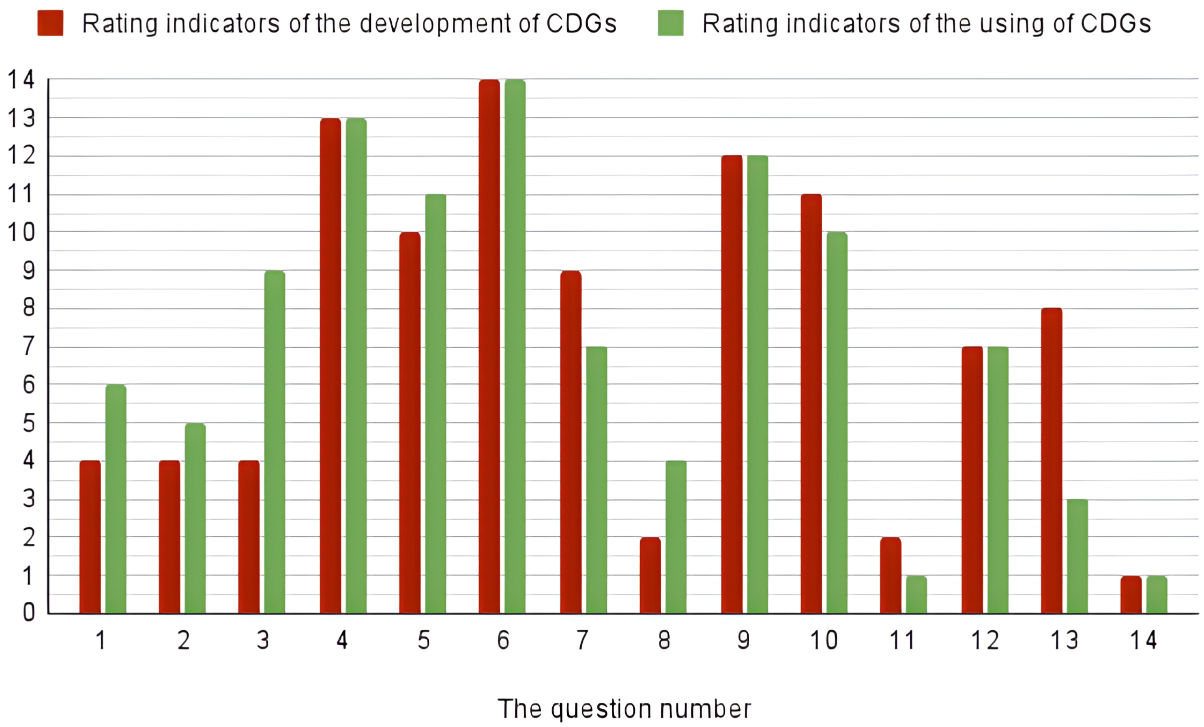

Figure 5: Hierarchy of computer science and mathematics teachers' value orientations as for the development and implementation of CDGs in educational process.

CDGs and their implementation into the educational process. The results of the survey of computer science and mathematics teachers show that following the methodology "Diagnostics of motivation for success and fear of failures" (Rean et al., 2000), 59,2% of teachers have motivation on the average level (the motivational pole is not clearly defined), 21,4% of teachers have a high level of motivation (motivation for success is diagnosed), and 19,4% of teachers have a low one (the motivation of fear of failure is diagnosed) (figure 6). The motivation for achievement activates subjective efforts of computer science and mathematics teachers, directed to the desired outcome in personal and professional development.

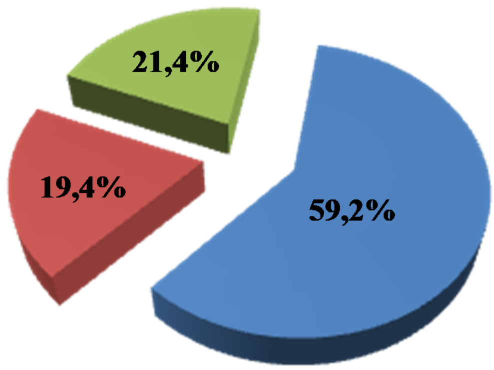

Figure 6: Results of the diagnosis of motivation for success and fear of failure (high level (motivation for success is diagnosed) – 21,4%, average – 59,2% (the motivational pole is not clearly defined), low – 19,4% of teachers (the motivation of fear of failure is diagnosed).) (Gurevych et al., 2020).

According to the results of the study of the motivational-value component of computer science and mathematics teachers' readiness to develop and use CDGs in educational process, in particular, its motivational-value component, we can conclude that 21,4% of teachers are diagnosed with motivation for success and 30,4% of teachers are diagnosed with high level of significance of readiness for the development and implementation of CDGs for successful professional activities.

Personality-reflexive component of readiness. This component was considered with the application of research methods of the ability to self-control and reflective potential of the individual. "Questionnaire to determine the percentage distribution of computer science and mathematics teachers by levels of the ability to self-control" (Peisakhov, 1984; Zverkov and Eidman, 1990) and "Questionnaire for determining the Indicators of personality-reflexive criterion for evaluation of computer science and mathematics teachers' readiness for CDGs development and implementation" (developed by Klochko (Klochko,

2018) based on Rean et al. (Rean et al., 2000) methods) were used for this purpose. Accordingly, the personality-reflexive component was used, which is characterized by the determination of the teacher's personal style of activities, the awareness of the content of activities, the abilities to evaluate outcomes and consequences, the skills of self-education, self-realization in the professional activities, and life-long learning. The indicators of this criterion are: the ability for self-analysis, self-control, self-organization; the availability of the personal style of activities; understanding the scope of the activities on CDGs developing and implementing; the self-education skills.

The study enabled us to set up the following system-creative factors that determine the ability of computer science and mathematics teachers for self-control: restraint, sense of duty, will power, disciplined manner, and responsibility.

The research results, using the ability to self-control and reflective potential of the individual methods, show that the average values of self-control quality levels of computer science and mathematics teachers were distributed as follows: high level – 39,8%, average level – 51,5%, low level – 8,7% (figure 7) (Gurevych et al., 2020). In our opinion, such results may be explained by job requirements and social context.

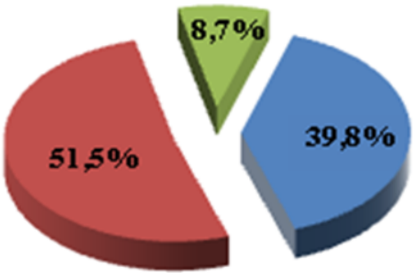

Figure 7: Percentage distribution of computer science and mathematics teachers by levels of the ability to self-control (high level – 39,8%, average – 51,5%, low – 8,7% of teachers).

Hence, as average indicators of the personality-reflexive criterion of computer science and mathematics teachers' readiness to develop and implement CDGs show that the highest rank belongs to teachers' striving for strong performance in this area, for awareness of shortcomings and sincere endeavor to improve performance (diagnosed using the "Questionnaire for determining the Indicators of personality-reflexive criterion for evaluation of computer science and mathematics teachers' readiness for CDGs development and implementation") (table 3, figure 8) (Gurevych et al., 2020).

Summarizing the results of the research through

Table 3: Indicators of personality-reflexive criterion for evaluation of computer science and mathematics teachers' readiness for CDGs development and implementation. (The question number column is labeled "№".)

№	In the sphere of CDGs development, ranking	In the sphere of implementation, ranking
1	7	4
2	5	2
3	6	6
4	1	1
5	2	3
6	4	5
7	3	7

their integrative consideration and interpretation within the semantic framework of the personality-reflexive criterion, we note that according to the self-control indicator, most computer science and mathematics teachers are diagnosed with medium and high levels of the ability to self-control. According to the results of diagnosing the indicators of the personal-reflective criterion for assessing the computer science and mathematics teachers' readiness to develop and use CDGs, it can be concluded that teachers mostly want to achieve high results in the areas of developing and using CDGs, know their shortcomings and strive to correct them, try to work in the direction of finding new methods of techniques, forms, ways of implementing CDGs, but to a lesser extent they work on improving acquired competencies in this area.

Cognitive-activity component of readiness. Formation of computer science and mathematics teachers' readiness for the development and implementation of CDGs into the educational process has to be based on practically oriented knowledge and intellectual skills. The indicators of the cognitive-activity criterion, which reflects the content and the technology of development and implementation of CDGs, as well as individual and psychological peculiarities of teachers' readiness, in particular cognitive, are: the field knowledge, the abilities to use the field knowledge for professional purposes and the cognitive activities.

Research according to the cognitive-activity criterion was carried out using the "Questionnaire for determining the indicators of cognitive-activity criterion of evaluation of computer science and mathematics teachers' readiness to develop CDGs and implement them into the educational process" (developed by Klochko (Klochko, 2018) based on Raven (Raven, 1989) methods), "Questionnaire to determine the percentage distribution of computer science and mathematics teachers by levels of the ability to self-governance" (Peisakhov, 1984; Sherer et al., 1982; Zverkov and Eidman, 1990), "Fedorets-

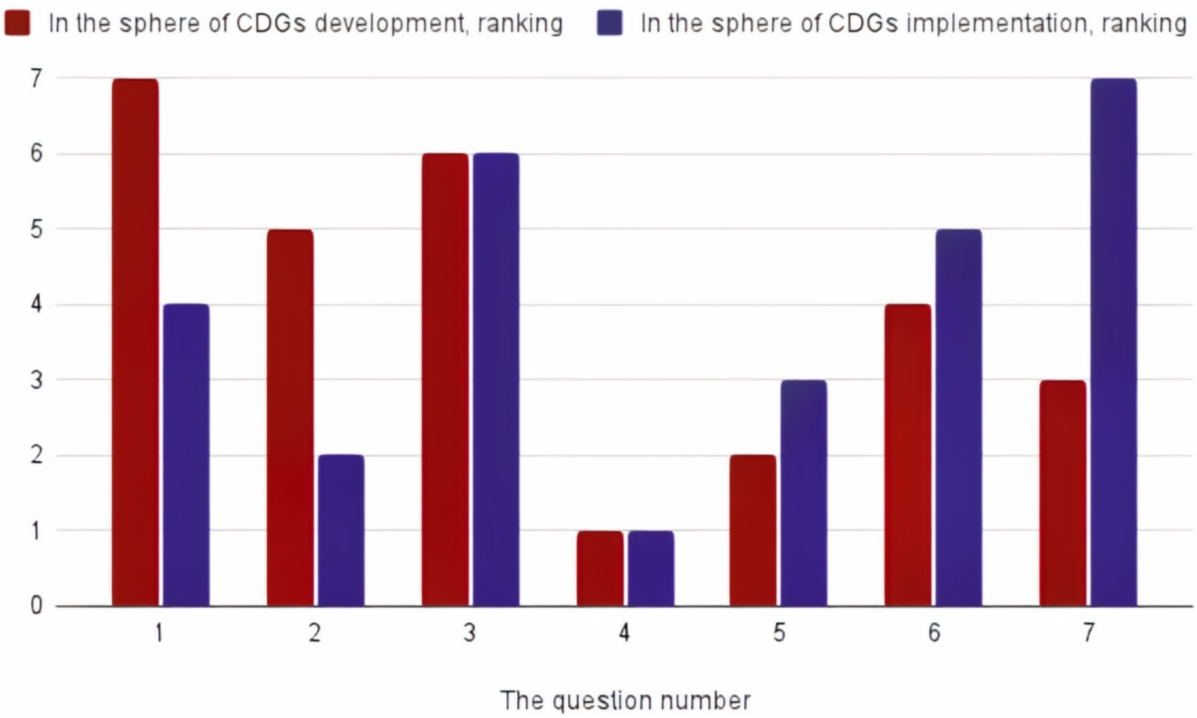

Figure 8: Indicators of personality-reflexive criterion for evaluation of computer science and mathematics teachers' readiness for CDGs development and implementation.

Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers", as well by the analysis of results of computer science and mathematics teachers' knowledge in CDGs development and implementation theory (the method of monitoring quiz (oral and written) were used). This criterion also reflects the importance of metacognitive strategies, which include the formed abilities for goal setting, self-evaluation, self-management, planning, control, and intellectual reflection. It is significant that the mentioned intellectual qualities should be essentially activity and, accordingly, aimed at the professional sphere of the teacher and, above all, at the development and use of CDGs. Within the framework of this criterion, spatiality is defined as an actual direction of the teacher's intellectual development. The spatial aspect is presented as spatio-cognitive and visual-spatial. Accordingly, within the semantic framework of spatiality, the problematic of the teacher's availability of valuable knowledge, understanding, intellectual intentions and reflections of both real and virtual spaces is actualized (Yevtuch et al., 2021). The cognitive-activity criterion for the evaluation of computer science and mathematics teachers' readiness for development and implementation of CDGs characterizes the level of theoretical knowledge, ability to use and create activities that are of significant importance in the professional practice of computer science and mathematics teachers.

The estimation of professional achievements, however, does not fully reflect the level of computer science and mathematics teachers' knowledge in this sphere, as it is a pretty formal indicator of their readiness for the development and implementation of CDGs. The average results of the quiz show that computer science and mathematics teachers' knowledge in theory of CDGs development and implementation is as follows: high – 4,2% and 24,8%; average – 11,2% and 46,5%; low – 84,6% and 28,7% (figure 9, figure 10) (Gurevych et al., 2020).

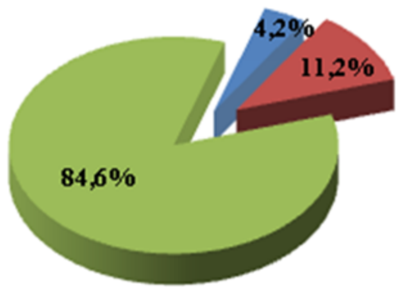

Figure 9: Average results of computer science and mathematics teachers' knowledge in CDGs developing theory (high level – 4,2%, average – 11,2%, low – 86,4% of teachers) (Gurevych et al., 2020).

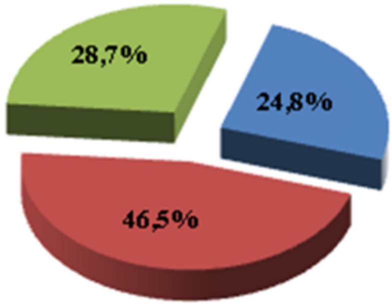

Figure 10: Average results of computer science and mathematics teachers' knowledge in CDGs implementation theory (high level – 24,8%, average – 46,5%, low – 28,7% of teachers) (Gurevych et al., 2020).

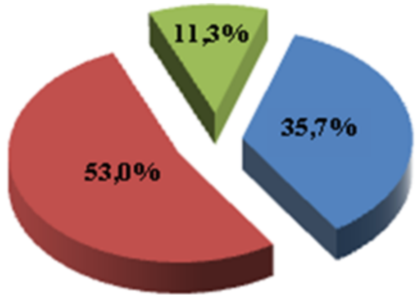

Figure 11: Percentage distribution of computer science and mathematics teachers by levels of the ability to self-governance (high level – 35,7%, average – 53,0%, low – 11,3% of teachers) (Gurevych et al., 2020).

Identifying the indicators of the cognitive-activity criterion, we proceeded from the importance of metacognitive strategies. Accordingly, with formed meta-cognitive strategies the computer science and mathematics teachers understand the process of development and implementation of CDGs as a focused and result-based management of the professional activities and life-long learning that simulates abilities to predict outcomes, plan, control, evaluate, monitor and manage this process, overcome difficulties at the time of achieving tactical and operational purposes as well as strategic goals. we assumed that computer science teachers understand the process of development and implementation of CDGs as a focused and result-based management of the professional activities and life-long learning that simulates abilities to predict outcomes, plan, control, evaluate, monitor and manage this process, overcome difficulties at the time of achieving tactical and operational purposes as well as strategic goals.

So, the results of the tests using the "Questionnaire to determine the percentage distribution of computer science and mathematics teachers by levels of the ability to self-governance" reveal that the computer science and mathematics teachers' ability to self-governance, mainly, is on the average level. The percentage distribution by ability levels is as follows: 35,7% – high, 53,0% – average, 11,3% – low level (figure 11) (Gurevych et al., 2020). These data show that computer science and mathematics teachers according to the self-governance indicator, which to a large extent integratively reflects the formation of metacognitive strategies, are ready to develop and use CDGs in educational process.

The study shows that the formation of the readiness of computer science and mathematics teachers to develop and implement CDGs into the educational process is impossible without the corresponding knowledge and intellectual skills in these spheres, such as: knowledge of CDGs' tools of development and implementation (classification, functional possibilities, didactic peculiarities, development requirements), skills in selection of topics, design development, knowledge of psychological peculiarities of students' age groups, etc. (table 4, figure 12) (Gurevych et al., 2020). The efficient management of this process demands knowledge of problem analysis, a clear vision of the situation, and the ability to forecast and plan future actions.

Table 4: Indicators of cognitive-activity criterion of evaluation of computer science and mathematics teachers' readiness to develop and implement CDGs into the educational process. (The question number column is labeled "№").

№	In the sphere of CDGs development, ranking	In the sphere of implementation, ranking
1	1	1
2	7	3
3	8	4
4	10	5
5	8	12
6	6	10
7	11	8
8	2	2
9	12	11
10	4	8
11	3	5
12	5	7

Summarizing the results of the research through their integrative consideration and interpretation within the semantic framework of the cognitive-activity criterion, we note that according to the investigated indicators of the cognitive-activity criterion, the majority of respondents are diagnosed with an average and high level of formation indicators of cognitive-activity and self-governance. The average level of theoretical knowledge of computer science and mathematics teachers on the development and use

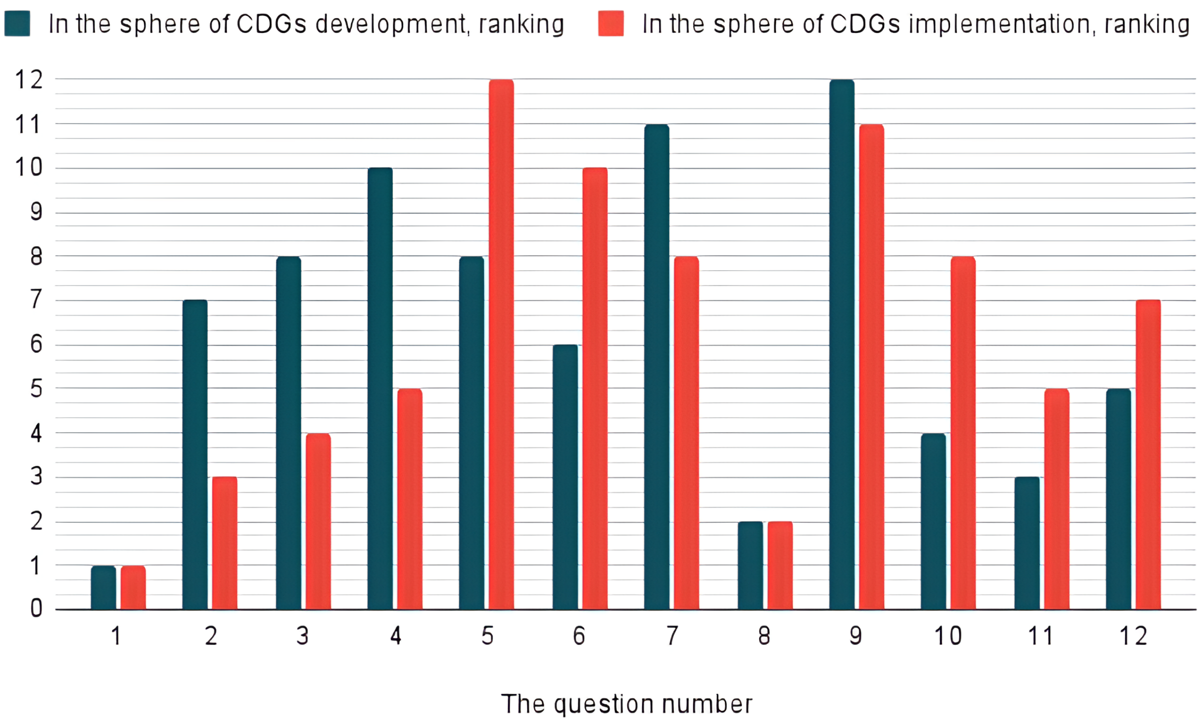

Figure 12: Indicators of cognitive-activity criterion of evaluation of computer science and mathematics teachers' readiness to develop and implement CDGs into the educational process.

of CDGs in the educational process was also diagnosed, respectively 11,2% and 46,5%, and the high level of theoretical knowledge of computer science and mathematics teachers on the use of CDGs, respectively 4,2% and 24,8%. It should be emphasized that 86,4% of respondents are diagnosed with a low level of theoretical knowledge on the development of CDGs. This may be due to the fact that in the process of training and retraining, professional development of informatics and mathematics teachers, less attention is given to the topic of developing computer games for use in the educational process. The study shows that computer science and mathematics teachers fully understand the process of development and implementation of CDGs, know how to choose games aimed at achieving lesson objectives. They have knowledge, skills and are able to use CDGs in the educational process but have little experience in their development. In their professional activities, computer science and mathematics teachers also face difficulties in understanding the psychological peculiarities of using CDGs by students. Teachers also have to deal with the issue of the definition of the main functionalities of CDGs, since their selection directly influences the realization of the student-centered approach.

During the II stage of the research, which took place in 2022, the value interpretations of space by a mathematics and computer science teacher were studied. This study is considered in the content-semantic framework of the formation of the cognitive-activity component of readiness that was studied. The spatial direction of the research is determined by the fact that the specificity of the development of the cognitive-activity component of readiness is the actualization of the spatial aspect. The spatial aspect is presented in two formats: visual-spatial, which helps to reveal visual-spatial intelligence, and spatial-cognitive, which is aimed at the teacher's use of spatial phenomena (both real and virtual spaces) for purposeful representation and illustration of relevant topics in mathematics and computer science.

Let's consider the results of the questionnaire using the "Fedorets-Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers" using the methodological and interpretive potential of cluster analysis. In the process of applying the SimpleKMeans algorithm to the clustering model, built on the basis of a set of data obtained during the questionnaire survey, 4 clusters (number 0, 1, 2, 3) were formed, the centroids of which are shown in the table 5 (figure 13).

Cluster № 0 is the largest in terms of volume and, accordingly, formed 53% of the responses. The specified cluster unites answers that define space (real and virtual) as a "pedagogical-technological" value that

Table 5: Model and evaluation of clustering data using the SimpleKMeans algorithm. (The question number column is labeled "№".)

№	Cluster № 0, 53%	Cluster № 1, 23%	Cluster № 2, 13%	Cluster № 3, 13%
1	2	1	1	3
2	3	1	1	3
3	2	2	0	3
4	2	1	0	3
5	2	1	0	3
6	2	0	1	3
7	2	1	2	3
8	2	2	2	3
9	2	1	0	3
10	1	0	3	3

is significant in the process of teaching mathematics and computer science when using didactic computer games (figure 14). This cluster defines the positive interpretation of space in quantitative representation as the middle between negative and highest. Accordingly, a positive understanding of space as an "pedagogical-instrumental" value can be purposefully applied in the educational process. Cluster 0 dominates in the specified sample is half. This dominance indicates that the studied teachers, who make up half of the sample, have a generally positive attitude towards this problem. At the same time, the indicated "middle position" in the sample indicates a not maximum readiness to actualize the spatial component when using didactic computer games. The not-total "fascination" with visual-spatial issues also indicates the critical thinking and personal and intellectual maturity of teachers, because the representation of space as an instrumental value is relatively new and for many teachers it was revealed through their questionnaires. As mentioned above, the purpose of the survey was not only diagnosis, but also actualization of the phenomenology of space as value-oriented and technologically oriented. The trends of Europeanization, democratization and humanization of Ukrainian education defined in the Concept of the New Ukrainian School (Zhorova et al., 2022) play a certain role in such a dominant, but at the same time, "moderate" or "medium" distribution. The specified educational trends contribute to the professional development of the teacher. Accordingly, the teacher develops as a competent, critical-thinking and independent person who finds and forms "his" teaching methodology and methods.

Clusters № 1 (23%) and Clusters № 2 (13%) (total 36%) include answers that represent space (real and virtual) as a "pedagogical-technological" value that is considered significant, neutral or negative in the context of teaching mathematics and computer science when using didactic computers computer games. Accordingly, the answers can be presented as a continuum from negative to positive – 0, 1, 2 and 3 (one answer). The presence of cluster № 1 and cluster № 2 (total 36%), which are quite significant in terms of volume, which makes up more than a third, speaks of a certain novelty and possible certain incomprehensibility of the actualized issues, which are represented in general terms, and not as a specific technology. It is clear that at this stage the specified "visual-spatial approach" is first of all revealed at the level of methodology in the form of general ideas and interpretations.

Cluster № 3, which is represented by 13% of respondents' answers, represents the highest level of teachers' interpretation of space (real and virtual) as a technological value that is significant in the process of teaching mathematics and computer science when using didactic computer games. We explain the relatively small percentage of people who, at the highest level, interpret space (real and virtual) in a value-oriented way, considering it as a probable component of the implementation of computer didactic games, by the relative novelty of such a spatial approach, the complexity and non-traditionality of its implementation (figure 14). In this aspect, it can be noted that the emergence of virtual space as a digital technology, as a specific "anthropo-techno-cultural" phenomenon and the actualization of game-based learning methods provides an opportunity to better understand the educational significance of the cognitive-valuable potential of real space. In general, we observe a "shift" in pedagogy towards the active use of environmental, contextual, "background" approaches to learning. Accordingly, the environment, including space and time, is understood not only as a background for the educational process, but also as a special meaningful and value-semantic aspect of learning or, even, a "visual-spatial educational tool".

Having analyzed the structure of the distribution

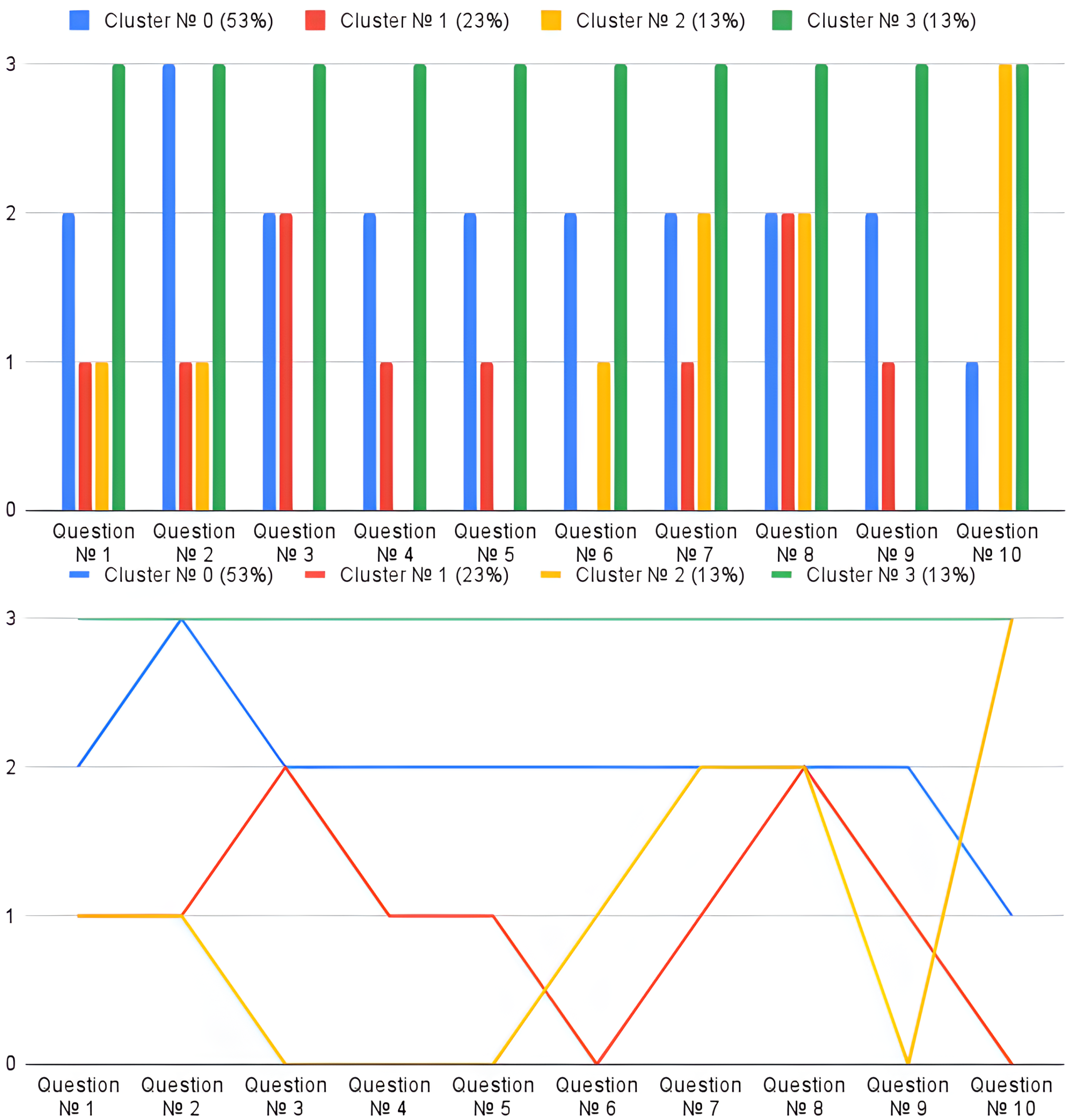

Figure 13: The centroid values of the clusters according to the question number of the "Fedorets-Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers" are presented in a bar and linear charts.

of answers by clusters, it can be noted that it reflects the indicated trends of the emergence and active development of contextual approaches (including visual-spatial) in education and the active use of digital technologies.

Summarizing and interpreting the results of the research of the spatial aspect in the system of the cognitive-activity component of the studied readiness, we can note that they reveal the relevance and significance of this "visual-spatial-cognitive" direction of the development of the specified readiness, first of all from a practical and pedagogical point of view. It is important that many teachers understand the phenomenology of real and virtual space as a significant pedagogical tool that corresponds to the current modern ideas of spatial pedagogy, existential pedagogy, child-centeredness, and contextual learning.

We can say that we are witnessing the beginning

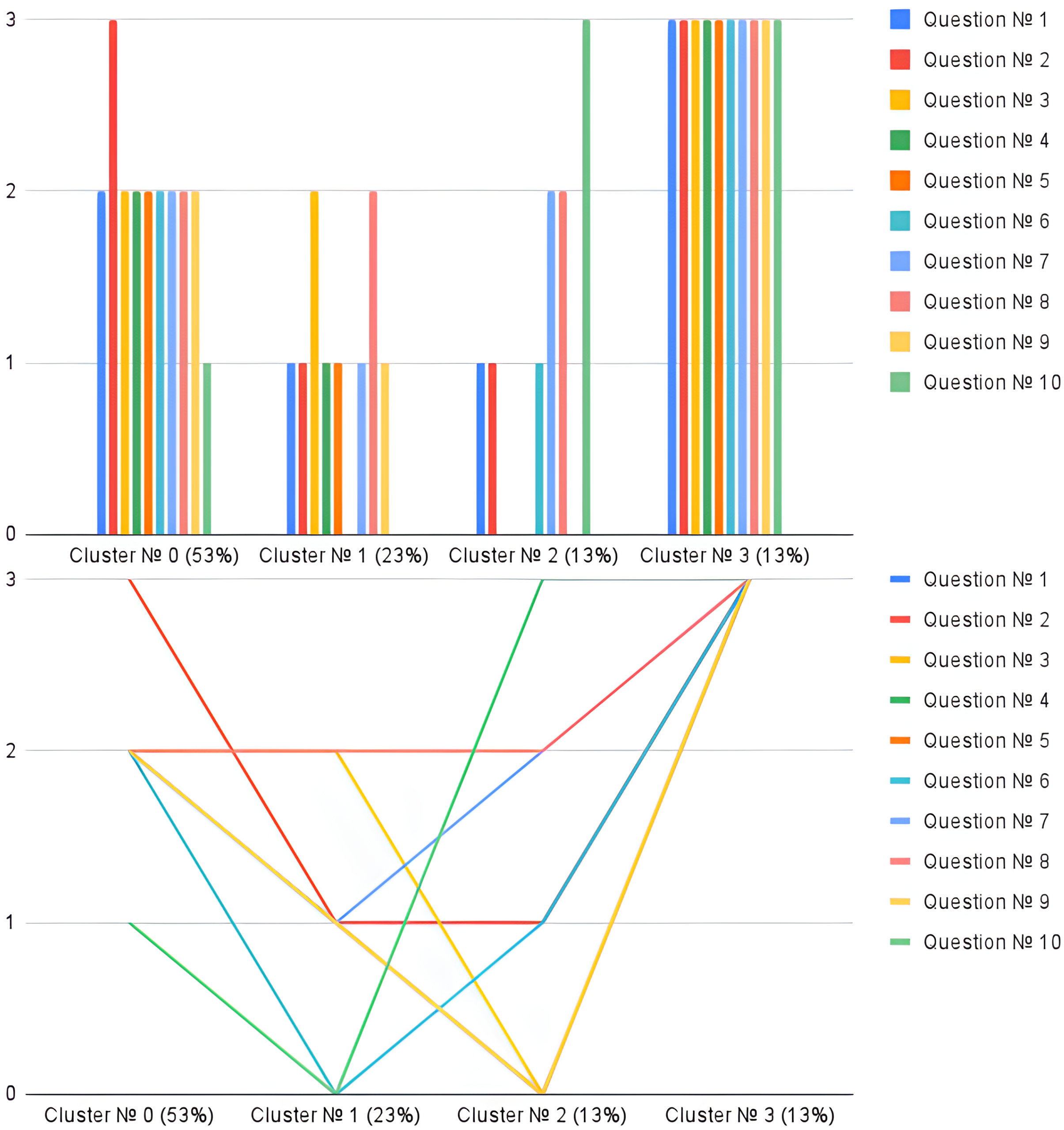

Figure 14: The centroid values of the clusters according to the cluster number of the "Fedorets-Klochko questionnaire for determining the value interpretation of space by computer science and mathematics teachers" are presented in a bar and linear chart.

of an active integrative application of digital, spatial, game, axiological methods and technologies, which corresponds to the paradigmatic attitudes of postmodernism, including the officially defined direction of sustainable development, which pays special attention to the "terrestrial space" and the person in it.

4 CONCLUSIONS

The readiness of computer science and mathematics teachers to develop and use CDGs in the educational process is a complex integrative personality-professional formation, consisting of motivational-value, cognitive-activity and personality-reflexive components, which specified in their corresponding criteria.

By the computer science and mathematics teachers' readiness to develop and use CDGs, we understand the integrated cognitive-activity professionalpersonal ability of the teacher, which contains expressive value-motivational and reflective components and is aimed at implementing CDGs into the educational process, and is also implemented on the basis of modern directions – innovative development, humanism, child-centrism, creativity, communicativeness, and taking into account spatial-temporal and cultural-educational specifics.

Determining the state of formation of the motivational-value component of readiness, we can indicate that according to the indicator of motivation for success in professional activity, 59,2% of teachers have an average level of motivation (the motivational pole is not clearly defined), 21,4% of teachers have a high level of motivation (success motivation is diagnosed), and 19,4% of teachers have a low level (diagnosed lack of success motivation). According to the indicator of the value of readiness for the development and implementation of CDGs for successful professional activity, the following levels were determined: 30,4% – high, 50,1% – medium, 19,5% – low. There is a certain correlation between the above indicators, which indicates both the formation of the motivational and value sphere and its professional orientation, as well as its focus on the application of CDGs. The following value orientations in the field of development and use of CDGs in the educational process were also determined to be significant for teachers: "Possibilities of introducing new methods and forms of working with students", which indicates developed innovativeness; "Development of students' interest in studying informatics", which indicates the child-centered orientation of teachers. Thus, analyzing and interpreting the values of the above indicators, we can note that according to the motivational-value criterion, an average level of formation of the motivational-value component of readiness is observed in most teachers.

According to the cognitive-activity component of readiness according to the indicator of the ability to self-governance, which reflects the formation of metacognitive abilities, which includes goal setting, self-esteem, self-management, planning, control, intellectual reflection, the obtained percentage distribution of its formation is 35,7% – high, 53,0% – medium, 11,3% – low in terms of levels. The presence of the prevailing high and medium levels indicates a sufficiently high initial level of formation of metacognitive abilities, which are included both in the composition of the studied readiness and in the professional and pedagogical competences of a computer science and mathematics teacher. The average level of theoretical knowledge of informatics and mathematics teachers regarding the development and use of CDGs in the educational process was diagnosed: average – 11,2% and 46,5%; high – 4,2% and 24,8%; low – 86,4% and 28,7%. Having analyzed the relevant training programs, we believe that the reason for such a state of the level of theoretical knowledge is insufficient training in the indicated direction, both during university studies and during advanced training in the conditions of postgraduate education. The state of formation of the cognitive-activity component of the readiness of computer science and mathematics teachers for the development and implementation of CDGs according to the spatial indicator, according to the results of the cluster analysis, professional interest was determined in 53% of teachers, in 13% – a formed positive attitude is present, in 36% – insignificant interest or negative attitude. We explain the small percentage of respondents who, at the highest level, interpret space (real and virtual) in a value-oriented way, considering it as a probable spatial-cognitive component of the implementation of CDGs, by the relative novelty of such a spatial approach, the complexity and unconventionality of its implementation. During the integrative examination of indicators of the formation of the motivational-value component in the semantic framework of its (motivational-value) criterion, its average level of formation is determined.

The state of formation of the personal-reflective component of computer science and mathematics teachers' readiness to develop and use CDGs according to the indicator of the ability to self-control is characterized by the following percentage distribution – high level – 39.8%, medium level – 51,5%, low level – 8,7%. Predominance of medium and high levels of self-control formation as a quality significant for the teacher's professional activity, including the implementation of developed professional mathematical and informational competencies. According to the personal-reflexive indicator, the vast majority of teachers are diagnosed with the desire to achieve high results, knowledge of their shortcomings and the desire to correct them, which indicates purposefulness, the presence of professionally directed reflection and innovative orientation. During the integrative examination of indicators of the formation of the personal-reflexive component in the semantic framework of its (personal-reflexive) criterion, the average level of its formation is determined.

Summarizing the results of the research based on consideration of motivational-value, cognitive-active and personal-reflective criteria, we can say about the diagnosis of the average level of computer science and mathematics teachers' readiness to develop and use

CDGs. Based on this, we define the following main strategies for its improvement: supplementing educational programs with topics that represent the ways and practices of applying CDGs in the preparation of future computer science and mathematics teachers, their retraining and advanced training; application of competency-based, activity-based approaches in order to develop teachers' professional orientation to the application of CDGs; to activate the use of innovative pedagogical technologies for the formation of computer science and mathematics teachers' readiness to develop and use CDGs; to carry out an analysis of the application of CDGs in other countries and the reception of positive pedagogical experience in this direction.

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Computer-Mediated Communication and Gamification as Principal Characteristics of Sustainable Higher Education

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Keywords: Computer-Mediated Communication, Educational Digitalisation, Gamification, Serious Video Games, Inclusive Education, Socionomics.

Abstract: Digimodernism and videoludification are the key drivers of present social transformations. Digital pedagogy, gamification, game-based learning and serious video games (SVGs) supported by computer-mediated communication (CMC) come to the foreground. Theoretical overview of the CMC, discussion of SVGs for e-learning in the time of the quarantine, two cases of SVGs' implementation into educational contexts, efficiency measurement of this implementation, comparison of obtained results with previous data are the aims of this article. To achieve these aims, qualitative and quantitative research methods were applied. We defined 'distance learning', 'e-learning' based on CMC, collected their characteristics, quality parameters and modes. We revised our previous work empirical data and conclusions. Later, we analysed 'gamification', 'game-based learning', 'serious video games' in contemporary education, presented two case studies of digital games' integration into educational process. We used a feedback form, a questionnaire, and a survey to measure the efficiency of the e-learning courses. We proved that they serve as informative quantitative measurement. We emphasised the topicality of the options for reorganising and refining distance and e-learning and brought forward the idea about the new vision of distance and e-learning, gamification of educational process and serious video games as one more variation of CMC that must drive our decisions about the use of technology, not vice versa. Therefore, the need to develop teacher-training programs to help educators understand, design, evaluate and apply CMC and gamified learning applications is set up as the vector of future work.

1 INTRODUCTION

The contemporary educational environment in Ukraine, as well as in many other countries, is driven by the post-industrial model of society and post-modernism that underlie rapid social changes. The transition from goods' production to the economy of services, extensive application of information and communication technologies, innovation, creativity and entrepreneurship, international travel, and migration serve as the main characteristics of societal models. In the workplace, it is characterised by professional flexibility and diversity; tasks, projects, and networks; the necessity to work in a team, technological complexity within a rapidly changing environment. Therefore, the very concept of 'education' is currently being revised to support the postmodern era based on such competencies as social and emotional intelligence, media literacy, ecological intelligence, creativity, collaboration and participatory problem-solving (Tokarieva et al., 2019). Today, there is an obvious need to address the demands of adult and senior learners as well. That is why, education now is being viewed as a process of individual development, the empowerment with knowledge from birth to death – the process that involves interconnectedness and interdisciplinarity, encouragement of students' autonomy in the form of self-guided learning and self-guided education enhancement.One of the important concepts of today's educational systems is 'ecosystemic relations' – individually oriented, based on the principles of autonomy, access to information and feedback,distributed powers, cre-

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ativity to solve problems, responsibility, dynamism, teamwork to jointly solve global problems (Luksha et al., 2018, p. 34-47). Education in the postmodern context is based on problem and project tasks without fear of making mistakes; play/game-based learning, game universes, virtual augmented reality, and computer-mediated communication (CMC), which have come to the foreground in the present context of COVID-19 lockdown and the after-pandemic period when pedagogies turned from in-personal to virtual instructions, including distance learning and e-learning to maintain the barrier-free educational environment.

Therefore, the discussions around educational digitalisation and CMC's implementation into various educational contexts continue to gather momentum and are reflected in many contemporary national and foreign scholarly works. For example, the scientific inquiry of Andreev (Andreev, 2013) is connected with didactics of distance learning, while Fedorenko et al. (Fedorenko et al., 2019) analyses the questions of informatisation in Higher Educational Institutions (HEIs). Bramble and Panda (Bramble and Panda, 2008) present the various distance and online learning models. Dabbagh and Bannan-Ritland (Dabbagh and Bannan-Ritland, 2005) focus on online learning concepts, strategies, and application. Palloff and Pratt (Palloff and Pratt, 1999) describe effective strategies for an online classroom. Rice (Rice, 2006), Bordia (Bordia, 1997), Androutsopoulos (Androutsopoulos, 2006), Dahlberg (Dahlberg, 2001), Kock (Kock, 2004), Hardaker (Hardaker, 2010), Joinson (Joinson, 2001), Walther (Walther, 1996) – these are just a few researchers' names to add to the list, which proves that both theoretical and practical interests in enhancing ways and methods based on CMC are topical on the global scientific scale (Artemyeva et al., 2005).

The literature review would be incomplete if we do not mention here the scholarly works about educational gamification and educational video games. For example, the definition and the structural characteristics of the gamification phenomenon are discussed by Deterding (Deterding, 2012). Education via gamification is analysed by Huotari and Hamari (Huotari and Hamari, 2012). Professional corporate training based on gamified applications is presented by Baxter et al. (Baxter et al., 2017). More recent studies, including works of Arnab et al. (Arnab et al., 2015), Becker (Becker, 2017), discuss the formal design paradigm for serious games. Wouters et al. (Wouters et al., 2013) present the analysis of motivational and cognitive effects of video games. Questions related to the game-based curriculum are analysed in theses of Alkind Taylor (Alkind Taylor, 2014) and Marklund (Marklund, 2015).

Considering this, the purpose of the article is to give an overview of the computer-mediated communication modes and means, as well as serious video games (SVGs) used for e-learning in the time of the quarantine by the university faculty; to present two new cases of SVGs' implementation into educational contexts; to discuss the efficiency of the implementation based on 'The Instructional Materials Motivation (IMMS)' survey by Keller (Keller, 2010b) and a feedback form developed by the research team; to compare the obtained results with the previous research data (Tokarieva et al., 2021).

Stemming from the aim, the following research tasks were outlined:

1) to generalise the main theoretical and experiential findings related to CMC modes and means;
2) to discuss in more detail gamification and SVGs in the context of contemporary educational reality;
3) to present two case studies based on SVGs' application to the learning process and evaluate the efficiency of this tool;
4) to compare the statistical data with the data from our previous research work;
5) to make the conclusions and draft the vectors for future research.

2 RESEARCH METHODS

To address the purpose of the article, a complex of qualitative as well as quantitative research methods was applied. Data collection methods were tied in with the tasks set in the research. There are four distinct stages of the present research work.

Stage number one – theoretical analysis of CMC (its means and modes) on which a literature study, backed up by general references, primary and secondary resources' analysis, a computer search of www and databases were used. On this stage the notions 'distance learning', 'e-learning', 'modes of e-learning' were studied in depth. We also revised the earlier received statistical data of the research conducted by the authors in 2020 in Prydniprovska State Academy of Civil Engineering and Architecture, the Department of Foreign Languages, related to CMC (Tokarieva et al., 2019).

On stage number two, we traced the transition from CMC application in education to its gamification, analysed the notions of 'gamification', 'game-based learning', 'serious video games', highlighted the difference between 'serious video games' and 'computer games'. We based this analysis on the revision and extension of our previous theoretical research (Tokarieva et al., 2019).

The theoretical part is supplemented with two case studies: an integration of 'Globall Manager' – a digital game for learning – into Cross-Cultural Communication course for students of Philology; and 'Auti-Sim' and 'Prism' – games for learning and training of Educators, Psychologists and Social Workers for inclusive education that we undertook on the third stage of the present work. To evaluate the effectiveness of these innovative learning tools we used 'The Instructional Materials Motivation (IMMS)' survey by Keller (Keller, 2010b) and a feedback form at the end of the study programmes. The criteria of the efficiency of the instructional material evaluation comprised the following parameters: attention – the incorporation of a variety of tactics to gain learner's attention; relevance – the consistency of the instructional material with students' goals, learning styles and past experiences; confidence – helping students establish a positive attitude, drive for success; satisfaction – is the maintenance of positive feelings about learning experiences, i.e. positive rewards and recognition (Keller and Suzuki, 2004; Keller, 2010a). On this stage we also used a Google Forms with multiple choice/unlimited choice questions to better understand the participants' experiences with video games.

The fourth stage and the task were to compare the results of the case studies with earlier data, collected at Prydniprovska State Academy of Civil Engineering and Architecture, the Department of Foreign Languages during March-May, 2020 connected with the measurement of the e-learning courses' design efficiency for which the above-described 'The Instructional Materials Motivation (IMMS)' survey that consists of 4 subscales and 36 items was used. The learners' motivation levels were measured by applying a 5-point symmetrical Likert scale.

The authors of the article participated in the development of the framework for the 'Globall Manager' game integration into Cross-Cultural Communication course, implemented the game into the educational process. Also, we collected and analysed the data from 'The Instructional Materials Motivation (IMMS)' survey, feedback forms about e-learning at the time of the quarantine; Google Forms results after 'Auti-Sim' and 'Prism' games work with educational and scientific student group 'Fundamentals of Support for Children with Special Needs and their Families for Pre-Service Specialists' Training in the Socionomic Sphere'.

3 RESULTS AND DISCUSSION

3.1 Stage One

We begin our results' discussion with the statement that because of the increased importance of international work settings, much of what we do and how we communicate have moved to the Web. Communication, access, and creation of information have become everyday life and work tasks that rely on the use of personal and networked technologies. Nowadays, we use Computer Mediated Communication (CMC) – any human communication that occurs through the use of two or more electronic devices and is extensively used in distance and e-learning – to get news updates from around the world, to research ideas, exchange photos, publish our thoughts, tell people where we are and share experiences of all kinds. This includes text messages, e-mails, blogs and discussion forums, social networks, virtual worlds, etc.

The focus of our present discussion is 'distance learning', 'e-learning', 'modes of e-learning'.

There are many definitions of the term 'distance learning' that reflect the diversity of approaches to its understanding. In the most profound studies of the phenomenon done by Andreev (Andreev, 2013), we can find the following definitions:

- distance learning is a mode of learning, along with full-time and part-time modes, in which the educational process uses the best traditional and innovative instructional techniques and tools, as well as the forms of learning based on computer and telecommunication technologies;
- distance learning is a purposeful asynchronous process of interaction between the subject and the object of learning mediated by electronic instructional tools, where the learning process does not depend on the spatial location of the participants;
- distance learning is a set of educational services provided to the general public in the country and abroad through a specialised information educational environment based on the exchange of educational information at a distance.

Palloff and Pratt (Palloff and Pratt, 1999) distinguish three main characteristics of distance learning: 1) it does not depend on spatial location and time; 2) services are provided through a specialised information environment; 3) learning process is controlled by a student him/herself.

The history of distance learning can be traced more than two centuries back and is connected with the emergence of the correspondence institution. Other forms of communication developed during the period of industrialisation and are associated with the invention of the radio and television, i.e., radiocourses and television courses. Later on, the appearance of the World Wide Web played the most significant part in the spread of the remote mode of learning. Consequently, the historical development of distance learning is reflected in its models' evolution – on the basis of a correspondence mode, an online mode, an e-learning mode (Bramble and Panda, 2008).

The term 'e-learning' also has a big number of interpretations and is used in different ways, depending on pedagogical goals and contexts. Our search for e-learning definitions via Google Search Engine yielded 1330000 entries. The generalised definition of e-learning describes it as a variation of distance learning that has gained active development due to the emergence of new technologies.

It is true that the e-learning model is the latest in the history of distance education and has a three-dimensional structure. Through the training based on e-learning principles, students can acquire knowledge anywhere, anytime, and at any speed (Im, 2006).

The Instructional Telecommunications Council defines distance education as "the process of extending learning, or delivering instructional resource-sharing opportunities, to locations away from a classroom, building or site, to another classroom, building or site by using video, audio, computer, multimedia communications, or some combination of these with other traditional delivery methods" (Dalziel, 1998).

The European e-Learning Action Plan defines e-learning as the use of the latest multimedia technologies and the Internet with the aim to improve the quality of the education through granting access to resources and services, distance exchange, and cooperation (Beauvois, 1997).

According to the method of interaction, such modes of e-learning can be distinguished: the interaction between a student-electronic environment, student-student, student-teacher, teacher-electronic environment, interaction inside the educational community. According to the time criterion, e-learning organisation is classified as asynchronous (different times of teaching and learning), synchronous (teaching and learning take place at the same time), or a combination of the two. For example, asynchronous communication (e-mail) allows using authentic speech and meaningful context. Compared to face-to-face communication and synchronous online tools, this environment gives students enough time to reflect and formulate their utterances. Synchronous communication – real-time communication (text chats) simulates conversation but is not complicated by the possible 'dominance' of direct discussions. Research confirms the fact that students participate more often and more proportionately in online discussions than in face-to-face communication. It should also be added that online discussions create a student-centred environment in which they are more willing to take risks (Abrams, 2006).

According to the criterion of technological means' utilisation, e-learning can be computer-based, laptop-based, video conferencing-based, forums-based, weblogs-based, etc. By the methods of information transfer – text, sound, picture, video, animation, simulation, interactive resources based, etc.

In our article, we use the term 'e-learning' broadly to relate to the learning environments where CMC is used as a fundamental of educational instruction.

We consider it necessary to illustrate the above-presented theoretical reflections with the summative overview of the empirical results obtained at the Department of Foreign Languages, Prydniprovska State Academy of Civil Engineering and Architecture at the time of the quarantine, the year 2020.

Based on the statistics received from 'Analysis of the E-Learning Tools Preferences' form disseminated among the teaching staff of the department (the sample of 30 teachers), the most popular video-conferencing platforms chosen by teachers of the department were Skype and Zoom, while Google Hangouts and Discord with video-conferencing features were found less popular. The popularity of Viber is also explained by its video-conferencing function. Social networking apps that were actively used by the faculty were Telegram and Viber. E-mail service was also chosen for the asynchronous correspondence with students. Google Classroom was applied by instructors to exchange texts, audio, video, and hyper-linked material (figure 1).

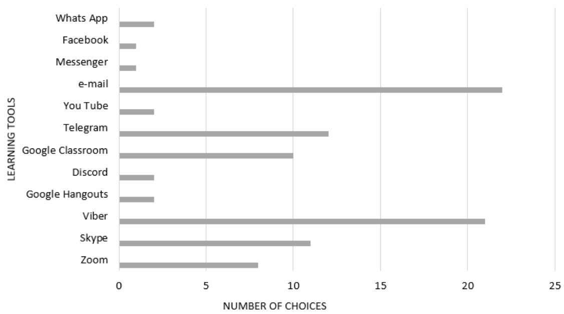

Figure 1: E-learning tools preferences.

Our experience has also provided qualitative data. For example, the benefits of Skype's application, according to our staffs' opinion, lie in the number of video chat participants (which is unlimited), the ease of operation on the screen, the inclusion of such activities as speaking, reading, and, partially, writing. Regarding the use of Google Hangouts application, which is almost identical to Skype, a 'Share Screen' feature that lets students see what the instructor demonstrates on the monitor: files, videos, etc., a 'Chat History' feature that records the number of people attending each class are regarded as supportive. At the same time, it does not have a file-sharing feature and the number of video chat participants is limited up to 10. When it comes to written assignments, the Google Classroom application is named as the best fit. Here, an instructor posts assignments and sets up the deadline, selects students for whom the tasks are assigned, evaluates students' works (the number of points is selected on a different scale principle following the instructor's choice). It is also interesting to mark here that back in March-May 2020 Google Meet was not as popular an application as it is now.

A separate part of our discussion was given to the Zoom platform's analysis, as teaching on this platform, judging by our teachers' feedback, is challenging. This is connected with the phenomenon, described as 'Zoom fatigue'.

Those teachers who used this video-conferencing platform complained that after two sequential sessions they were more tired than after the same number of face-to-face lessons in a real class setting. One of the explanations for this is provided by (Joosten, 2022). She attributes it to the Gallery view when all the sessions' participants appear, which challenges the brain's central vision, forcing it to decode many people at a time. Moreover, 'one of those boxes on the screen is you', which may mean that we spend more energy on monitoring our non-verbal communication than we do in person (Supiano, 2020). What we also experienced was a shift towards teacher-centricity and one-way communication that contradicts the conclusions of the Instructional Telecommunications Council about the effectiveness of e-learning that lies in its individually-oriented nature and student-centricity (Dalziel, 1998).

On this stage, we also organised a brief questioning of students as to what most difficult aspects of e-learning they could name. The question we asked was 'What is the most challenging for you in e-learning?' The possible alternatives were pre-formulated for the students to choose from and the number of choices was not limited. Our statistics look as follows:

1. Problems with self-organisation, high level of distraction – eight students – 34.8%.
2. The excessive number of educational tasks – eight students – 34.8%.
3. Dependence on technical means – twenty students – 86.9%.
4. Poor quality of home Internet – fourteen students – 60.8%.
5. Restrictions on obtaining practical skills – five students – 21.7%.
6. Lack of opportunity to communicate freely with the teacher – none – 0%.
7. Lack of control over the level of knowledge – three students – 13.04%.
8. Insufficient duration of classes (time limit) – none – 0%.
9. The quality of the material taught – four students – 17.4%.
10. Insufficient theoretical materials to perform tests and/or tasks – seven students – 30.4%.
11. Lack of opportunity to communicate with other students – thirteen students – 56.5%.
12. The need to learn how to work online – three students – 13.04%.

It is necessary to mention here, that we had a chance to compare the results of our questionnaire with the results, obtained in Alfred Nobel University, Dnipro from the same questionnaire introduced during the period from 8 to 14 April 2020 in electronic form. The total number of interviewees there made up 1062 students. According to the form of education, the interviewed students were distributed as follows:

- full-time students – 911 people – 85.8%;
- part-time students – 24 people – 2.3%;
- correspondence courses' students – 127 people – 12%.

Alfred Nobel University's statistics look as follows:

1. Problems with self-organisation, high level of distraction – 351 students – 33.1%.
2. The excessive number of educational tasks – 330 students – 31.1%.
3. Dependence on technical means – 302 – 28.4%.
4. Poor quality of home Internet – 300 – 28.2%.
5. Restrictions on obtaining practical skills – 286 – 26.9%.
6. Lack of opportunity to communicate freely with the teacher – 249 – 23.4%.
7. Lack of control over the level of knowledge – 186 – 17.5%.
8. Insufficient duration of classes (time limit) – 162 – 15.3%.
9. The quality of the material taught – 122 – 11.5%.

10. Insufficient theoretical materials to perform tests and/or tasks – 110 – 10.4%.
11. Lack of opportunity to communicate with other students – 108 – 10.2%.
12. The need to learn how to work online – 55 – 5.2%.

Based on the comparative analysis, we got very close statistical data on statements one, two, five, seven, and eight, though the size of the samples interviewed varied.

Overall, the results of this stage can be summarised as follows: distance learning and its later version – e-learning should be applied with the organisational culture analysis in mind. The most popular video-conferencing platforms named by the faculty are Viber, Skype, and Zoom, while Google Hangouts and Discord are found less popular. Social networking apps actively used by the faculty are Telegram, Viber. The most debatable is the Zoom platform as, on the one hand, it has a lot of advantageous features both for teachers and students. At the same time, such a phenomenon as 'Zoom fatigue' is marked by the faculty as a disadvantageous one.

With the reference to the students' feedback from as for the e-learning during the quarantine – 'dependence on technical means' is named as the main challenge, followed by the poor quality of the Internet, problems with self-organisation, the number of tasks given, the restriction on exercising practical skills, which helps highlight the current e-learning situation in HEIs, reveal challenges and needs to further action.

3.2 Stage Two

Moving on to the discussion of the second task, we would present the idea expressed by Kirby (Kirby, 2006) that digimodernism is the mainstream cultural logic of contemporary society and both the video game (as another variation of CMC) and the video gamer are its principal object and subject. In broad context, video games have fitted perfectly well in the globalised spider-web of information flows and have generated revenues as high as C22 billion in Europe in 2020 according to Global News Wire, with the number of people playing video games 1.553.5 million worldwide. 51% of the EU's population played video games, which equals to some 250 million players in the EU, the average playtime per week was 8.6 hours (Interactive Software Federation of Europe, 2022). As a response, digital pedagogy, gamification, game-based learning, and serious video games are gradually becoming a part of the everyday toolkit of educators (figure 2).

Figure 2: Video games in broad context.

Gamification is the use of game elements (such as points, badges, leader boards, competition, achievements) in a non-game setting with the aim to turn routine tasks into more refreshing, motivating experiences (Deterding, 2012). The main idea of gamification evolved parallel with the Internet. Gamification is based on the basics of games, though, with the development of mobile phones and applications, it is actually can be used almost in every sphere, including education. For example, interactive quizzes like 'Kahoot', 'Quizlet', 'ClassDojo', 'Duolingo', 'Edmodo' or gamified learning management systems like 'Classcraft', 'Lingua Attack', 'Socrative', 'DyKnow'. At the same time, serious video games are those that are built on game-based learning principles, include basic elements of video games, and are used not for the entertainment (Zemliansky and Wilcox, 2010). The examples here are many, including educational games (or games for learning, like 'Code.org', 'GloBall Manager', 'MinecraftEdu'), games for training (e.g. 'AbcdeSIM', Kognito, 'Auti-Sim', 'Prism'), games for change (or social games, like 'Against all Odds', 'Ayiti – The Cost of Life', 'Copenhagen Challenge').

We think it necessary to note that 'video games' are considered an activity that includes one or more players, has definite goals, rules, limitations, rewards and outcomes, is artificial with the element of a competition. At the same time, 'serious video games' are those that are built on game-based learning principles, include basic elements of video games and are used not for the entertainment (Zemliansky and Wilcox, 2010).

Game-based learning (GBL) is a type of gameplay with defined learning outcomes (Shaffer et al., 2005). In the process of GBL, learners use games as a tool to study a topic or related topics. They work individually or in teams. It is expected that in this process, the use of games will enhance the learning experience through challenge, exploration, interaction, reflection, and decision-making while maintaining a balance between the content, gaming, and its application to the real world. Having a play at its base, game-based learning is effective in motivating and improving students' engagement, promoting creative thinking and developing approaches towards multi-disciplinary learning. As for educational digital games – they proved to hold great promise for instruction that is appropriate for today's learners.

Based on our previous research revision, we may state that video games present a different learning environment (with a wide spectrum of built-in assistive features) where players interact, experiment, discover and research. They are good at helping to memorise studied material (at 'grinding' things). The material studied in games is stored longer in players' memory. Games let play through the same situation applying different behavioural models, methods and approaches. Games are cost-effective and efficient in training for hazardous situations (firefighters, ambulance, pilots). Games appeal to different learning styles (visual, audio, kinesthetic). Games are adaptable to a particular player's level (with the increase of difficulty based on the player's performance). Games help develop movements' coordination and spatial sensation. As a novel educational instrument, games increase motivation. Games stimulate players' interaction, participation, discussion, and reflection (Tokarieva et al., 2019).

3.3 Stage Three

The third stage of our article is connected with the description and the discussion of two cases of serious games' implementation into the educational process. The first game for learning that was used is 'GloBall Manager' game that was developed within the GA-BALL ('Game-Based Language Learning') project – a joint project between the Engineering Faculty of Porto Politech Institute (ISEP), Virtual Campus Porto, Technical University of Gabrovo (Bulgaria) and Federal University Pelotas (Brazil) (Editorial Team, 2013). The main objective of the project was to improve students' linguistic and sociocultural skills, necessary to take part in e-marketing and e-commerce; develop skills to establish connections via social platforms; encourage students to entrepreneurial activity. The methodological approach chosen – the application of a video game as a learning tool that would provide the participants with rules, everyday professionally-oriented situations, create a cooperative environment in which players try to reach specific educational goals, and increase personal skills and social competencies. The game can be played in seven languages through six different scenarios: 1) internationalisation diagnostics; 2) participation in a fair; 3) business culture; 4) e-commerce and e-marketing management; 5) online communication; 6) institutional negotiation (figure 3).

Figure 3: Globall Manager game (Virtual Campus Lda, 2015).

The game was implemented into the Cross-Cultural Communication course delivered for the four-year course students of Philology, University of Customs and Finance, Dnipro, Ukraine. The aim of the course is to study intercultural professional communication, develop cross-cultural sensitivity of students, form theoretical knowledge about the essence, communication structure and its peculiarities in a cross-cultural environment; linguistic, psychological and socio-cultural features of cross-cultural communication; development of the skills that can help students be effective in intercultural communication. The game was used at practical classes one time per week, 30 minutes for each session during the first semester of 2021. The game was demonstrated from the main (lecturer's) computer. Students' work was initially organised as individual, pair or mini-group work and in online learning mode later on – as teacher-class interaction. Business Culture Scenario was chosen as the study material and was played from the beginning till the end. The scenario was played in English. 46 students were enrolled in the course.

It is important to say that the above-presented game was used as the study material, around which lesson plans were developed. It is an acknowledged fact that educational digital games' integration into a specific educational context is a complex process as, during a digital game-based lesson, a teacher acts as tech support, IT administrator, a moderator, a debriefer. The teacher may be an active player and provide feedback from 'inside' the game. Also, there are three distinct stages in a digital game-based lesson, i.e., before the game-play stage, during the game-play stage, after the game-play stage, accompanied by preparing a lesson plan, setting up the game-play situation, guiding learners in the game-play process, finalising game-play experience.

We also wanted to understand the quality of the course with a video game integrated into it. Therefore, we organised a survey based on 'The Instructional Materials Motivation Survey (IMMS)' by Keller (Keller, 2010a).

There are several models that help estimate the quality of e-learning. The existing models can be divided into two categories: those based on empirical data and those based on theoretical developments. An example of the first category is the quality model proposed by the Institute for Higher Education Development 'Quality on the Line: Success Factors for Distance Learning' (IHEP, 2000); 'Critical Success Factors in Online Education' by Volery and Lord (Volery and Lord, 2000). The second category includes model 'Seven Principles for Good Practice' by Chickering and Gamson (Chickering and Gamson, 1987); model 'Quality Guidelines for Technology-Assisted Distance Education' by Barker (Barker, 1999); 'The E-learning Maturity Model' by Marshall (Marshall, 2010) (Masoumi and Lindström, 2012).

There are also a number of models that have been developed to measure the quality of a course (including distance learning) through measuring learners' motivation in order to improve a course design or to adapt a course to learners' motivational needs (Keller and Suzuki, 2004). The questions of motivation, its structural components and measurement have been studied from different theoretical perspectives in the context of the Social Cognitive Theory, the Expectancy Value Theory, the Self Determination Theory (Silva et al., 2018).

Keller (Keller, 2010a) has developed and tested a model known as the ARCS model based on its acronym (Attention, Relevance, Confidence, and Satisfaction).

Attention – is the importance of incorporating a variety of tactics to gain learner's attention by the use of interesting graphics, animation, an event that introduces a conflict, mystery, unresolved problems, and other techniques to stimulate the inquiry in learners. Relevance – the consistency of the course and the instructional material with students' goals, learning styles, and past experiences. The connection of the content to the learners' future jobs or interesting topics.

Confidence – lies in helping students establish a positive attitude, drive for success, and the experience of success as the result of their ability and efforts.

Satisfaction – is the maintenance of positive feelings about learning experiences, i.e., positive rewards and recognition (Keller and Suzuki, 2004).

The main ideas behind the ARCS model are that motivation is influenced by the degree to which a teacher and the instructional materials arise curiosity, are personally relevant with challenge levels that promote confidence, and do not contain stressors that would inhibit students' effort (Keller, 2010a).

The ARCS model and the IMMS inventory (that is an integral part of it) can be used with print-based self-directed learning, computer-based instruction, or online courses, have been successfully applied to different educational settings and proved to be informative as an instrument for the efficiency of a course measurement (Huang and Hew, 2016).

The IMMS (the Instructional Materials Motivation) survey consists of 36 items and 4 subscales. The 4 subscales are attention (12 items), relevance (9 items), confidence (9 items), and satisfaction (6 items). It measures learners' motivation level by applying a 5-point symmetrical Likert scale.

We consider it necessary to give here examples of questions for each of the subscales.

Examples for the 'Attention' subscale: 'There was something interesting at the beginning of this course that got my attention'. 'These materials are eye-catching'. 'This course is so abstract that it was hard to keep my attention (an example of a reverse question)'.

Examples for the 'Relevance' subscale: 'It is clear to me how the content of this material is related to things I already know'. 'There were stories, pictures, or examples that showed me how this material could be important to some people'. 'The content of this material is relevant to my interests'.

Examples for the 'Confidence' subscale: 'When I first looked at this course, I understood it would be easy for me'. 'This material was more difficult to understand than I would like it to be (a reverse question)'. 'After working on this course for a while, I felt confident that I would be able to pass a test on it'.

For the 'Satisfaction' subscale: 'Completing the exercises in this course gave me a satisfying feeling of accomplishment'. 'I enjoyed this course so much that I would like to know more about this topic'. 'I really enjoyed studying this course'. 'The wording of feedback after the exercises, or of other comments in this course, helped me feel rewarded for my effort' (Keller, 2010a).

46 four-year students of Philology enrolled in the Cross-Cultural Communication course took part in the survey. The data we obtained are presented in the table 1.

Table 1: Motivation level range.

Motivation level	Scores	Number of participants ($N = 46$)	Percentage
High	4.00–5.00	18	39.2%
Upper Medium	3.50–3.99	7	15.2%
Medium	3.00–3.49	13	28.2%
Low	< 3.00	8	17.4%

The results of the third stage can be summarized as follows: 18 (39.2%) out of 46 students demonstrated high level of motivation, 7 (15.2%) had upper-medium motivation level, 13 students (28.2%) of medium motivation level and 8 (17.4%) – low motivation level.

The second case discussed here is based on 'Auti-Sim' and 'Prism' – serious video games for Teachers, Psychologists and Social Workers trained for inclusive education. The idea to use video games in their study programmes is grounded in the assumptions that educational and entertaining games are central to a child's social development because, for example, they allow the child to form independent relationships with peers (Piaget, 1997). Many researchers have recognised that the development of gaming skills and using games to engage people with autism can be helpful. If we compare digital and analog games, digital games have several advantages over analog games, namely, in-game results' tracking, easier customisation, better visual interaction, which can be especially important for people with autism (Atherton and Cross, 2021).

'Auti-Sim' game attempts to simulate the experience of a child with autism, presenting an experience of auditory hypersensitivity on a school playground. The player walks around a school playground, full of talking children. As they approach the children, the noise level increases, creating a total audio distortion. This makes it quite difficult to stay around the other children for an extended period of time. As a result, the player spends most of their time at the edges of the playground, isolated from the rest of the world. The silence in the game is as powerful as the sound (Adev123 @TaylanK, 2013). Figure 4 gives understanding of this game's aesthetics and the atmosphere the players submerge in.

'Prism' game attempts to help neurotypical children aged 8 to 10 understand their peers who have autism. It is a game for the children to play, paired with a discussion framework. It is a tool to help a generation of children grow up with increased awareness and understanding for their autistic peers (Zhu et al., 2018). The unique graphics of the game is presented in figure 5.

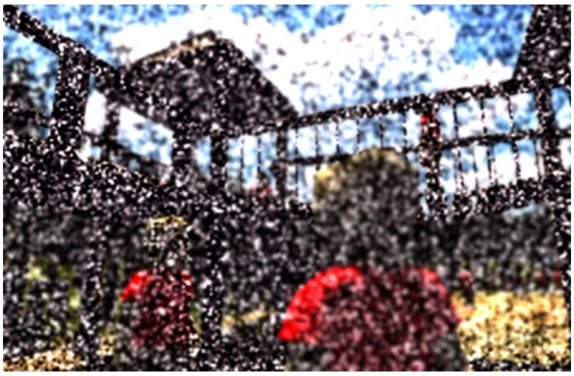

Figure 4: Auti-Sim game (Adev123 @TaylanK, 2013).

Figure 5: Prism game (Zhu et al., 2018).

The games were used within the framework of the University Social and Psychological Service (Alfred Nobel University, Dnipro) and the meetings of an educational and scientific student group 'Fundamentals of Support for Children with Special Needs and their Families for Pre-Service Specialists' Training in the Socionomic Sphere'. Here, the variety of teaching methods to develop students' theoretical knowledge and practical skills are used: starting from a review and analysis of documentary mini-films and educational-scientific films of the researched problem; psychoanalysis of blogs, websites, educational portals, groups on social networks that are social workers, social educators, psychologists, working with families raising children with special needs, ending with game therapeutic programmes designed by foreign scholars and practitioners, in particular, joint puzzle games Nintendo Wii, ADDventurous Rhythmic planet, social robot (KASPAR); Daisy, ECHOES, Pico's Adventure, Let's Face It (LFI), Go-Go Games (Atherton and Cross, 2021). A separate educational and methodical seminar was organised to experiment with 'Auti-Sim' and 'Prism' games and to discuss their potential to develop communication skills, emotional recognition, formation of relationships with peers. At the end of the seminar, a feedback form was distributed with the questions related to the experience of the participants with the video games and their attitude towards this tool. Multiple choice/unlimited choice questions were prepared, among which there were the following:

1) How would you describe your experience with two video games?
2) How would you describe your feelings about two video games?
3) Do you think that through video games there is an opportunity to develop (a set of skills and qualities)?
4) What benefits can video games have as an educational and therapeutical activity?
5) How do you rate the experience of video games as an activity in a class?
6) How prepared are you to use video games in your work?

18 participants of the seminar were asked. The generalised statistics we got help us understand that the participants' experience with video games is a new one and is perceived as a tool that helps find out something new (44%); 36%% of the respondents marked game-play experience as a positive one; 16% answered that they were emotionally involved; it's motivating – (64%). As for the attitude of the participants to the video games: they help organise teamwork – (64%); they help develop useful skills – (44%); they motivate to learn – (64%); they can engage – (44%); they develop independent learning – (48%); they develop skills of understanding – (72%).

As for the readiness to use video games: 60% answered that they would like to use them but need more information on how to use; 20% feel confident; 16% will use the material that they are familiar with and are used to; 4% answered that it is risky.

Among the obstacles to use video games in their practice, the respondents named the absence of specific knowledge – (68%); low level of digital competence – (48%); low level of equipment and Internet connection – (48%); some doubts as for the possible efficiency of video games as an instructional tool – (32%).

3.4 Stage Four

The task for the fourth stage was to compare the results obtained in the present study with those that we got earlier at Prydniprovska State Academy of Civil Engineering and Architecture, the Department of Foreign Languages during March-May, 2020 and connected with the measurement of the e-learning courses' design efficiency. In both cases, the IMMS instrument was used. Figure 6 represents the comparative results of two studies.

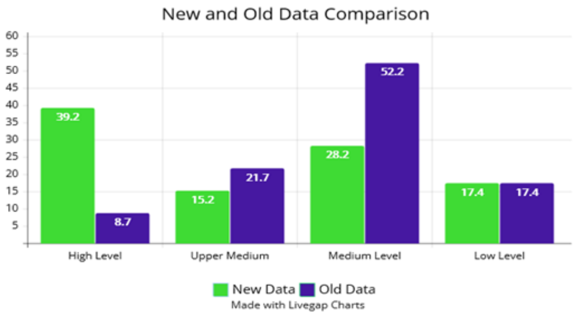

Figure 6: New and old data comparison.

The results of the fourth stage reflect the comparative new and earlier received statistics, where we may see a significant increase in students' motivation when the serious video game 'GloBall Manager' was used – 39.2% of High Level in a new study against 8.7% received earlier. At the same time, there is a decrease of Upper Medium and Medium Levels' data, which is logical as there is an increase of High Level figures. Interesting enough is the fact that the Low Level data from both studies coincide, i.e., 8 students of 46 demonstrated it in the new research and 4 out of 27 in the old one, which gives us 17.4%. We would describe the new generalised data as the demonstration of 'positive disposition' of students towards the e-learning material (with an integrated video game) whereas the previous research results gave us 'satisfactory disposition' to the e-learning courses. This difference can be explained by a thorough consideration of SVGs' integration peculiarities that resulted in better-structured material that students interacted with, better contextualisation of the material, the ability of a video game to arise curiosity, present a safe environment for experimentation, relevant study content. Also, we would mention a homogeneity of the course (as there was one instructor and one course was measured) among the factors that contributed to students' motivation increase. In the earlier work, different courses with different instructors and different syllabuses were evaluated.

4 CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Digimodernism and videoludification of the society are visible through the gamification process applied to education, labour, business, therapy, social relationships. Virtual reality, augmented reality, social networking platforms (Twitter, Facebook, Instagram, etc.) are the key contributors to the complex contemporary social and cultural transformations (Muriel and Crawford, 2018). Nowadays, a playful approach to teaching and learning is seen as effective in motivating and improving students' engagement, promoting creative thinking towards learning, and developing multi-disciplinary learning approaches. Moreover, 'play' is considered to be a powerful learning process for adults in higher education, as it is embedded in a constructivist theory of learning, and is based on experience and reflection as constitute parts of the learning process (Rice, 2009). Therewith, ICTs (information communication technologies), AI (artificial intelligence) and the digitalisation of education, including higher education, are now viewed as indispensable elements of the learning process, and computer-mediated communication and gamification as the structural components of sustainable higher education.

In the present work, we undertook the tasks of overviewing the computer-mediated communication (CMC) modes and means that have become the primary channel of communication in the context of COVID lockdown and after-pandemic period; we discussed gamification, SVGs, and game-based learning as a part of contemporary educational reality; presented the results of the courses' efficiency measurement through the application of 'The Instructional Materials Motivation (IMMS)' survey by (Keller, 2010a) and the feedback form developed by the research team.

Distance learning and its later version – e-learning that expands the educational process by giving access to knowledge from anywhere, at any time, at any speed and is backed up by the CMC, the latest multimedia technologies and the Internet, should be applied with the organisational culture analysis in mind. We maintain that the model of 'any time', 'any place', 'any way', 'any speed' needs to be supplemented by a cultural component under which we mean the culture of a particular institution (European Information Society, 2003). This, in turn, implies the need to understand what e-learning modes are used by an organisation, measure their effectiveness, and suggest the most efficient model and the ways of e-learning integration into a particular HEI according to its needs' analysis.

The most popular video-conferencing platforms and tools chosen by the teachers of the department and discussed in the earlier article (Tokarieva et al., 2021) were Viber (with its video-conferencing feature), Skype, and Zoom, while Google Hangouts and Discord with the same video-conferencing feature were found less popular. Social networking apps actively used by the faculty were Telegram, Viber; e-mail service was used as the asynchronous mode of correspondence with students.

Skype was chosen by many because of the unlimited number of video chat participants, the ease of operation on the screen, the inclusion of such activities as speaking, reading, and, partially, writing. Google Hangouts application – because of a 'Share Screen' feature that lets students see what the instructor demonstrates on the monitor, a 'Chat History' feature – because it records the number of people attending each class, Google Classroom – as it lets post assignments and set up the deadline, evaluate students' works according to a variety of evaluation scales.

The most debatable was the Zoom platform as, on the one hand, it does not limit the number of the participants, is quite easy in operation, has a session recording feature, an instructor's screen demonstration, a whiteboard to write comments, a group chat feature, a waiting room (to prevent unregistered participants join the conference), a conference room – to split students into separate mini-groups. At the same time, such a phenomenon as 'Zoom fatigue' was marked by teachers, which can be partially explained by the presence of many people at a time on the screen, the need to monitor our non-verbal language as instructors, to shift to teacher-centricity and one-way communication. It is also worth mentioning here that back in March-May 2020 Google Meet was not as popular an application as it is now.

With the reference to the students' feedback from the distance work during the quarantine – 'dependence on technical means' was named as the main challenge, followed by the poor quality of the Internet, problems with self-organisation, the number of tasks, restriction on exercising practical skills. Though the experimental sample was quite small and limited to thirty instructors and twenty-three students, we maintain that the experience of our department at the time of the quarantine due to the COVID-19 situation still highlights the current e-learning situation in our HEIs, reveals several challenges and needs, helps layout further strategies to support fluid, holistic, seamless, pervasive, personalised education optimised by technology.

Digital pedagogy, gamification, game-based learning and serious video games based on CMC and nowadays, mobile technology are becoming principal parts of contemporary education. They are capable to enhance learning through challenge, exploration, interaction, reflection, 'positive failure', adaptability to a particular player's decision-making level, etc. Practical work, based on two video games, that is described in task three proved positive results (e.g. students' increased motivation) and positive attitude of the pre-service training students in the socioeconomic sphere towards video games as a way of instruction. We would explain this 'positive disposition' of students by a better-structured material that students interacted with, better contextualisation of the material, the ability of a video game to arise curiosity, present a safe environment for experimentation and relevant study content.

Video games were also described as capable to develop skills of team-working, problem-solving, critical thinking; to enhance self-guided learning skills. At the same time, a strong need for pedagogic training that may empower teachers with the required knowledge and skills about gamified learning applications, educational digital games and digital competencies development was identified. This confirmed the earlier conclusions about the need to increase the level of digital and pedagogical skills of HEIs faculty; to further develop their didactic skills in mastering new approaches to academic courses' material design in e-learning format; to encourage the culture of cooperation and sharing, as well as to experience a wide range of applications, digital tools, and services that support the process of education; the development of an educational content to be accessed by students at any time, from any place, from any computer, the increase of students' digital literacies (Tokarieva et al., 2021). All of the above brings us to the conclusion about the topicality of what information technology offers – the options for reorganising and refining distance and e-learning. But the new vision of distance and e-learning, gamification of educational process and serious video games as one more variation of CMC must drive our decisions about the use of technology, not vice versa. Therefore, the need to develop teacher-training programs to help educators understand, design, evaluate and apply CMC and gamified learning applications is set up as the vector of future work.

5 LIMITATIONS

Our present research holds certain limitations as for the generalisability of its results. Among them are the size of the sample. The obtained results were compared with a similar survey, which makes the comparison results as the first approximation. There is also a need for further tests of the questionnaire's reliability and validity.

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Mnemonic Techniques and Formation of Teachers' Ability to Use Them

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Keywords: Mnemonics, Mnemovisual Models, Teachers' Training, Training.

Abstract: The article reveals the problem of the expediency of teachers' training to use mnemonics in professional activities. This problem is caused by the intensification of the educational process, when the amount of information accumulated by mankind is many times greater than the amount of knowledge that can be assimilated by a particular person. It has been established that mnemonics should be used in the process of learning mathematics as a way of perceiving new information through the formation of associative connections with the help of special methods and techniques. The expediency of teachers' trainings for use of different mnemonics methods is substantiated. The classification of software used to create mnemovisual models is presented. The training on mastering mnemonic methods of teaching material development has been developed and implemented. The prospects of scientific research through the development of methodological support for the teachers' training to use the techniques of mnemonics in professional activities are outlined.

1 INTRODUCTION

Modern youth is developing in an environment saturated with powerful and intense information flows. The amount of information accumulated by mankind is many times greater than the amount of knowledge that can be acquired by a person. The constant increase in information, combined with high competition and the demands of society, leads to an intensification of the educational process. On the other hand, the intensification of the educational process leads to a number of problems in the mental and somatic health of students. In such conditions, the problem of the educatee's cognitive load appears, which consists in the fact that a person can achieve the optimal level of assimilation of material only if there is an adequate load on the subject's memory.

The success of training depends on the level of development of mnemonic processes that ensure the memorization, preservation, and reproduction of information in the brain obtained during human interaction with the outside world. Therefore, the introduction of effective approaches to memorizing a variety of information can partially solve the problem of cognitive load. As one of such approaches, we consider the use of mnemonics as a way to improve new information by creating associative relationships using special methods and techniques.

The problem of using mnemonics in the educational process is presented in the following findings:

- Scruggs and Mastropieri (Scruggs and Mastropieri, 2000) describe the effects of specific mnemonic (memory-enhancing) strategies in decision problem of memoring for academic content;
- Yesavage et al. (Yesavage et al., 1990) describe of treatment elderly, which included imagery mnemonics for remembering names, faces, and lists;
- Richter et al. (Richter et al., 2016) consider memory as medical aspect and proposed consider memoring as mnemonic representation that links present experience with overlapping past experience;
- Miller and Mercer (Miller and Mercer, 1993) provide examples of acronym mnemonics that have

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been used successfully to improve the math performance of students with learning disabilities;

- Nelson et al. (Nelson et al., 2013) describe the effects of a mnemonic strategy on the retention and application of single-digit multiplication facts with students with math difficulties;
- Manalo et al. (Manalo et al., 2000) touch upon influence of mnemonic instruction on the computational skills performance of 13- to 14-year-old students with mathematics learning disabilities;
- Kayaaltı (Kayaaltı, 2018) touch upon to investigate university Saudi students' attitudes towards the mnemonic keyword method;
- Sarıçoban and Başıbek (Sarıçoban and Başıbek, 2012) make the comparison analysis of the effects of using mnemonic technique providing some keywords to students and context method on the retention of the vocabulary items;
- Falkovskaya et al. (Falkovskaya et al., 2018) touch upon many mnemonic methods, which, based on the positive resources of native speaker development, contribute to the painless memorization and further use of difficult material.

In the above-mentioned findings, it is proved that mnemonic techniques are used to improve the assimilation of complex information that does not have established logical connections between its elements from the point of view of the person who remembers it. Mentioned above findings and other ones confirm that the use of mnemonics improves the volume and accuracy of memorization and development of cognitive processes, increases the duration of storage and the quality of reproduction of acquired information.

Analysis of findings related to the teachers' training to use mnemonics in Ukraine, revealed the fragmentary nature of such scientific research, for example, a special course devoted to mastering the mnemonic techniques by pre-service mathematics teachers was described in (Drushlyak et al., 2021).

Survey of teachers (135 Mathematics, Physics, Computer science, Ukrainian language, Biology, Chemistry, English, History teachers) on their knowledge of mnemonics showed that only half (55.5% of respondents heard about mnemonics, only a third of these (39.3%) use mnemonics at their lessons, and, as a rule, all ideas are borrowed from the Internet (100% of those who use mnemonics) (table 1).

Therefore, regarding the effectiveness of the positive impact of mnemonics on the results of educational activities and lack of teachers' awareness of various subjects in mnemonics, the problem of preparing teachers to use mnemonics in professional activities is relevant.

The Research Purpose. To describe the common mnemonic techniques to support the educational process and justify the effectiveness of training in mastering the mnemonic techniques for service teachers.

2 RESEARCH METHODS

The achievement of the research objective was facilitated by the use of a set of appropriate methods: analysis of scientific literature in order to establish the state of development of the problem being studied, determining the categorical and conceptual apparatus of the study; synthesis, generalization, systematization for the theoretical justification of the appropriateness of training teachers to use the of mnemonic techniques and methods in professional activities; empirical: diagnostic (questionnaire), statistical (the sign test) to assess the appropriateness of using trainings.

The experimental base of the study is the institutions of general secondary education in Kiev, Sumy and Irpin, Makarenko Sumy State Pedagogical University, Borys Grinchenko Kyiv University.

3 RESULTS AND DISCUSSION

The process of memorizing educational material is more intensive provided that subjects are engaged in active thinking, using their operations of comparison, analysis, synthesis, classification, generalization. Use of memos, tables, instructions, visual supports that help students gradually, without overload, to perceive and remember significant objects are effective.

An essential characteristic of the process of memorization is a measure of understanding the memorized material. Therefore, meaningful and mechanical memorization is usually emphasised.

Mechanical memorization is memorization without awareness of the logical connection between the various parts of the material (memorization of historical dates, statistics, etc.). The basis of mechanical memorization is related associations. One part of the material binds to the other only because it follows it in time. To establish such a connection, it is necessary to repeat the studied material several times.

Meaningful memorization is based on an understanding of the internal logical connections between the individual parts of the material. Two positions, one of which is derived from the other, are remembered not because they follow each other in time, but because they are logically connected. Therefore, meaningful memorization is associated with thinking

Table 1: The results of a survey of teachers on the use of mnemonics in professional activities.

No	Question	Answer	Mathematics teachers	Physics teachers	Computer science teachers	Ukrainian language teachers	Biology teachers	Chemistry teachers	English teachers	History teachers	Total
			22	15	23	12	15	13	18	17	135
1	Do you know the mnemonics techniques?	Yes/ No	17/ 5	6/ 9	13/ 10	7/ 5	7/ 8	6/ 7	10/8	9/ 8	75/ 60
2	Do you use mnemonics at your lessons?	Yes/ No	14/8	5/10	10/13	4/ 8	4/11	5/ 8	5/ 13	6/11	53/82
3	Do you think it is appropriate to use the mnemonics techniques in the educational process?	Yes/ No	17/ 5	6/ 9	13/10	4/ 8	4/11	5/8	5/13	6 /11	60/ 75
4	What mnemonic techniques did you use at your lessons?	1. Visualization 2. Color Accent 3. Comedian 4. Storytelling 5. Analogy 6. Fiction 7. Rhyming 8. Hyperbole 9. Interpretation	1, 2, 5	1, 2, 4, 5	1, 2, 5, 8, 9	1, 2, 7	1, 2, 5	1, 2, 5	1, 2, 5, 7, 9	1, 2, 4, 6	1, 2, 4, 5, 6, 7, 8, 9
5	Where do you get ideas for mnemonics?	A. Author's B. Internet C. Colleagues' D. Advanced training	B, C, D	B	B	B, C	B	B	B, C	B	B, C, D

processes and relies mainly on generalized relationships between parts of the material at the level of the second signaling system.

It is worth paying attention to the meaningful memorization of the material studied. To do this, it is necessary to divide its semantic group into parts with the separation of the main and essential in each of its parts. In addition, it is necessary to find and highlight semantic support points in each part, that is, thoughts, expressions and images that define the essence of this part and the oral or written formulations of this essence in the form of short headings for each part. Finally, it is necessary to establish links between the selected parts and understand the logical sequence of their location, to draw up a general plan for the location of educational material.

In order to meaningful memorize educational material, mnemonic methods and techniques are determined (figure 1).

The work of Chepurnoy and Bura (Chepurnoy and Bura, 2015) on educational mnemonics as a technology of effective assimilation of information became a reference point for us.

Link Method is a method of combining information units by creating associative links between them.

The method consists of the following techniques: *Storytelling technique* (using stories), *Rhyming technique* (using music, rhyme, chants, poems, songs, counting out rhymes, etc.), *Sequential Associations technique* (sequential associative connections are created), *Bonding technique* (combining information units into a single holistic image with preservation of the main features and functions), *Synthesis technique* (information units are combined into a single integrated image with a common associative connection), *Key Letters technique* (an associative connection is created between the first letters of words, you need to remember, and the first letters of words of a

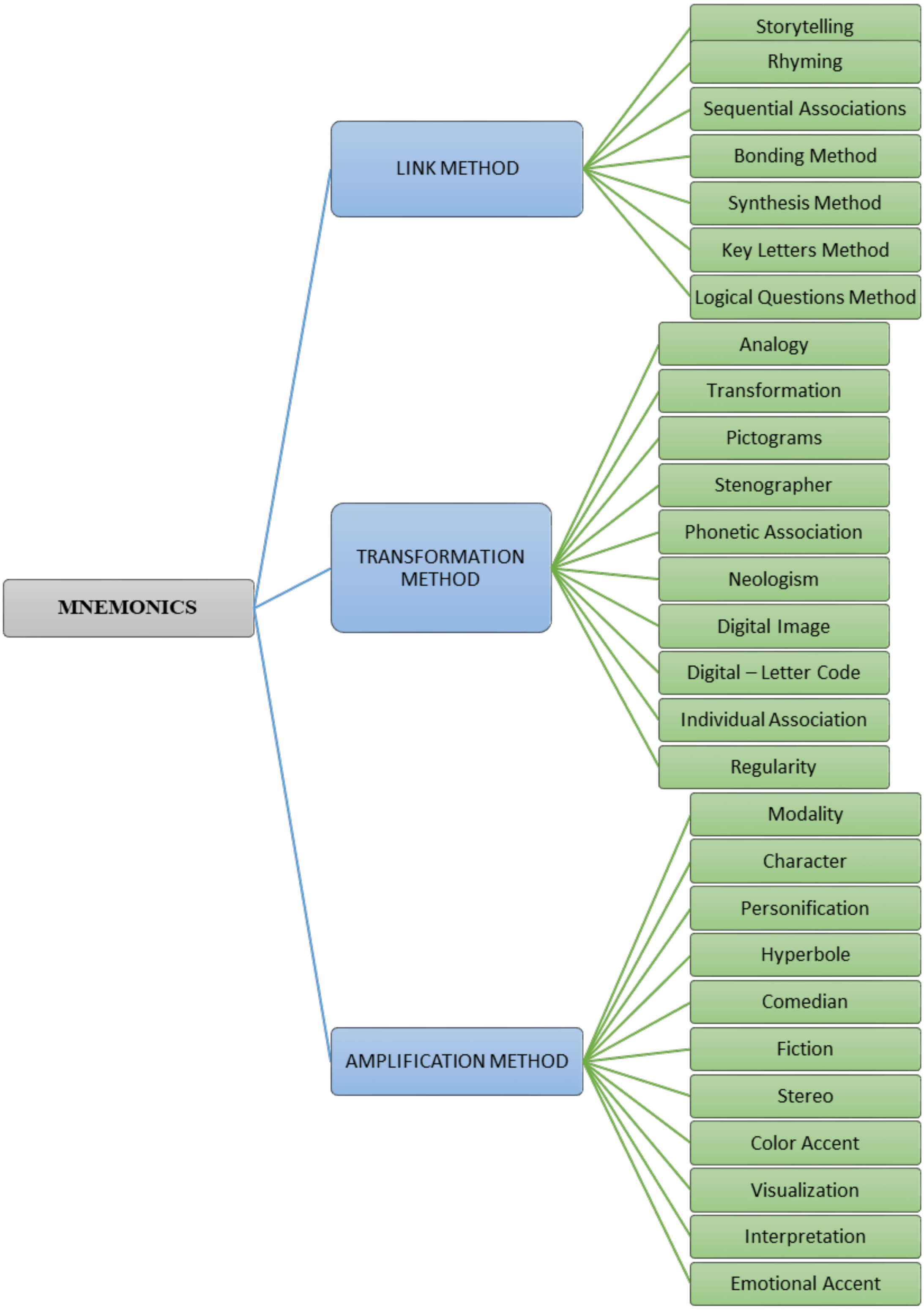


Figure 1: Mnemonic methods and techniques.

specially created sentence), *Logical Questions technique* (an additional logical associative connection is created between images remembered through answers to the main questions – What? How? Why? etc. about the relationship between them).

Key Letters Technique (Mathematics). In the study of the topic "Disclosure of brackets. Similar terms and their construction" it is worthwhile to draw the attention of students to the sign that appears before the brackets. If there is a *minus*, then we change all signs to the opposite, if *plus*, then leave the expression unchanged, for example:

- – (a + b) – "**M**inus" – **M**iniaiemo znaky (in Ukrainian), **M**inus – **Ch**ange the signs; in Ukrainian, the words minus and change begin with the letter **m**;
- + (a + b) – "**P**ljus" – **P**erepysujemo bez zmin (in Ukrainian), **P**lus – **R**ewrite without changes; in Ukrainian, the words plus and rewrite begin with the letter **p**.

Key Letters Technique (English). Memorizing the spelling rules of some words.

Teacher – There is an **ache** in every te**acher**.

Measurement – Be **sure** of your mea**sure**ments before you start work.

Principal – Your princi**pal** is your **pal**.

Necessary – **N**ever **E**at **C**risps, **E**at **S**alad **S**andwiches, **A**nd **R**emain **Y**oung!

Transformation Method is a method of primary processing of information, which turns information that is difficult to perceive into convenient for efficient reproduction.

The method consists of the following techniques: *Analogy* (between the informational units of the memorable find common signs, properties, qualities, development trends, etc.), *Transformation* (the objects of the memorable are transformed into others in value and in order to facilitate memorization), *Pictograms* (abstract or such information must be remembered, schematically depicted by simplified drawings, pictograms), *Stenographer* (text information that is memorized is recorded using separate key letters, special characters and a number of abbreviations), *Phonetic Association* (a consonant word or part of it is selected to memorize an unfamiliar word, which associatively associated with the meaning of the original word), *Neologism* (to improve the memorization of information (words, letters, symbols) new words, terms, concepts, phrases are created) (figure 2), *Digital Image* (digital information when memorizing is associated with certain images or systems about times), *Digital–Letter Code* digits of numbers in letters to compose specially selected words for the purpose of their further memorization), *Individual Association* (for information that is memorable, associative connections are found with individually known data, events, information), *Regularity* (for remembering information, certain logical, mathematical or other regular relationships are found and rules).

The *Amplification method* is a method of increasing the efficiency of perception, preservation and reproduction of created associative connections and images formed by the methods of transformation and binding.

The method consists of the following techniques: *Modality, Character, Personification, Hyperbole, Comedian, Fiction, Stereo, Color Accent, Visualization, Interpretation, Emotional Accent*. Examples of the use of some techniques are shown in figures 3, 4.

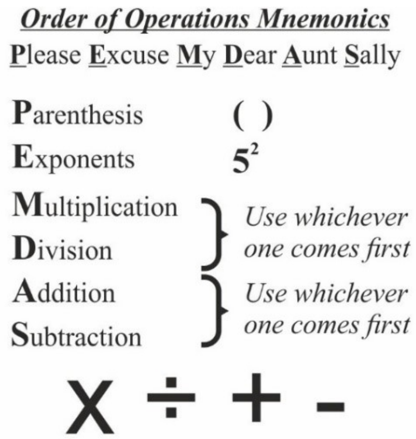
To confirm the appropriateness of mastering the mnemonic techniques, pedagogical survey was conducted. During March-May 2019, we conducted a survey of 32 service mathematics teachers in Kiev, Sumy, Dnipro and Irpin on the expediency of using mnemonic techniques in professional activities. In May 2021, we conducted a similar survey of 135 teachers, but in different subjects (Mathematics, Physics, Computer science, Ukrainian language, Biology, Chemistry, English, History). The data were integrated and analyzed. In particular, we found that 87% of teachers (Mathematics teachers in 2019) and 44.4% of teachers of various subjects (in 2021) said about the expediency of using mnemonic techniques, of which 77.2% of mathematics teachers were in favor of using mnemonic techniques.

Among the techniques Visualization, Color accent, Analogy, Storytelling, Rhyming and Interpretation are in favour. The figure 5 summarizes the results of the 2019 and 2021 surveys.

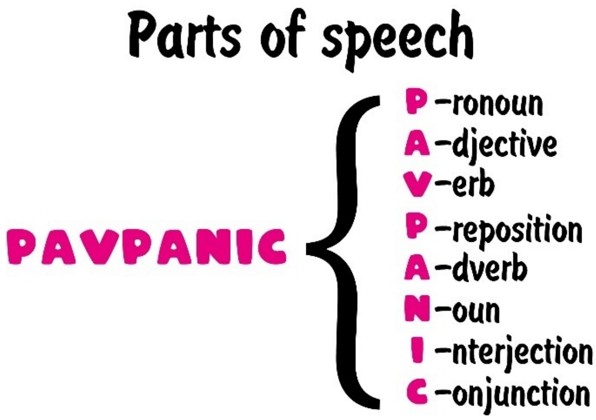
Based on the teachers' opinion that Visualization and Color Accent are the most effective techniques, which contribute to the meaningful memorization of educational material. We can paid attention to the software for creating visual models:

1) Office software products with Smart objects;
2) Mind Mapping software;
3) services for creating whiteboard animation (scribing) presentations;
4) software for creating infographics.

Let's describe these groups. The office software package (MS Word, MS Excel, MS Power Point) is offered with the function of constructing Smart objects that allow you to efficiently create mnemovisual models in the form of a list, connection, matrix, process, cycle, hierarchy, pyramid (figure 6).

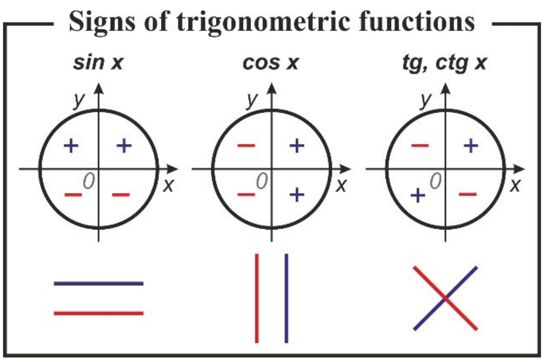


(a)

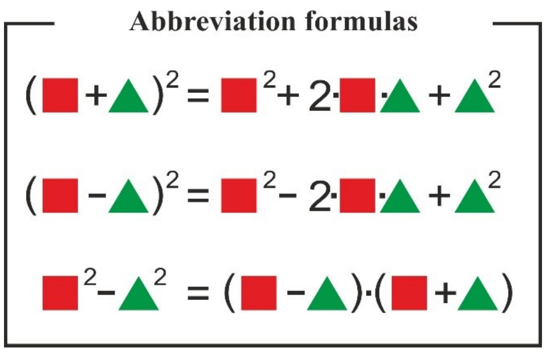


(b)

Figure 2: Neologism technique.



(a) “Signs of trigonometric functions”.



(b) “Abbreviation formulas”.

Figure 3: Color accent technique.

Mindmapping is a technology that allows you to efficiently restore information (past), generate and capture New Ideas (future), draw conclusions and establish connections between them by building mind maps. Mind maps is the development of Tony Busan – a British psychologist who began developing the concept of smart cards back in the 1970s (Buzan, 2022). Interesting Ideas and technologies for creating smart cards in the process of teaching mathematics are presented in the works of modern scientists: Choo et al. (Choo et al., 2014), Solmi (Solmi, 2016).

To build mind map software X-Mind, Free-Mind, Coggle, Mind-Meister are used. Such software help to fix ideas, organize them into various diagrams, use these diagrams together with other users. The mentioned software allow you to build mind maps (figure 7, 8), Ishikawa diagrams (fishbone diagrams or cause-effect diagrams), tree diagrams, logic diagrams, tables.

The main areas of application of mind maps in the professional activities of teachers include: creating lesson plans of any type; planning educational activities; algorithms for solving problems; study of new educational material; consolidation and verification of the studied material; systematization and repetition of the studied material in preparation for the state final certification, external independent evaluation.

Scribing technique is used to activate the cognitive and mnemonic activity of educatees, to visualize the educational process. Scribing is a mnemonic technology for the visualization of educational material, which provides the display of key moments of its content (properties of the learning object, its internal and external connections) by using simple graphic elements (drawings, pictograms, symbols, words, circuits, diagrams) sequentially created on the screen in according to the oral presentation (or audio).

The appearance of whiteboard animation (video scribing) is associated with the Andrew Park, who popularized this technology (We are Cognitive, 2023). Sarkar (Sarkar, 2009) notes that this way of presenting information has become more productive for explaining to the audience, because it uses the parallel effect when the audience simultaneously hears

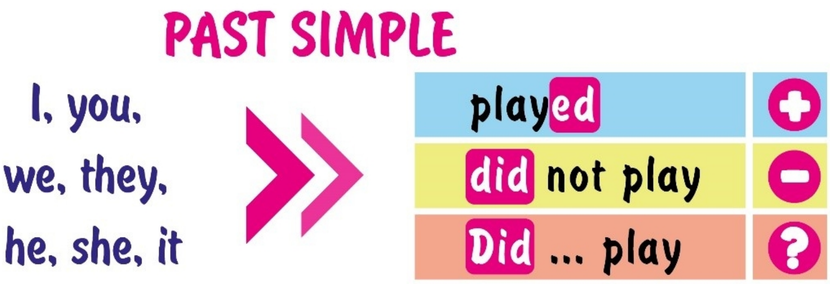


Figure 4: Color accent technique "Past Simple".

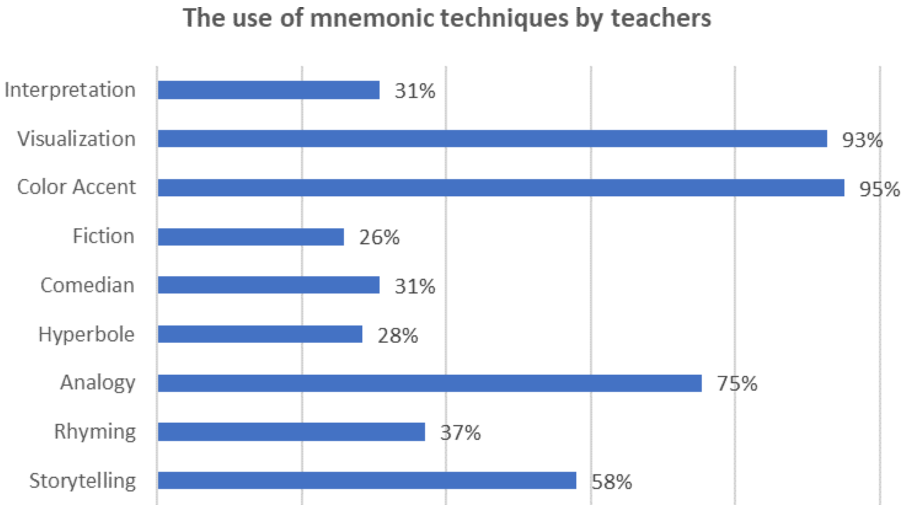


Figure 5: The use of mnemonic techniques by teachers according to the results of surveys in 2019 and 2021 (%).

and sees about the same thing, while the graphic series is fixed on key moments of the audio sequence.

Among a large number of services there are several useful for creating video scribing presentations such as: Sparcol Video Scribe (https://www.sparkol.com/en/, figure 9, 10), Powtoon (https://www.powtoon.com/), Vyond Studio (https://www.vyond.com/), Plotagon Story (https://www.plotagon.com/).

Infographics is the technology of the presentation of educational material in the form of statistical graphs, maps, charts, diagrams, tables that "explain". Educational visibility is used not only for illustration, but also as an independent source of knowledge (figure 11). Services for creating infographics are Infogram, Easel.ly, Parchment, Venngage and more.

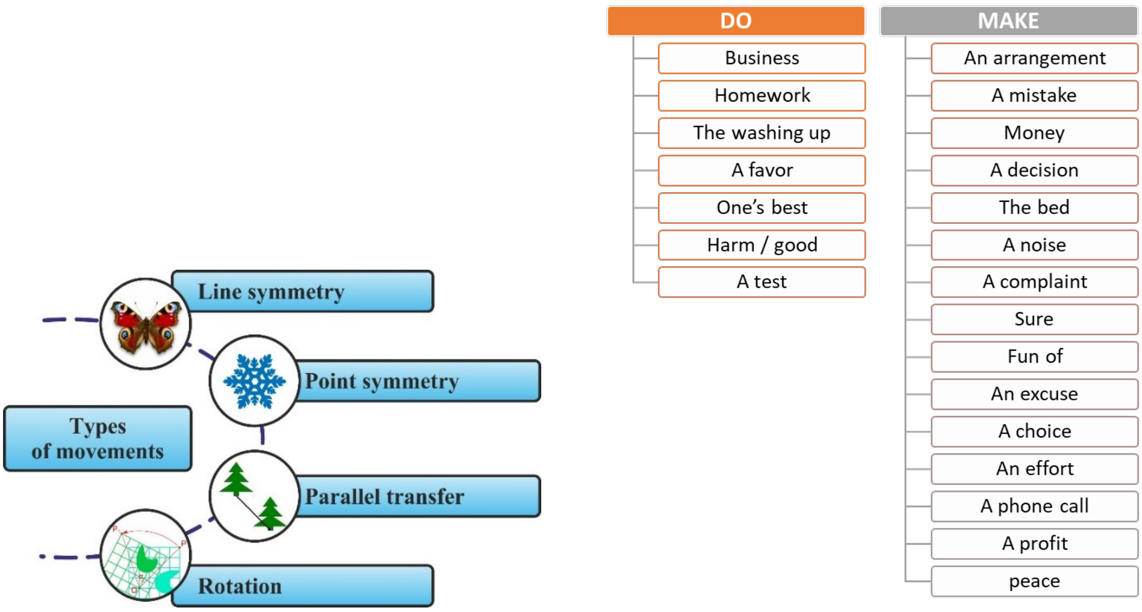
Starting in 2020, we have launched trainings for teachers on mastering the mnemonic techniques (3 hours) (table 2). Teachers of various subjects were invited to the trainings. The total number of teachers involved in the training was 135 persons. The training is based on training for students, pre-service mathematics teachers (Drushlyak et al., 2021).

We investigated the impact of training on the development of teachers' skills of various subjects to create and use mnemonic didactic materials.

To determine the level of awareness of teachers in mnemonics, a survey was conducted (135 respondents). 39% (53 people) of teachers confirmed, but fragmentary, the use of mnemonics in their own lessons. Among the positive aspects of the use of mnemonic techniques, teachers noted the revival of the learning process (39%, 53 people) for students and the development of creative thinking for teachers (33%, 45 people). According to them, the lack of time to search for or develop mnemonic didactic materials (30%, 41 people) and the lack of developed mnemonic didactic materials for each topic (33%, 53 people) are negative in the use of mnemonic techniques.

4 STATISTICAL ANALYSIS OF RESULTS

At the beginning of each training, teachers were assessed for their ability to reproduce any of the mnemonic techniques using digital technology (office package and online services was allowed to create



(a) (b)

Figure 6: Mnemovisual models created using Smart objects.

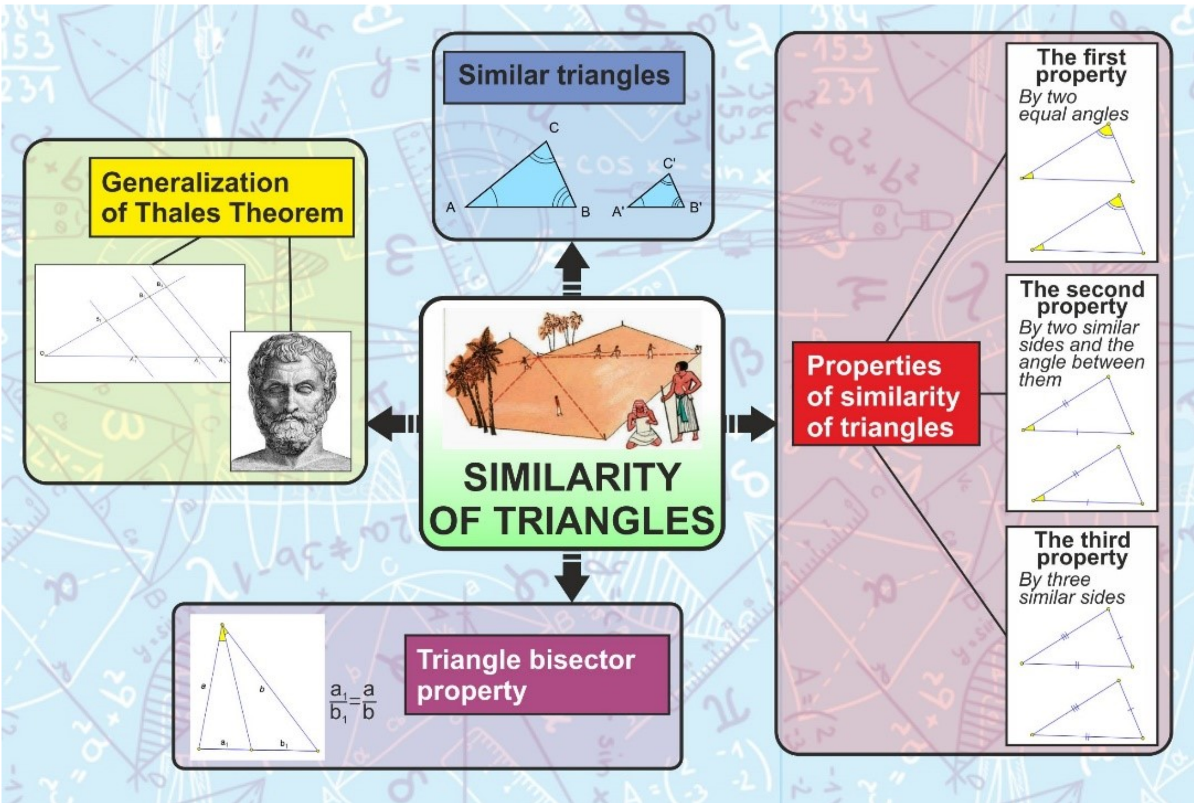


Figure 7: Mind Map "Similar triangles".

images). The evaluation criteria were: comprehensibility of reception (1 point), rational choice of digital technology (1 point), quality of visual content (1 point), determining the didactic purpose of the created

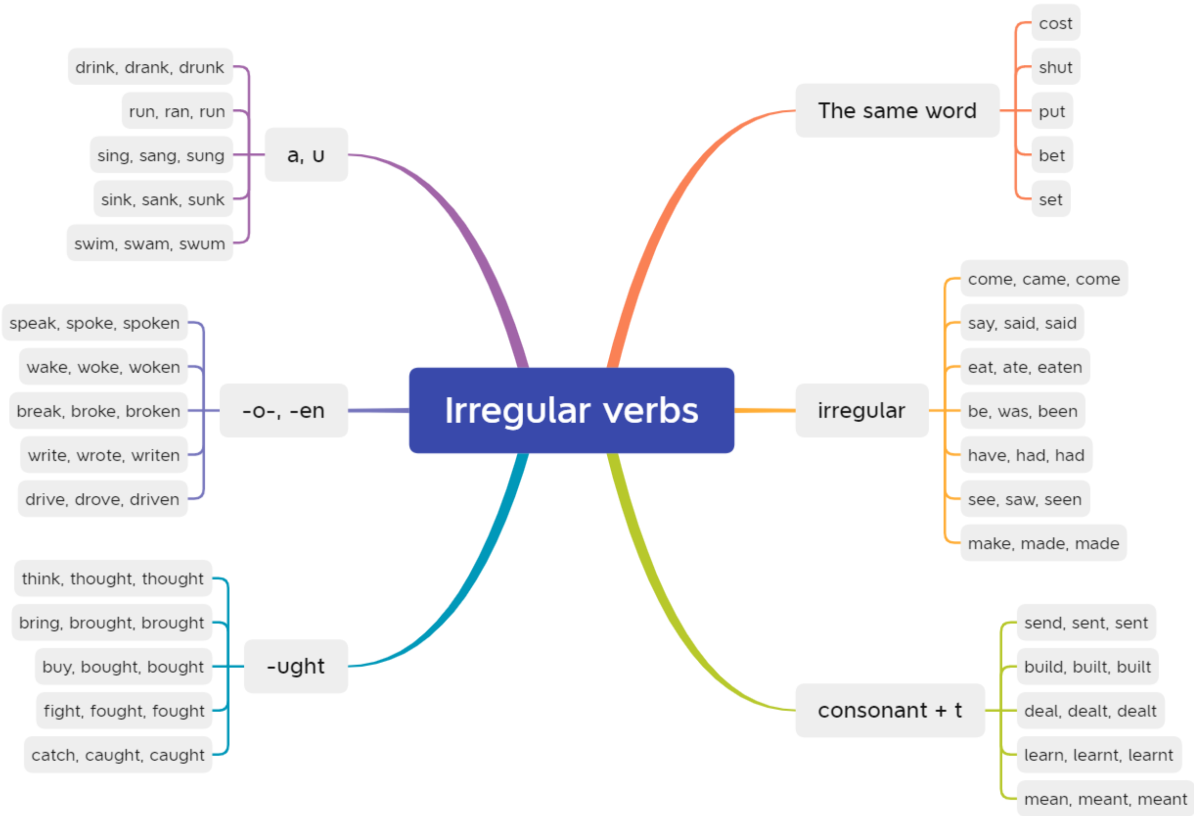
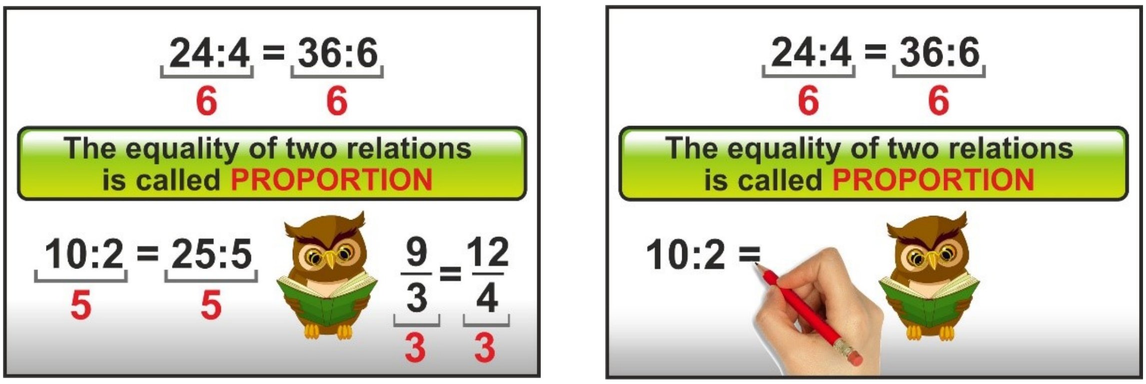


Figure 8: Mind Map "Irregular Verbs".



(a) (b)

Figure 9: Video scribe "Proportion".

mnemonic means (1 point).

After the training, teacher evaluation was conducted again (a similar task with the same evaluation criteria was used).

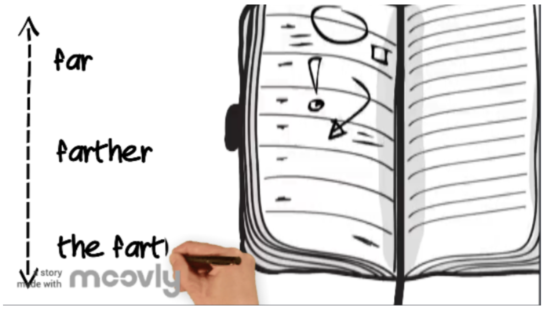
Some of the works of teachers are presented in figures 7, 10, 11.

According to the results of data processing, the positive impact of training on the development of teachers' skills in various subjects to create and use mnemonic didactic materials was confirmed.

Statistical analysis of the results was performed on the basis of non-parametric sign test for dependent samples. We compiled comparative tables, which recorded the dynamics of results for each of the trainings (2020 – 2 trainings, 2021 – 2 trainings). Each time the results were collected on samples of 32, 35, 37, 31, respectively. 30 pairs of results taken at random from the total set of results were studied (table 3).

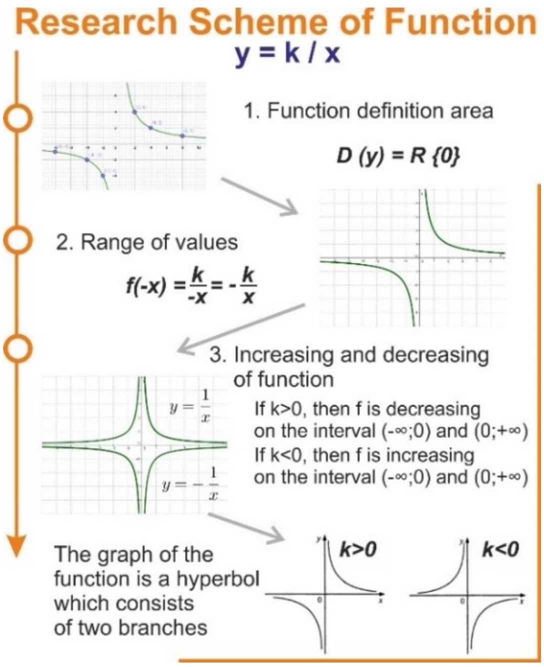
These points (table 4) determined the number of

(a)



(b)

Figure 10: Video scribe "Degrees of adverb comparison".



(a) "Function Research".

(b) "Prepositions of Time and Location".

Figure 11: Infographics.

respondents whose total score decreased ("–"), did not change ("0") and increased ("+").

In accordance with the objectives of the experiment, a null hypothesis was formulated: the organization of training does not promote the development of skills of teachers of different subjects to create and use mnemonic didactic materials. Then an alternative hypothesis: the organization of training promotes the development of such skills.

The constructed hypotheses defined a one-sided sign test for testing dependent samples. According to the decision-making rule (Grabar and Krasnjanskaja, 1977) we have: value $T_{exp} = 16$ (number of "+" in the sample), $n = 20$ (number of respondents, which have changes in results), acceptance interval of null hypothesis: [6, 14] at the significance level 0.05.

Since T_{exp} is not included in the acceptance interval of hypothesis H_0, we reject the null hypothesis and accept the alternative one, concluding that the training promotes the development of teachers' skills of different subjects to create and use mnemonic didactic materials. Since the value of T_{exp} went beyond the interval on the right, we concluded that the positive dynamics of the number of teachers who have developed the ability to create and use mnemonic didactic materials.

Additionally, we studied the ability to create authorial examples of mnemonic techniques and the ability to reproduce them in digital form. It should be noted that natural sciences and mathematics teachers, as a rule, had no problems with the technical implementation of the plan in contrast to humanities teach-

Table 2: Detailing the content of the training on the development of mnemonic techniques.

The number of hours	Contents	Training methods	Learning tools	Expected learning outcomes
0,25	Memory. Mechanical and meaningful memorization	Verbal methods (story, conversation)	Presentation	An idea of the mechanisms of human memory, knowledge of the types of memorization of educational information; development of teacher professional competence
0,75	Educational mnemonics as a technology for the effective assimilation of information. Mnemonics and their corresponding mnemonic techniques	Verbal methods (story, conversation), visual methods (demonstration, display), Interactive methods (brainstorming)	Presentation	Knowledge of the methods and techniques of mnemonics: Link Method (techniques: Sequential Associations, Key Letters Method), Transformation Method (Analogy technique), Amplification method (techniques: modality, character, personification, hyperbole, comedian, fiction, stereo, color accent, visualization, interpretation, emotional accent); development of teacher professional competence
0,5	Specialized software for supporting mnemonic techniques	Visual methods (demonstration, display)	Presentation, Specialized software: 1) office software products with Smart-objects; 2) mind mapping programs; 3) services for creating scribing presentations; 4) programs for creating infographics	The concept of specialized software groups for supporting mnemonic techniques, knowledge of specialized software (including freeware) and its computer tools for supporting mnemonic techniques; development of teacher professional competence
1,5	Development of copyright materials for mnemonic support	Interactive methods (brainstorming, case-method)	MS Power Point, X-Mind, Free-Mind, Powtoon Easel.ly	Knowledge of specialized software examples, knowledge of software tools (MS Power Point, X-Mind, Free-Mind, Powtoon, Easel.ly), the ability to use specialized software tools to accompany mnemonic techniques; ability to analyze created products; development of teacher professional competence

ers, who rather presented ideas of mnemonic techniques, but spent more time implementing the technical part of creating mnemonic didactic materials.

5 CONCLUSIONS

In the process of analyzing the scientific literature, it was found that the level of development of mnemonic processes that ensure the memorization, storage and reproduction of information in the brain, depends on the success of learning. In order to introduce effective ways to memorize a variety of information, mnemonics is considered as a way of perceiving new information through the formation of associative connections using special methods and techniques.

The method of "Binding" consists of techniques: Storytelling, Rhyme, Sequential Associations, Gluing, Synthesis, Key Letters, Logical Questions. The method of "Transformation" consists of techniques:

Table 3: Results of evaluation of respondents.

Respondent	The first assessment	The second assessment	Respondent	The first assessment	The second assessment	Respondent	The first assessment	The second assessment
1	2	4	11	3	4	21	2	3
2	4	4	12	2	3	22	1	4
3	3	3	13	2	2	23	4	5
4	3	3	14	3	2	24	1	3
5	3	3	15	3	3	25	1	2
6	1	2	16	3	3	26	4	5
7	2	3	17	3	3	27	3	4
8	2	2	18	4	5	28	3	2
9	4	3	19	2	3	29	3	4
10	3	3	20	3	4	30	3	2

Table 4: Comparison results.

Dynamics of points	Number of respondents
Negative, ”–”	4
Without changes, “0”	10
Positive, ”+”	16
Number of changes, *n* = “–” + “+”	20

Analogy, Transformation, Icons, Stenographer, Phonetic Association, Neologism, Digital Image, Alphanumeric Code, Individual Association, Regularity. The method of “Amplification” consists of techniques: Modality, Sign, Personification, Hyperbole, Comedian, Fable, Stereo, Color Accent, Visualization, Interpretation, Emotional Accent.

As a result of the teacher’s survey, a positive attitude to the use of mnemonics was revealed, the most popular of mnemonic techniques were Visualization, Color Accent, Analogy, Storytelling, Rhyme and Interpretation.

The classification of software used to create mnemonic didactic materials is given: a package of office software with Smart-objects; mind mapping software; services for creating video scribing presentations; software for creating infographics.

The training on mastering mnemonic methods of presenting educational material was developed. According to the results of the training, its positive influence on the development of skills to create and use mnemonic didactic materials by teachers of various subjects was confirmed. At the same time, it was noted that natural sciences and mathematics teachers had no problems with the technical implementation of the plan in contrast to humanities teachers, who rather presented ideas of mnemonic techniques, but spent more time implementing the technical part of creating mnemonic didactic materials.

The effectiveness of the training was confirmed by the sign test.

Prospects for further research are seen in the developed methodological support for the training of pre-service teachers to use the techniques of mnemonics in professional activities.

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The Potential of Higher Education Digitalization in Central and Eastern Europe

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Keywords: Digitization, Global Indicators, Grouping, SWOT Analysis, Pandemic, War.

Abstract: Digital has penetrated into all spheres of life. Since 2020, due to the pandemic, all countries around the world have started using online learning. The digitalization of higher education during the war in Ukraine is especially important, because avoided the collapse of the educational system. The aim of the article is to highlight the potential of higher education digitization in Eastern and Central Europe. To achieve the goal of the article, the following tasks were set: to study the theoretical basis of the digitization of education, to analyze the trends and problems of the higher education digitalization in Central and Eastern Europe, to develop recommendations for improving the higher education digitization. The article analyzed the ranks of the Network Readiness Index, Digital Skills Gap Index (DSGI), and IMD World Digital Competitiveness Ranking in terms of technological readiness of universities and digital skills of academic teachers and students. The article offers a case study of the Ukrainian university for the implementation of an e-learning environment and new instruments of e-learning during the war in Ukraine. The authors grouped countries of Central and Eastern Europe according to their potential for higher education digitalization. For these groups of countries, the authors identified specific criteria. SWOT analysis of the higher education digitalization was conducted for the countries of Central and Eastern Europe.

1 INTRODUCTION

Digital transformation involves the transformation of all areas of public life under the influence of advanced innovative information and communication technologies (ICT), including in the education system, which is the foundation of an innovative economy and shapes its human potential. This determines the relevance of accelerating the digital transformation of education in the countries of Central and Eastern Europe. The digital transformation of education is necessary to ensure that the educational process meets the needs of the labor market, increases the level of participation in these processes of educational institutions of all levels and other organizations of the educational system, as well as scientists, managers and specialists of government agencies, representatives of the private sector of business.

The huge potential of digitalization for higher education is that online platforms, online courses, online universities can be used in the face of global challenges. First of all, these are pandemics, when social contacts need to be reduced, and war, when there are many refugees, the territorial connection of students with their university is lost. Especially in the current war between Ukraine and Russia, the issue of effective use of the potential of digitalization of higher education is relevant, given the large number of Ukrainian refugees (including students) in neighboring Eastern and Central Europe.

The *aim* of the article is to highlight the potential of higher education digitization in Easternand Central Europe. The object of the research is the digitization of higher education. The subject of the research is the potential of higher education digitization in Eastern and Central Europe.

The *scientific novelty* of the research is the grouping of the countries of Central and Eastern Europe according to their potential of higher education digitalization. The practical significance of the study is that the results of the article can be used during the war in Ukraine, when hundreds of thousands of entrants and students leave the country for Central and

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Eastern Europe.

The *research methods* used in the article include literature analysis (a review of research to date in the field of higher education digitalization) and taxonomic methods used to determine the development and potential of higher education digitalization in the countries of Central and Eastern Europe, according to the ranks of the Network Readiness Index, Digital Skills Gap Index, and IMD World Digital Competitiveness Ranking in terms of technological readiness of universities, academic teachers and students for online education, as well as the method of SWOT analysis (according to the higher education digitalization in Central and Eastern Europe).

2 LITERATURE REVIEW

The VOSViewer and SciVal tools were used to conduct a brief bibliometric analysis on the re quest "digitalization of education". The array of publications for analysis was obtained from the Scopus database (https://www.scopus.com/).

Bibliometric analysis using the VOSViewer tool (base for analysis – 1408 articles for the period 2010-2020) (figure 1) made it possible to identify the main keywords that are most often found in scientific papers in connection with the direction of digitalization in education. The cluster "education" is of great interest for analysis, which links the terms "e-learning", "virtual reality", "augmented reality", "decision making", "sustainable development", "economics" and, in fact, demonstrates the model of university development. in this direction. The relevance of considering this cluster is confirmed by a number of domestic works that are devoted to. in particular, digitalization of education in general (Yarovenko et al., 2021), state regulation and management of the quality of education (Vorontsova et al., 2020; Pavlenko et al., 2020), ensuring the quality of education in subject areas (Onopriienko et al., 2021; Lyeonov and Liuta, 2016), quality of education and sustainable development goals (Artyukhov et al., 2021).

It should be noted that in the world the topic of digitalization of education is gaining momentum, as can be seen from the data in figure 2 (SciVal bibliometric analysis tool). However, the number of publications in comparison with other industries is insignificant, which confirms the relevance of studying various aspects of this direction.

Continuing the analysis, it is also necessary to address the topics that are most often associated with the request for digitalization of education (figure 3, SciVal bibliometric analysis tool). The combination of keywords shown in the figure that add up to topics (the figure shows top-1% of topics by prominence, 2510 articles for the period 2011-2020 were used for analysis) leads the reader to the main promising ("breakthrough") directions of the development of the digitalization model of education. These areas can be taken as general ones when creating a digitalization strategy for the educational process at the university.

Thus, the data of bibliometric analysis provide a basis for finding optimal solutions for the digitalization of education in the region, which is studied in this work.

With regard to scientific papers on the digitalization of education, it is worth paying attention to the research of such authors. The problem of using digital technologies in education was studied by Henderson et al. (Henderson et al., 2017), Turuk (Turuk, 2021), Pettersson (Pettersson, 2021), Kafyulilo et al. (Kafyulilo et al., 2016), Sahu (Sahu, 2020), Artino (Artino, 2010), Alqurashi (Alqurashi, 2019). The authors examined the prospects for the digitalization of education, as well as the attitude of students towards distance and online learning. This issue has become esppesiallt important since beginning of COVID-19 pandemic.

The digitalization of education in Central and Eastern Europe was dealt with by Chitez et al. (Chitez et al., 2020), Rogobete and Chitez (Rogobete and Chitez, 2019), Simakhova et al. (Simakhova et al., 2022), Frances and Fleck (Frances and Fleck, 2020), Zinovieva et al. (Zinovieva et al., 2021). These scientists have studied the strategies, models, phases and problems of digitalization of education in Central and Eastern Europe.

Despite the mentioned studies, the issue of comparing, grouping and highlighting the potential of higher education digitalization in Central and Eastern Europe has not been resolved. This led to the relevance of this article.

3 CASES OF HIGHER EDUCATION DIGITALIZATION IN CENTRAL AND EASTERN EUROPE

The total quarantine and the abrupt conversion of educational institutions to distance learning in March 2020 revealed some of the problems with the digitization of education in the countries of Central and Eastern Europe.

Since the beginning of the quarantine in March 2020, higher education institutions in Ukraine were

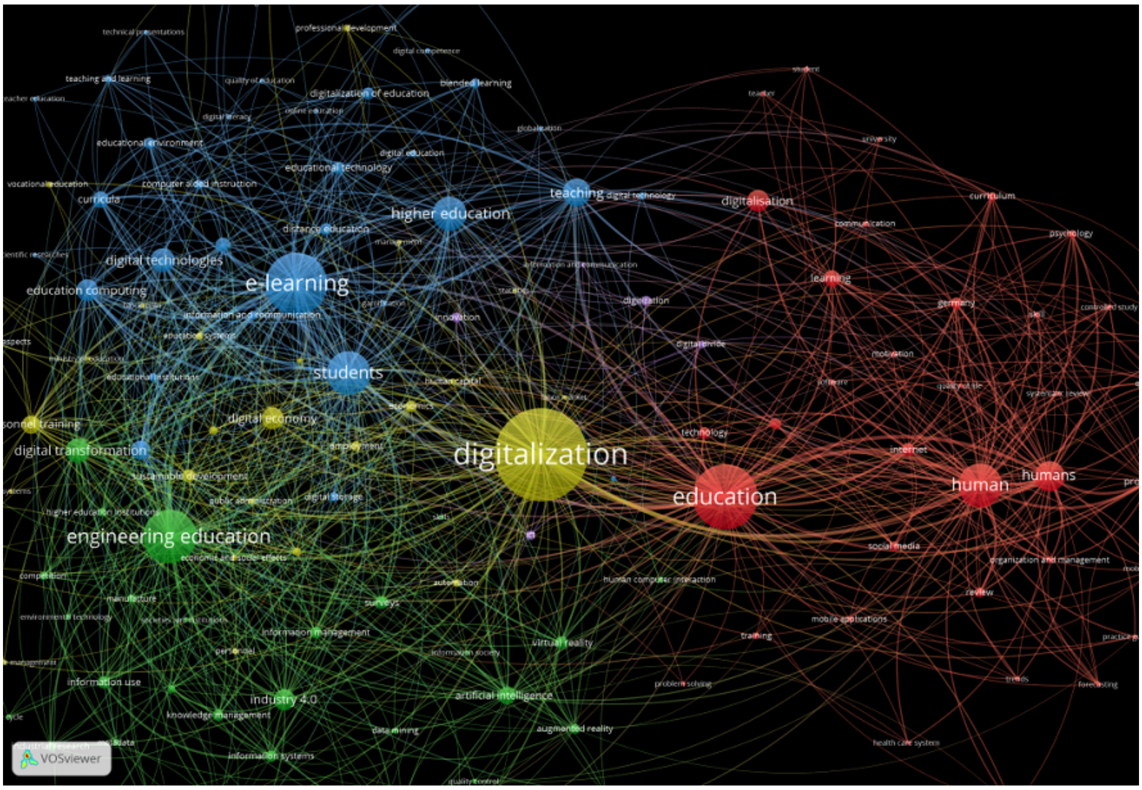

Figure 1: Results of bibliometric analysis using VOSViewer tool.

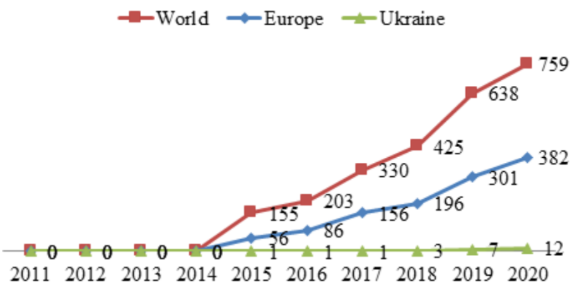

Figure 2: Number of publications in the field of digitalization of education.

not fully prepared for online education, they used only certain elements of online education. And online teaching methods needed development and clear regulation. During the interviews in May-June 2020, most HEIs noted that their institutions used certain elements of online education before the quarantine and relied heavily on the Moodle system. In addition, the development of online education had a specific date and was a response to the demands of time or circumstance. Thus, some online courses were introduced for students of the displaced HEI's (HEI's who were resettled from Donetsk and Luhansk region (Stukalo and Simakhova, 2020)).

Nevertheless, online training courses on digital platforms, online courses, were established in the first month. In addition, the session, certification and even passing the state exams in the summer of 2020 were held online.

It is worth noting that Ukrainian universities have positive experience with online accreditation.

For two years now, the countries of Central and Eastern Europe have had the experience of distance learning at universities on various online platforms.

The European Commission has approved a Digital Education Action Plan (2021-2027). It focuses on two important areas (EU, 2020):

- promoting the development of an effective digital education system (infrastructure, communications, technical means, development of teaching and teaching competencies, high-quality educational content);
- improving digital skills (basic digital skills from an early age, combating misinformation, ensuring equal access for women and girls to digital learning, etc.).

Distance education, new requirements for the educational process have become a challenge for the educational system. The pandemic has affected the habitual lifestyles of students, their families and teachers, caused economic and social consequences, ex-

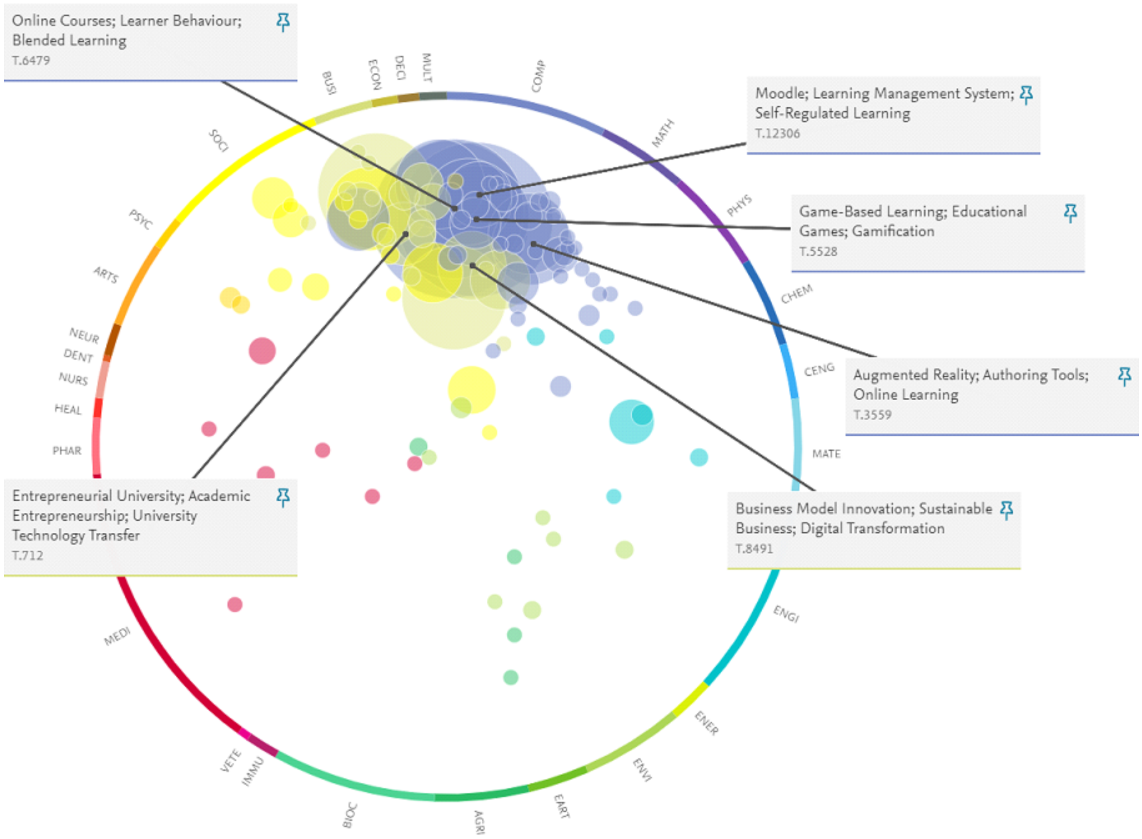

Figure 3: Top-1% of topics by prominence on digitalization of education.

acerbated a number of socio-economic problems, including (MON, 2020):

- Equitable access to education (disparity in families' provision of distance education resources and unequal access to quality Internet);
- Provision of educational services for children with special educational needs (children with certain pathologies are not able to receive educational services at a distance);
- other socio-economic problems caused by the pandemic.

In Ukraine at the beginning of 2020, 86% of Ukrainian teachers did not have significant experience in using online education tools, so universities provided teaching to teach skills in using these tools, creating or transferring courses online and organizing learning in general – by issuing instructions, creating YouTube channels, Telegram, Facebook groups, instructions for creating syllabus courses for online learning, etc. (Nazarenko and Polishuk, 2021). But an important problem was the increase in the workload of teachers, including additional time to master the skills of using digital technologies in education, creating or transferring their courses to distance education systems, their regular updating, supplementation and communication with students. It was noted that the time spent on communication with students has increased, as explaining the task in writing (or adding a description to the online course) is longer than in the classroom, as well as possible additional individual questions from students, and correspondence with them also increases working hours of teachers. In addition, the reason for irregular working hours was the need to develop classes in a new format and search for additional materials (Nazarenko and Polishuk, 2021).

In Ukraine about half of Ukrainians are negative about the introduction of distance education in connection with the pandemic, 32% of citizens supported this step. Categorically negative assessments are most in the Southern (29%) and Eastern (28%) regions (Razumkov Center, 2020).

The most significant problems faced by Ukrainians in connection with the transition to distance learning are the decline in children's achievement (26%), lack of attention of teachers to children's learning needs (22%) and technical problems: poor quality of the Internet (21%) or lack of devices for online learning (19%). About 20-30% of citizens in small towns (up to 100 thousand inhabitants) report a lack of technical means (Razumkov Center, 2020).

Thus, the survey showed problems in the technical equipment of participants in the educational process.

The Ministry of Education and Science of Ukraine in May 2021 prepared a draft Concept of Digital Transformation of Education and Science for the period until 2026 (MON, 2021), which is a strategic document with a state vision for the development of these industries and solving the problems of their development.

Digitalization of higher education in Poland is more developed than in other Eastern European countries. Kozminski University, Lodz University of Technology, Warsaw School of Economics and the Jagiellonian University are universities with different educational profiles combining exemplary use of digital tools in scientific, administrative and research activities. All four universities were the first in Poland to be awarded in the Most Innovative Universities Program and to receive the title of "Microsoft Cloud University" (BRIEF, 2021).

Despite the fact that Poland has more experience in distance education than Ukraine and Belarus, some important problems appeared in 2020 and 2021:

- insufficient supply of computers to participants of the educational process (97% of households have at least one computer, but many of them have difficulties because computers have to be shared by siblings, etc.) (Delmanowicz, 2021);
- reduced bandwidth of connection and limited amount of monthly data transfer;
- lack of digital skills among teachers (85% of teachers reported that they had very little experience in using the tools needed for distance education, and only 5% of them described their skills in this area as "very good". Only 8% of students believe that teachers are very well prepared for online learning, and 62% of them consider distance learning ineffective) (Delmanowicz, 2021).

Thus, the problems of digitization of education in Poland are similar to Ukrainian problems.

4 PROBLEMS OF DIGITALIZATION OF HIGHER EDUCATION IN CENTRAL AND EASTERN EUROPE

The main problems of digitization of education in Central and Eastern Europe:

- inadequate preparation of teachers for distance education (use of methods of cyber-pedagogy, work on online platforms, underdeveloped digital skills);
- management problems (insufficiently developed digital competences among representatives of the management of educational institutions);
- lack of technical equipment in educational institutions (virtual classrooms, electronic laboratories, etc.);
- lack of quality Internet connection among individual participants in the educational process in connection with their place of residence;
- insufficient provision of individual computers for all participants in the educational process;
- lack of methodological support for distance learning courses (workshops, lectures, etc.);
- increase the time load on teachers due to increased online communications and development of online materials for students.

As the above analysis has shown, the countries of Central and Eastern Europe have similar problems in providing digitalization of higher education. Let us analyze the ranks of the Network Readiness Index (NRI), Digital Skills Gap Index (DSGI), and IMD World Digital Competitiveness Ranking in terms of technological readiness of universities and digital skills of teachers and students (table 1, 2, 3).

According to the NRI rating of the studied countries, Switzerland, Germany and Austria have the highest positions – 5, 9 and 18, respectively. Also in terms of technological support, Switzerland has a higher position, and Germany – 7th. Thus, the Central European high-income countries of the group have a greater potential for digitalization of higher education than the countries of Eastern Europe.

According to table 2, for DSGI Switzerland, Germany and Austria also have the highest positions. Romania, Moldova and Ukraine have the lowest scores of DSGI.

IMD World Digital Competitiveness Ranking represents 64 countries. Among the studied countries, Moldova and Serbia are not represented in this report. As for other Central and Eastern European countries, Switzerland, Austria and Germany have the highest rank. Croatia and Ukraine have the lowest rankings according to this global indicator. The same situationthere is for the level of country preparedness to exploit digital transformation.

Thus, the analysis of global indicators showed different readiness and potential for the introduction of remote and digital technologies in higher education in Central and Eastern Europe.

Table 1: Network Readiness Index ranks in 2020.

Countries	NRI rank	NRI score	Technology (Pillar) Rank	Technology Sub-pillars			Income group
				Access	Content	Future Technology	
Ukraine	64	49.93	62	79	46	53	Lower-middle-income
Poland	33	61.80	36	32	34	60	High-income
Bulgaria	46	55.03	43	50	33	78	Upper-middle-income
Czech Republic	28	66.33	26	33	20	32	High-income
Hungary	39	60.05	31	21	32	44	High-income
Moldova	71	47.09	74	56	66	126	Lower-middle-income
Romania	49	51.14	46	18	48	82	High-income
Slovakia	35	60.78	34	38	37	37	High-income
Austria	18	73.92	16	35	15	17	High-income
Croatia	43	55.94	52	49	38	118	High-income
Serbia	52	52.96	53	51	42	103	Upper-middle-income
Slovenia	27	66.58	29	24	26	35	High-income
Germany	9	77.48	7	27	10	3	High-income
Switzerland	5	80.41	1	4	1	7	High-income.

Table 2: Digital Skills Gap Index (DSGI) in 2021.

Countries	Score	Rank
Ukraine	4.8	69
Poland	5.6	42
Bulgaria	5.0	60
Czech Republic	5.5	44
Hungary	5.2	50
Moldova	4.7	73
Romania	4.7	74
Slovakia	5.1	52
Austria	6.5	21
Croatia	4.8	66
Serbia	4.8	64
Slovenia	5.7	40
Germany	7.1	14
Switzerland	7.2	11

Table 3: IMD World Digital Competitiveness Ranking in 2021.

Countries	Rank	Future Readiness Rank (Level of country preparedness to exploit digital transformation)
Ukraine	54	58
Poland	41	39
Bulgaria	52	55
Czech Republic	33	37
Hungary	45	61
Romania	50	49
Slovakia	47	46
Austria	16	16
Croatia	55	60
Slovenia	35	40
Germany	18	18
Switzerland	6	3

5 POTENTIAL OF HIGHER EDUCATION DIGITALIZATION IN CENTRAL AND EASTERN EUROPE

The above analysis allowed the authors to group the countries of Central and Eastern Europe according to their potential for the higher education digitalization. Authors have highlighted specific criteria (table 4).

Thus, authors proposed 3 groups of Central and Eastern European countries according to their potential for higher education digitalization of with their indicator. Also, it is necessary to mention that this potential correlates with countries' income group.

High potential for the higher education digitalization have the countries of Central Europe – Austria, Germany, Slovenia and Switzerland. So, the universities of these countries will be more attractive for foreign students in modern conditions of globalization.

Lower-middle potential for higher education digitalization has Ukraine and Moldova. This is an alarming signal given today's war in Ukraine. Firstly, Ukraine currently has a large outflow of young people due to the war. At the end of March 2022, more than 3.8 million people left Ukraine due to the war, mostly young people. Secondly, according to the study, Ukrainian universities and society as a whole have less potential for digitalization of higher educa-

Table 4: Grouping Central and Eastern European countries according to their potential of the higher education digitalization.

Group	Countries	Indicators	Income group
High potential for the higher education digitalization	Switzerland, Germany, Austria, Slovenia	NRI rank $\leq$27, DSGI rank$\leq$ 40,	High-income
Middle potential for higher education digitalization	Romania, Bulgaria, Poland, Slovakia, Hungary, Croatia, Serbia, Czech Republic	28$\leq$ NRI rank $\leq$ 60, 41$\leq$ DSGI rank $\leq$ 67	High-income, Upper-middle-income
Lower-middle potential for higher educationdigitalization	Ukraine, Moldova	NRI rank >60, DSGI rank >68	Lower-middle-income, Upper-middle-income

tion than other countries in Central and Eastern Europe. Thus, it is possible to predict the outflow of Ukrainian entrants and students to the countries of the group of high potential for the higher education digitalization and middle potential for higher education digitalization.

In our opinion, the practical recommendations for higher education digitalization is public-private partnerships with the participation of manufacturers and suppliers of advanced information and communication technologies that have prospects of application in the educational process in higher education institutions of countries.

In the future, the higher education digitalization will ensure the development of digital competences for all participants in the educational process, the formation of ecological and digital awareness among students (Stukalo and Simakhova, 2019), the adaptation of educational programs to changing socio-economic conditions and the scientific and technological revolution, and the development of a digital economy.

To summarize the results of the study, a SWOT analysis of the potential of the higher education digitalization for the countries of Central and Eastern Europe was carried out (table 5). SWOT analysis is a model for forming an information base and developing on its basis the most effective option for managing socio-economic processes (including the higher education digitalization). It is assumed that SWOT analysis is used to assess the situation under conditions of uncertainty and to regulate individual parameters. In this case, the regulation of parameters is understood as the correction of the values of control parameters for the implementation of the optimal development scenario at a certain segment of the planning period.

6 E-LEARNING ENVIRONMENT: UKRAINIAN UNIVERSITY'S CASE

As an example, let us present the case of Sumy State University (Ukraine) on the creation of an e-learning platform based on its own unique developments. The e-learning environment is shown in figure 4.

The e-learning ecosystem includes various tools for the implementation of distance, e-learning and blended learning, platforms for creating educational materials, a platform for massive open online courses, a repository of educational materials. The developer of educational materials works autonomously, without involving technical services in the software implementation of the project in the process of creating a package of tasks. In the process of creation, only the developer communicates with consultants of various levels. After agreeing on the content, the materials are reviewed and posted in open or closed (directly for course students within the university) access; programmers implement only non-trivial tasks within the framework of educational courses (interactive elements, virtual and augmented reality, etc.) (figure 5).

As part of the implementation of various models of electronic learning, they are constantly being improved on the basis of feedback from developers of educational materials, reviewers, programmers, and listeners. As an example, the questionnaire of a survey of developers of educational materials of the "Mix" platform (blended learning) in 2021 is given.

The advantages of the "Mix" platform:

- all teachers and students are in a single learning space;

Table 5: SWOT analysis of the higher education digitalization for the countries of Central and Eastern Europe.

Strengths	Weakness
- high digital skills of academic teachers (DSGI Score 4.8); - state support; - relevant regulatory framework; - high level of country preparedness to exploit digital transformation.	- negative attitude of population to distance education (30%); - lack of methodological support for distance courses; - increase the time load on teachers
Opportunities	**Threats**
- development of the digital economy and distance education; - the future of technology; - opportunities for education during pandemics and war; - creation of the Digital European University with Artificial Intelligence	- different level of provision of families with means for online learning (21% of families have poor quality of the Intern; 19 % – lack of devices for online learning); - low level for readiness for future technologies in Eastern Europe (Score: 60-126)

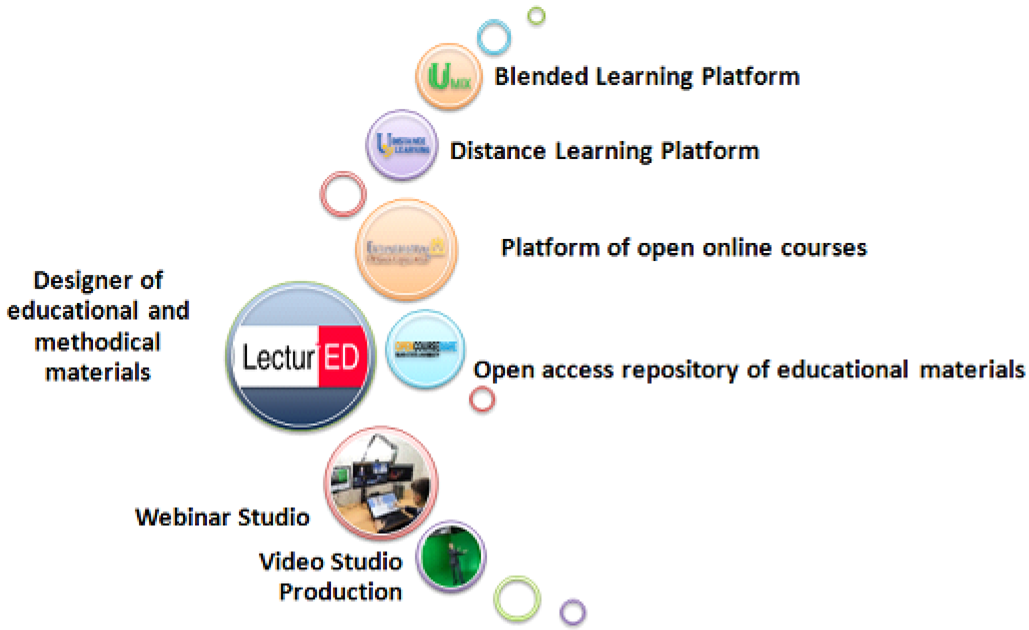

Figure 4: E-learning environment: Sumy State University case (Ukraine).

- the ability to control the educational process in real time;
- the platform is synchronized with the unified information system of the university;
- systematic support from the university;
- the opportunity for teachers to work collectively both in the creation of materials and in virtual classrooms;
- unified tools simplifies the use of the platform for all users;
- automatic connection, control, archiving;
- the ability to manage user registration, define roles, manage content;
- creation of virtual classes, adjustment of the necessary parameters.

Disadvantages of the “Mix” platform:

- instability of work;
- inconvenient interface for working with mobile devices;
- insufficient functionality to provide the necessary activities;
- difficulty in settings;

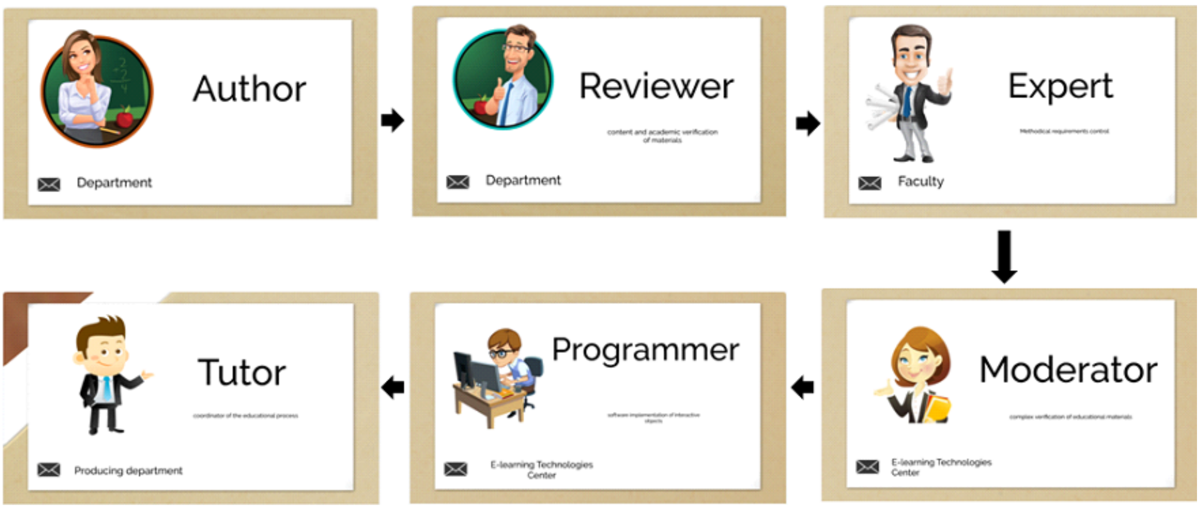

Figure 5: Algorithm for creating educational materials.

- inconvenient interface for working with a personal computer;
- insufficient level of technical support for users;
- excessive openness and transparency for control by the university.

Measures to improve the "Mix" platform:

- integration with services for webinars (Meet, Zoom, Microsoft Teams, etc.);
- integration with plagiarism testing services;
- mobile version with chat;
- integration with additional services of ACS "University".

The proposed e-learning system has proven to be an effective tool for remote work during a pandemic. The use of this system in synchronous-asynchronous training during the war for the independence of Ukraine, which began on February 24, 2022 with the invasion of the Russian Federation, became even more relevant. Due to the destruction of individual universities or the impossibility of studying in the occupied territories, students resort to internal mobility, which is possible under the conditions of creating a proper educational environment for e-learning. Currently, the National Agency for Higher Education Quality Assurance has compiled a list of about 50 universities (the list continues to expand), which is ready to ensure internal academic mobility of students with subsequent transfer of credits to home university (students who have the opportunity to continue online learning) more than 20 Ukrainian universities that continue the educational process, showed that at least 50% of the contingent are ready to join synchronous learning. Another 20-25% are ready to study asynchronously in the e-learning environment.

For the above reasons, the e-learning system can be upgraded by introducing the following educational components:

1. Creating a model of student learning, which is the simultaneous use of "Rotation" (study time is divided between individual e-learning and online meetings with tutors, "flipped classroom") and "Flex" (most of the curriculum is mastered in e-learning with group or individual consultations) models. The basis of the combined model are active teaching methods (problem lecture and lecture-visualization, group work on creative tasks, etc. – face-to-face learning) and e-learning technologies (distance learning, work with simulators, author's open electronic resources, electronic resources of the world's leading universities). also in order to identify his propensity for a particular activity pi after graduating from university.
2. Lecture "puzzle"

The model proposed above has sometimes proved inflexible in terms of the ability to master 10 skills that employers need in the last 2–3 years. The model only partially satisfied the conditions for acquiring skills and is now obsolete in terms of developing e-learning opportunities. In addition, the monotony of the types of work led to a significant reduction in student productivity.

"Puzzle": each lecture is formed from blocks F2F, MOOC, VR and AR+.

Element 1: in block F2F there is a possibility to move from one type of lecture to another, for example, "problem" – "knowingly wrong answer" – "discussion" (complex multilevel problem solving, critical thinking, forming one's own opinion and decision making).

Element 2: in the F2F block there is an opportunity to move from lecture to practical classes using the practice of active learning, MOOC, VR and AR+ (creativity in the broadest sense)

Element 3: the F2F block uses the practice of interactive learning, "substitution" of teacher-student communication for student communication with each other (emotional intelligence, customer orientation, negotiation skills).

3. "Project – incentive – motivation"

In today's educational environment, some teachers are "info-gypsies" – translators of their courses, which have no practical significance.

Mentoring is one of the most promising tools for professional development of students. However, it is a misconception to use pseudo-mentoring for a group of people (within traditional practical classes), which is ineffective due to the individuality of each learner. Implementing mentoring in classroom conditions is quite difficult. Individual work with the student is limited to discussing the individual task with the teacher – the head of educational or qualification work and does not transfer consideration of the issue of motivation, support. Mentoring as an element of "guardianship" of the learner is a tool for learning competencies, which does not motivate the student (there is only an incentive – the need to defend the task to obtain a certain number of points) and among other things implements the function of advice.

The institute of mentoring has become widespread in foreign universities, but in fact it can be called an institute of mentoring. Mentoring "as is", by analogy with domestic universities, has problems with implementation due to the inability to work with students individually in the classroom. Extracurricular work as an element of the training course due to the lack of a mechanism for its evaluation does not contribute to the teacher's role as a mentor. Thus, solving the problem of mentoring in online learning will provide an opportunity for students to acquire new skills and awareness of the phenomenon of motivation at the level of mental processes. The selection of mentoring and mentoring as separate teaching methods allows us to trace the evolution of the teacher on the path of "info-gypsy – mentor – mentor" with the change of functions at each stage.

7 CONCLUSIONS

Thus, the countries of Central and Western Europe can be divided into three groups according to global indicators of their potential for digitalization of higher education. The most attractive for students are the countries of the first group with high potential for digitalization, namely Austria, Germany, Switzerland, and Slovenia.

The pandemic COVID-19 has led to the active digitalization of higher education. Despite the fact that in the beginning of 2020 there were many problems with online learning, for two years now the higher education system has been operating effectively at a distance. It is the digitalization of higher education that will overcome the negative consequences of the migration of entrants and students from Ukraine through the war to Central and Eastern Europe. In view of this, it would be promising to create a European platform for teaching Ukrainian students, where, along with English, the languages of Central or Eastern Europe, it would be possible to study subjects in Ukrainian.

The case study of the implementation of digitalization tools in Ukrainian universities showed that the digitalization of higher education ensured the continuity of the process of persuasion during the pandemic and war in Ukraine.

The recommendations for improving the digitalization of education are:

- public-private partnerships with the participation of manufacturers and suppliers of advanced information and communication technologies that have prospects of application in the educational process in higher education institutions;
- teachers training in e-tools of online learning;
- mentoring use for professional development of students.

So, the higher education digitalization allows minimizing the negative social consequences of global challenges such as pandemics and wars. The perspectives of further higher education digitalization of Central and Eastern Europe is the creation of a Digital European University with artificial intelligence based on a partnership between the state and business.

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Using Online Services to Create Comics with Elements of AR in the Educational Process of Elementary School

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Keywords: Cloud Services, Comics with AR Elements, Comic Book Creation Algorithm, Readiness, Educational and Methodological Materials.

Abstract: The article presents the actual state and practical ways to solve the problem of students and teachers of elementary school readiness to use cloud services to create comics with AR elements. The didactic potential of comics as a means of learning in the educational process has been clarified. A comparison of modern cloud services, programs, and applications for creating comics is given. Their advantages and disadvantages are highlighted. The functionality of AR programs for creating content based on comics (Vuforia, EasyAR, Maxst, ARCore, AR.js, 8th Wall) is analyzed. The results of a survey of teachers on distinguishing the most popular cloud services are given, among them are Pixton, Marvel HD, Comica. Algorithms of the educational materials' development in these cloud services for the creation of comics are presented. The levels of readiness for the use of cloud services for creating comics with AR elements (elementary, basic, creative) have been developed. The real state of readiness of teachers and students to use cloud services to create comics with AR elements is presented and characterized. Educational and methodological support has been developed for implementation in the practice of university education and the teacher development system. The prospects of the study, which are to further monitor the readiness of students and teachers to use cloud services to create comics with AR elements after the introduction of the author's educational and methodological support, are given.

1 INTRODUCTION

Modern teaching methods in elementary school focus on the use of non-traditional, in particular interactive and playful methods of working with children. The traditional lesson is often not effective, which encourages teachers to look for new means and forms of teaching. The teacher should become an innovator and be able to organize an interesting lesson-play, lesson-travel, lesson-quest, etc. One of such educational tools is comics, which allow forgiveness, visualization, and virtualization of complex information. The visual quality of comics increases the level of learning. Movies and animation, unlike comics, are visual, but "time-limited". Language and actions in cinema and animation are "fast-paced". Time in the comic book progresses as fast as the reader moves his eyes across the page. The speed of information transmission is fully determined by the reader. We agree with Chykalova (Chykalova, 2020) that comics is one tool for the development of imagination and fantasy, skills to clearly and capaciously formulate and express their opinion, to distinguish the main, key from the text. Working with comics contributes to the formation of the skills of younger schoolchildren of the 21st century: to emphasize the main thing and be able to cooperate in a team.

Today, educational technologies for the use of comics have proven to be quite effective and productive. As evidenced by the pedagogical experience of the authors of the study, educational materials containing or based on AR technology are especially popular. However, the analysis of the real practice of the educational process in primary school allows us to state a lack of high readiness of teachers to apply comics in pedagogical activities in general and with

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the use of AR in particular. On the one hand, there is a lack of methodological developments on the use of comics with AR elements in training. Another significant problem is the weak capacity of teachers to develop and use comics with AR elements using cloud services. This outlines another significant problem – the preparation of future primary education teachers for the use of cloud services for creating comics with AR elements in professional activities.

2 ANALYSIS OF PREVIOUS RESULTS

The importance of comics used as a means of learning is outlined in several studies (Panchenko et al., 2020; Panchenko, 2021; Kuzminsky and Omelyanenko, 2008; Danylenko, 2010; Olshansky, 2002; Pustinnikova, 2013; Danylenko, 2011; Bilousova et al., 2021). Of particular interest in the context of the problems of our work are studies on the use of digital technologies as a means of effective visualization in the use and development of comics. The works (Azman et al., 2016, 2015) analyze the modern software Bitstrips, Comic Life, Pixton, MakeBeliefsComix, Cartoon Maker, and Graphix Comic Builder, their functions, characteristics, capabilities, and disadvantages. Fragments of the use of the said software for implementing the educational process are presented. Zerkina et al. (Zerkina et al., 2019) analyzed the possibilities of using Pixton to form the ICT competence of engineering students using a project approach. Different didactic possibilities of the specified cloud service are given in the studies (Meyers, 2014; Cabrera et al., 2018; Hobri et al., 2019). Weber (Weber, 2015) considered the use of cloud-based graphic narrative software in medical ethics teaching. In addition, the theoretical and practical aspects of data visualization and the use of digital technologies for this are presented in the works (Segel and Heer, 2010; Yuksel-Arslan et al., 2016; Sadik, 2017; Bodnenko et al., 2014). The subject of research is the use of augmented reality to work with comic book-based teaching material (Damopolii et al., 2022; Nidhom et al., 2019; Koutromanos and Alivisos, 2018).

3 THE OBJECTIVE OF THE RESEARCH

The purpose of the article is to reveal the possibilities of using online services to create comics with AR elements in the educational process of elementary school.

The purpose of the study is specified in the following tasks: to identify the most popular cloud services for creating comics among teachers and characterize them; to reveal the algorithms for developing educational materials in cloud services for creating comics with AR elements; to investigate the actual state of readiness of future teachers and students to use cloud services for creating comics with AR elements; to develop educational and methodological support for the use of these cloud services in the educational process.

4 RESEARCH METHODOLOGY

To implement the study, the following methods were used: theoretical (analysis and synthesis of psychological, pedagogical and methodological sources, programs, handbooks, systematization and generalization of theoretical material; study of the experience with the research problems; clarification of the basic knowledge of the studied problem), empirical (pedagogical observation, interviews with teachers and questionnaires, writing methodological recommendations, formulating conclusions and determining the sequence of research), statistical (Pearson's criteria for identifying the real state of readiness of students and teachers for the use of cloud services).

The study was conducted based on Borys Grinchenko Kyiv University, 11 schools in Kyiv during March – to December 2021. The study was attended by 28 primary school teachers, as well as 84 students of the specialty "Primary Education" of 1–4 years of study.

5 RESULTS AND DISCUSSION

5.1 Analysis of Cloud Services for Creating Comics

Comics are a new, effective and democratic tool of the primary school teacher in the formation and comprehensive development of the initiative and creative personality of the schoolchild. Combining visual and playful nature, comics can satisfy the interests and meet the peculiarities of the course of mental processes in modern junior schoolchildren, representatives of the generation, to prevent the occurrence of stress during the study (Chykalova, 2020). There are plenty of online services and apps to create comics. However, not all of them are suitable for the teacher to organize work in class. Most services are paid, too complex, and require special knowledge and skills, or their content is not created for children's audience. Finding the right program, service, or app is difficult and time-consuming, which teachers usually lack.

Lack of time for training is also a problem because the service must not only be found but also learn to work in it and know how and when to use the developed materials.

In the study, we were interested in functional, free and, most importantly, simple services that provide easy access to programs for both teachers and students (table 1).

Each of these online services contains a certain number of templates grouped by types:

- people (children, teens, young men, adults, elderly people);
- animals;
- things;
- transport;
- special characters;
- backgrounds (school, forest, city, houses, historical and mythological views, nature, etc.).

When creating a plot, you can choose the expression of the face, the position of the body, the mood of the hero, change his appearance, clothes, etc.

It should be noted that in table 1 you can also get acquainted in detail with the main characteristics of modern online services, programs, and applications for creating educational comics, which can be used not only for working online but also for working in the classroom with the ability to print material.

All offered by us online services, programs, and applications for creating comics can use instant translation in Ukrainian and maintain it in the services themselves. Using these services, the teacher can diversify the form of educational material presentation, will be able to convey complex ideas and concepts using minimal artistic means, and will be able to organize not only face-to-face but also distance learning qualitatively and interestingly. It is also possible to organize work with services not only individually but also in a group format.

The services are quite simple, so schoolchildren will be able to work with them. Most of them do not require users to register, and they can start working with them right away. Talking about the advantages of using these services, we can note the following:

- Availability of services in material terms (most are free or have the possibility of using the trial/free version);
- Simple interface (intuitive);
- Use of templates (each service has its template database for use);
- The ability to create a completely new product (the ability to download own resources is provided);
- Dissemination of materials (it is possible to disseminate or embed the created materials of the author);
- Versatility (materials can be used to work in any lesson for individual or frontal work, both online and printouts). It is also worth highlighting the disadvantages:
- Other-language interface (most programs are foreign, but there is a possibility of using Google instant translation);
- Preliminary training of teachers and students;
- Conversion (not all file formats are supported; their size is limited).

The creation of training materials such as comics using the specified software can be supplemented with AR elements. The experience of implementing the educational process using AR also allows us to highlight programs for developing and working with AR.

- Vuforia can easily create marker-based AR, markerless-based AR, and cloud-based AR. Provides sufficient support to create an application for minor tasks. In particular, it allows you to recognize 2D and 3D objects, English text (the vocabulary contains over 100,000 words, or you can use your dictionary) and allows you to play videos.
- EasyAR offers its next-generation SDK, which has some features such as SLAM, 2D–3D screen tracking and recording, cloud-based object recognition, and unlimited recognition requests. In addition, the free version can store up to 1000 tags on the device.
- Maxst offers two types of augmented reality software: Maxst AR SDK 2D and Maxst AR SDK 3D. The first tool can only recognize 2D images, and the other is much more powerful and can track 3D objects. The Maxst AR 3D SDK has features such as SLAM, physical engine effect, and occlusion effect. The Maxst AR SDK 2D features multiple image recognition (up to 200 images per channel), video zoom, instant object tracking, image and marker tracking, and a QR/barcode scanner.
- ARCore is not only supported on Android, but also on iOS devices, allowing you to develop

Table 1: Modern online services, apps and applications for creating comics.

Online services		*Need to be uploaded*	
StoryboardThat	Price: Free basic version; Language: English.	Comic Life	SW: Windows/macOS; Price: Free version – 30 days; Language: choice.
Pixton	Price: Free; Language: Italian.	Krita	SW: Windows; Price: Free; Language: choice.
Make Beliefs Comix	Price: Free; Language: choice.	MediBang Paint Pro	SW: Windows/macOS; Price: Free; Language: choice.
Debate365	Price: Free; Language: English.	*Mobile apps*	
Canva	Price: Free; Language: Ukrainian.	Comica	SW: Android/iOS; Price: Free; Language: choice.
Write Comics	Price: Free; Language: English.	Comic and cartoon maker	SW: Android/iOS; Price: Free; Language: choice.
Marvel HD	Price: Free; Language: English.	MomentCam	SW: Android/iOS; Price: Free; Language: choice.

cross-platform AR applications. Features of the application include: in addition to identifying key points, ARCore can detect flat surfaces, and can also estimate the average illumination around them; determining the size and location of vertical, horizontal, and inclined surfaces; tracking movement according to the position of the phone, accurate placement of virtual objects; assessing light and understanding depth.

- AR.js is an open-source AR SDK based on JavaScript. Can create AR scenes based on markers. The tool comes with an A-Frame and three.js extension that works with any smartphone, regardless of its OS version, including Android, iOS, and other. Markers are stable but limited in shape, color, and size.
- 8th Wall provides support for markers (Image Target), World Effects, Face Effects, SLAM. Video recording, light evaluation, and relative zoom function are available. Can be used in combination with Unity and Unreal engines.

When choosing modern online services, programs, and applications for creating comics, as well as AR, which a teacher can use in his educational activities to study in elementary school, we were guided by three main criteria:

- Service availability;
- Easy to use;
- Functionality.

As a result of a survey of primary education teachers, it was found that all services meet such requirements, but separately, for working with primary school students, the following services are most often distinguished: for teachers – Pixton; for schoolchildren's work – Marvel HD, and the app installed on the gadget – Comica.

5.2 Algorithms of Development of Educational Materials in Cloud Services for the Creation of Comics

Let's start with Pixton comic book designer that allows you to create your stories almost from scratch. Allows you to customize models, background images, people's postures and emotions, and other image details, allowing you to create interactive comics. We start working at Pixton by choosing the type of user (teacher, pupil, parent, or business). We are interested in the user-teacher. A sign-up window appears, indicating that you can sign up for free. After registration, the user is flipped to the configuration panel. Suggested three steps to set up the service.

Step 1 – Watch an introductory video where pupils who work with this service share their impressions. After watching the video, click the "Next Step" button.

Step 2 – Familiarize yourself with the process of creating comics in the Pixton service. Press the button "Create a comic book" and go to the Pixton work field. The work field contains a page panel, four comic creation toolbars, a search bar, and a comic display area. In the first toolbar, select the background of the comics (for example, the pupil's room) and the main characters (the girl). Use the search bar to enter the name of the desired background or character (in English) or use the suggested groups (under the search bar). You can also upload your own materials – the camera icon under the comic book display area. Go to the toolbar to focus the image. Select the desired type of drawing (for example, "to the right"). Next, go to the text panel and enter the lines of the characters. This can be direct language (round dialog window), thoughts (window-cloud), shout (orange window), and whisper (dotted window). In the face setting panel, choose the desired emotion, for example, a thoughtful look. There is also the option to choose the character's look. The last panel is the position setting of the hero's body. Here you can choose the posture, the direction of movement and the possibility of holding objects in the left or right hand. In the upper-right corner, click the "Finish" button and go to the third step of the settings.

Step 3 – enter the name of the comic book and choose a class. Next, the service offers to make a teacher's avatar, which is created similarly to the comic, following the instructions offered by Pixton. Then the user is moved to the personal account, where the existing 4 sections (created classes, student comics, class photos and printed versions of comics) are also displayed on the right-hand side, where the "Link for pupils" button is displayed, from which the teacher can invite students to the virtual classroom. A fragment of work with the program is shown in figure 1.

Figure 1: Example of a comic created using the Pixton online service.

The following program, which was chosen by us, is excellent for both individual and group work of junior school students. It is not required to register and fill out various forms here. There is an opportunity to create the simplest comic with ready-made templates.

Write Comics – is the easiest service to create comics and stories. After all, this is just one page where you can set all the parameters of your plot: characters, background; text box.

We start by entering the name of the comic. Scroll the cursor further and select the characters in our story, dragging them to the desired location in the comic book image area. Next, we choose the background, the place where the events of the story take place and enter the lines of the characters. Press the "Finish" button, the comic book is ready (see figure 2).

The next program that can be used to create comics in primary school is Comica. This is an app that you can use to create a comic from your own photos. First, you need to download the app and install it on your gadget. It can be done in any user-friendly service (for example, in the Play Market).

Open the app and view the menu: Gallery – processing of one photo in the comic book editor; Camera – instant photo creation; Multi is the comic book editor.

Select "Multi", set the number of episodes in the picture (for example, 3 pictures), click on the field and select a photo from the gallery. We process the photo in the photo editor and choose the comic style. We individually adjust brightness and contrast, if needed. Next, we select the stickers and the comic book elements that the user needs. We do the same thing with the other two photos and create an episode of the comic. Download the comic book or share it (see figure 3).

These services are quite convenient and understandable. The key value of resources is that in each program there is an opportunity to use ready-made templates of drawings, characters, backgrounds, signs, objects, etc., and to adjust them as needed. Working with these applications does not require special knowledge and skills, which is why it is an immense advantage. After all, even junior school students will be able to work in the service.

However, a significant disadvantage is that the de-

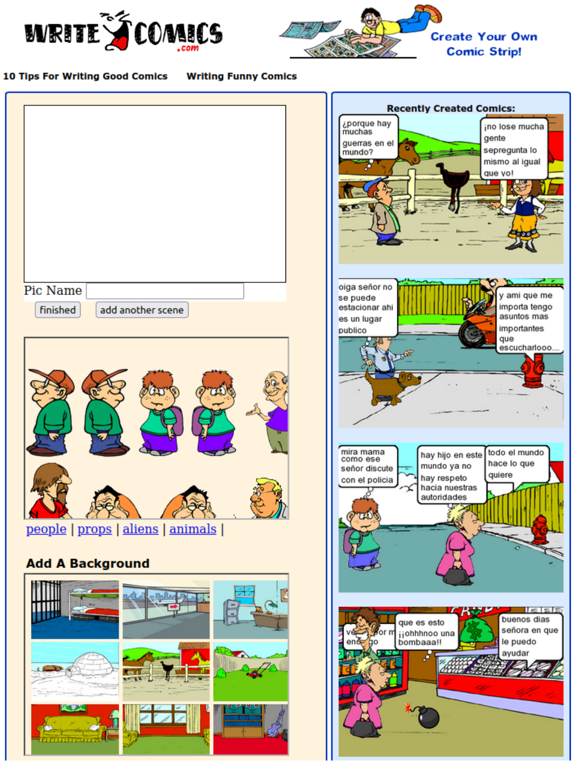

Figure 2: Fragment of work with the Write Comics service.

velopers of these online services and applications do not provide any instructions on how to work with them, so users have to deal with the way applications work by themselves.

5.3 Determination of the Real State of Readiness of Teachers and Pupils to Use Cloud Services to Create Comics with AR Elements

As a result of a survey of teachers, it was found that many people "do not know where to start" or consider it an impossible mission to create comics on their own. Many teachers know about cloud services, where you can find ready-made developments, but can not select the appropriate comic for a particular learning situation or lesson. Most teachers do not know how to create comics, including with AR elements, using cloud services. These and some other circumstances keep many teachers from introducing this kind of teaching activity into teaching practice.

The analysis of the student survey also shows that within the informatics disciplines at the university, the use of cloud services for creating comics is not given due attention (table 2).

As a result of the experiment, we found the willingness of teachers and students to use cloud services

Figure 3: Comic Book Editor Comica.

to create and use comics in educational practice. Appropriate criteria and levels of readiness have been identified and developed.

- Level 1 – elementary, characterized by superficial knowledge of working with cloud services to create comics with AR elements;
- Level 2 – basic, characterized by a focus on the use of cloud services at the demonstration level;
- Level 3 – creative, characterized by the active use of cloud services to create comics with AR elements.

As a result of the questionnaires developed by us on the theoretical principles of using cloud services, tasks on working with cloud services and the results of self-assessment, the real state of readiness of teachers and students to use cloud services for creating comics with AR elements was revealed (table 3).

According to the results of the study, students and teachers showed approximately the same ability to use cloud services. Most students (63.1% of the total number of respondents) and teachers (67.9%) have an elementary level of readiness. Only 10.7% of students and 8% of teachers reached the creative level.

The results confirmed the problem of the the preparation of future primary education teachers for the use of cloud services for creating comics with AR elements in professional activities.

Table 2: Levels of readiness of teachers and students to use cloud services to create comics with AR elements.

Level	Characteristics of the level	Teacher skill level requirements
Elementary	Lower awareness of cloud services use, in particular AR. The teacher knows fragmentarily about the peculiarities of working with these cloud tools, but does not have a goal to learn how to create comics, cannot relate to the pedagogical expediency of their use.	Using the pedagogical capabilities of comics at the starting level, for example, conducting a lesson with a multimedia presentation or a ready-made animated resource already developed by a bulk product with AR elements. Using didactic materials with the help of cloud services, already developed and ready for the lesson comics.
Basic	Uses cloud services to create comics and AR at the demonstration level (presentations, pictures, slides). Formulates the request in relation to the specific topic of the upcoming lesson. Can associate with the pedagogical feasibility of their use. Can create his own comic book by analogy, including with AR elements, using step-by-step instructions.	Designing tasks for pupils using cloud services that involve the use of comics, including with AR elements in class and outside classroom hours, for example, for homework tasks related to search and selection of information, including on the Internet.
Creative	Actively uses cloud services to create new and use ready-made comics with AR elements. Disseminates its developments and participates in network communities.	Integrated use of cloud services and modern educational technologies: integrated lessons, project activities of pupils using comics with AR elements. Advise colleagues on using and working with resources to create comics with AR elements.

Table 3: The state of teachers and students readiness to use cloud services to create comics with AR elements.

Level	Students (84 persons), %	Teachers (28 persons), %
Elementary	63.1	67.9
Basic	26.2	25.0
Creative	10.7	7.1

Table 4: Critical value of the Pearson criterion χ^2.

χ^2 $(p = 0.05)$	χ^2 $(p = 0.01)$
5.991	9.21

To compare the results obtained, we used the Pearson criterion χ^2. For this purpose, statistical hypotheses are formulated:

H0 – the level of students' readiness to use cloud services does not exceed the level of teachers' readiness;

H1 – the level of students' readiness to use cloud services exceeds the level of teachers' readiness.

The obtained empirical value of the Pearson's criterion $\chi^2 = 0,932$ we compared with the tabular values (for the number of degrees of freedom 2 (table 4).

Thus, we accept the hypothesis H0 that the level of students' readiness to use cloud services does not exceed the level of teachers' readiness.

Note that given the insufficiently large sample size, we certainly do not claim a strong scientific justification for the state of this readiness in the context of the activities of all teachers and students of primary education. The data obtained, rather, indicate an overall trend regarding the research problem and require finding ways to improve it.

5.4 Educational and Methodological Support for Teachers

As a result of a survey of teachers, we identified fundamental problems with the use of cloud services. Among them, we can note the lack of time for self-education and learning.

Taking into account this problem, Iryna R. Chopyk have developed a website, where the necessary information was collected and methodological recommendations were prepared on the organization of the teacher's work using cloud services for creating comics in classes in primary school (https://blogger090.wixsite.com/comics).

This educational website helps elementary school students and teachers improve their own competencies in using cloud services to create comics.

Thus, the work of the website is aimed at helping the primary school teacher to create their own development of interactive educational content, as well as using them in lessons in primary school. The website contains 4 sections:

1. Homepage;
2. "About the project";

3. “For teacher”;
4. Feedback.

The homepage provides a brief description of the project, links to articles, and a contact window where anyone can contact the author of the website if needed. At the top, the site menu is presented, which is intuitive and allows the user to go to the following categories (figure 4).

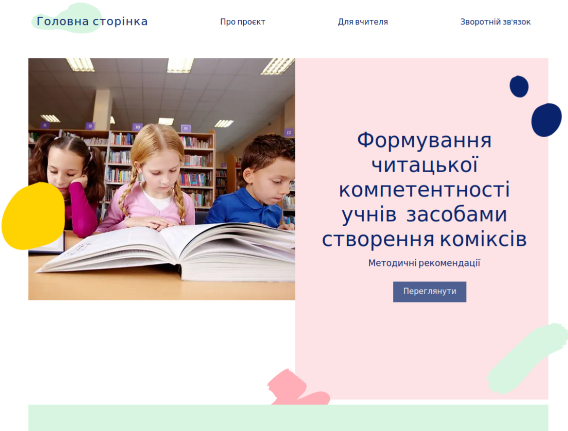

Figure 4: The main page of the developed website.

The section “About the project” provides basic information about the master’s study, the purpose of creating the site, what its work is aimed at, and short theses “Here you will learn”:

- What is a tutorial comic?
- How to work with online services to create comics?
- How to organize work in the classroom using the comic book technique?

The category “For the teacher” contains three subdivisions:

- “Theoretical information”, which provides information about what is the process of reading and its importance in human life, reveals the essence of basic concepts, describes the reasons for the popularity of educational comics, and identifies the strengths of their application in education;
- “Services”, where the user can find a list of free and available online services for creating their educational comics. Separately, in the section, there are links to instructions for the described services.
- “Methodological recommendations”, which provides practical advice and methodological recommendations for working with the technology of using comics in primary school. The unit provides a step-by-step description of the technology of working with comics, describes the preparatory work with pupils, defines the rules for selecting the subject of comics, provides examples of building educational tasks for working with comics and links to online resources for creating educational comics.

Looking at the “Services” section in more detail, users can see the rating from the TOP-3 online services for creating educational comics. This rating of tools was formed based on three key criteria: functionality, affordability (all services are free) and ease of use of the service for both teachers and pupils.

Each presented service contains instructions for use, which the user will be able not only to view but also to download to himself on a PC as a MS Word document.

Each service title contains a link to its main page, which the user of the site will be able to start working on creating his own educational comic, using the downloaded instructions and methodological recommendations presented on the educational website.

Thus, the work of the educational website is aimed at helping teachers of primary education in the development of relevant educational comics using online services Pixton, Write Comics and Comica for conducting lessons in primary school, as well as for methodological support of educators.

6 CONCLUSIONS

1. It has been established that the use of comics with AR elements in primary school is one of the effective didactic means that increases the interest of children in learning, and allows simplifying, visualizing ,and virtualizing complex information. As a result of the analysis of modern cloud services, programs and applications for creating comics, their advantages are highlighted: the availability of services in material terms; a simple interface; the use of templates; the possibility of creating a completely new product and distributing materials; versatility. The major disadvantages have been clarified: a foreign language interface, the need for preliminary preparation for working with them; conversion. The functionality of AR programs for creating content based on comics (Vuforia, EasyAR, Maxst, ARCore, AR.js, 8th Wall) is analyzed. As a result of a survey of 28 primary school teachers, considering the availability, ease of use and functionality, the most popular cloud services are highlighted: for teachers – Pixton; for pupils – Marvel HD and the app installed on the gadget – Comica. Algorithms of the development

of educational materials in these cloud services for the creation of comics are presented.

2. The levels of readiness for the use of cloud services for creating comics with elements of AR (elementary, basic, creative) are highlighted. It is established that most teachers and students have an elementary level of readiness. To improve the real state of readiness of teachers and students to use cloud services, an educational website has been developed. Its goal is to help primary school students and teachers improve their competencies in using cloud services to create comics. Methodological recommendations on the use of comics in primary school using digital technologies have also been developed.
3. The next step of the study will be the implementation of the developed methodological recommendations in the practice of university education, in the system of teachers certification training, as well as further monitoring of the readiness of students and teachers to use cloud services to create comics with AR elements in the main school.

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Mobile Application for Advertising Educational Services and Research the Efficiency of Its Use

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Keywords: Augmented Reality, Vuforia, Intelligence Analysis, Descriptive Statistics, Processing of Data Processing of Data, Advertising.

Abstract: The article shows the use of augmented reality technology and the creation of a mobile application for advertising educational services of the Faculty of Information and Computer Technologies of Zhytomyr Polytechnic State University, Ukraine. Today, augmented reality technologies are one of the most relevant for application in the field of advertising. However, little research has been conducted to determine the effectiveness of its use. The purpose of the study is to create and determine the effectiveness of using a mobile application for advertising educational services. The object of the study is the technology of creating mobile applications using augmented reality technology and analyzing the feasibility of its use in advertising. The application was created using the Vuforia Software Development Kit in Unity and compiled for various platforms. It can be used on iOS and Android mobile devices, creating a wide range of uses. To determine the effectiveness of the proposed mobile application, statistical and visual analysis methods were used, namely descriptive statistics and exploratory analysis. Based on the results of the analysis, the effectiveness of using a mobile application in career guidance has been proven. It is proved that the interest of applicants who have used the created application in the proposed specialties has increased. The proposed mobile application can be used to get acquainted with the list of specialties in an educational institution, increase the information content of advertising flyers and increase the interest of applicants. In the future, it is planned to expand this mobile application for use in all faculties of the university.

1 INTRODUCTION

Human-computer interaction is a dynamically developing area of science. The constant improvement of technology leads to the possibility of innovative user interface paradigms. The globalization of virtual reality has led to the introduction of a new related terms like augmented reality into scientific circulation. If current user interface technologies focus mainly on human-computer interaction, then augmented reality (AR) with the help of computer technology offers an improvement in the interaction between humans and the real world.

At the moment, augmented reality is one of the most relevant objects for research. Augmented reality is a concept that describes the process of augmenting existing reality with virtual objects.

Smartphones and tablets are becoming more powerful as the share of web browsing using desktop PCs is reduced to 48.7% (Wha, 2022). Currently, the number of people using a mobile device exceeds the population of China, India and Europe combined. The balance between mobile and desktop traffic will never be restored.

Currently, the vast majority of educational institutions teach on a state and commercial basis. In addition, the constant increase in the number of private educational institutions leads to the fact that universities are forced to “fight” for each entrant. Having the same areas of training and educational programs contributes to the deterioration of perception and memory of the educational institution by potential entrants and their parents. To attract customers, strengthen their position in the market of educational services and increase competitiveness, universities should use rele-

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vant marketing tools and instruments.

Therefore, the combination of mobile devices and augmented reality technologies will give even more advantages in the advertising purposes of educational services.

Advantages of using AR for advertising purposes:

- informing entrants and their parents;
- creating a positive impression;
- increasing the level of recognition of the university;
- increasing the efficiency of career guidance activities.

On the basis of the Department of Computer Science of Zhytomyr Polytechnic State University, Ukraine, specialists in the field of game development and augmented reality created the software product UniAd. The development was presented in detail on May 20, 2022 at The 5th International Workshop on Augmented Reality in Education at Kryvyi Rih National University.

The purpose of this study is to determine the effectiveness of a mobile application UniAd for advertising educational services of the Faculty of Information and Computer Technology (FICT), Zhytomyr Polytechnic State University, Ukraine using augmented reality technology. It is planned to conduct the study:

- use the data collected during career guidance work;
- make a sample of the required data;
- to conduct intelligence analysis;
- to conduct statistical analysis in terms of various indicators;
- draw conclusions based on the analysis.

2 LITERATURE REVIEW

At the AREdu 2020 (Augmented Reality in Education 2020) conference, AR technologies were considered as part of their use in science education (Burov et al., 2020).

Particular attention should be paid to the development of AR applications as a promising area of research for students (Bilous et al., 2020). The article outlines the essence of AR, directions and advantages of using AR technology in the educational process. It has been proven that AR is a unique tool that allows educators to start a new digital generation in a readable, understandable form and is the basis for developing interest in learning to share work.

The current state and relevance of the use of augmented reality are discussed in many articles. The described developed software application demonstrates the behavior of solar system objects in detail with augmented reality technology (Hordiienko et al., 2020). The described application has its own features, because to implement the distance to the planets uses dimensions in scale that correspond to the real.

The development of technology and the increasing use of mobile devices affects the educational process. He et al. (He et al., 2014) describes a study demonstrating the best results in learning English using AR technology. Using the mobile camera, a bright picture appears to represent the English word on the card. This approach improves children's interest in learning. Vakaliuk et al. (Vakaliuk et al., 2021) demonstrates the possibilities of using AR technology to create a software application in the field of local lore "Monuments of the city of Zhytomyr". The application was tested during city tours with the participation of elementary school students. As a result of this approach, the interest of schoolchildren in studying the history of the native city has increased. Zhou et al. (Zhou et al., 2020) presents a mobile application, the purpose of which is to popularize the lifestyle in augmented reality, allowing users to enjoy it. The initial goal of the project is to give children the opportunity to combine practical skills and visuals in order to better realize multidimensional intelligence development.

Nechypurenko et al. (Nechypurenko et al., 2023) explains the current state of augmented reality (AR) technology use in contemporary chemical education and the potential for using augmented reality technology to enhance students' chemistry research projects. The article describes the development of augmented reality software to support the research activities of 11th grade chemistry students in the form of an AR-based virtual chemical laboratory, as well as its implementation in the teaching and learning process. The article (Krainyk et al., 2019) considers the development of a historical guide based on augmented reality technology. Hruntova et al. (Hruntova et al., 2018) theoretically substantiate the application of augmented reality technology and its features in higher technical educational institutions. Bilyk et al. (Bilyk et al., 2022) shows the feasibility of using augmented reality in the case of STEM education in Ukraine. The expediency of using augmented reality in the case of using STEM education in Ukraine is shown.

All considered articles are aimed at achieving the effectiveness of the educational process. In addition to the educational process, augmented reality technologies are used in various spheres of human life.

The application described in (Jung et al., 2020) is intended for virtual tours of Jeju Island. Sometimes it is difficult to find time to travel, but such software applications allow you to get acquainted with the cultural heritage of even remote regions. Wang et al. (Wang et al., 2021) examines the popularity of augmented reality mobile applications in 4 categories: augmented reality mobile games, advertising, videos and augmented reality shopping for mobile devices. As a result of the research, the author's team came to the conclusion that augmented reality mobile games are most often used.

The role of virtual and augmented reality for accessibility and marketing in tourism is studied in (Ozdemir, 2021). AR has both strengths, such as enriching knowledge, expanding experience, and weaknesses, such as high cost, insecurity. The high cost of both technologies limits availability and marketing.

Wang et al. (Wang et al., 2020) analyzing the status of the application of AR technology in domestic logistics and the benefits of using technology. This article summarizes 36 applications of augmented reality technology in domestic logistics. In addition, the prospects for the application of augmented reality technology in logistics are summarized and analyzed.

Osadchyi et al. (Osadchyi et al., 2021) analyzes the possibilities of using innovative AR technologies in the process of forming the viability of the future specialist based on the implementation of competence and subject-personal approach to the introduction of AR technologies in the educational process. Research by (Hu et al., 2021) aims to study the attributes of theatrical performances using augmented reality in theme parks that affect the emotional experience of visitors. The results showed that the use of AR technology had a positive effect on nostalgia and emotional arousal of visitors, which caused a sense of belonging to the theme park.

Carmigniani et al. (Carmigniani et al., 2011) considers the current state of augmented reality technologies, systems and applications. The problems of augmented reality mobile systems and the requirements for successful mobile systems are considered.

Young and Koo (Young and Koo, 2020) discusses the development of library services of the university with the use of technology and content of virtual and augmented reality (VR/AR). Based on the results of the research, questions were suggested that should be taken into account when using VR/AR technologies and content to provide university library services.

AR is used in various fields and is increasingly used in the educational process. Although research on the use of this technology in education is still scarce, the research literature points to its potential and effectiveness. The research results by Wyss et al. (Wyss et al., 2022) show that students have a very positive attitude towards augmented reality technologies and are very interested in working with this technology. With the advent of information technology, AR has made a significant contribution to industrial applications, namely: medicine, aviation, manufacturing, etc.

Park (Park, 2021) introduces ARLooper, an iOS augmented reality application for multiplayer audio and performance. The aim is to explore the possibility of using mobile augmented reality technology to create new music interfaces and collaborative audio-visual experiences.

Based on the analysis of recent publications and the experience of using augmented reality technologies, it can be concluded that this technology can also be used in education for advertising purposes.

3 THEORETICAL BACKGROUND AND SYSTEM DESIGN

3.1 Augmented Reality Technology

Augmented reality is a concept that describes the process of complementing existing reality with virtual objects. AR is evolving rapidly and is ready to take off and will be as important a technological advancement as the Internet or mobile devices. AR is the most important tool for brands, which attracts consumers, improves communication with people and strengthens consumer confidence. The camera transforms AR from gaming technology into a complete experience that makes people's lives exciting and rewarding. Augmented reality is already here, widely recognized as both interesting and useful, and also promotes rapid implementation and growth. There is an untapped demand to increase the number of applications in AR. Consumer demand for AR needs to be met, and now is the time to act for brands, platforms and developers.

The introduction of augmented reality is associated with a boom in the use of mobile devices – by 2025 almost 75% of the world's population and almost all smartphones users will be frequent users of AR. Deloitte Digital and Snap Inc. conducted a survey of 15 thousand people and published global "Consumer Augmented Reality" report, according to which (Deloitte Digital, 2021):

- 73% of people successfully identify augmented reality when they see it, but when they talk about it, it's hard for them to tell if a description of what it is.

- 65% of augmented reality consumers worldwide use AR to have fun; most discover AR through social/communication programs.
- Augmented reality is usually considered a "toy", but 76% of people expect it and want to use AR as a practical "tool" in everyday life.
- The use of augmented reality technology in advertising leads to a 94% increase in conversion rate compared to companies that do not use AR in advertising. Consumers are 41% more likely to prefer a product that uses AR technology to promote.

AR can be implemented using applications for ordinary smartphones and tablets, augmented reality glasses, stationary screens, projection devices and more. The essence of augmented reality technology is to combine the real image with its complement and the output of the final image on the visualization device.

The basis of augmented reality technology is an optical tracking system. There are several options for using AR technology: marker-based, markerless.

Marker-based technology is easier to use. It is easier to recognize by the camera and gives a tighter binding to the location for the virtual model. This technology works almost smoothly. A sheet of paper with some special image often acts as a marker. The type of image can vary greatly and depends on image recognition algorithms. You can use pictures, photos, booklets, but of good quality. The advertising booklet of the Faculty of Information and Computer Technologies of Zhytomyr Polytechnic State University, Ukraine is used in the work. Before using the booklet, to activate the application, you need to mark it with Vuforia. The booklet image must be less than 2 megabytes in size, with a clear picture or photo. You need to upload it to the Vuforia website and get a rating. It is better not to use a 1-2 star rating, because the speed and quality of recognition will be very low and incorrect program reviews are possible. The booklet to be used has a rating of 4-5 stars. This means that the recognition in the software application does not take much time and will be displayed reproduced information about the specialty.

Marker technology using Vuforia creates static markers and uses them to enable an object to be activated (figure 1).

The left part of figure 1 shows an advertising flyer of the Faculty of Information and Computer Technologies of the Zhytomyr Polytechnic State University, Ukraine. On the right in the same figure is a flyer with markers on it with Vuforia.

3.2 Create 3D Objects

A number of graphics have been developed to create the UniAd mobile AR application. All 3D models are developed in Blender.

Figure 2 shows the main 3D models that were created. The main, but the most time-consuming model is the university building. In addition to the main facility, a number of others have been created. Models of trees whose leaves should have animation – movement in the wind. Models of people can also be seen in figure 2. Each human object has an animation of walking on its own trajectory. Models of benches, lanterns and a model of a fountain located at the main entrance to the university were also created.

In addition to 3D models, the mobile application has added a number of 2D models that act as buttons. With the help of buttons the user has the opportunity to select certain actions (figure 3).

The orange plus button expands a kind of menu with different buttons, where each has its own function. The green button with the letter "i" is responsible for displaying information cards for each specialty of the Faculty of Information and Computer Technology (FICT). The button, with the image of the social network Facebook, will take the user to the main page of FICT in this network. The button showing the point on the map is responsible for the location of the university on Google Maps. The button of the social network Instagram is responsible for going to the main page of the faculty in this social network. The button with the symbol of the university is responsible for the user's transition to the official website of the educational institution.

3.3 Design and Implementation of Individual System Modules

The Unity engine is used to create the program. Its main advantage is the use of a component-oriented system of working with objects. All interactivity and gameplay in Unity are based on three fundamental blocks: GameObject objects, components and variables (Scr, 2022). Any object in the application is a GameObject, be it characters, light sources, special effects, scenery and everything else. Components determine the behavior of game objects to which they are attached and control them.

Figure 4 shows a precedent diagram. This diagram demonstrates possible user actions when using a mobile application. The precedent corresponds to a separate service of the system, determines one of the options for its use and determines the typical way of user interaction with the system. Usage parame-

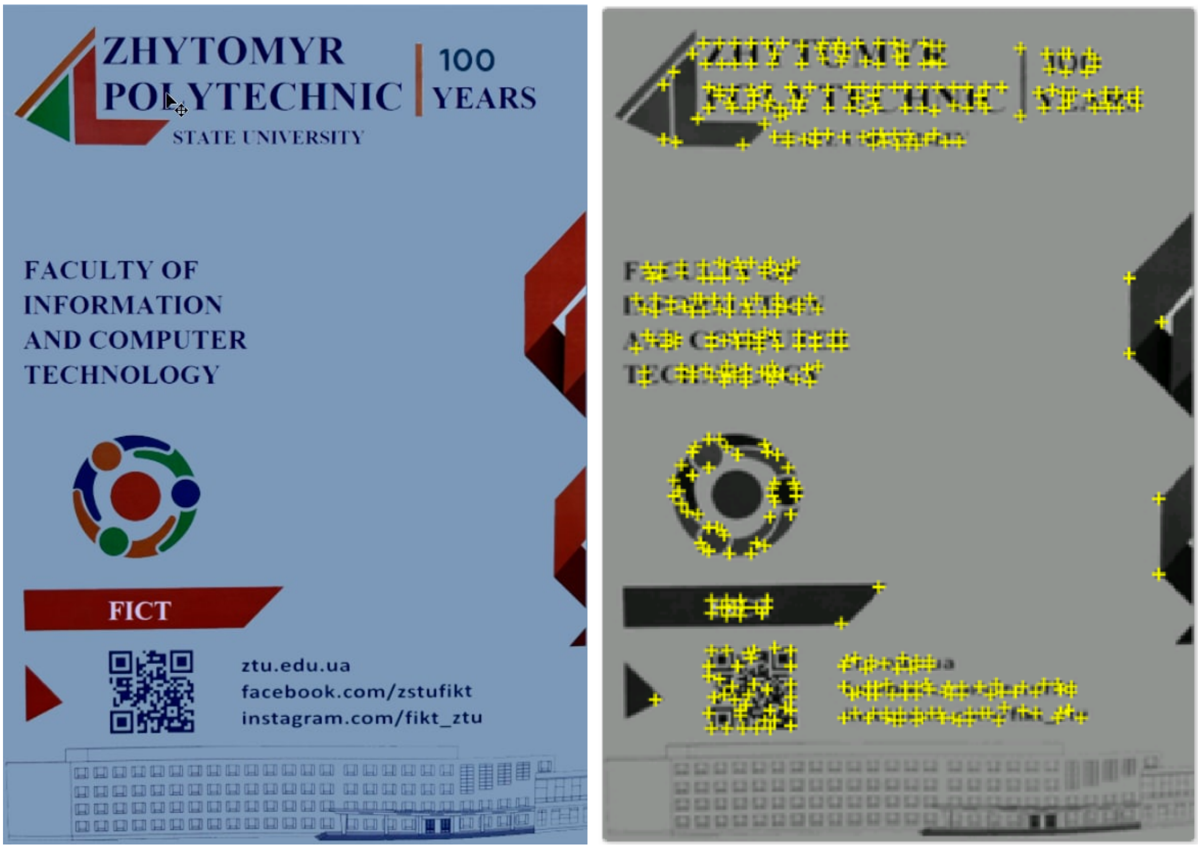

Figure 1: Creating targets on the booklet for the UniAD application.

ters are commonly used to determine system requirements.

The Activity diagram was used to describe the behavior of the mobile application (figure 5). The diagram reflects the dynamic aspects of system behavior. In essence, this diagram is a flowchart that illustrates how the control flow moves from one activity to another.

3D application simulation was created using the Blender development environment. The main model created is the university building. Auxiliary objects on the stage have also been created – bushes, benches, trees, and a fountain, which are partially animated. Many animations have been created in the mobile application. Animation of the university building – it can be viewed from all sides, rotating 360 degrees. Implemented bone animation of 3D characters of students moving near the university. The animator controller is created by Unity and allows you to manage a set of animations for GameObject and switch between them when you need to meet certain conditions.

After launching the mobile application, as soon as the user hovers over the image of the paper advertising, the “Start” button will appear and the melody will start playing. After that, the user can press a button, and then the animation of the appearance of the university as if from the floor and scrolling the building 360 degrees will begin. Other objects located on the ground will also appear. Gait animation is applied to objects in the form of people, the movement of leaves on trees under the influence of wind is realized. The animator controller is created by Unity and allows you to manage a set of animations for GameObject and switch between them when you need to meet certain conditions.

The scheme presented in figure 6 shows the general algorithm of the system. With the help of an AR camera, the focus is on the booklet of the Faculty of Information and Computer Technology. If the appropriate markers are found in the image, the “Start” button is displayed.

Let’s take a closer look at some of the Vuforia methods that were used to create the software application. This piece of code helps to determine how you can “catch” the marker.

```
public enum TrackingStatusFilter {
  Tracked,
  Tracked_ExtendedTracked,
```

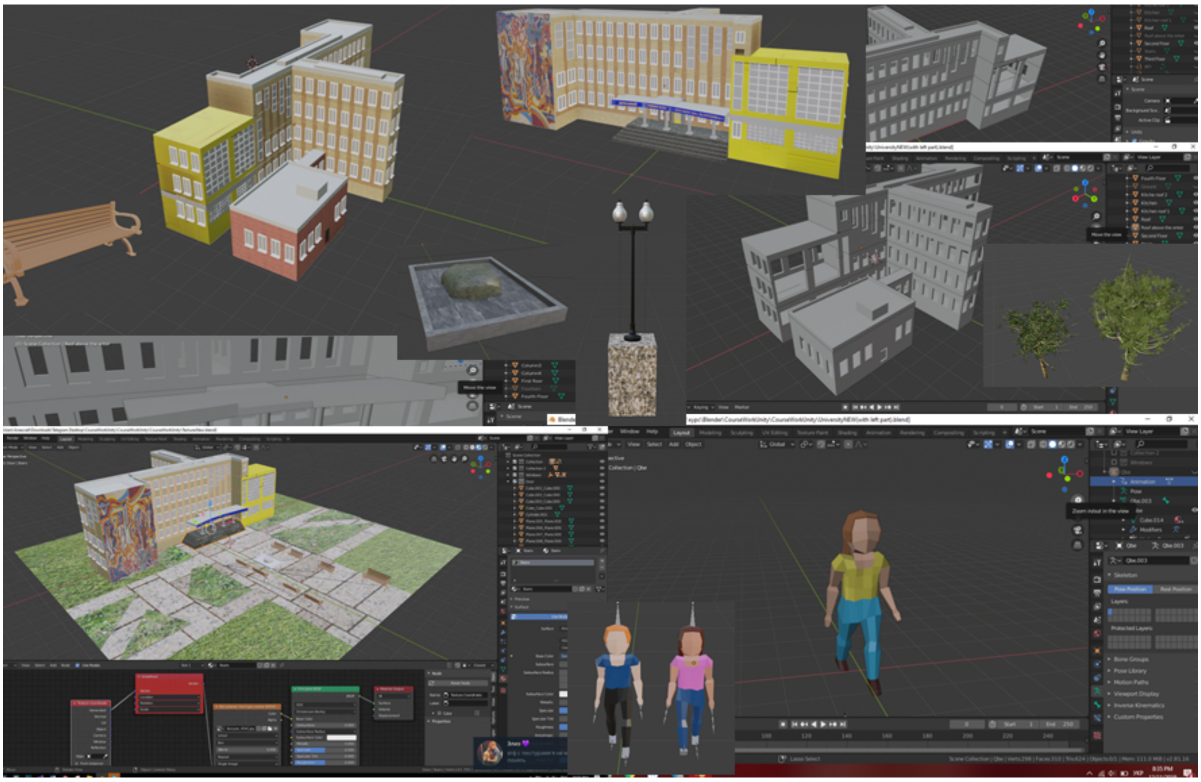

Figure 2: 3D models developed in Blender.

Figure 3: Buttons.

```
  Tracked_ExtendedTracked_Limited
}
```

The part of the code that is responsible for pressing the “Start” button and launching the animation on the stage of the software application.

```
public class GIFShow : MonoBehaviour{
  public GameObject gif;
  public GameObject hide;

  public void ShowGif() {
    if (gif != null) {
      bool isActive = gif.activeSelf;
      if (!isActive)
        gif.SetActive(true);
      else
        if (isActive)
          gif.SetActive(false);
    }
    if(hide != null) {
      bool isActiveHide = hide.activeSelf;
      if(!isActiveHide)
        hide.SetActive(true);
    }
    else
      if(isActiveHide)
        hide.SetActive(false);
}
```

After pressing the “Start” button, the main scene of the program starts. 3D models and textual information appear on the stage. A piece of code that is responsible for tracking the camera’s position and rotates the text toward the camera so that it can be read.

```
public class TextCenter : MonoBehaviour{
  public GameObject target;

  void Start() {}

  void Update() {
    Vector3 targetPosition =
        new Vector3(
          target.transform.position.x,
          target.transform.position.y,
          target.transform.position.z);
    transform.LookAt(targetPosition);
  }
}
```

A sprite animation has been created for each spe-

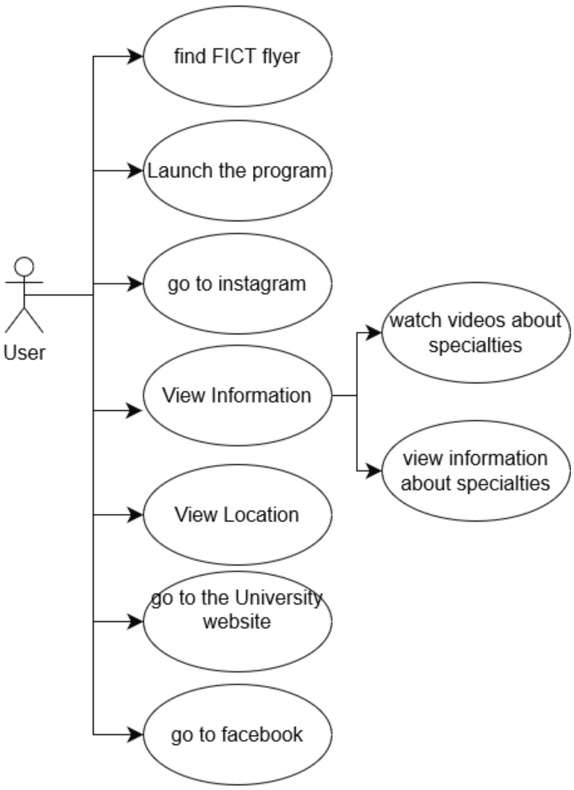

Figure 4: Use Case diagram of a mobile application.

cialty available in the application, which reflects the specifics of the specialty. An array of graphic images is used to play the animation. The part of the code that is responsible for converting an array of images into a sprite animation.

```
public class AnimationGIF : MonoBehaviour
{
  public Sprite[] animatedImages;
  public Image animateImageObject;

  void Start() {}
  void Update() {
     animateImageObject.sprite =
        animatedImages[(int)(Time.time*10)
        % animatedImages.Length];
  }
}
```

The code snippet that is responsible for defining items in the Dropdown menu. Each list item has its own method.

```
public class DropdownAction: MonoBehaviour
{
  public GameObject Image;
  private Animator animator;

  void Start() {
    GetComponent().value  = 5;
  }
  void Update() {}
  public void ShowImage() {
    if(Image != null) {
      bool isActive = Image.activeSelf;
      if(isActive == false)
        Image.SetActive(true);
      else
        if(isActive == true)
          Image.SetActive(false);
    }
  }
  public void ValueChanged() {
    Debug.Log("Choosen element:  " +
      GetComponent().value);
    if(GetComponent().value == 0) {
      Application.OpenURL(
"https://www.instagram.com/fikt_ztu/");
      GetComponent().value = 5;
    }
    if(GetComponent().value == 1) {
      Application.OpenURL(
"https://goo.gl/maps/Me2vbsnkUzmLfxrN6");
      GetComponent().value = 5;
    }
    if(GetComponent().value == 3) {
      Application.OpenURL(
"https://www.facebook.com/zstufikt");
      GetComponent().value = 5;
    }
    if(GetComponent().value == 4) {
      Application.OpenURL(
"https://ztu.edu.ua/");
      GetComponent().value = 5;
    }
    if(GetComponent().value == 2) {
      ShowImage();
      GetComponent().value = 5;
    }
  }
}
```

Unity supports C# scripting that follows one of two main approaches: the traditional and widely used object-oriented approach and the information-oriented approach.

3.4 Mobile Application Interface

The application is implemented using Unity and Vuforia. Vuforia Engine is a software development kit (SDK) for creating Augmented Reality apps. Management is carried out with the help of the camera of the smartphone on which the application is installed,

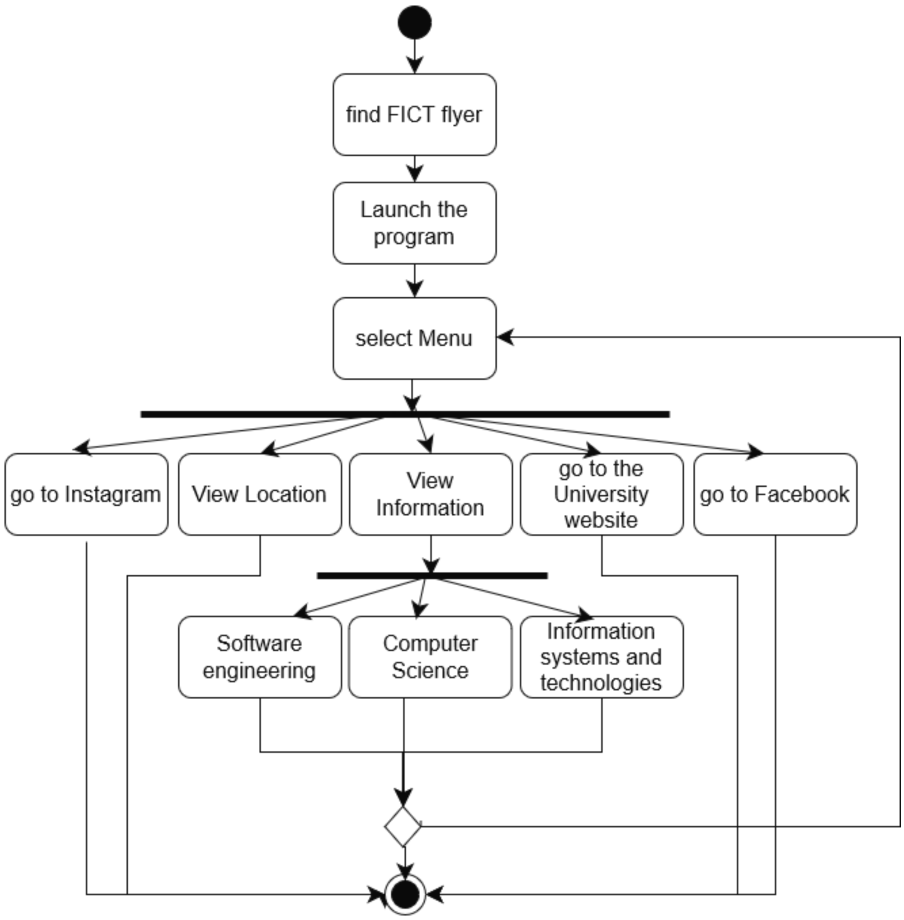

Figure 5: Activity diagram.

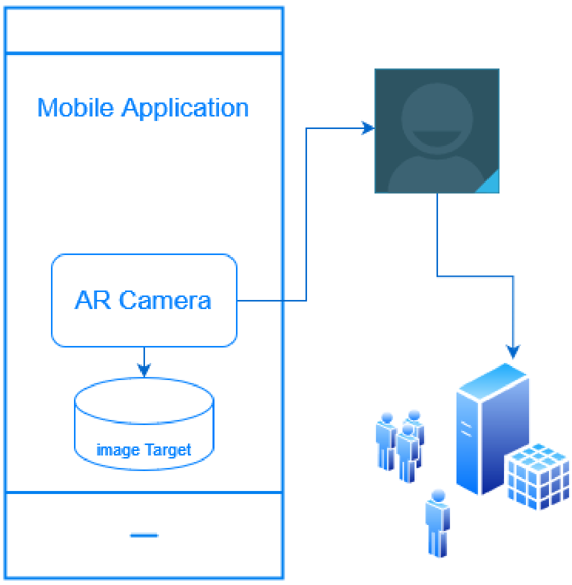

Figure 6: Scheme of project elements and its works.

and the booklet of the faculty on which the user has to point the camera.

The application can be used on devices with Android operating system version 10 and higher and requires 210 MB of free memory. The interface of the application is quite simple. Management is carried out using the camera of the smartphone on which the application is installed, and pictures of triggers (advertising paper advertising of the faculty) on which the user must point the camera.

After launching the mobile application and pressing the “Start” button, calm music starts playing and the animation of the university appearance will start. Near the university there are people who have an animation of walking, trees whose leaves have an animation of rustling, as well as benches, lanterns, a fountain, an inscription above his head. Another “Menu” button appears on the screen. An image of the program after clicking the “Start” button can be seen in figure 7.

Currently, you can view the model of the university by turning around a paper advertisement with ad-

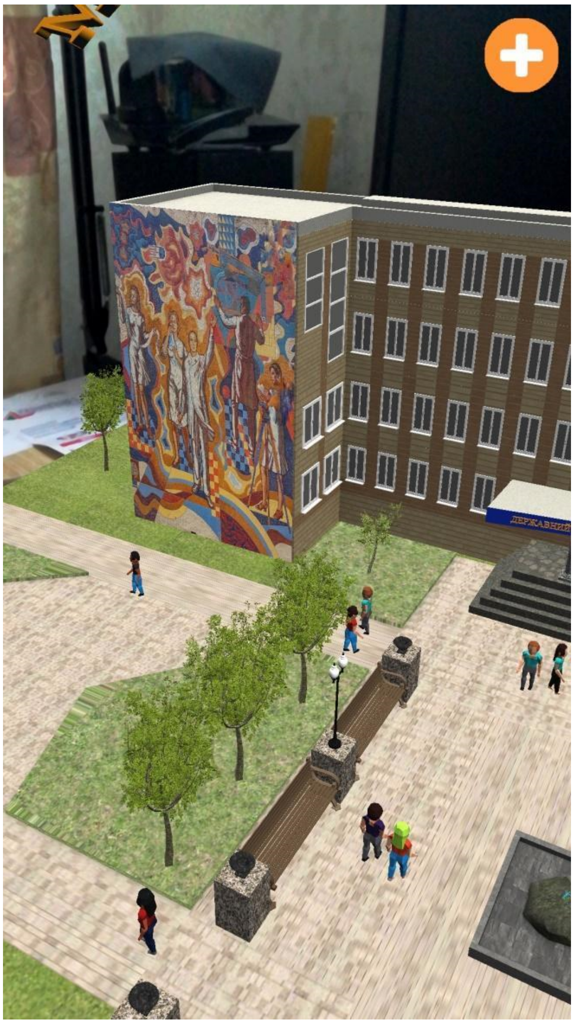

Figure 7: General view of the program after pressing the Start button.

vertising, it is also possible to enlarge or reduce the image of the institution.

The user has the opportunity to open a drop-down menu, where you can go to additional resources of the university: the main site of the university, Instagram, Facebook. It is also possible to open the Google Maps service, which will indicate the location of the Zhytomyr Polytechnic State University, Ukraine.

By pressing the “I” button, the user will open seven cards. All cards have the same design (figure 8 – they are depicted in the form of a rectangle with round edges, but each of them is a representation of a separate specialty at the faculty.

At the top of the card you can see the name and number of the specialty. Below is a list of preferences, subjects or interests about each specialty. At the bottom of the card, the user sees a button labeled “View animation”, when pressed instead of the card appears sprite animation related to the main activity, which is studied in a particular specialty. Figure 8 shows an animation showing an IT professional creating software. This animation reflects the essence of the specialty 121 “Software Engineering”. By flipping the screen to the left, the user can see all the animations and all the cards. To close the card view, the user must click on the “I” icon again.

When the user loses sight of the camera paper advertising with advertising, all objects, music and sounds will be lost. To view the program again, you need to point the camera at the paper advertising again.

4 THE RESULTS OF THE STUDY

The application was intensively used during the career guidance work of the Faculty of Information and Computer Technology in 2021. In the process, a set of data was accumulated, on the basis of which the analysis was conducted. A data set in CSV format was used for analysis. The file contains 1086 records. The data set is represented by the following fields: submitted documents, saw AR advertising, entered the university, competitive score. Among them, 3 fields are categorical data (0 or 1, saw advertising -1 did not see -0) (figure 9).

It is better to use descriptive statistics in the initial stages of the analysis of the created dataset. Measures of the central tendency were considered, where the following indicators were revealed: the minimum value on the competitive score is 125 points, the maximum – 200 points.

The scope is 27 points. The arithmetic mean is one of the most common measures of the central trend. The average value indicates that the “typical” score in the dataset is approximately 160.76. Accordingly, most entrants have a fairly high competitive score. Estimation of tightness established by Spearman’s rank correlation established a connection between two parameters – competitive score and admission. There is still a small relationship between parameters such as admission and ad viewing. The distribution of observations showed the following data: the first quarter is 152, the second quarter – 162, the third quarter – 166. The standard deviation of the competition score is 13.32.

After profiling the file, it was determined that out of all applicants who submitted documents, 630 saw advertising, which is 58% of all submitted documents.

Of all entrants who submitted documents, 60% (652) of applications were submitted for specialty 121 “Software Engineering”, 23.8% (259) for spe-

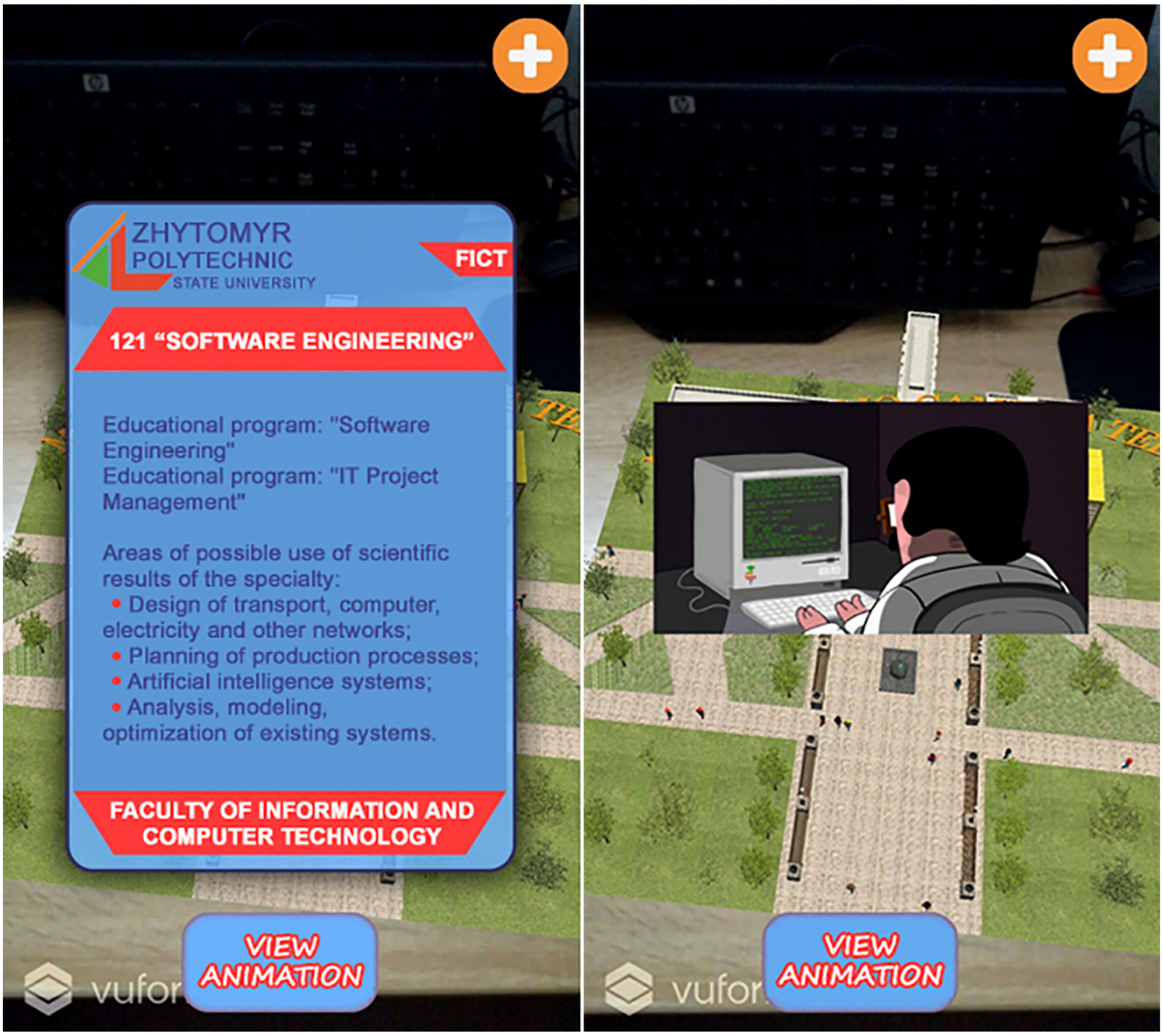

Figure 8: The result of pressing the "I" button

	video_pres	sex	entered	competitive_ball	speciality
0	1	1	1	175	125
1	1	1	1	172	125
2	1	1	1	175	125
3	1	1	1	162	122
4	1	1	1	165	125
5	1	1	1	183	125
6	0	1	0	145	122
7	0	1	0	149	125
8	0	1	0	144	126
9	1	1	1	142	121
10	0	1	0	182	121

Figure 9: Fragment of a data set.

cialty 122 "Computer Science", 6.9% (75) for specialty 125 Cybersecurity, 5.5% (60) for specialty 123 "Computer Engineering", 3.7% (40) for specialty 126 "Information Systems and Technologies".

Of all the applicants who applied, 374 became students of the Faculty of Information and Computer Technology of Zhytomyr Polytechnic State University, Ukraine.

Figure 10 shows the general schedule of all applicants and those who enrolled and those who saw the advertisement. The results show that not everyone who used the mobile application enrolled at the Faculty of Information and Computer Technology of the Zhytomyr Polytechnic State University.

Figure 11 shows the data for the target variable entered. Elements of the sample according to the value of the target variable entered are divided into

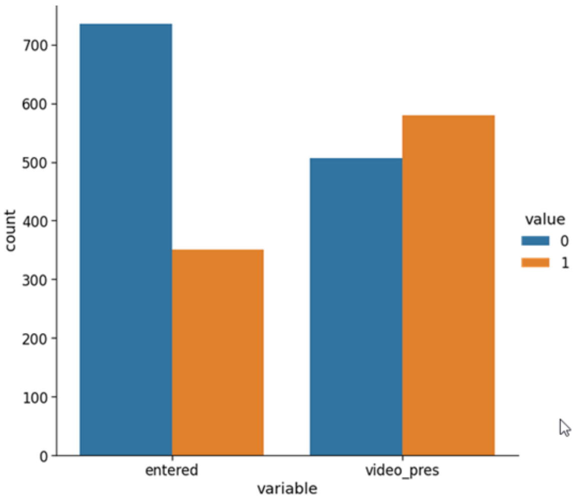

Figure 10: The general schedule of all applicants and those who enrolled and those who saw the advertisement.

two graphs, which show a separate number of applicants who did not enroll in FICT, but saw advertising and those who saw advertising and enrolled in FICT. From the received schedule it is possible to draw conclusions that on two values, the number of entrants who saw advertising is more. This demonstrates the search conducted before admission and increased interest in specialties at the university.

Figure 12 shows a histogram showing the data on the viewing of advertising using the application and the number of students enrolled in terms of specialties FICT. The histogram is an estimate of the central trend for a numerical variable and gives an idea of the uncertainty of this estimate using the error bar. It is interesting to note that in the specialty 122 “Computer Science” the number of entrants who viewed the ad is less than the number of entrants. Although specialty 122 is given special attention to the study of augmented reality technology, on the basis of which the created and researched mobile application UniAd is built. Analyzing in more detail the data of entrants to the specialty 122, it was found that a significant number of students came from other regions of Ukraine than Zhytomyr region (Lviv, Luhansk, Kyiv, Khmelnytsky, Rivne regions) and did not have the opportunity to use applications and are not reflected in the collected statistics. The coverage of a larger number of geographical regions of Ukraine has a great influence.

The results show a significant number of entrants who saw the ad, but did not enroll. This is due to various factors. One of them is the low competitive score of entrants (figure 13). The next factor – the fact that the passing score for admission was quite high (different in each specialty) – this created a significant competition. The graph in figure 13 establishes the relationship between categorical and continuous variables. Vertical segments indicate part of the data of a particular category.

Another factor influencing admission is the lack of budget places (for new specialties), due to which entrants are looking for other specialties or universities.

Considering the data in the context of gender, shown in figure 14, we can observe a much smaller number of female entrants to technical specialties. In contrast, the girls’ competitive score varies between 154-176, which is above the mean, and the standard deviation is less than the total. It should also be noted that girls are more interested in specialties 121 “Software Engineering” and 122 “Computer Science”.

Based on the analysis of the data set, it can be concluded that advertising services using a mobile application based on AR technology are effective. Such applications attract entrants, as information about the specialty is provided in an interesting way. Not always textual information is perceived qualitatively and in full. The information presented in the animated video briefly represents the essence of the specialty that improves perception.

Methods of descriptive statistics and exploratory analysis were used for the analysis. This is implemented using the Python programming language, namely the libraries numpy, pandas, seaborn, matplotlib.

5 CONCLUSIONS

In the process of studying the effectiveness of the use of a mobile application for advertising educational services of the Faculty of Information and Computer Technologies of the Zhytomyr Polytechnic State University was an analysis of data collected during career guidance work. The metrics for the analysis were: the number of entrants who submitted applications, taking into account the specialty, the number of entrants who used the mobile application, the competition score and the number of entrants.

According to the results of the study, we can conclude that it is appropriate to use the developed mobile application. This is proved by the fact that the enrollment of first-year students in 2021 has increased for all specialties of the faculty. The number of submitted applications exceeded the number of licensed volumes by specialties (Marchuk et al., 2023).

Therefore, we believe that the use of augmented reality technology is appropriate to promote the educational process and advertising of the educational in-

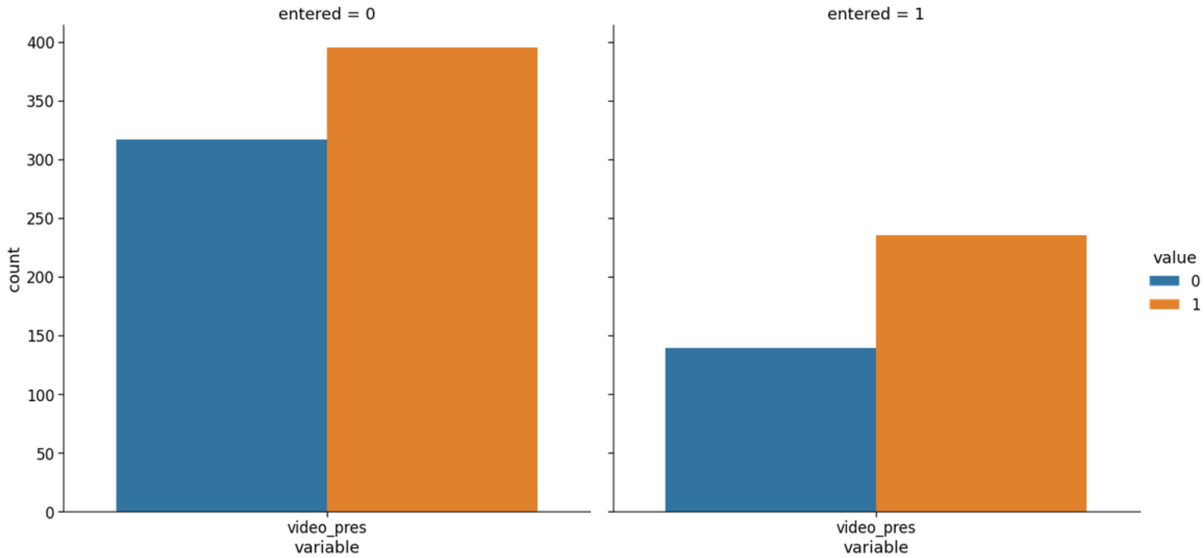

Figure 11: Data on the target variable entered.

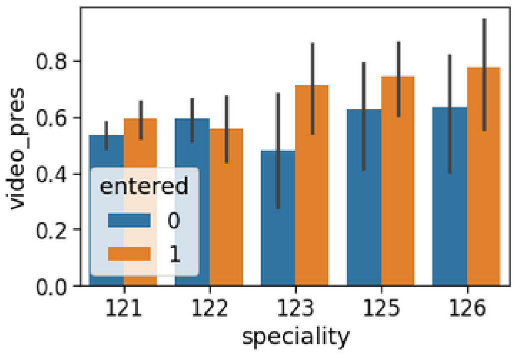

Figure 12: Histogram of views of advertising and specialties entered.

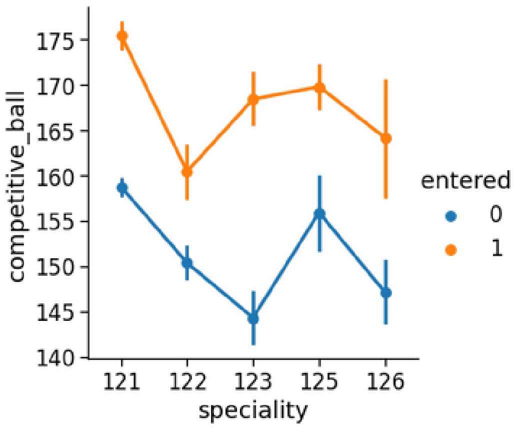

Figure 13: Data on the competitive score of entrants by specialties.

stitution. This will undoubtedly increase the interest of applicants, as well as increase the level of perception of information about the specialties of the faculty. This is achieved through diversity, interactivity and visual presentation of information.

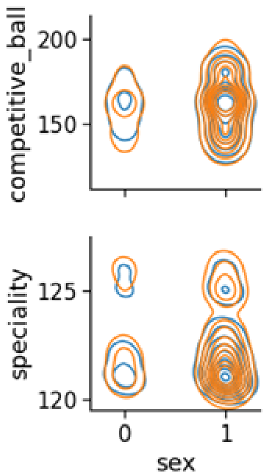

Figure 14: Diagram of advertising views by gender.

The mobile application was tested on the basis of the Faculty of Information and Computer Technologies of the Zhytomyr Polytechnic State University, Ukraine. In the future, it is planned to expand it so that it can be used by various faculties and published in the Play Market.

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Mathematical Interpretation of Educational Student's and Scientific Studies in Form of Digital Ontologies

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Keywords: Ontology, IMRAD, Structuration, Scientific Studies, Biogas.

Abstract: Because of the problem of the large amount of scientific data generated, it is relevant to develop structuring and processing methods. Using ontology graphs is the modern perspective way of their representation. Considering that most studies are written based on IMRAD, it was used to provide integration of different studies at a single structure and provide structuration at all. The different ways to create integrated ontology using IMRAD are described. To get the necessary level of abstraction, IMRAD elements as part of a set of the specific studies were decomposed as levels of abstraction from L1 (general node that describes a branch of science) to L5 (specific papers with detailed data) depending on the abstraction. The content of each node in the form of metadata and its further processing is described. The particular way of using proposed modes has been described in the example of describing studies in biogas production. The mathematical model of the proposed ontology is developed and presented. It is shown that a set of corteges describes IMRAD representation of the scientific studies in the form of ontologies.

1 INTRODUCTION

The data nowadays is generated with colossal intensity. Due to this, Big Data processing is a trend (Globa et al., 2019; Stryzhak et al., 2021). Processing a considerable amount of data in real life is complicated by the high gain of publishing scientific studies. In general, it seems like an exponentially growing of the publications. According to lens.org, in 1900, only 532 M of scientific papers were published, but their amount in 2015 was near 10 B (figure 1).

Considering the development of STEM, studies are provided not only by experienced scientists by youth. Such a considerable number of studies generated complicated tasks to process such data. One of the problems of low spreading and usage (in the example of Ukraine (Hrynevych et al., 2021; Martyniuk et al., 2021; Shapovalov et al., 2020b; Stryzhak et al., 2017)) may be related to difficulties with the processing of science.

Now, scientific studies are published in different forms of report, such as articles, conference proceedings, books, etc. However, its process is complicated due to studies are low-structured. Sure, they are all built by a similar structure named IMRAD (Oriokot et al., 2011; Pardede, 2012). It envisages requirements for the paper to consist of some generalized Introduction, describing used Materials and Methods, naming the Results of the study and the Discussion by comparing with other scientific materials or providing use cases. However, it seems not enough. Here just some examples of problems due to it:

- it is hard to start the researcher carrier due to complicated process of understanding of the methods and equipment that need to be used in specific fields of study;
- it is hard for youth scientists to understand main parameters that have measured to provide study analysis;
- for expired scientists, it is hard to analyze and collect data of new studies.

These are only very few cases that are a problem due to high amount of data of scientific studies. However, these cases are makes relevant to develop new methods to provide better structuration and data processing of scientific studies.

Sure, there are few solutions for this problem that provides automated science data processing (Klampfl et al., 2014; Portenoy and West, 2020; Gorashy and Salim, 2014; Shakeel et al., 2018; Paschke and

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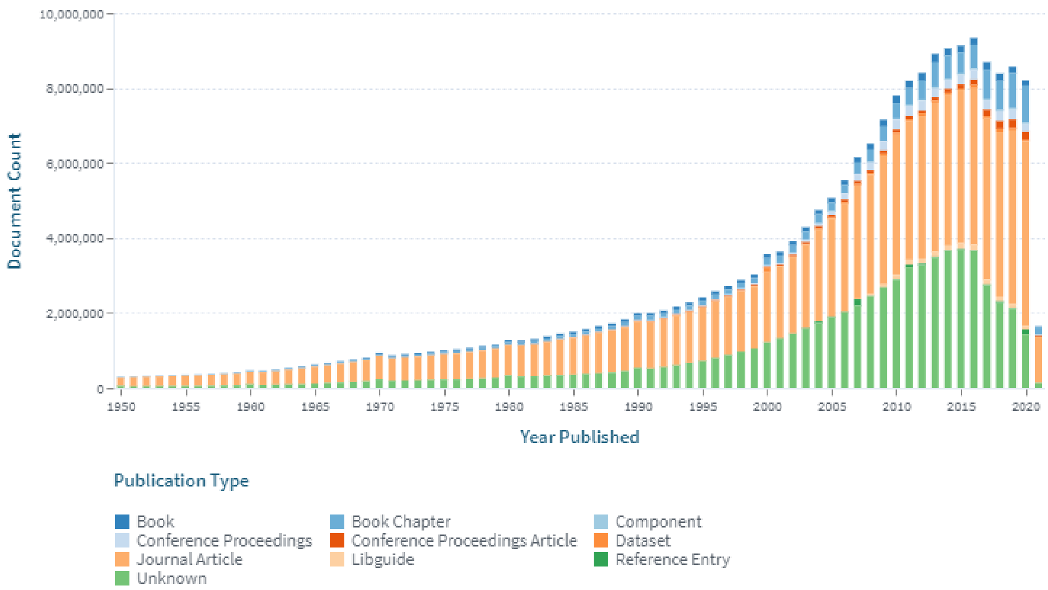

Figure 1: Dynamic of published papers according to Lens.org web service.

Schäfermeier, 2018), but it seems that they do not take to account IMRAD. One of the appropriate methods to solve the problems is ontology taxonomies (Globa et al., 2015; Mintser et al., 2018; Stryzhak et al., 2018; Schäfermeier et al., 2021) with semantic technologies (Alnemr et al., 2010). Also, ontology taxonomies have a lot of advantages, such as the possibility to combine with other types of materials (Gruber et al., 2020), including interactive and web-based courses (Bovtruk et al., 2020; Slipukhina et al., 2018), other information technologies (Markova et al., 2019; Modlo and Semerikov, 2018) and GIS GIS (Stryzhak et al., 2019). This research aims to develop a model that can structure the set of the studies using IMRAD.

Previously, it was proposed to provide support using ontologies for single specific study, but not to create glossaries and structured sets of data. To provide it tools Open provenance, Ontologyt and EXPO (da Cruz et al., 2012) were developed. Another ontology solution in the field of science is MoKi that provides creation of wiki-based information scientific sources (Dragoni et al., 2014; Ghidini et al., 2012). There some specific ontology tools such as Gene ontology (Smith, 2008) or Centralized educational environment (Stryzhak et al., 2021). However, creation of ontology to structure the set of the studies seems relevant due lack of approaches to provide it.

2 METHODS OF THE RESEARCH

In the paper, the ontology model has developed using the main principles of Graph Theory, Set Theory, and a Theory of Abstraction (Giunchiglia and Walsh, 1992). The graph was modelled using a simple hierarchical algorithm that foresees using only nodes and links. So, such a model further may be updated using the more comprehensive graph building tools such as weight coefficients. However, without simple modelling, providing it will not be possible. To provide structuration generally accepted structuring method IMRAD has been proposed and used.

To model data processing was developed taking to account the processing possibilities of the Polyhedron system due it has some advantages compare well known Protégé (The Board of Trustees of the Leland Stanford Junior University, 2020; Ameen et al., 2012) and OWL tools (Sinha and Couderc, 2012; Soldatova and King, 2006). Furthermore, the features of cognitive IT-platform tools Filtering, Audit, and Ranking to provide decision-making (Stryzhak et al., 2021; Shapovalov et al., 2019a,b) were described in equitations to describe the data processing in the ontology model.

3 RESULTS AND DISCUSSION

3.1 Using IMRAD to Provide Structure

As was noted before, IMRAD is used to prepare science papers. So, to provide structuration, it is possible to use parent nodes that represent IMRAD components. IMRAD – Introduction, Methods, Results, and Discussion. The discussion part can't be structured by ontology because it contains the obtained data analysis and comparison. That is why discussion will be represented as the processing of the results.

$$(D \in S) \implies (P \in S) \quad (1)$$

where S – study (or set of studies), D – discussion of studies' results, P – processing of the results of a set of studies.

Approximate, ontology can be devoted to a specific field of science or integrate different fields. Depending on it, the ontology will have 5 or 4 abstract levels of deep. In the case of general ontology, the parent node will be "Scientific studies", and its subsidiary nodes will name a specific field. In the case of a specific ontology, the parent node will name a specific field. Then it links with elements of IMRAD structure. Each element of IMRAD has its specific representation, and it's in turn linked with more specific for the study describing the element of IMRAD. And the leaf node will be a set of specific studies belonging to the field. Let's name each level with L symbols taking to account position in the hierarchy:

L1 – General name of parent's node "Scientific studies",

L2 – Name of field of the study,

L3 – Part of IMRAD,

L4 – Specific representation of IMRAD (specific method, used materials, specific type of the results),

L5 – Specific study where were used specific representations of IMRAD L4.

Therefore, the hierarchy in a specific study will have a form of {L2, L3, L4, L5} or the general ones will have a form of {L1, L2, L3, L4, L5}. Interoperability of the L2 nodes of two different graphs may be provided by using the graph constructor. It provides the possibility to merge graphs in two ways. The first foresees that graphs will be constructed as a general graph in the form of {L1, L2, L3, L4, L5} and with the same name of L1. And the second is to create L1 in the constructor and add there two specific graphs in the form of {L2, L3, L4, L5}. Schematic representation of the general ontology is shown in figure 2, and taxonomy of the specific field is shown in figure 3.

An alternative and a more humanly more human-readable way to provide abstraction are to revert this model and begin with L5 and end with L1. In this case, ontology will have structure form {L5, L4, L3, L2, L1}. The graph based on the abstraction that begins from specific studies L1 and ends by field of the research is shown in figure 4.

However, the main disadvantage of such a graph is evident and is the consequences of the structure:

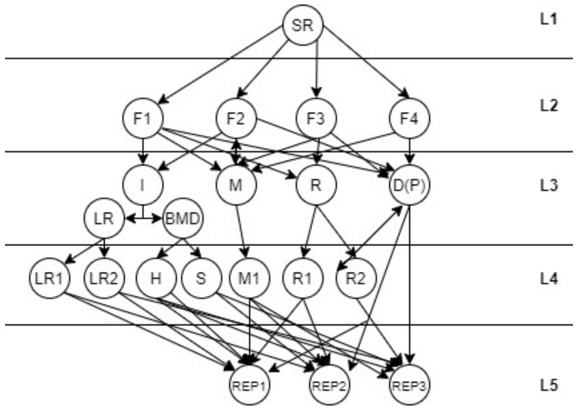

Figure 2: The taxonomy of the general science report ontology, where LR1, LR2, M1, R1, R2 – are abstract classes of literature review (LR), Methods and results of object.

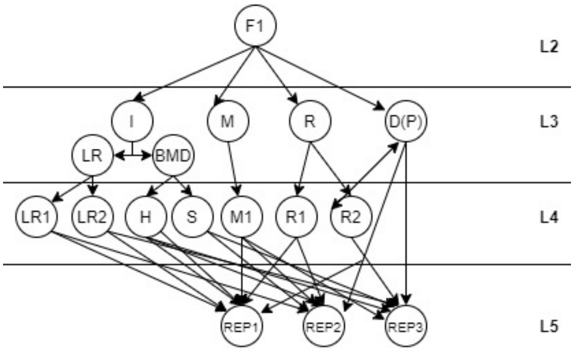

Figure 3: The taxonomy of the specific field science report ontology.

the leaf node SR ("Scientific study") will be not very useful for users. Anyway, this type of graph may be built as {L5, L4, L3} and in this case, it will be used to evaluate the specific report, for example, during qualifying work evaluation (PhD or Master's study). It will show abstract classes of each specific part of IMRAD for each specific study and can provide an evaluation of the set of methods and results that the researcher obtained. Anyway, in this research, we'll use the first way to provide hierarchies in the form of {L2, L3, L4, L5}, and {L1, L2, L3, L4, L5}.

As it can be seen, the general science report ontology is significantly more complicated due to links between L1 and L2 levels, and also, there will be some problems with a vast amount of methods, results, etc. that can be not necessary to the user that looking for information on the specific field. Also, it will be much harder to create such type of graphs due it will have two levels of links "one to many" (see figure 2, links between L2 and L3 level and links between L4 and L5 levels) compare to only one in case of specific ontology (see figure 3, only links between L4 and L5 levels). It may be unreasonable to create a compli-

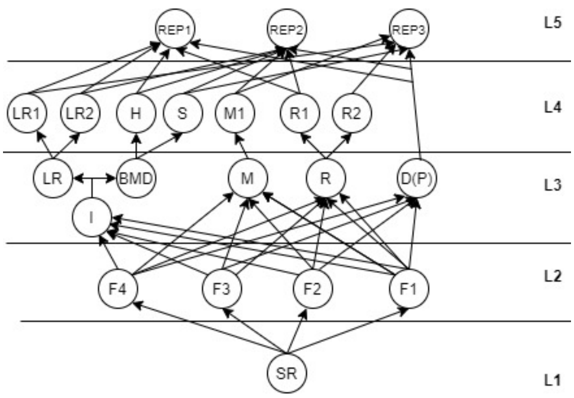

Figure 4: The graph based on the abstraction that begins from specific studies L1 and ends by field of the research.

cated graph. Therefore, it seems relevant to provide both types of hierarchies. To provide it, the ontologies should be created in specific fields and then merged, as noted before.

In this case, specific parts of IMRAD will be used as subsidiaries nodes in the field of the study, and specific studies will be used as leaf nodes. So, the general structure of such ontology may be represented as:

$$\{I, M, R, P\} \in REP \tag{2}$$

where I – sets of Introduction of all studies, M – set of Materials and Methods an of all studies, R – set of Results of all studies, P – processing of the results of a set of studies; replaces discussion; REP – report (or set of report).

To provide better systematization and we have split the introduction into two different parts due to their specific – basic metadata and literature review; it is possible to represent the introduction as further:

$$I = \langle BMD, LR \rangle \tag{3}$$

where BMD – is set of basic metadata of study, LR – set of Sources used for Literature Review.

Basic metadata of the study node linked with graph nodes that characterized the essential data on the study, such as hypothesis, object, subject, practical value, and scientific novelty. And so, a node of the primary report's metadata of the study can be presented as a further equation:

$$BMD = \langle H_i, O_i, S_i, PV_i, S_i \rangle \tag{4}$$

where H – hypothesis or hypotheses of each specific study; O – object of the study; S – the subject of each specific study; PV – practical value of each specific study; SC – the scientific novelty of each specific study.

Each work of the set of the Introductions, Methods, Results, and Processing of the data (Discussion). Then each work will be represented as the future:

$$S_I = \langle I_I, M_I, R_I, P_I \rangle \tag{5}$$

$$S_{II} = \langle I_{II}, M_{II}, R_{II}, P_{II} \rangle \tag{6}$$

So, these articles can be integrated into a single ontology using IMRAD:

$$\langle S_I, S_{II} \rangle = \langle I_I, M_I, R_I, P_I, I_{II}, M_{II}, R_{II}, P_{II} \rangle \tag{7}$$

3.2 Using Taxonomy Nodes as Structure of Science Data

The main advantages of using such structures are that some parts of the introduction (for example, keyword), materials and methods and results elements (entities and measured parameters) of studies/report in the same field can coincide and, in this case, such coinciding sub-nodes will be used as links for them and provide their interoperability. The proposed approach uses IMRAD to collect and process the data with ontologies. In this way, the ontologies are constructed not by the specific structure of each work but by the generally accepted IMRAD structure. The parent node will be a specific area to which a set of the studies belongs to (L2 $= \sum_i^n RS_{Ii}$, where L2 – specific area and RS – set of the represented studies). The L2 node is linked with I, M, R, P nodes (representing IMRAD). Each IMRAD node is linked with a specific node (such as ammonia determination by Nessler's method (for methods) or "chicken manure" or "glycerine" (for subjects)) that belongs to such types. And each specific IMRAD type is linked with leaf nodes of ontology – specific studies where such entities were used.

In this case, a few studies/report (REP1, REP2, and REP3 that belong to L5) will be integrated with some of the methods or results (M1, R1, R2 that belong to L4). So, the L4 level will be used to provide the structuration of the studies (L5). The user can use it in both ways: to find which method, result, etc., that belong to L4 were used in a specific report that belongs to L5; and define in which studies belong to L5 specific method, result, etc. that belong to L4 were used.

The same approach will be provided for each element of the structure. General can be represented as:

$$\text{L4}(M) = \sum_i^n M_i \tag{8}$$

where M_i – every separated scientific method.

Case of coinciding of the methods may be represented as single mortises of methods of each study:

$$M_I = \{M_a, M_b, M_c, M_d\} \tag{9}$$

$$M_{II} = \{M_b, M_d, M_f\} \tag{10}$$

Therefore, in this case, M_b can be used as a parent node that connects two different studies. The node

M_b itself will contain general theoretic information on it, and node S_I and S_{II} will contain information on the specific case of its usage and measured parameters using it.

Also, for example, there will be a hierarchical way of representing and using the keywords:

$$K_w(BMD_i) = Kw_a Kw_b, Kw_c, Kw_d \quad (11)$$

where $K_w(BMD_i)$ – node of the basic metadata that integrates all keywords; Kw_i – specific keyword of the specific research.

In this case, some of the studies, same as for the methods, Kw_i will be elements of two different studies $(Kw_a, Kw_c \in S_I, S_{II})$. This will be useful, especially for students and young scientists looking to find methods (M_I) and parameters that can be used in specific fields and their usage in practice. Also, this way provides a list of the parameters and methods used in specific fields.

3.3 Metadata Processing

The metadata of each work will be used for processing the data. It may be included for each node. For example, metadata of L4 nodes will represent the general information (for example, the essence of the method itself), and the resulting leaf nodes will contain the specific metadata related to a specific study (such as specific results of the study obtained using set methods M; for example, metadata: "5,35", and it's class: "Ammonium nitrogen content, g/l). And so, metadata with the same class will be processed by filtering by users' request or by ranking by providing the rank of nodes by specific class (or their set) based on the user's request. So, each node located on each level E_i contains metadata with the abstract level that corresponds to several levels; for level 1st – it will be the most abstract metadata, and for 5th – it will be the most specific.

As can be seen, all data in levels L1-L4 contains generalized metadata and wouldn't be used to process specific study, but just used to get generalized abstract information on entities used in specific fields. Only the L5 level contains metadata related to a specific study and will be used for further processing.

3.4 Using Metadata to Provide Data Processing

Specific mechanisms "Filtering", "AUDIT" and "RANK" of cognitive IT solution Polyhedron are used to provide processing of the information. It will be used for the case when different studies will have the same Class and Type of information, but different values:

$$\{Class : C1; Type : Number; Value : V1\} \in REP1 \quad (12)$$

$$\{Class : C1; Type : Number; Value : V2\} \in REP2 \quad (13)$$

$$\{Class : C1; Type : Number; Value : V3\} \in REP3 \quad (14)$$

And the values V_1, V_2, V_3 can be equal or not equal. Anyway "Filtering", "AUDIT" and "RANKING" can be used to process the data. Filtering can be described by function if:

If $(V_{min} < V < V_{max})$ then (display nodes with such V)

or

If $(V = V_{set})$ then (display nodes with such V)

where Vmin, Vmax, Vset are maximum, minimum, and given (set) values, respectively, that inputted by the user.

The function of AUDIT can also be described as a function if:

If $(V_i = V_{set})$ than (mark red such V_i); for each V_i.

The ranking is much more complicated and can be described as:

$$RANK_{abs(i)} = \sum(OR_i \times IMP_i \times \frac{V_i}{V_{max}}) \quad (15)$$

where $RANK_{abs(i)}$ – ranking rank in absolute value for i's node OR_i – orientation maximum or minimum for metadata of i's object (can be +1 or -1); IMP_i – importance coefficient for metadata of i's object; V_i – the value of metadata of i's object; V_{max} – maximum value of the set of metadata.

$$RANK_i = \frac{RANK_{(abs(i)}}{RANK_{max}} \quad (16)$$

where $RANK_i$ – the relative value of the rank (can be maximum =1) of each object; $RANK_{max}$ – the maximum value of the RANK for all sets of objects.

3.5 Formalization Description

The object of formalization is specific scientific studies. The result of formalization is a specialized research-oriented subject area formed precisely from existing research and allows to familiarize with the specialized subject area. Any research essentially has the same components (which are proposed to be systematized in the form of graphs) – introduction (landscape, object of research, subject of research, novelty, etc.), methods (a set of methods that ensures the achievement of a scientific result or measurement), specific achievements and results (e.g., systems and approaches developed or metrics) and discussion. All components except the last one can be formalized using the IMRAD approach in such a way that they form an ontology of the subject area of a specific field of research. Discussion, in its essence, is finding the place

Table 1: Description of the metadata on each ontology of proposed ontology model.

MD(L1)	**no metadata**
MD(L2)	{Class: Information about the field; Type: String; Value: Description}
MD(L3)	[MD(LR); MD(BMS); MD(M); MD(R)]= LR, BMS, M, R{Class: General information; Type: String; Value: Describing and detailing of meaning results, methods, literature review, etc.}
MD(L4)	$\sum[MD(LR_i);MD(BMS_i);\{\ MD(M_i);MD(R_i)] = \{$ Class: Essence of the name (specific method, results, etc.; Type: String; Value: Describing of way of providing or specific measured parameter}
MD(L5)	$\sum${Class: all metadata of specific study; Type: Number or String; Value: Text or number}

of this research in the system of scientific research – that is, it is the process of comparing the results of research, numerical and other data with existing other data and providing explanations of the differences of this specific stud. In fact, such processing is provided by the ranking tools and the CIT Polyhedron alternative.

4 DISCUSSION

4.1 Case of Usage: An Example on Biogas Production

So, for the specific case of biogas production studies (Ivanov et al., 2019; Shapovalov et al., 2020a; Plyatsuk and Chernish, 2014; Bochmann et al., 2020), it seems relevant to use ontology for a specific field (in the form of {L2, L3, L4, L5}). In this case, a node in the L2 line will be single and named "Studies on anaerobic digestion". It will be linked with nodes Introduction, Methods, Results, and Processing. As for all other cases, Introduction will be divided into Basic Metadata and Literature review (L3 level).

Basic Metadata will be linked with nodes Objects, Subjects, Aims, Practical Value, Scientific novelty, Hypothesis, Keywords, Abstract, Conclusion (L3 level).

Each of these nodes will be connected with specific nodes relevant to the set of the structured studies (L4 level). Each specific L3 will have metadata with general information on the described object. So, an example of values of metadata in the "Basic metadata" elements node in the L4 level is shown in table 2.

*verbs "are defined" or "has provided" etc. and articles "the", "a" and "an" aren't use due to their huge vitiation and to provide better structuration and to have more coincidences between nodes and metadata

Each such node will be connected with the study where it was used (L5 level). For example, "Biogas production from the poultry waste" or "Utilization of the meat production wastewater using anaerobic digestion".

The Literature review node (L4 level) will be connected with specific studies used in a set of studies. Its name will be the name of the study (paper, article, conference processing, thesis, etc.), similar to the name of the study used to provide structuration with the addition of the publishing year. For example, it can be named "Utilization of the meat production wastewater using anaerobic digestion, 2011". In addition, each such node should be connected to one of the few studies used to provide structuration (L5 level).

The most useful will be Methods and Results nodes. They will be helpful to students and youth scientists who want to be familiar with methods used in the field and set the measured parameters used in the field of science. Sure, the established scholars will use such a tool too to increase outlook. The Materials and Methods node will be divided into Methods, Equipment, and Materials. An example of material and methods and results nodes, their links and metadata are presented in table 3.

Each such subsidiary node is connected with a leaf node that is a specific study. For example, the Processing node has metadata with type link and its value in the form of a link to Audit and Ranking tools for the structured set of studies. Detailed algorithms of its usage are described before.

Each work has metadata that mostly duplicates the structure. For this, all numeric and semantic data of the works is added to a node of the specific work it belongs to. Examples of the metadata of the leaf nodes are presented in the table. It is foreseen to provide automatically. For example, it will be necessary to provide filtering, Audit, and ranking. An example of metadata and its classes (subclasses) of the specific report node is shown in table 4.

Table 2: An example of “Basic metadata” elements nodes in L3 level and linked with them nodes in L4 level.

Parent’s node (L3)	Metadata of the parent’s node	Linked nodes (L4)
Objects	General definition of the elements of basic metadata	“biogas production”, “inhibition”, “waste utilization”
Subjects		“Effect of ammonium nitrogen content on biogas production”, “Optimization of the process of waste treatment by optimization of the waste destruction rate”
Aims		“Provide mathematical modeling of the anaerobic digestion of high-ammonium waste”, “Define of influence of the addition of spirulina to the process of anaerobic treatment of straw”
Practical Value		“Main kinetic parameters of the anaerobic digestion”, “Model of ammonia effect on the anaerobic digestion”
Scientific novelty		“Relation between ammonia content and biogas production”
Hypothesis		
Keywords		“Straw”, “Sludge”, “Meat wastewater”, “Biogas”, “Methane”, “Ammonium nitrogen”
Abstract		–
Conclusion		–

Table 3: An example of material and methods and results nodes links and metadata

Parent’s node	Metadata of the father’s node (type: text)	Linked subsidiary nodes	Metadata
Methods	General information what is methods	“Dry organic matter by frying”, “Methane content in biogas using gas chromatography”, “Free acid content by titrimetric method”	Methodology of using of each specific method (type: text)
Equipment	General information what is equipment	“Digital microscope”, “Burette”, “Gas chromatograph”	Description of each specific equipment (type: array) Link to ontology of the equipment (type: text)
Materials	General information what is material	“Straw”, “Sludge”, “Meat wastewater”, “Water”	Description of each specific materials (type: text)
Results	General information what is results	“Biogas”, “Methane”, “Ammonium nitrogen”	Description of each measured parameter (type: text)

4.2 Role of the Proposed Model

Ontology models are the basis of the effective ontology creative process. Such models like proposed and others (for example, ontologies of educational environments, will be useful to build a set of the different ontologies and have similar conceptual states of abstraction. Using such approaches and providing semantic technologies can be useful to provide interoperability (Alnemr et al., 2010).

Sure, the proposed research focused on the ontology of the specific field in the form of {L2, L3, L4, L5}, but it is proposed to use an integrator of the ontologies of fields and create general ontology in the form of {L1, L2, L3, L4, L5}. The proposed integration is important to provide transdisciplinary (Dovgyi and Stryzhak, 2021). The proposed approach will be useful and relevant for most fields. Anyway, it will be very specific to process humanitarian data where less standardization and numeric data, but it seems that some automated tools like recursive reducer (Stryzhak et al., 2018) can process and provide structuration even in such fields.

4.3 Perspectives of Development

Currently, the proposed approach has a few user stories implemented by the proposed model. They are helpful for all scientists, but as the development of the proposed model was provided in the Navigational center Of Junior Academy of Sciences of Ukraine, it has much more advantages for youth students involved in activities of the organization. The mathematical interpretation of educational students and sci-

Table 4: An example of metadata and its classes (subclasses) of the specific report node.

Name of class	Name of subclass	Type	Values example
Methods	–	Array	"Dry organic matter by frying", "Methane content in biogas using gas chromatography", "Free acid content by titrimetric method"
Results	Biogas content, ml/ g TS	Number	"305.15"
	Methane content, %	Number	"55"
	Ammonium nitrogen content, g/l	Number	"3.6"
Materials	Straw/TS content, %	Number	"95"
	Straw/Ammonium nitrogen content, g/l	Number	"0.3"
	Sludge/TS content, %	Number	"0.05"
Main metadata	Keywords	Array	"Straw", "Sludge", "Meat wastewater", "Biogas", "Methane", "Ammonium nitrogen"

entific studies in the form of digital ontologies provides the possibility to easily manage information of science studies to simplify finding of relevant studies and simplify familiarization process with some specific subject area.

The proposed approach

1) allows very quickly (especially for a young scientist) to research the subject field related to this field of research by using → Introduction → Keywords (contains the main terms of the subject field of specific research) and other components of the Introduction (for example, scientific novelty formulates the directions of research, which formulates relevant research directions);
2) allows to process numerical research data using the ranking tool and find such works that are necessary for research;
3) allows you to quickly familiarize with the existing research methods used in this field → Methods;
4) allows to quickly familiarize with the indicators used in research in a specific field (→ Results) Communication with L5 vertices is essential because it is he who forms the novelty (since the approaches to the ontological display of subject area have been known for a long time);
5) allows the researcher/student (young scientist) to quickly find practical examples where this or that element of research is used – for example, quickly find all works where ammonia was measured using the Nessler method or works where graph theory was used.

In addition, this approach has the potential for development, which is as follows:

- the possibility of providing scientometrics based on ontologies (similar to scientific databases) – since it is possible to calculate how many times a particular work has been referred to due to the connections in such a taxonomy;
- the possibility of interoperability providing with educational programs;
- the possibility of adding one's own research for a few clicks to the general ontology.

5 CONCLUSIONS

It is firstly proposed the model of ontology based on IMRAD to provide a set of different studies that belong to the same field and to provide generation of the integrated ontology that collected the data of different fields. Using such a method will provide both structuration of the set of studies by using specific elements of IMRAD that belongs to the set of the studies of the same field and processing such studies' data.

A specific case of usage is shown in the example creation of such ontology in the field of biogas production. It is shown in both model and example using single sets of keywords, results, methods, etc., to provide structuring and data processing.

It seems relevant to provide additional further studies of the proposed model to improve it and make it even more automatized, for example, by using weight mechanisms.

The proposed approach in case of providing property infrastructure and widespread will provide interoperability of data located in papers. Therefore, it will simplify providing of scitintific studies and simplify determination of relevance and practic value of scientific works. To provide such interoperability graphs of specific fields should be created and proivded their further merging. So, the onotologies type {L2, L3, L4, L5} must be integrated into single one with form of {L1, L2, L3, L4, L5}.

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The Current Level of Competence of Schoolteachers on How to Use Cloud Technologies in the Educational Process During COVID-19 and the Russian-Ukrainian War

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Keywords: Competence, Cloud Technologies, Cloud Services, Distance Learning, Educational Process, COVID-19.

Abstract: During the period of total lockdown, teachers had to move to distance learning to organize a continuous educational process, which is not possible without the active use of modern information and communication technologies, including cloud services. Because of this, at the beginning of the pandemic, Zhytomyr Polytechnic State University conducted several free distance online courses for teachers, which included studying the possibilities of using cloud technologies in teaching in a pandemic. Somewhat later, some secondary schools in Zhytomyr expressed a desire to take the same courses, but in person. 98 teachers of schools of the city of Zhytomyr were covered by training on courses "Cloud technologies in the educational process in the conditions of quarantine". After face-to-face courses, teachers in Zhytomyr schools have significantly increased their competence in the use of cloud technologies in the educational process in the context of the COVID-19 pandemic. Not only has their level increased in general, but the horizons regarding the variety of cloud services that should be used in distance learning have expanded. Course training, organized according to scientifically sound methods, helps to increase the motivation of students (teachers) to self-study, as well as to the future use of cloud technologies in the educational process. The two-year pandemic and the start of a full-scale war between Russia and Ukraine contributed to the fact that teachers of secondary schools began to actively engage in self-education and self-development. If earlier (at the beginning of the pandemic) it was difficult for teachers to switch to online learning, then with the outbreak of war, teachers were already ready to use various online tools in their practice. As the study showed, all the interviewed teachers continued their self-education in different ways, studied a large number of services that can be used in the educational process, and provided the authors with ideas for further expanding the courses according to their desires, which should be used in the educational process. It should be noted that it is important that all the respondents unanimously approved that they use the acquired competencies in their professional activities during the period of Russian aggression. In addition, in additional comments, teachers noted that among their acquaintances there are many teachers who want to take such courses since at one time they had no desire or motivation.

1 INTRODUCTION

With the spread of COVID-19, the educational process of foreign and domestic educational institutions

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is undergoing significant changes. During the period of total lockdown, teachers had to move to distance learning to organize a continuous educational process, which is not possible without the active use of modern information and communication technologies (ICT), including cloud technologies and services. Many teachers had to simultaneously increase their competence in using such services and teach students to do it. Students and teachers had to cope with many challenges for the proper and effective use of cloud services in the organization of such training.

With this in mind, at the beginning of the pandemic, Zhytomyr Polytechnic State University conducted a series of free distance online courses for teachers, which included studying the possibilities of using cloud technologies in teaching in a pandemic. A scientifically sound methodology was developed, which contained a semantic component with a list of topics and features of forms, methods, and means of conducting such courses were described in the previous work (Vakaliuk et al., 2021b). 1,500 teachers were registered for the course, and 816 people completed the course. Therefore, some institutions of secondary education in Zhytomyr expressed a desire to go through the same courses, but full-time mode. It was decided to hold such courses for schoolteachers. Before starting the courses, it was necessary to find out the current level of their competence in the use of cloud technologies in the educational process in the context of the COVID-19 pandemic. The courses were held at Zhytomyr Polytechnic State University in August 2020 full-time.

2 THEORETICAL BACKGROUND

Throughout the pandemic, scientists from around the world have raised questions about the use of different information and communication technologies in the educational process, the introduction of distance and blended learning, and more.

In particular, Nagaraju et al. (Nagaraju et al., 2021) analyzed the effectiveness of online learning during the COVID-19 pandemic and studied adapting teaching and learning in times of COVID-19. According to an online survey of 683 respondents (teachers and students), 38% did not even start such training, although it is inevitable in such a situation.

Falfushynska et al. (Falfushynska et al., 2021) identified various ICT tools for the implementation of distance learning, including Zoom, Moodle, Google Meet, BigBlueButton, and Cisco. The study showed the satisfaction of subjects and their positive attitude to distance learning, satisfaction with the quality of such tools. During the pandemic, the readiness of students and pupils to organize independent learning becomes especially important, which requires them to be motivated to learn, keep track of time, can use modern ICT, self-discipline, and control.

Korobova et al. (Korobova et al., 2019) created an educational environment uses Google's cloud services, the use of which allows taking into account the individual characteristics of students in education, the geographical region of their residence, etc.

Korobeinikova et al. (Korobeinikova et al., 2020) show an example of the use of cloud services in their activities as a means of improving student learning and teaching disciplines, in particular Google Classroom, which allows you to manage the independent work of students while studying disciplines. The authors emphasize that when organizing the educational process using cloud technologies, it is necessary to move to the application of the model of blended learning in universities.

The analysis of domestic and foreign experience in the use of cloud services for the formation of professional competence of future teachers is demonstrated by Shyshkina and Marienko (Shyshkina and Marienko, 2020). Particular attention is paid to the development of the professional competence of future mathematics teachers. Researchers have defined this competence and identified two components: digital and subject competence. Emphasis is placed on the feasibility of using cloud services in the formation and development of this competence, in particular, the prospects for using the CoCalc cloud service are described.

The issue of professional training of teachers for the organization of learning with the help of cloud services was studied by Velychko et al. (Velychko et al., 2021), who conducted a survey of mathematics teachers on the use of ICT in the educational process. The authors found that 82% of mathematics teachers who participated in the survey use cloud services in education, implement on their basis modern methods and forms of teaching, use a variety of modern cloud services to teach mathematics.

The connection between the concepts of cloud systems and cloud learning environments is covered in the study of Popel and Shyshkina (Popel and Shyshkina, 2019). The authors define the cloud learning system as a component of such an environment. Scientists consider approaches to defining the cloud learning system – the first approach is based on the definition of such a system as a set of cloud services or technologies, the second – defines the cloud learning system as a separate type of cloud service (Popel and Shyshkina, 2019).

The use of cloud services in the organization of training affects the quality of training of future professionals. Such practical experience is described in (Volikova et al., 2019). It is emphasized that it is impossible to build a new educational environment without cloud services as a means of learning, which is a powerful tool for mastering new competencies of both teachers and students in the study of fundamental disciplines.

Markova et al. (Markova et al., 2019) dealt with the research of cloud learning technologies, cloud-based learning environment, provision of cloud educational services for the organization of professional training of future IT specialists, who concluded that it is advisable to use different models of cloud services (SaaS, PaaS, IaaS), as well as the possibilities of new tools for parallel programming.

In (Astafieva et al., 2019) the expediency of using cloud learning technologies for the formation of skills of future teachers of mathematics of the 21st century, in particular critical thinking, is emphasized. The authors consider forms and methods of teaching based on the GeoGebra computer system and cloud technologies. To evaluate the effectiveness of this approach, the methods of fuzzy set theory are used.

The professional competence of a teacher according to European standards is described by Morze and Glazunova (Morze and Glazunova, 2019), which presents a model for the development of this competence of information technology teachers, consisting of stages, subjects, and resources. The authors emphasize the need to use existing e-CF and ISTE standards to develop this competence in teachers.

In the conditions of the introduction of cloud services and means of distance learning in the educational process of modern secondary education institutions, one of the main competencies of teachers becomes information and communication competence. The methodology for the development of this competence in teachers of the military education system is presented in (Yahupov et al., 2020), in particular, the main tasks of its development are identified. Teaching aids have been identified, among which ICT tools are mandatory: computer-based educational systems in the multimedia versions; laboratory remote workshops; simulators; electronic libraries with remote access, etc. In addition, the expediency of the introduction of active learning methods, which are implemented through the use of computer networks, audio-video, and other telecommunications, including the Internet.

In (Moiseienko et al., 2020) one of the modern competencies is considered – digital, as one of the factors of formation of the information society in Ukraine. Based on the analysis of the definition of digital competence, its interpretation is given, the didactic conditions of its formation are singled out.

It is also worth noting that a number of authors have studied the development of digital competencies associated with the use of cloud services. Basilotta-Gómez-Pablos et al. (Basilotta-Gómez-Pablos et al., 2022) study a systematic literature review for teachers' digital competencies in higher education; Findeisen and Wild (Findeisen and Wild, 2022) research general digital competences of beginning trainees in commercial vocational education and training; Spada et al. (Spada et al., 2022) explored problems are universities ready to deliver digital skills and competences. Tzafilkou et al. (Tzafilkou et al., 2022) are development and validation of students' digital competence scale. In particular, Vakaliuk et al. (Vakaliuk et al., 2021a) also studied the formation of digital competence of CS bachelors in the use of cloud-based learning environments, and Morze et al. (Morze et al., 2022) researched systems for digital professional development of university teachers.

According to Spirin (Spirin, 2019), any individual can move faster in learning a new profession through online courses. Because with such training there is a possibility to combine online and offline courses. Various platforms have recently been used to conduct online courses, such as Coursera, MIT OCW, Prometheus, Udemy, edX, Udacity, Stanford online, etc. The author pays special attention to course aggregators. In particular, Course Buffet is an aggregator that allows you to choose a specialization from a certain set of courses. This specialization will correspond to the number of credits in the specializations of different universities around the world. As a result, it is possible to study according to the same subject load as at the university, where the educational process takes place according to traditional teaching.

In the conditions of quarantine in March-April 2020 in Ukraine in general secondary education institutions, the use of the web service Zoom for conducting video lessons in combination with Google Classroom became widely popular. However, the use of the latter imposes some requirements and restrictions, in particular:

- participants must have a Google account;
- the system must be registered as an educational institution, otherwise, the teacher's own disk space is used, which is limited for an individual user;
- Google's children's profile is limited to 13 years for the free use of resources, including no access to videos used for educational purposes on YouTube.

In addition, as of the end of December 2022, the most popular (in terms of trust rating and a number of downloads from Google Workspace Marketplace) digital video conferencing services, webinars, and organizers are: Zoom, Yamm, and MS Teams (Google, 2022).

That is why the purpose of the article is to determine the current level of competence of schoolteachers on how to use cloud technologies in the educational process during COVID-19 and the Russian-Ukrainian war.

3 RESULTS

The purpose of training on the courses "Cloud technologies in the educational process in quarantine" was to get acquainted with the basic methodologies of using cloud technologies in education; a general overview of existing cloud technologies and consideration of the main provisions of cloud technologies for use in the educational process. The course was completely identical to the course conducted in the period March-April 2020 (Vakaliuk et al., 2021b). The main difference was that teacher training was conducted traditionally – in the classroom.

98 teachers of schools of the city of Zhytomyr were covered by training on courses "Cloud technologies in the educational process in the conditions of quarantine". At the beginning of the course, a survey was conducted to clarify general issues. To the question "Do you have a computer (laptop) at home?", 98.98% of respondents answered in the affirmative.

The same answer was given to the question "If you have a computer at home, is it connected to the Internet?" and "Can you find the information you need on the Internet?" (figure 1a). Interestingly, 100% of respondents indicated that "the Internet is necessary for his / her professional activity".

These general questions are also important because, unfortunately, nowadays not all teachers (including those from villages) have their own computer or access to the Internet.

In response to the question "Are you able to choose and use software to optimally present the different types of materials needed for the learning process?", 63.92% of respondents indicated that they know how to choose and use software for optimal presentation of different types of materials, necessary for the learning process, while all the others answered that they do not know how (figure 1).

The next question of the general unit was whether teachers have their website or blog. In response to this question, only 23.71% of respondents answered that there is, and 76.29% do not (figure 2) At the same time, 96.91% of respondents indicated that they had a website for their school, and only 3.09% said no (figure 2).

The following questions were about whether the course participants know what cloud technologies and services are, to which 60.82% of respondents answered in the affirmative, 39.18% answered "no" (figure 3). At the same time, only 44.9% used cloud technologies in teaching their subject before taking the courses, and 55.10% did not use them before taking the courses (figure 3).

The following questions served to establish the competence of teachers on the use of cloud technologies in the educational process during COVID-19 and were studied before and after the courses that included the acquisition of basic competencies for working with cloud technology in the educational process in the conditions of a pandemic.

When finding out what motives motivate teachers to use cloud technologies in the educational process (table 1 and figure 4), it was found that more than 50% of respondents in both cases chose the need to be able to use different cloud technologies (at the end of the experiment respondents who chose this type of motive increased by 4.2%), the need for self-study using various cloud technologies at the beginning of the experiment was chosen by 25.54% of respondents, at the end – 22.10%. Regarding the other two motives – there was an interesting dynamic: the need to be acquainted with cloud technologies before the experiment chose 10.2%, after – 5.81%, when choosing the need to study the main types of cloud technologies – the situation was the opposite – at the beginning of the experiment 6.12%, at the end – 11.63%. Accordingly, at the beginning of the experiment 2.04% and at the end of 1.16% of respondents did not see the need to use cloud technologies in the educational process in general.

In general, according to the results of the survey, after the courses, the motivation of teachers to use cloud technology in the educational process has increased.

Determining which of the proposed motives motivate teachers to self-study using cloud services, it was found that 76.54% (before the experiment) and 69.88% (after the experiment) of respondents chose the need for self-improvement and self-development in future professions; the need to understand the significance of the acquired skills before the experiment was chosen by 12.24% and after – 16.87%; the need to understand the significance of the acquired knowledge was chosen by 10.2% and 7.23%, respectively (table 2 and figure 5).

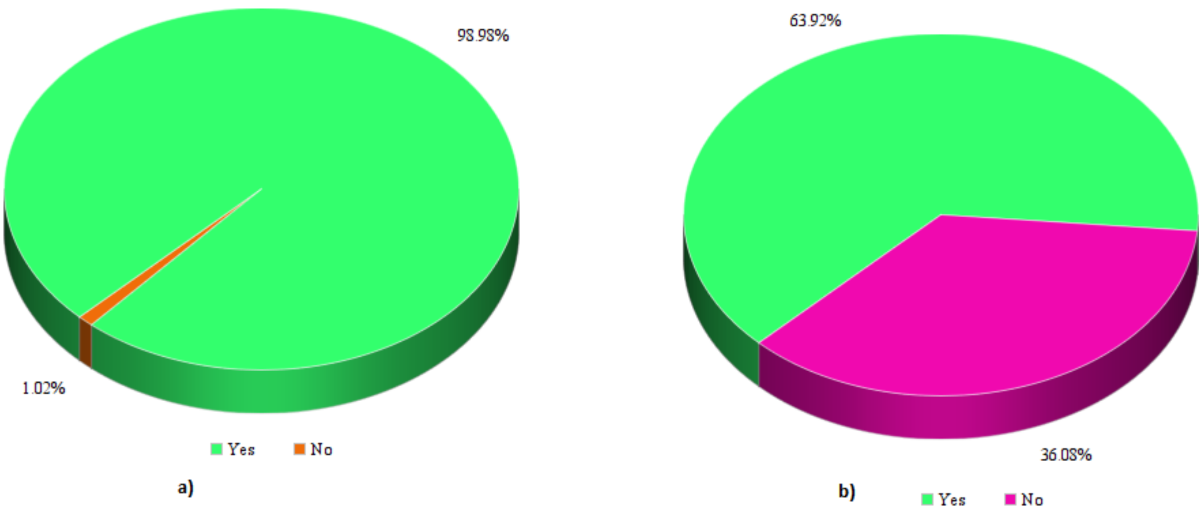

Figure 1: Survey results to the question “If you have a computer at home, is it connected to the Internet?”, “Can you find the information you need on the Internet?”, and “Are you able to choose and use software to optimally present the different types of materials needed for the learning process?”.

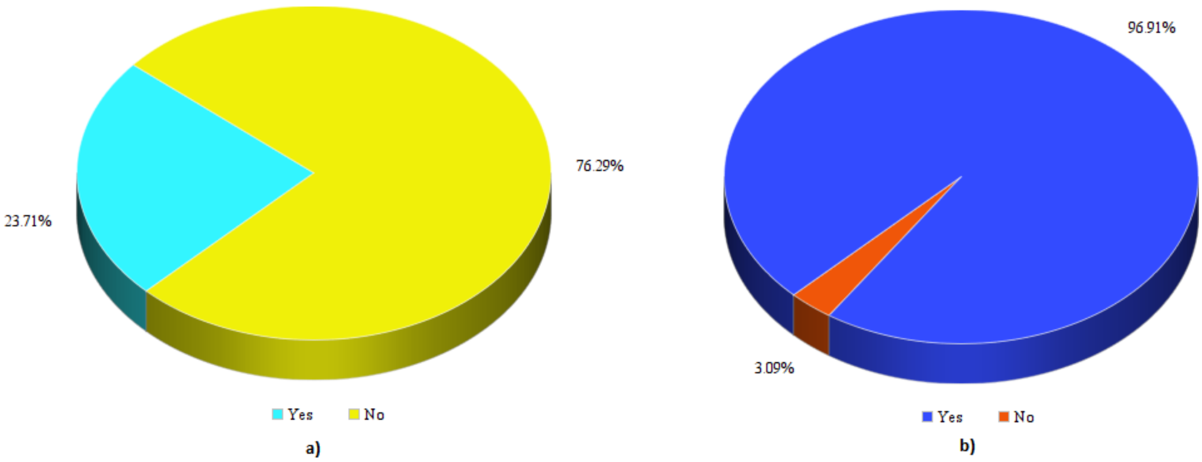

Figure 2: Survey results to the question “Are you have their website or blog?” and “Are you have a website for your school?”.

Table 1: Respondents’ answers to the question “Which of the following motives motivate you to use cloud technologies in the educational process?”

	At the beginning of the experiment	At the end of the experiment
The need to be able to use different cloud technologies	55.10%	59.30%
The need for self-study using various cloud technologies	26.54%	22.10%
The need to get acquainted with cloud technologies	10.20%	5.81%
The need to study the main types of cloud technologies	6.12%	11.63%
I do not see the need to use cloud technologies in the educational process	2.04%	1.16%

The need to be a leader was not a priority, and some respondents did not see the need for self-study at all.

Regarding the level of teachers’ knowledge of cloud technologies, at the beginning of the experiment, 51.02% of respondents only knew what cloud technologies were (while after the experiment the share of respondents was 9.64%), at the end of the experiment 53.01% of respondents already knew basic cloud services that can be used in the educational process (at the beginning of the experiment, this percentage was 24.49%). It should be noted that 17.35% did not hear about cloud technologies at the beginning of the experiment, while this figure decreased to

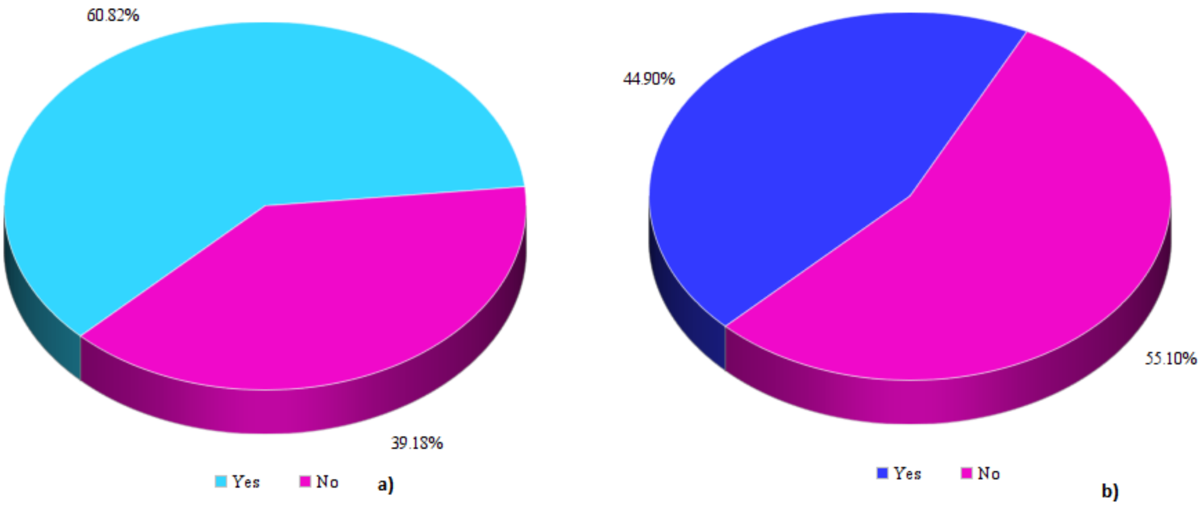

Figure 3: Survey results to the question "What is cloud technologies and services?" and "Do you used cloud technologies in teaching your subject?".

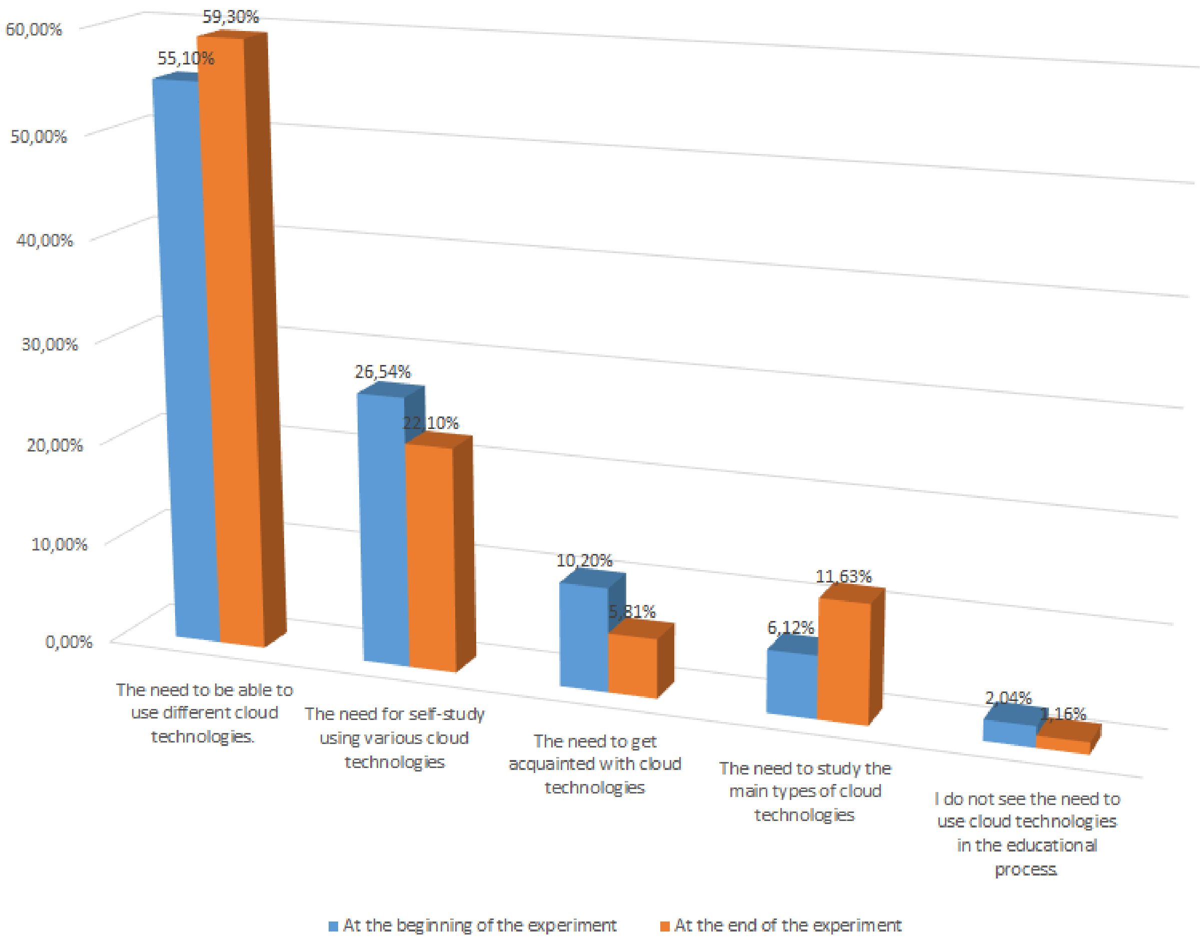

Figure 4: Respondents' answers to the question "Which of the following motives motivate you to use cloud technologies in the educational process?"

2.41% at the end of the experiment (table 3 and figure 6).

Regarding the level of teachers' mastery of the ability to use cloud technologies, the following was

Table 2: Respondents' answers to the question "Which of the following motives motivate you to self-study using cloud services?"

	At the beginning of the experiment	At the end of the experiment
The need for self-improvement and self-development in future professions	76.54%	69.88%
The need to understand the significance of the acquired knowledge	10.20%	7.23%
The need to understand the significance of the acquired skills	12.24%	16.87%
The need to be a leader	1.02%	3.61%
I do not see the need for self-study at all	0.00%	2.41%

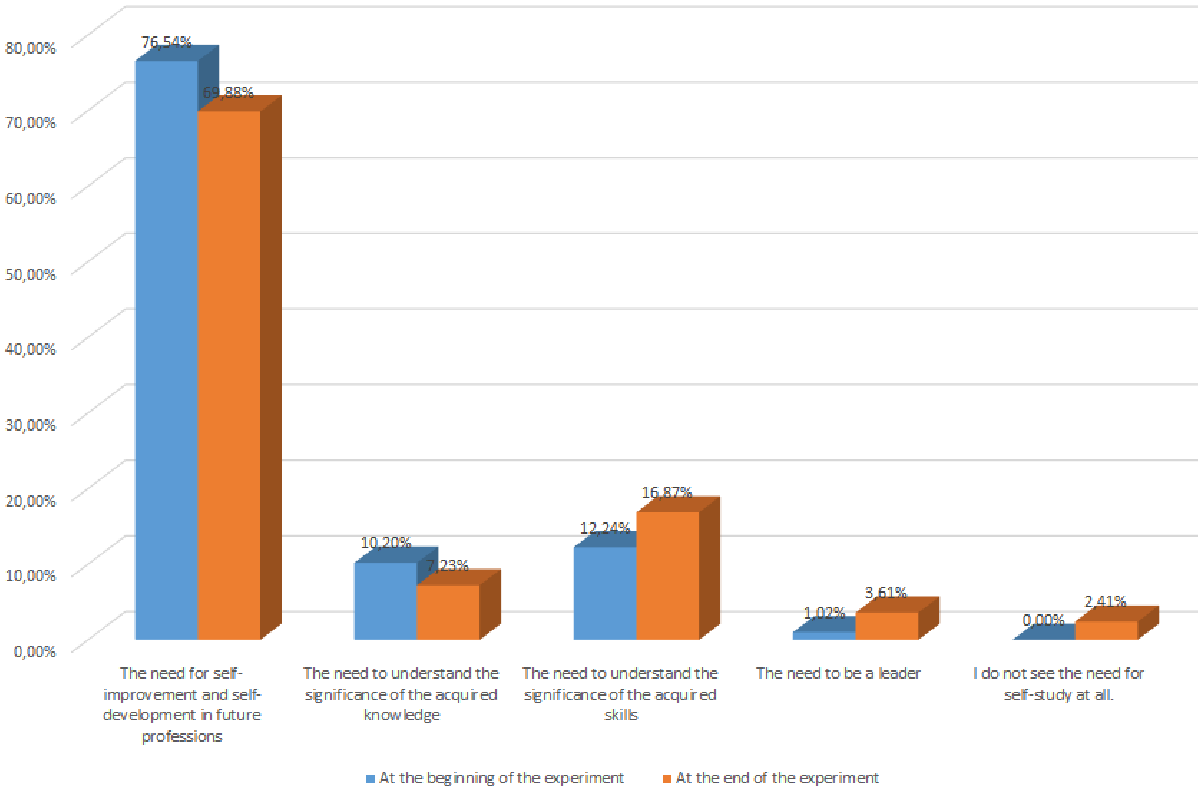

Figure 5: Respondents' answers to the question "Which of the following motives motivate you to self-study using cloud services?"

Table 3: Respondents' answers to the question "What is the level of your mastery of cloud technology knowledge?"

	At the beginning of the experiment	At the end of the experiment
I haven't heard of cloud technology at all	17.35%	2.41%
I know what cloud technology is	51.02%	9.64%
I know the difference between cloud computing, cloud technology, and services	4.08%	7.23%
I know the basic cloud services that can be used in the educational process	24.49%	53.01%
I know the peculiarities of using different cloud services, and ways to choose the best cloud service	3.06%	27.71%

found: 53.01% of teachers after the courses (compared to 14.29% before the courses) can work with cloud technologies, while at the beginning of the course 48.98% only knew what cloud technology was; from 5.1% to 19.28% increased the number of teachers who can use cloud technology for self-study.

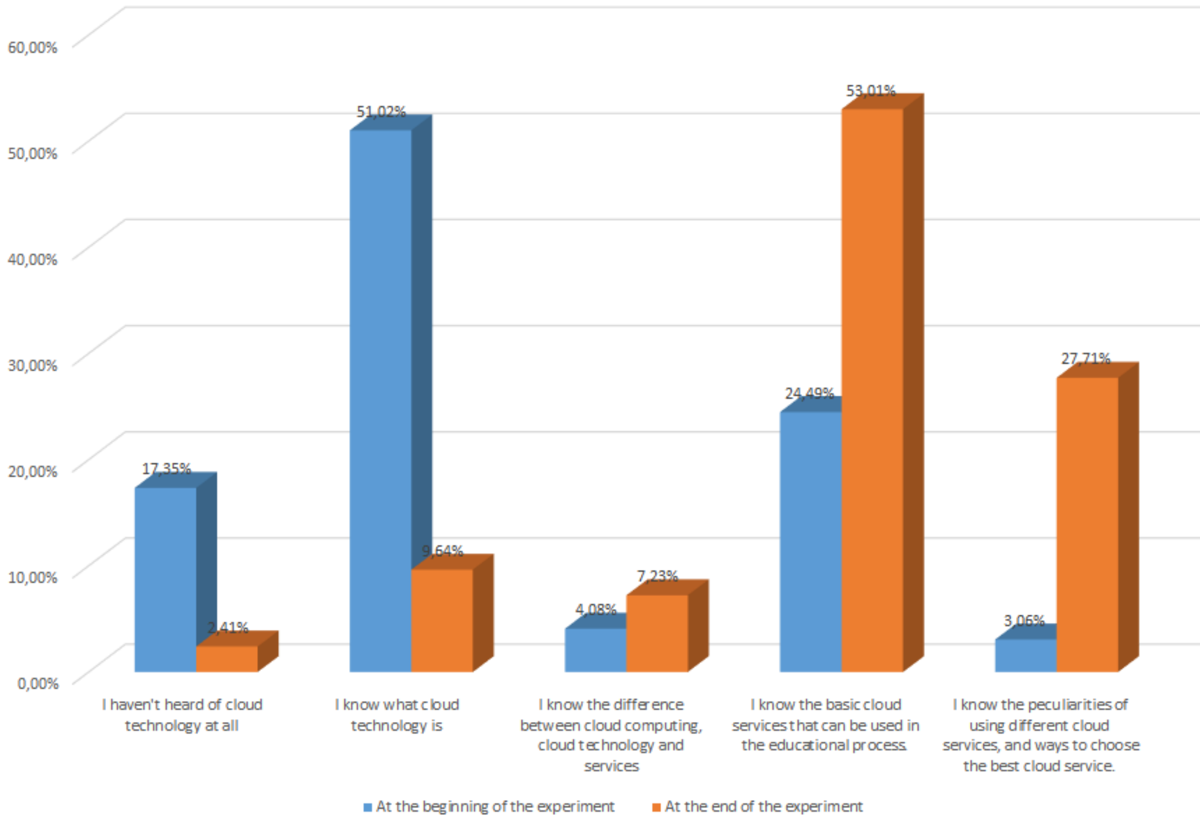

Figure 6: Respondents' answers to the question "What is the level of your mastery of cloud technology knowledge?"

It is worth noting that the percentage of those teachers who do not know what cloud technologies are and what they are used for has decreased from 20.41% (before the courses) to 2.41% (after the courses).

A detailed presentation of the level of teachers' mastery of the skills to use cloud technologies is presented in the table 4 and figure 7).

Since in the course of the courses attention was paid to certain types of cloud tools, it was important to ask how many teachers have learned to use different tools in the learning process. In particular, the level of teachers' mastery of the ability to use cloud-based mind maps in the educational process can be described as follows. They did not know at all what mind maps were and what they were used for – 51.02% at the beginning of the experiment, and this percentage dropped to 1.2% after the experiment; 41.84% of respondents knew what mind maps were before the courses, and there were isolated cases of knowledge of different cloud-based mind maps, skills to work with cloud-based mind maps and the ability to use cloud-based mind maps for self-study. After the experiment, the number of those who knew different cloud-based mind maps increased from 2.04% to 12.05%, as well as those who knew how to work with cloud-based mind maps – from 3.06% to 48.19%. The percentage of those who were able to use cloud-based mind maps for self-study increased from 2.04% to 19.28%. A detailed presentation of the level of teachers' mastery of the ability to use cloud-based mind maps is presented in the table 5 and figure 8).

Working on a joint project plays an important role in distance learning, as well as in blended learning. Therefore, establishing the level of mastery of teachers' ability to work on a joint project in the use of cloud technologies was also important. As a result, it was found that 42.86% of teachers (at the beginning of the experiment) did not know what a joint project was and how to work on it in the conditions of using cloud technologies, and after that, the percentage significantly decreased to 1.20%. Among teachers, 42.86% also knew what a joint project was before the courses.

The percentage of those who knew different cloud services to work on a joint project, knew how to choose different cloud services to work on a joint project, and knew how to use different cloud services to work on a joint project, even in self-study, was too small at the beginning of the experiment (9.18%, 3.06%, 2.04%, respectively). At the same time, after

Table 4: Respondents' answers to the question "What is the level of mastery of your skills to use cloud technologies?"

	At the beginning of the experiment	At the end of the experiment
I do not know what cloud technology is and what it is used for	20.41%	2.41%
I know what cloud technology is	48.98%	10.84%
I know different cloud technologies	11.22%	14.46%
I can work with cloud technologies	14.29%	53.01%
I can use cloud technologies for self-study	5.10%	19.28%

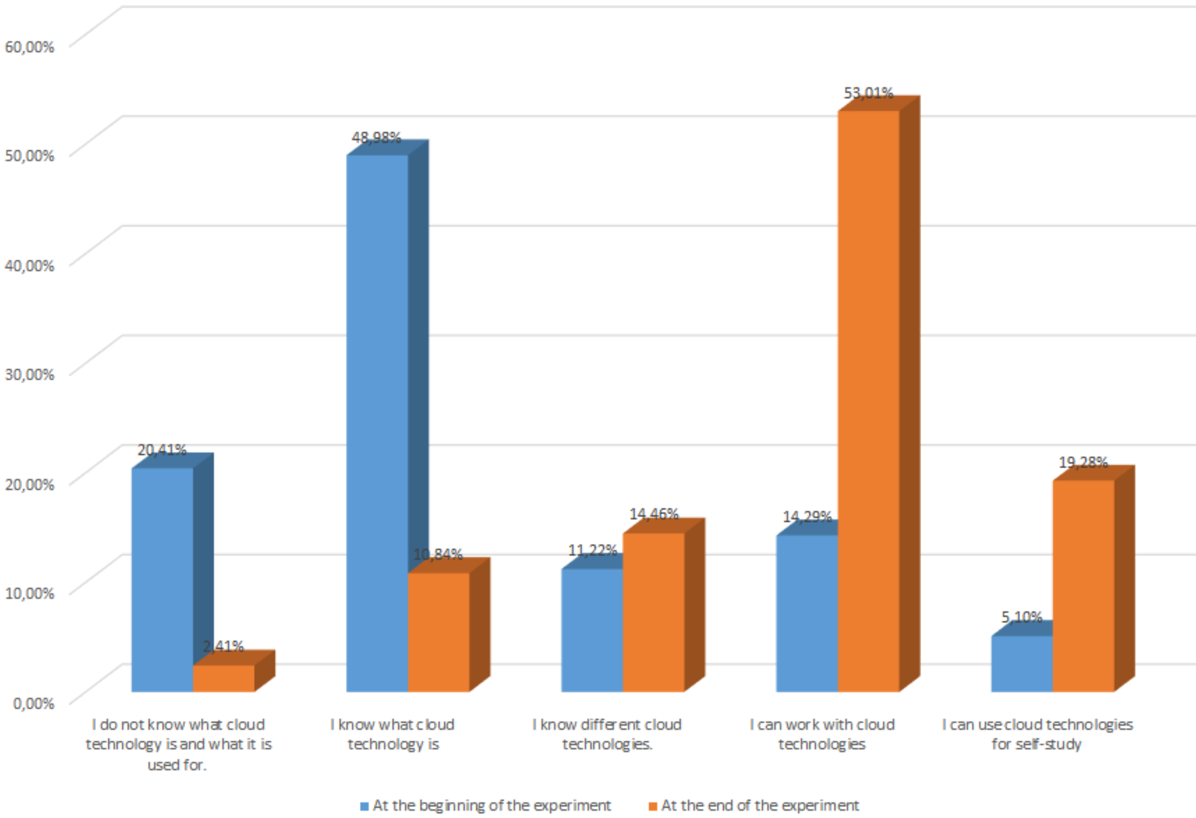

Figure 7: Respondents' answers to the question "What is the level of mastery of your skills to use cloud technologies?"

Table 5: Respondents' answers to the question "What is the level of mastery of your skills to use cloud-based mind maps in the educational process?"

	At the beginning of the experiment	At the end of the experiment
I do not know at all what mind maps are and what they are used for	51.02%	1.20%
I know what mind maps are	41.84%	19.28%
I know different cloud-oriented mind maps	2.04%	12.05%
I can work with cloud-based mind maps	3.06%	48.19%
I can use cloud-based mind maps for self-study	2.04%	19.28%

the courses, these indicators increased significantly – 14.46%, 37.35%, and 30.12%, respectively.

A detailed presentation of the level of mastering the skills of teachers to work on a joint project in the use of cloud technologies is presented in the table 6 and figure 9).

The next indicator that was evaluated was the level of teachers' mastery of the skills of using cloud-based learning management tools. Again, before the courses, 44.9% did not know what cloud-based learning management tools were and what they were used for, while after the experiment, this percentage

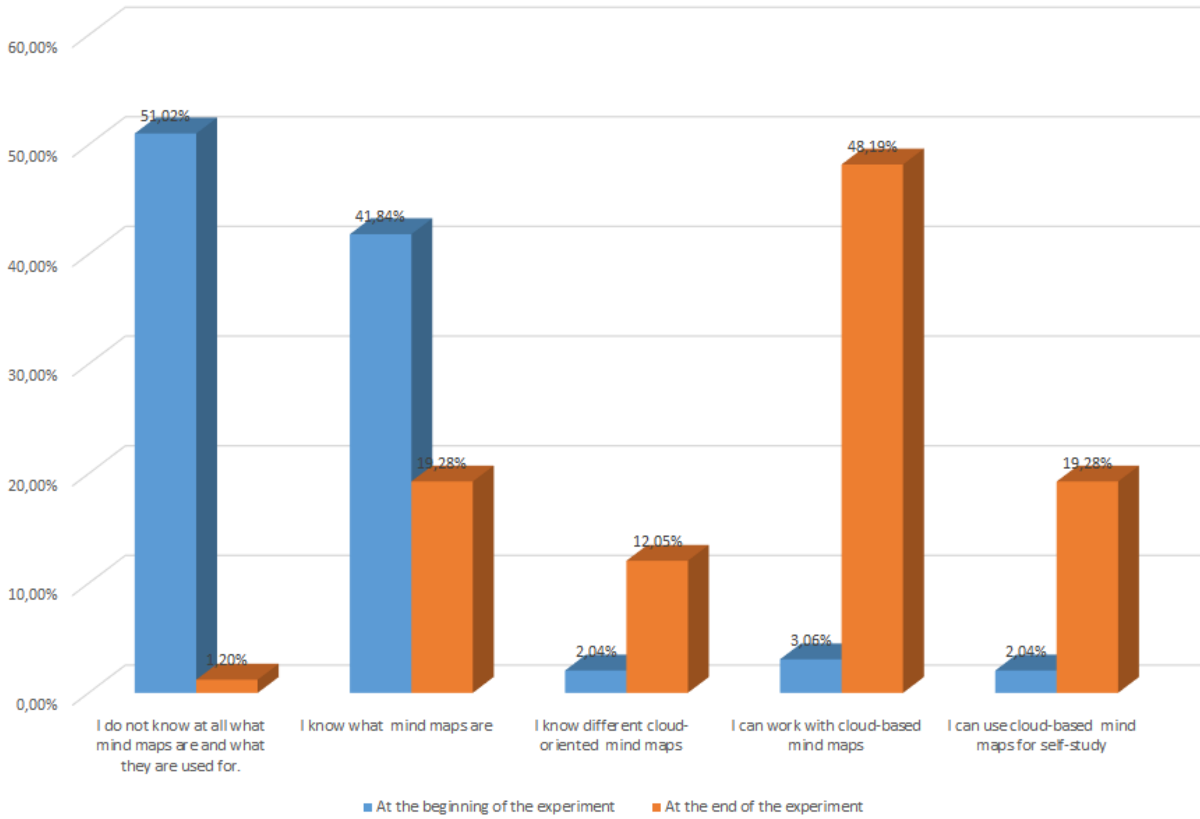

Figure 8: Respondents' answers to the question "What is the level of mastery of your skills to use cloud-based mind maps in the educational process?"

Table 6: Respondents' answers to the question "What is the level of mastering your skills to work on a joint project in the use of cloud technologies?"

	At the beginning of the experiment	At the end of the experiment
I do not know at all what a joint project is and how to work on it in the conditions of using cloud technologies	42.86%	1.20%
I know what a joint project is	42.86%	16.87%
I know different cloud services to work on a joint project	9.18%	14.46%
I can choose different cloud services to work on a joint project	3.06%	37.35%
I can use various cloud services to work on a joint project, even with self-study	2.04%	30.12%

dropped to 2.41%. At the beginning of the experiment, 32.65% of teachers knew what cloud-based learning management tools were, and there were few cases when teachers knew different cloud-based learning management tools (15.31%), we're able to work with cloud-based learning management tools (7.14%). At the same time, no teacher was able to use cloud-based learning management tools for self-study before the experiment. After the courses, 46.99% of teachers knew different cloud-based learning management tools, 19.28% were able to use cloud-based learning management tools for self-study.

A detailed presentation of the level of mastering by teachers of the skills of using cloud-based learning management tools is presented in the table 7 and figure 10).

The level of teachers' mastery of the skills of using cloud-based means of presenting educational materials after the courses have significantly increased (table 8 and figure 11).

Also, the level of mastering by teachers of skills of using cloud-oriented means of communication has significantly increased, which is presented in the table 9 and figure 12).

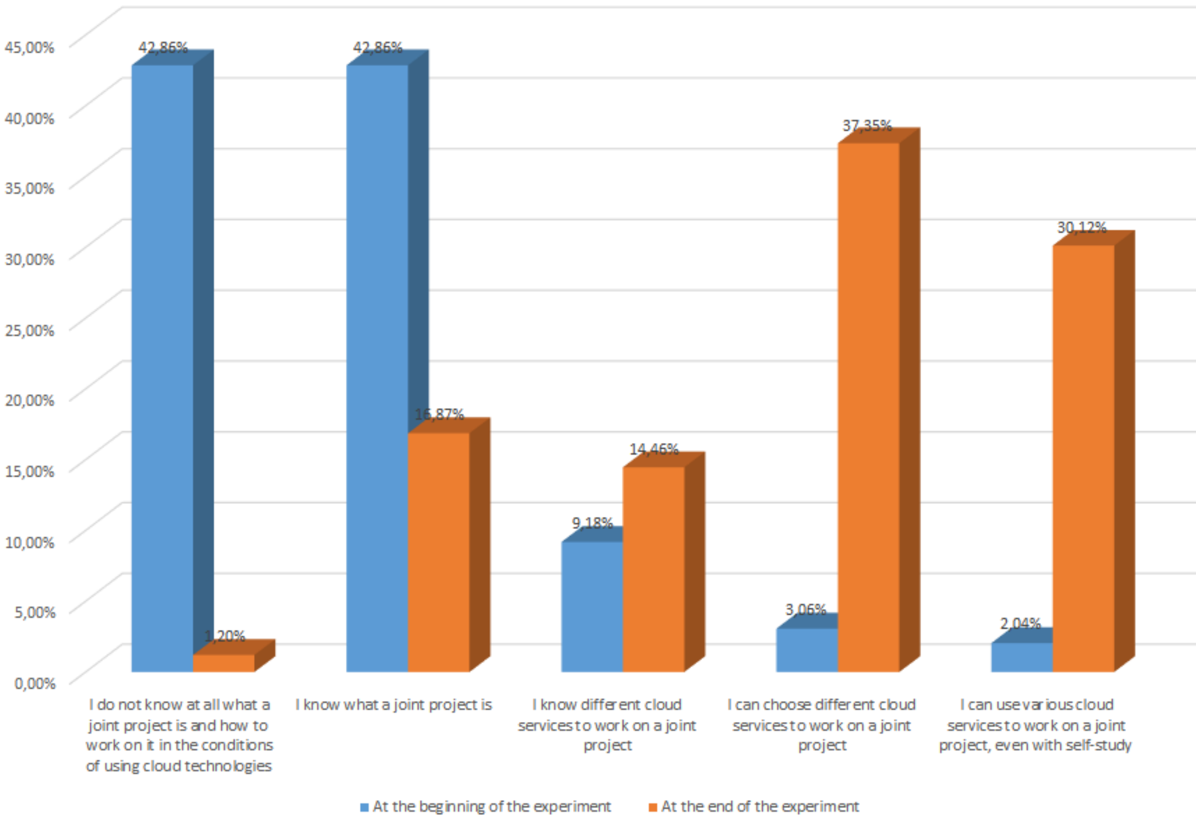

Figure 9: Respondents' answers to the question "What is the level of mastering your skills to work on a joint project in the use of cloud technologies?"

Table 7: Respondents' answers to the question "What is your level of mastery of the skills of using cloud-based learning management tools?"

	At the beginning of the experiment	At the end of the experiment
I do not know at all what cloud-based learning management tools are and what they are used for	44.90%	2.41%
I know what cloud-based learning management tools are	32.65%	20.48%
I know various cloud-based learning management tools (electronic journal, calendar, placed in the cloud)	15.31%	10.84%
I can work with cloud-based learning management tools	7.14%	46.99%
I can use cloud-based learning management tools for self-study	0.00%	19.28%

Table 8: Respondents' answers to the question "What is your level of mastery of the skills of using cloud-based teaching materials?"

	At the beginning of the experiment	At the end of the experiment
I don't even know what cloud-based learning materials are	39.80%	1.20%
I know what cloud-based teaching materials are	30.61%	12.05%
I know various cloud-oriented tools for presenting educational materials (electronic library, presentations, video files, electronic textbooks placed in the cloud, cloud data warehouses)	21.43%	25.30%
I can work with cloud-oriented tools of presenting educational materials	7.14%	38.55%
I can use cloud-based tools for presenting educational materials for self-study	1.02%	22.89%

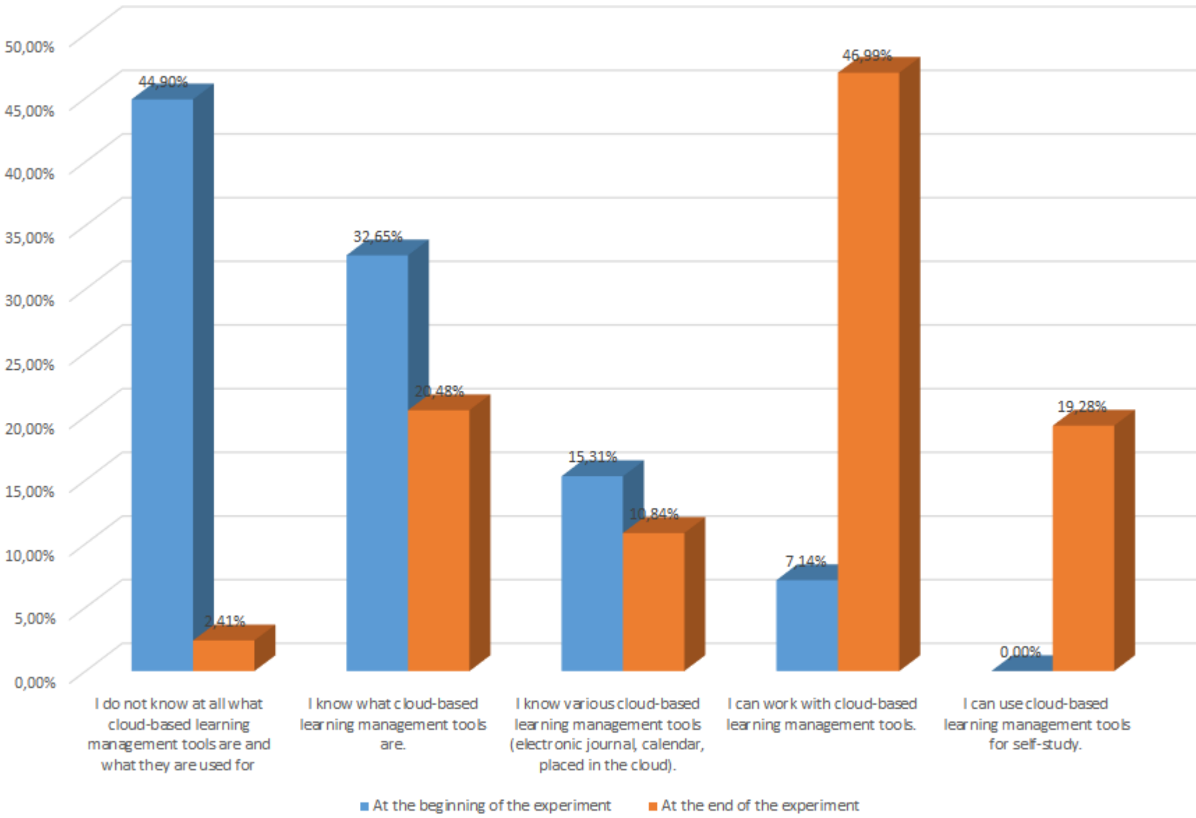

Figure 10: Respondents' answers to the question "What is your level of mastery of the skills of using cloud-based learning management tools?"

Table 9: Respondents' answers to the question "What is your level of mastery of cloud-based communication skills?"

	At the beginning of the experiment	At the end of the experiment
I don't even know what cloud-based communication is	37.76%	0.00%
I know what cloud-based tools of communication are	34.69%	12.05%
I know various cloud-based tools of communication (discussion, chat, on-line consultations, webinars)	18.37%	21.69%
I can work with cloud-based tools of communication	7.14%	42.17%
I can use cloud-based communication tools for self-study	2.04%	24.10%

After face-to-face courses, teachers in Zhytomyr schools have significantly increased their competence in the use of cloud technologies in the educational process in the context of the COVID-19 pandemic. It is worth noting that not only their level, in general, has increased, but also the horizons regarding the variety of cloud services that should be used in distance learning have expanded. Course training, organized according to scientifically sound methods, helps to increase the motivation of students (teachers) to self-study, as well as to the future use of cloud technologies in the educational process.

Finally, it should be noted that the advantages of full-time education include: clarity, accessibility, comprehensibility, and the advantages of distance learning include: mass, no need for classrooms, no need to transfer university teachers, and school teachers' classes.

The continuation of the COVID-19 pandemic and the beginning of Russian aggression in Ukraine prompted the authors of the article to determine how useful the competencies acquired by teachers were and whether they improved them over the past 1.5 years.

Accordingly, a questionnaire was prepared and sent to all participants who were involved in the described courses, which included the following questions:

1. How useful were the competencies you received?

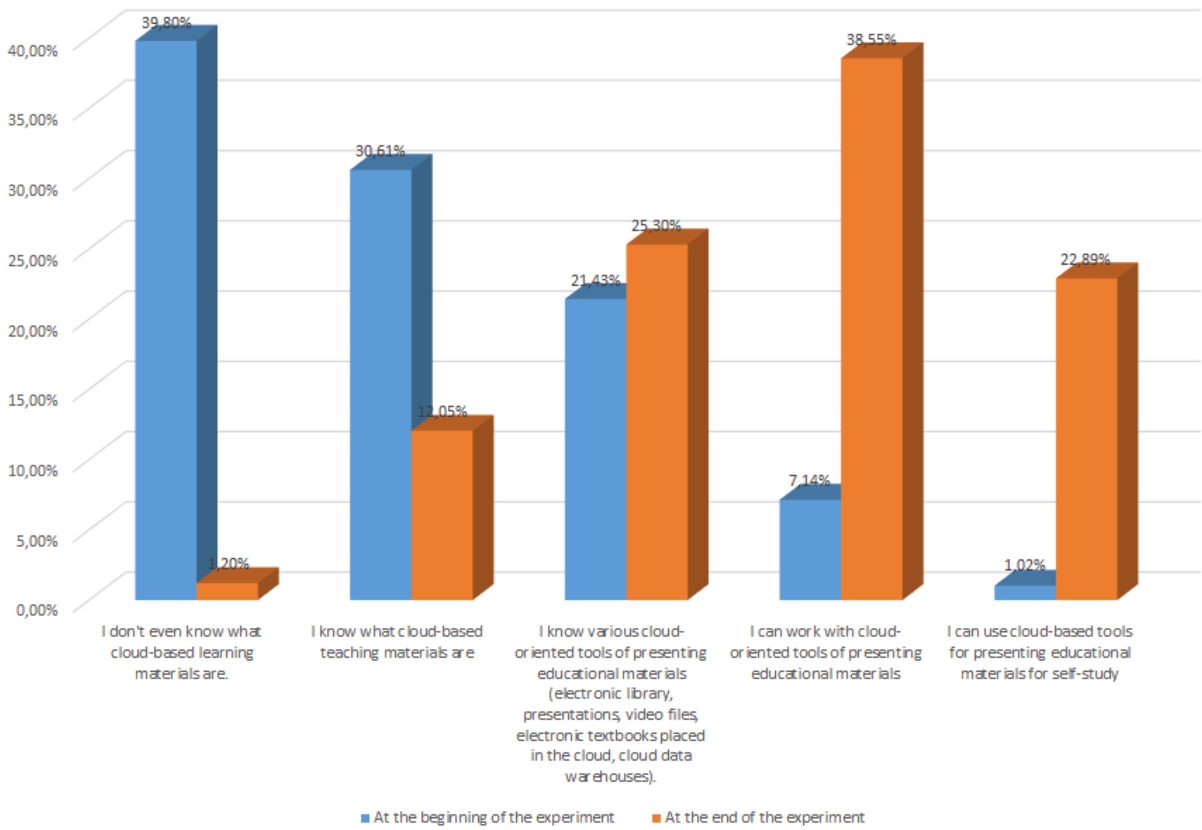

Figure 11: Respondents' answers to the question "What is your level of mastery of the skills of using cloud-based teaching materials?"

2. Do you use acquired competencies in your professional activities during the period of Russian aggression?
3. What cloud services are you currently using?
4. Did you improve your level of ICT competence in the period September 2020-May 2022?
5. If the answer to the previous question is yes, how?
6. What purpose of massive open online courses did you use to develop your competence?
7. Which ICTs that you have become familiar with during this period do you use in your activities?
8. Which ICTs that you have become familiar with during this period would you recommend to other teachers?
9. What other services would you like to get acquainted with in the future for effective professional work?

As a result, the survey involved 90 school teachers in the city of Zhytomyr, previously involved in the courses (which is 92%). For certain reasons, not all teachers could complete the proposed survey (the lack of the ability to view any information via the Internet, the absence of the Internet itself, lack of any technical means (laptop, tablet, personal computer), etc.).

When answering the first question, 100% of respondents indicated that the acquired competencies were useful to them, of which 77% indicated a high level of usefulness, and 23% – medium.

All the respondents unanimously approved that acquired competencies in professional activities were used during the period of Russian aggression. Also, in additional comments, teachers noted that among their acquaintances there are many teachers who want to take such courses because at one time they had no desire or motivation.

When asked what services you currently use, 80% chose all the services they learned during the courses, 15% chose most services (except for one, each had their own), and 5% of respondents chose only services. Google Classroom and Google Meet. This indicates that the services we have chosen for training have not lost their relevance over time.

The next question was about the development of teachers in the period 2020-2022. Namely, the question was whether teachers improved their level of ICT competence in the period September 2020-May 2022.

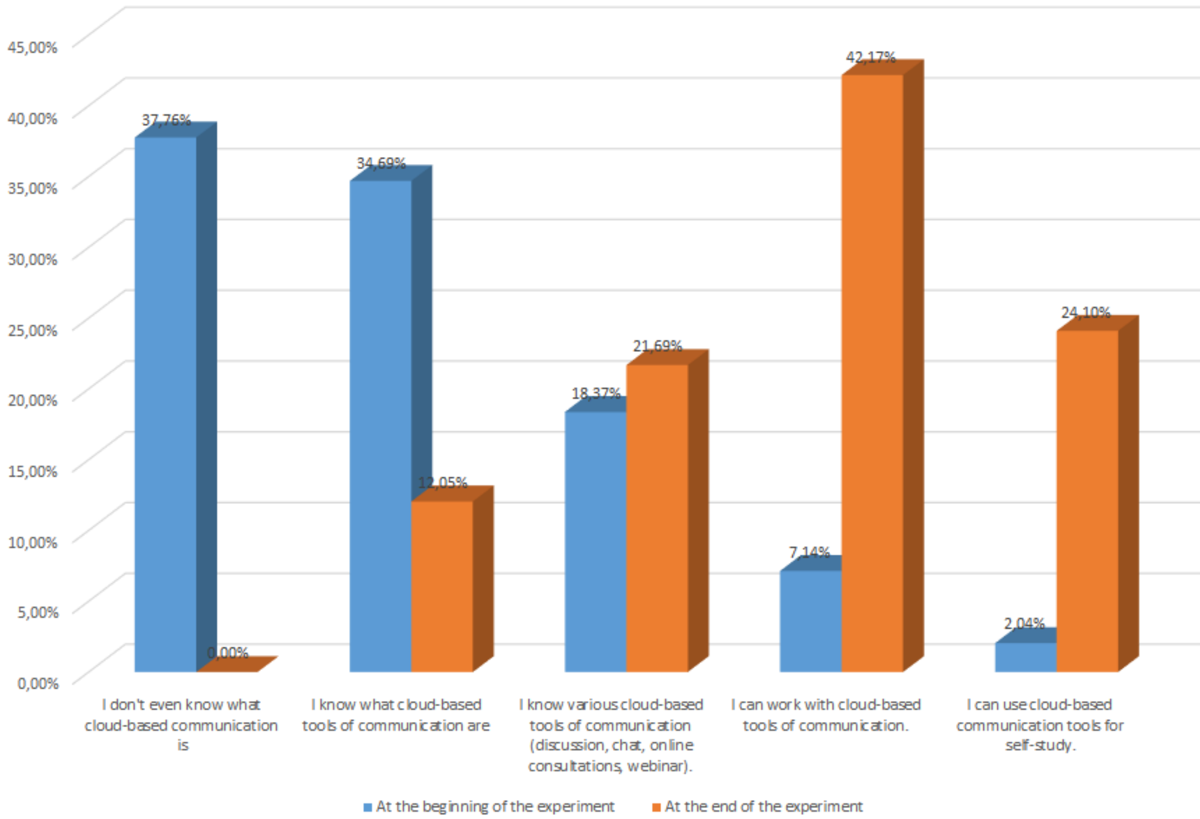

Figure 12: Respondents' answers to the question "What is your level of mastery of cloud-based communication skills?"

At the same time, 70% of teachers answered yes to this question. At the same time, the majority of these 70% (89%) chose self-study as a means for their own professional development, 63% chose advanced training courses, and 71% indicated massive open online courses.

When determining which massive open online courses teachers preferred, it was found that 67% of those who chose massive open online courses went through MOOC related to the use of various ICTs in the educational process, 44% chose massive open online courses to improve their foreign language proficiency, and 22% chose massive open online courses to improve their knowledge native language.

It is worth noting here that the Prometheus platform turned out to be the most common for passing massive open online courses, since the platform itself is Ukrainian-language, and most of the courses on this platform are Ukrainian-language. In particular, teachers noted that on this platform, most of the respondents were interested in the Science of Education course: "What the leader of an educational startup should know" (https://courses.prometheus.org.ua/courses/course-v1:PCSC+SL101+2019_T3/about). This course is designed for 30 hours, which can be completed in 3 weeks. The teachers were most interested in the fact that among the questions to study there are such as: for whom digital education is needed, what is the essence of the educational project, digital security and privacy during online learning, psychological support for online project participants, etc. As a result of taking this course, teachers noted that they improved: their own knowledge of modern trends in the development of education; features of the processes of teaching and learning of schoolchildren; the specifics of digital education and understanding of what it is intended for, improved their own skills (creativity, initiative, critical thinking, etc.), improved the ability to work with digital educational online tools and improved the method of teaching their subject, taking into account the psychological characteristics of all participants in the educational process.

Mathematics teachers also singled out such a service as: Learning with passion (https://novatika.org/uk/). This service includes a range of simulators for learning mathematics from grades 1 to 8. The specificity of this service is that the simulators are divided not only by classes, but also by sections and topics.

All teachers, not only in mathematics, answered that they often use ready-made online tests in their own subjects in their practice. There are a lot of such tests on the Internet now, so there is a choice. The only thing that the teachers emphasized was that each time before using any tests, they should be reviewed by themselves and checked for relevance to the topics being studied. The use of such tests ensures the interest and stimulation of students and promotes the development of creativity, initiative, creativity, independence, and other qualities necessary in the educational process.

All teachers surveyed unequivocally answered that they recommend all the services they have read to their colleagues.

The last question was creative and included the establishment of what services teachers would like to get acquainted with in the future for effective professional work. As a result, the following was established.

Biology teachers noted that in their educational activities it is advisable to use augmented reality applications to familiarize students with individual topics for study (human anatomy, animal structure, etc.), as well as various game services to interest and motivate students.

Geography teachers noted that they would also use augmented reality applications in their activities to familiarize students with the features of different types of terrain, different countries, modeling processes, and phenomena.

Computer science teachers noted that in their activities there are many online tools for use in the educational process (online compilers, automated systems for checking solutions to programming problems, massive open online courses, diagramming tools, etc.), but they became more familiar with gaming programs for learning languages and simulators for studying the structure of a computer.

Chemistry teachers noted that there are few different tools in their educational activities, and they would prefer any specialized tools to improve their own teaching methods.

English teachers noted that it would be advisable to get acquainted with additional services for learning English (by the level of knowledge, by grades, by topic), including game services for primary schools since learning English in most schools in Ukraine starts from 1 class.

Physical education teachers noted that there are no services at all for teaching their subject, except for watching various videos on the YouTube channel. For them, this issue is quite relevant and requires a separate study.

All teachers agreed that online learning lacks a quality service that would replace a regular blackboard at school. Although there are a large number of online boards on the Internet, however, ordinary teachers are not fully functional enough to be used in the educational process.

Also, all teachers unambiguously agreed that everything they studied in the previous courses is useful to the present. Since now the use of cloud services for distance learning has become an even more urgent problem.

4 DISCUSSION

Here it should be noted that the reason for the self-development of teachers is of their own free will, namely the situations that have developed in the world in general and in Ukraine in particular. The global pandemic caused by the COVID-19 virus was only the beginning of this. The full-scale offensive of the Russian troops was a second impetus for even greater awareness of the need to master the skills of using various information and communication technologies when teaching their subject. After all, in such periods it is necessary not only to teach your subject in a quality manner but to use various information and communication technologies to motivate and interest students, as well as to take into account the psychological characteristics of all participants in the educational process in such a difficult time.

In addition, not the possibility of learning in the classroom simply requires the teacher to master all the means of information and communication technologies, including cloud services, to improve and conduct classes in general. In this regard, those positions are advantageous when teachers have mastered some means of teaching either on their own or with the help of certain courses. And it is cloud services that are a means of providing distance learning in the conditions that have arisen before Ukraine.

As for the teachers who chose massive open online courses to improve their native language skills, this, in our opinion, is connected with the beginning of Russian aggression against Ukraine. After all, part of the population of Ukraine spoke Russian, and for them, the transition to their native language became important only after the start of a full-scale invasion.

The massive open online courses for the study of foreign languages is also connected precisely with the need to consider the possibility of moving to another country after the start of a full-scale invasion of Russian troops into the territory of Ukraine.

It should be noted that in additional comments to the survey, some teachers indicated that during the war they lost the opportunity to use technical means in connection with a forced quick move to another area (village, another region, another country). Some of the respondents indicated that some teachers lost their technical equipment, which was in the occupied territories. As a result, we have that not all teachers can perform their functional duties in such conditions. Here we can only state that during the development of our state in the post-war period, the Ministry of Education and Science of Ukraine should provide the possibility of purchasing technical equipment for teachers who suffered as a result of a full-scale war.

5 CONCLUSIONS

The two-year pandemic and the start of a full-scale war between Russia and Ukraine contributed to the fact that teachers of secondary schools began to actively engage in self-education and self-development. If earlier (at the beginning of the pandemic) it was difficult for teachers to switch to online learning, then with the outbreak of war, teachers were already ready to use various online tools in their practice.

As the study showed, all the interviewed teachers continued their self-education in different ways, studied a large number of services that can be used in the educational process, and provided the authors with ideas for further expanding the courses according to their desires, which should be used in the educational process.

It should be noted that it is important that all the respondents unanimously approved that they use the acquired competencies in their professional activities during the period of Russian aggression. In addition, in additional comments, teachers noted that among their acquaintances there are many teachers who want to take such courses since at one time they had no desire or motivation.

It is also important that all teachers expressed their desire to study in the future with a division into subjects of study. Therefore, here it should just be emphasized that it is important for teachers to study certain methods of using various information and communication technologies in the educational process.

In the future, we plan to develop a continuation of the courses, the specifics of which will be the distribution into separate groups according to the subjects of teaching for a more detailed study of the methods of using various specific services within the framework of the study of individual disciplines (physics, mathematics, chemistry, biology, geography, foreign language, computer science, etc.). Also, in further research, we see the use of other practice-oriented methods to determine the level of formation of teachers' competence.

Also, since this was not the object of this study, in the future we see the prospects for studying teachers' digital competence levels depending on their age.

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Cloud Service Blogger as Effective Communication Tool of Teacher and Students at the University

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Abstract: The article outlines the important problem of communication between teachers and students in a mixed form of education. The Blogger cloud service is considered as a mean of communication. Based on the analysis of the service functions and the available definitions, the own interpretation of the cloud service Blogger is presented. Its advantages and disadvantages are highlighted. We developed the strategy of creation of the block in Blogger cloud service, consisting of 7 stages: formulation of the name, choice of design, selection of topics, determining the frequency of publications and target audience, building a scheme of blog creation, testing. Fisher's test proves the effectiveness of the Blogger cloud service in the educational process, in particular in the learning process of the discipline "Methods of teaching linguistic disciplines". As a result of the survey, it was found that the systematic work of the blog has a positive effect on the formation of a conscious and active student movement.

1 INTRODUCTION

The implementation of the educational process in terms of social distancing encourages the search for alternative forms and methods of communicative interaction between teachers and students. Effective means of communication aimed at minimizing gaps in communication between participants in the educational process become especially relevant. One of such tool is a blog – a notable cultural and social phenomenon that, due to its popularity, ease of use and creation, has a significant impact on today's youth. The advantages of the blog, which are especially important in a mixed form of education, include: the ability to work on an Internet project of several people; openness and availability of information; interactivity, providing feedback and reviews from users – students, applicants and teachers. Therefore, we consider it appropriate to analyze the features of the blog as a means of communication on the example cloud service Blogger, who does not require additional software; to explore the practical application of the Blogger cloud service in a university environment.

Today, the research of many scientists is devoted to the creation of information educational environment. In particular, Burov et al. (Burov et al., 2020) studied the effectiveness of teaching individuals with the use of electronic education resources. Zhaldak et al. (Zhaldak et al., 2021) believed that by using cloud services in the work, users can use those resources that are on remote servers. Kukharenko et al. (Kukharenko et al., 2022) was inclined to think that it is important for both students and teachers to develop their competencies, which are related to modern ICT. Popel and Shyshkina (Popel and Shyshkina, 2019) believed that in the modern environment of information and educational technologies there are new models of educational activities organization, which

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are primarily based on innovative solutions for the organization of technological infrastructure of the environment, to which we can also include cloud-oriented. Bodnenko et al. (Bodnenko et al., 2022) revealed the importance of using the Yammer cloud service to organize project-based learning methods. Bodnenko (Bodnenko, 2013) revealed the role and the impact of informatization on the professional teacher competences.

The problem of the "blog" integration and its features have been studied in the works of many scholars. Thus, Nosenko and Bogdan (Nosenko and Bogdan, 2015), Ifinedo (Ifinedo, 2018), Dovzhik et al. (Dovzhik et al., 2021), Winster and Swamynathan (Winster and Swamynathan, 2010), Garcia et al. (Garcia et al., 2019) considered issues highlighting the definition of "blog", on the features of using cloud services to create blogs. Tsetsos and Prentzas (Tsetsos and Prentzas, 2021) focused on a survey of approaches integrating blogs in school education. Bondarchuk (Bondarchuk, 2013) emphasized the compatibility of Blogger with other Google subsidiaries and support for "drag and drop when setting up a page".

We consider interesting the scientific achievements in which it is revealed methodological aspects of the implementation of the educational blog "Development of a creative child. ICT" as part of educational course "Database Management System Microsoft Access" (Pokryshen et al., 2019).

2 THE OBJECTIVE OF RESEARCH

The object of the study is a cloud service from Google Corporation – Blogger. The subject of the research is the use of Blogger to organize communication between teachers and students at the university. The aim of the study is to reveal the relevance and expediency of using the cloud service Blogger for communication of students and professors of the university.

To achieve this goal next tasks were performed: analyze the main definitions of the study; highlight the advantages and disadvantages of using the Blogger cloud service; explore the strategy of creating a blog on the cloud service Blogger; to test the developed blog among university students

3 RESEARCH METHODOLOGY

The following research methods were used to implement the outlined tasks:

1) comparative and analytical, which became leading in the study of the basic terms "blog" and "Blogger" and the study of their features;
2) structural, through which the advantages and disadvantages of cloud service Blogger were identified;
3) descriptive, which presents all the main stages of creating and filling the blog "Students IF";
4) statistical (Fisher's method) to prove the importance of using the Blogger cloud service as a communication tool for teachers and students at the university.

The study was conducted based on Borys Grinchenko Kyiv University during September – December 2021. The survey involved 1324 students and 358 teachers of Grinchenko University.

4 RESULTS AND DISCUSSION

4.1 Theoretical Framework

The dynamic development of technology creates new challenges for society, but at the same time, it is driven by a desire to meet the growing needs of society. One of the important needs is communication, the range of means of providing which has significantly expanded due to the rapid improvement of information technology. Forms of communication are changing in the context of globalization, and one such form is the blog. The blog acquires special significance for the implementation of communication between teachers and students at the university, especially in the conditions of distance learning.

Let's define the definition of "blog". For our study, seems to be an acceptable definition proposed by Nosenko and Bogdan (Nosenko and Bogdan, 2015): blog (from "weblog", "online journal or event diary") is a website whose content is regularly accompanied by entries with text, images or multimedia. We agree with the authors that the key feature of the blog is short posts, placed in reverse chronological order, which are public, i.e. available to all Internet users who have the opportunity to view and comment on them.

There are several classifications of blog features. Herring identifies three main social goals of the blog: "Get information; to impress others; have fun" (Herring, 2007). Følstad et al. (Følstad et al., 2021) identifies five functions: "Maintaining contact with relatives and friends; getting information; entertainment; public opinion monitoring; socialization". In turn, Polyuzhin and Vrábely (Polyuzhin and Vrábely, 2005) give a more detailed classification of blog functions, he singles out "Communicative function, self-presentation function, entertainment function, function of cohesion and maintenance of social ties, function of memoirs, function of self-development and reflection, psychotherapeutic function". The last classification will be used in our study.

It should be noted that the use of blogs in online education implies a clear definition of didactic goals and tasks:

- actualization of basic knowledge and skills;
- understanding the essence of concepts, methods of activity;
- consolidation of acquired knowledge;
- solving problem situations, control and assessment of knowledge, level of satisfaction with classes, etc.

Applying blogs during online education to fulfill set didactic tasks creates

- a creative nature of educational and cognitive activity;
- elements of competition, game nature of the lesson are introduced;
- intergroup and group interaction of students is organized;
- constant monitoring of their satisfaction, emotional comfort, etc. is carried out.

Therefore, the communication of teachers and students at the university with the help of a blog as a digital tool promotes cooperation, understanding, tolerance and benevolence, enables the implementation of personally oriented learning. Given that the mentioned communication in the blog is implemented mainly in the conditions of cooperative learning, when each student contributes to joint achievements, it is worth considering the availability of the necessary technical equipment and the availability of digital tools and services.

Their selection was based on the following requirements for the implementation of communication between teachers and students:

1) understanding that the collective way of organizing learning, joint educational activity is an effective form of the educational process;
2) creation of conditions for group interaction;
3) activation of independent assimilation of educational material in the course of subject-subject dialogue;
4) processing of educational information in different forms and at different levels of complexity;
5) mandatory reflexive activity in the process of group work.

To find out if blog as a form of communication meets the needs of society, the service Blogger was chosen. Because many people are users of Google Mail, which allows free access to all of Google's cloud applications. "Blogger is a leader in the means of publishing materials on the Internet – the creation of so-called web blogs or blogs" (Pyatak, 2012). Scientific papers provide various definitions of this service, for example, the most succinct of which is the definition that "Blogger is a website whose main content is recordings, images or multimedia that are regularly added" (Alekseienko and Usata, 2019). Pyatak (Pyatak, 2012) gives a more detailed definition: "Blogger is a blogging platform, formerly known as Pyra Labs, which Google acquired in February 2003, a web tool that allows you to quickly and easily post messages on the Web".

After analyzing and summarizing the definitions offered by scientists, the following definition was derived: Blogger is a free blogging service that allows you to freely blog, meet and communicate with new people without resorting to programming and without worrying about installing and configuring software.

The blog creation algorithm is easily accessible to most PC users, as "there is no need to create program code or install any server software or scripts" (Pyatak, 2012), as the process involves three important steps to start filling your blog: "Choose a profile, name a blog, choose a template, then the user will be given a domain like name.blogspot.com" (Bondarchuk, 2013). Posting a blog post is done by filling out a simple form on the Blogger cloud site. An important feature of Blogger is"freedom of speech", because censorship contradicts the concept of this service. Bondarchuk et al. (Bondarchuk et al., 2020) also noted an interesting detail that "Blogger, as a division of Google, allows you to place Google Adsense ad units and thus earn money from traffic (which is impossible in LJ). Also, the service is fully compatible with other Google products – Picasa Web Albums, Google Data API support, supports drag and drop when setting up the page".

Systematic and long-term work with Blogger service allows analyzing its advantages and disadvantages. The study focused on aspects such as accessibility, administration, appearance, functionality and interaction of the blog with other platforms. The Blogger cloud service allows one user to create several blogs at the same time (about a hundred for one user), which, in turn, indicates a number of additional benefits: a wider range of problems coverage; mutual advertising between blogs; more audience coverage. Instead, the service has an imperfect procedure for moving files between blogs, as it is not possible to share images.

The next attractive aspect of using Blogger is its accessibility and that it is free: its construction is as simple as possible, so any PC user can manage and populate the blog, and the usage policy provides free access to Google Account holders.

A significant bonus for users is the ability to share one blog. This allows the team of authors to co-create content and maintain the collaboration. Users share many services, and it is Blogger that can allow a niche to be hosted by several people. However, even this advantage does not extend the range of available features. The toolkit offered in the free version is a template and cannot be expanded, but the number of designs is sufficient to create an original blog. A preview feature is also available.

Another important feature is backup: all users can save their own data and thus secure it. This option is possible because Blogger is a subsidiary of Google. However, this can be seen as a disadvantage of this service. Google bought Blogger in the early 2000s, and during that time the site has been advanced and improved, but the company has not released an update recently and seems to be shutting down the service (as has happened with Google Reader, AdSense).

When creating its own blog, the user should understand that a company that provides a free service may suddenly terminate it or switch to paid mode. However, the cooperation of the cloud service with such a large corporation provides several nice bonuses, free subscriptions among them. In addition, the service distributes news, adds a blog to the newsletter, shows a panel and a chart of visits. The site is actively promoted in the Google search engine. The author can add his blog to the search engine and thus facilitate the promotion process and avoid problems associated with indexing new pages. Plus for users – all those who are already registered in the system and have a Google account can subscribe to a blog.

So, the Blogger cloud service is the best platform for those who want to start promoting their own blog. Despite the limited number of templates, the service has enough tools to implement own ideas. In addition, working with Google provides the site with a number of features: availability, backup feature, access to other services, etc. So, the site is easy to use, which deserves its audience.

4.2 Development of a Blog of the University Structural Unit

In order to implement communication between teachers and students with the help of a blog, we have highlighted a number of approaches to ensuring this communication.

The systematic approach. It ensures the integrity, unity and interconnectedness of communication between teachers and students. The value of the mentioned approach is that it allows you to outline the communicative process as a unity of theory and practice, goals, tasks, forms and methods, etc.

The systematic approach makes it possible to consider the use of blogs in the learning process from the point of view of integrity, mutual enrichment, and interdependence.

The competency-based approach is one of the leading in the modern educational process, the most relevant in the modern paradigm of education, defines the list of competencies of teachers and students to ensure communication.

The activity approach is aimed at developing the skills of using blogs for communicative interaction. The educational process is based on the internal motives of the specified activity, which allows it to be perceived as personally meaningful.

This approach promotes the development of research skills, initiative, and the disclosure of creative potential. This will contribute to the formation of a valuable attitude to the use of blogs in the communication process.

The personally-oriented approach. It directs the teacher to take into account the individuality, originality and uniqueness of students on the basis of universal human values. The attitude towards them is implemented in the context of existing features, interests and abilities.

The mentioned approach resonates with the student-centered approach, which involves:

- encouraging students of higher education to play the role of autonomous and responsible subjects of the educational process;
- creation of an educational environment focused on meeting the needs and interests of higher education seekers, in particular, providing opportunities for the formation of an individual educational trajectory;
- construction of the educational process on the basis of mutual respect and partnership between the participants of the educational process.

The environmental approach makes it possible to create special conditions and organize the educational process due to their impact on students.

We believe that the approaches that we have outlined are integrated, complemented and specified by the environmental approach, as they are implemented within the educational environment as an important lever of using blogs to implement communication.

The axiological (value) approach, which is based on the concept of value and makes it possible to find out the qualities and properties of objects, phenomena, processes capable of satisfying certain needs of an individual or society. Such needs appear in the form of norms and ideals. The subject of pedagogical axiology is the process of forming a system of values, value attitudes of an individual.

The cultural approach is important for the formation of prognostic competence of future bachelors of computer sciences, as it involves purposeful consideration of cultural heritage, human values, provides opportunities for personal and professional growth, development of their creative potential. In this context, it resonates with a creative approach that enables the use of non-standard teaching methods in the process of professional training.

The process of communication between teachers and students using a digital blog follows the following patterns:

- correspondence of the content, forms, methods and means of using blogs to the demands of real practice;
- unity of purpose and results of the process of using blogs to ensure communication between teachers and students;
- orientation in education to material and technical resources, including availability of high-speed Internet;
- the intensity of feedback between teachers and students as a guarantee of the process of using blogs in communication.

We will also outline the principles (system-forming factors (requirements and rules)).

The principle of scientificity and interdisciplinarity, which makes it possible to take into account in the process of using digital blogs for the communication of modern scientific theories, concepts and views.

The principle of continuity and perspective. We believe that the use of blogs in education should be experience-oriented, continuous, step-by-step, and outline the prospects for student growth. In addition, take into account individual characteristics of students, focus on creative development, disclosure and realization of potential opportunities, enrichment of subjective experience.

The principle of focusing on digital technologies, which involves the systematic use of open educational resources, computer and multimedia tools, software, mobile devices, etc.

The principle of reflexivity, which prompts teachers and students to analyze and correct the process of using digital blogs.

The principle of culturology. The implementation of communication between teachers and students is based on the recognition of such activity as the highest value, the ability to realize the personality in professional life.

Analysis of the needs and desires of students and teachers of the Institute of Philology of the Borys Grinchenko Kyiv University has become decisive in choosing the topic of the blog, which is implemented within the research of the Blogger service. The survey showed that potential readers would be most interested in reading the news of the Institute of Philology. To implement the study, a number of stages were performed: from the formulation of the title and the choice of design to the content of the blog.

Stage 1. Formulation of the title. When choosing the name of the blog, we were guided by three, in our opinion, the most important features – accessibility, functionality and content. That's why the blog was named "Students IF".

The chosen title of the blog should be clear to the readers on whom it is aimed and easy to remember, as this will increase the audience. Second, Latin letters were used in the title, as it significantly expand the boundaries of the target audience and the possibility of its use to promote the blog. Regarding the third feature, the content and informativeness of the blog name is important. The title should evoke in the recipient a wide range of associative and give the opportunity to predict its thematic direction, so readers immediately understand whether this blog is in their area of interest.

Stage 2. Choosing a design. Blogger service can only use standard templates, which are quite limited: a few options for posting, choosing colors, setting your own main photo blog. To design the overall look of the blog, a typical model № 1 was chosen, as it is the most convenient to use: the news is arranged in chronological order, i.e. from current to the oldest (figure 1).

As for colors, the choice was due to two factors. First, the Grinchenko University has an approved Brand Book, which sets out recommendations for the use of corporate identity, it regulates the corporate colors of educational units, in particular, the

Figure 1: Typical model № 1 cloud service Blogger.

Institute of Philology has a green color. Another important factor is the recognizability of philologists by color, which is caused by the active promotion of corporate products, the availability of appropriate design corridors of the educational unit, the use of different shades of green when preparing additional materials for the educational process (figure 1). The third feature of the Blogger service is that you can choose the main photo, which will meaningfully complement the name of the blog.

In our opinion, the logo of the Student Self-Government Council correlates most accurately with the name of the "Students IF" channel (figure 2). It reflects the most important values of a student of the Institute of Philology: a book, sleep, Wi-Fi and coffee – an associative series of words that are necessary for the full existence of each student. The introduction of common values evokes emotions in all those involved in the educational process, which increases the likelihood of their involvement in the readers of the blog.

Stage 3. Selection of topics. The content plan of the blog "Students IF" was developed based on the results of the survey (figure 3) and contains four main thematic areas.

According to the results of the survey, the most interesting to readers (75.9%) is information about events in different directions of Kyiv and Ukraine – the first thematic block. Coverage of such news will help raise awareness and active involvement of student youth in events of various levels (city, na-

Figure 2: Logo of the Student Self-Government Council of the Institute of Philology of the Borys Grinchenko Kyiv University.

tional, international), which, in turn, will strengthen existing partnerships with the Ministry of Education and Science of Ukraine, National Agency for Quality Assurance in Higher Education, Kyiv City State Administration and youth public organizations (PO "Ukrainian Student Association", "Foundation for Regional Initiatives", "Ukrainian Academy of Leadership").

The second most popular was the thematic area related to the events of active student life of the Institute of Philology (71.3%). Over 100 events are held at Borys University in Kyiv every month: educational-professional, scientific, volunteer, entertaining, etc. So informing the participants of the educational process will positively affect the involvement of students in events they can choose depending on their interests.

Another important aspect of interest to potential users of the blog "Students IF" is related to changes in

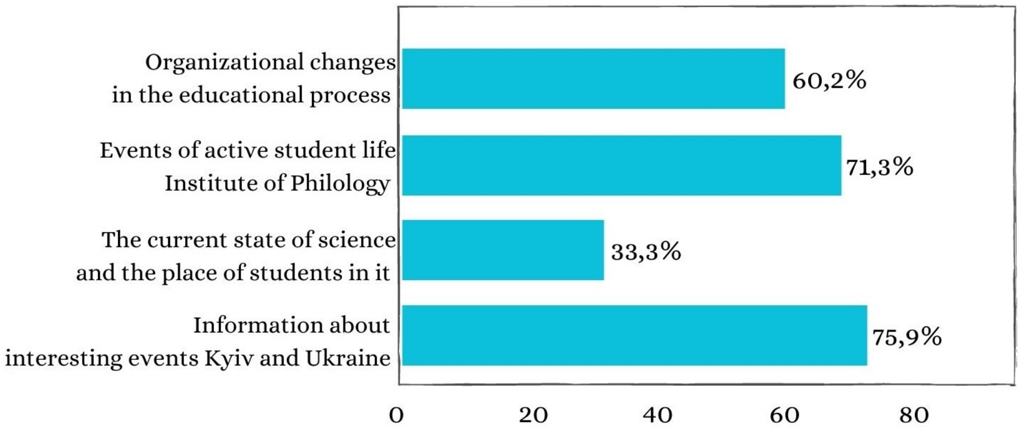

Figure 3: Content of the blog "Students IF".

the organization of the educational process (60.2%) – changes in the schedule, the transition to distance learning, urgent headmaster and more. Today's students are active Internet users, so blogging in this direction is more effective because it covers a larger number of students, and the dissemination of information requires much less time and effort.

The fourth thematic block is the current state of science and the place of students in it (33.3%). Science is an integral part of the educational process, so the coverage of scientific events and the results of such events (conferences, round tables, workshops, webinars, lectures, etc.) will expand the circle of stakeholders and motivate them to start a scientific career.

Stage 4. Determining the frequency of publications. The survey showed that the majority of potential readers (72.2%) believe that placing publications in the blog "Students IF" should depend on the availability of news, as certain time periods are rich in events, so we consider it best to disseminate information in the order of its receipt (figure 4).

Stage 5. Defining the target audience. Among potential readers of "Students IF", which is the focus of the blog, can be divided into three major groups: students, research and teaching staff and entrants. First, the content of this information channel is interesting for students because it is a means of one-way communication between the educational unit and students. Second, the blog is useful for the research and pedagogical staff of Grinchenko University, where they get to know the students better, which allows them to build the best individual educational trajectory for applicants. The third and most numerous group are potential applicants. The "Students IF" blog, a so-called university life diary, is a powerful career guidance tool.

Stage 6. Building a scheme of blogging strategy. During the implementation of research and work with the cloud service Blogger, considering all its advantages and disadvantages, we have developed a scheme that contains step-by-step instructions for creating your own blog (figure 5).

As a result of working with the Blogger cloud service, students should:

- know: practical methods and methods of building blogs; methods of organizing activities for working with blogs; modern development trends, methods of creating blogs;
- be able to: work with software tools for solving tasks related to creating blogs; apply the acquired knowledge when solving actual problems of theory and practice, making forecasts and comprehensive assessments;
- have: practical skills of working with the Blogger cloud service; practical experience of drafting review reports, descriptions of the development of situations and assessment of trends in the development of activities related to the creation of blogs.

Stage 7. Approbation. The relevance and demand for the blog "Students IF" was tested among students of the Institute of Philology of the Grinchenko University (figure 6). To determine the level of communication with users of the "Students IF" blog, a survey was published on the format of study in the second semester, which was attended by over 1500 readers, which testifies to the relevance of this blog and its further development. Analysis of students' responses showed that the majority (68.2%) want to resume full-time study in the second semester, but 22.7% of these applicants are convinced that lectures should be left online. Some respondents (31.8%) prefer distance learning. The results of the survey were passed on to the administration of the educational unit and can serve as one of the key ar-

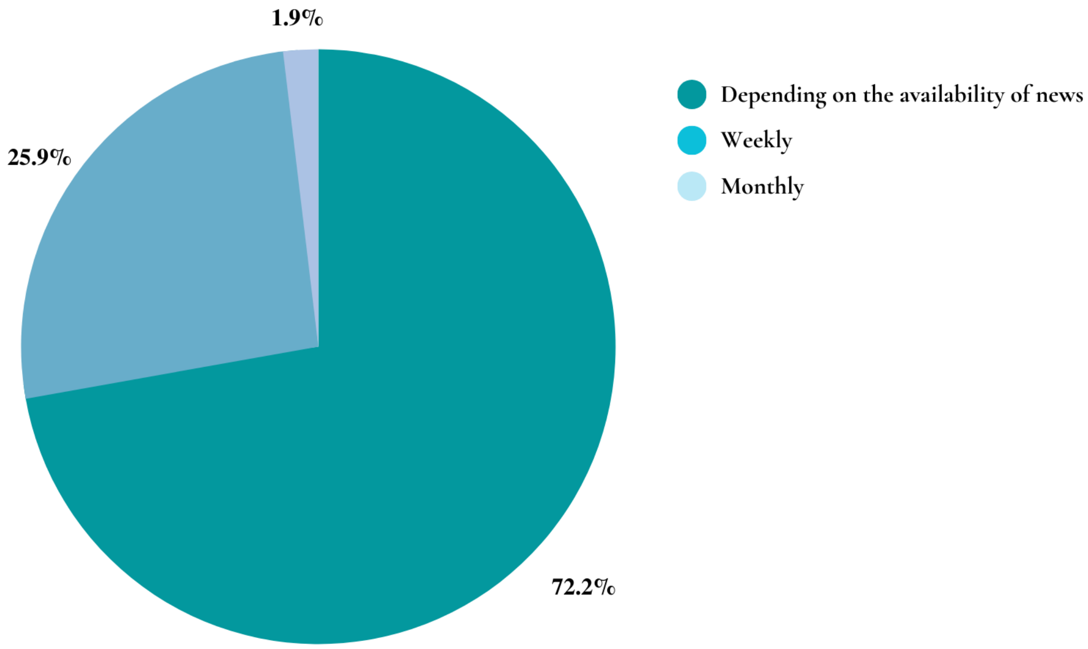

Figure 4: Frequency of publications in blog.

guments when deciding on the format of education in the future.

The results of the survey showed that contact with the applicants was established, so it was decided to go beyond the structural unit. To interest a wider range of readers, content has been expanded. The blog has publications that apply to applicants for various specialties. The expansion of the topic contributed to the rapid growth of the audience. Today, our readers include representatives of all departments of the university. The analysis of the audience showed that the content is interesting to applicants for various specialties.

Increased activity on the “Students IF” blog was the impetus for the launch of the Blogger cloud service in the educational process. First of all, we tested this service on the educational program “Ukrainian Language and Literature”, during the implementation of the mandatory component “Methods of teaching linguistic disciplines”. The task was to create and fill the teacher’s educational blog as one of the ways to present theoretical information.

During the internship, undergraduate students (11 persons) had the opportunity to test their blogs on students of 1–2 courses of the Institute of Philology. Applicants were divided into two groups: one submitted part of the theoretical material through the cloud service Blogger (experimental group), another used traditional methods (control group).

Examples of using the Blogger service in the educational process are shown in figure 7.

We consider the study successful if, according to the results of the test, students received grades A, B, C (at least 75 out of 100 points), see table 1.

Table 1: Comparison of control and experimental group.

	Control group	Experimental group
Number of students who received grades A, B, C	15 (62%)	18 (78%)
Number of students who received other grades	9 (38%)	5 (22%)

Using Fisher’s test, it is established that

$$\varphi*_{emp} = 2.489,\ \varphi*_{cr} = \begin{cases} 1.64 & p \leq 0.05 \\ 2.31 & p \leq 0.01, \end{cases}$$

therefore, hypothesis H1 accepted, the difference in the learning outcomes of the experimental and control groups is statistically proven.

The functioning of the “Students IF” blog for 3 months was productive and effective. This is confirmed by the analysis of the involvement of applicants at the beginning of the school year and after a few months from the launch of the blog (figure 8). Looking at the chart, we see that the figures have increased significantly. We are convinced that the further systematic work of the blog “Students IF” will have a positive impact on the formation of a conscious and active student movement.

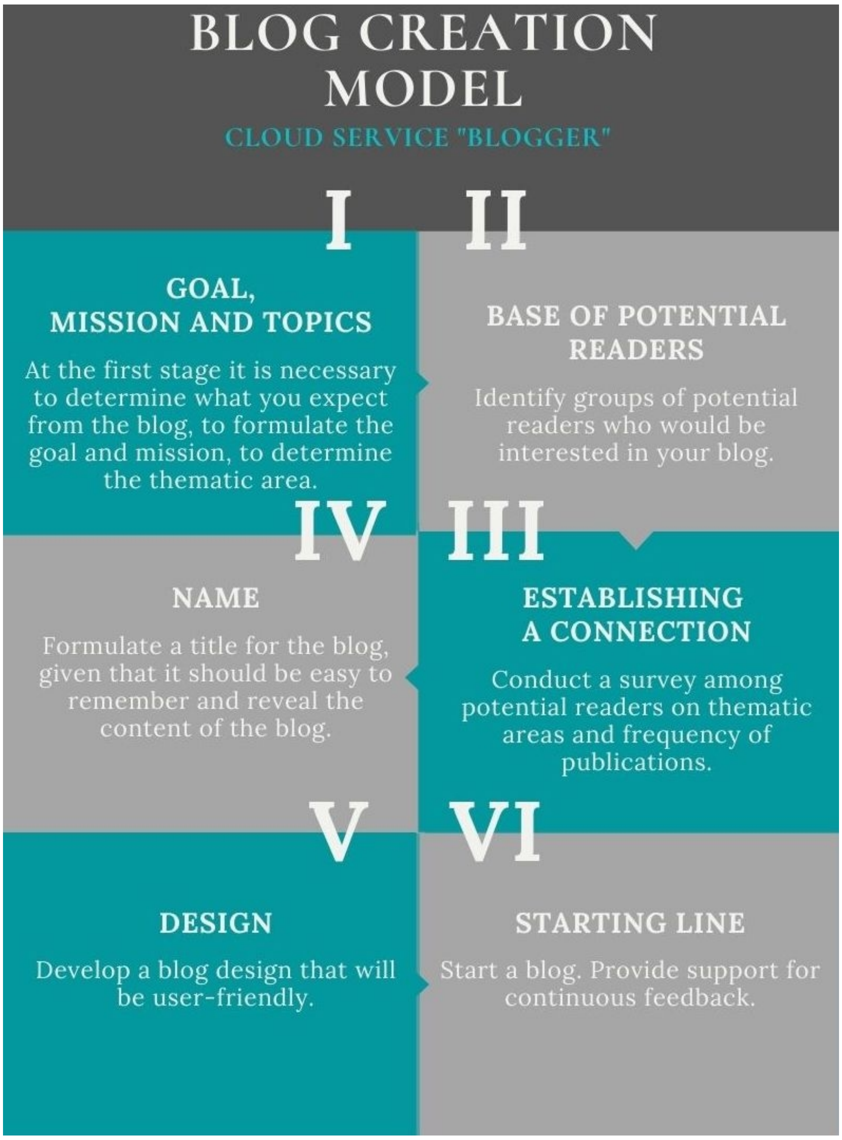

Figure 5: Scheme of blog creation in the cloud service Blogger.

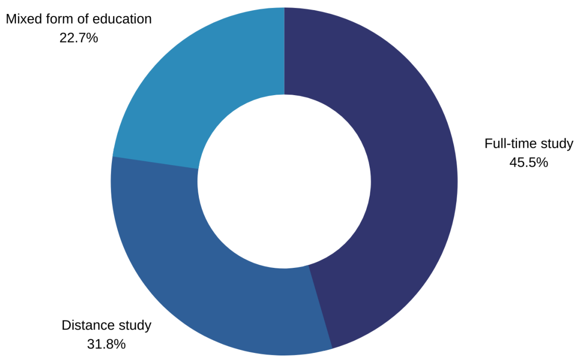

Figure 6: Format of study in the second semester.

It is interesting that as a result of the survey of teachers, the types of various educational activities of students, within which it is possible to develop educational blogs with the help of cloud services, were summarized:

- an interdisciplinary practical session, which is conducted by teachers of various educational disciplines with the aim of realizing interdisciplinary connections;
- analytical workshop where professional situations are worked out;
- a webinar-conference where students present reports on given topics with further discussion;
- workshop-discussion;

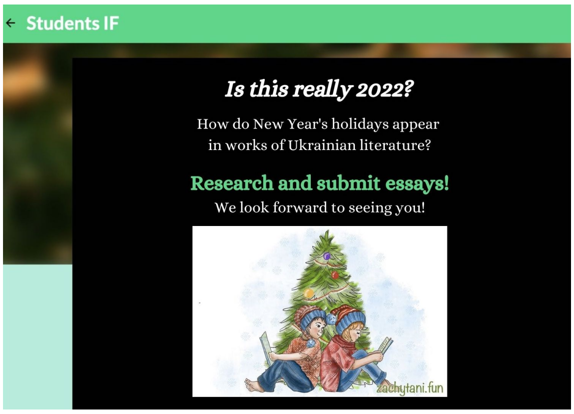

Figure 7: An example of using a blog during the educational process.

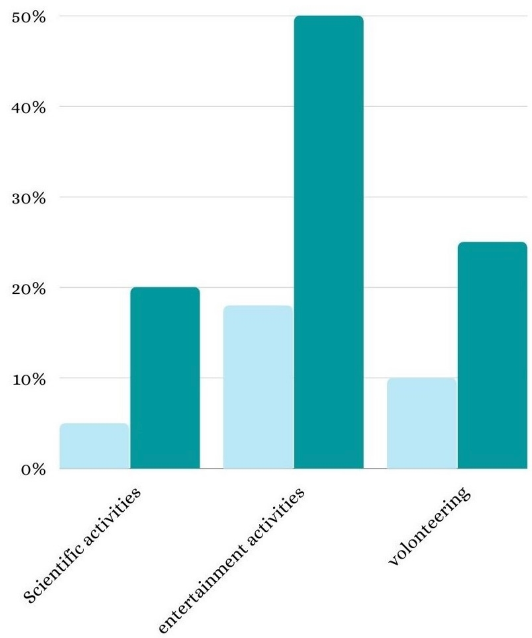

Figure 8: Statistics of applicants' participation in various directions events.

- research practicum, which involves the implementation of research-oriented training;
- a business game that simulates a real problem situation;
- practicum – "brainstorming", students are offered a case in advance, then students offer options for solving the problem with further discussion and selection of the most effective proposal;
- workshop – a master class from stakeholder representatives;
- practicum – meeting with graduates of the educational and professional program.

The main areas of implementation of research-based education and enabling the creation of research-themed blogs are also highlighted:

1. Work of students in scientific laboratories, centers, problem scientific groups and other scientific associations.
2. Individual research work of students.
3. Studying the theoretical foundations of setting, methodology, organization and execution of scientific research, planning and organization of a scientific experiment, processing of scientific data within the framework of specialized courses included in the OPP.
4. Independent scientific research carried out during informal education (taking courses on open online platforms).
5. Carrying out tasks of a research nature, laboratory works, coursework, projects that contain elements of scientific research or are of a research nature.

Methodical development of the implementation of educational activities and research work of students, which involves the creation of blogs using cloud services, will become the perspective of our further research.

5 CONCLUSIONS

The study confirmed the relevance and feasibility of using the Blogger cloud service for communication between teachers and students at the university.

1. Analysis of definitions of "blog" and "Blogger" gave grounds to formulate own definition, which shows the functionality of these terms. The advantages and disadvantages of the Blogger cloud service have been identified. Among the advantages are the following: one user can have several blogs, page filling and management can be done by several authors; a number of additional opportunities that open up through collaboration with Google, etc. Disadvantages include the limited number of design templates and tools.
2. Having found out the desires and needs of potential readers through a survey, the stages of creating a blog using the cloud service Blogger were identified, which meets the needs of users and helps to raise awareness of higher education students about the organization of the educational process and active student life. A blogging scheme has been developed in the Blogger cloud service. It was announced that the results of the study are more applied than theoretical.

3. Successful approbation of the blog “Students IF” among students of the Institute of Philology of Grinchenko University was confirmed by Fisher’s test. This shows that Blogger is the optimal platform for organizing training, quality communication of higher education institutions with applicants. The blog also helps to improve the level of information and consideration of students’ opinions, serves as a platform for discussions, consultations, etc.

Prospects for further research we seen in the development of methodological recommendations for the use of the Blogger cloud service in implementing practical classes at the university.

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Developing Translators' Soft Skills in a Cloud-Based Environment Using the Memsource System

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Keywords: Soft Skills, Cloud-Based Learning Environment, Memsource System, Translator.

Abstract: The paper deals with the possibilities of developing translators' soft skills in a cloud-based learning environment using the Memsource system. The main advantages of Memsource in the educational process are identified. The main advantages of Memsource in the educational process are identified: accessibility through the offer of a demo and an academic programme, easy for mastering, the user-friendly interface, a wide functional range. Experimental training of students in groups for translation projects with mastery of the tasks of team members of different statuses was carried out. Students' evaluation of the functionality of the Memsource system was analysed in terms of learning effectiveness and application in their future professional life. A list of soft skills improved by students during the experiential learning period was identified: digital skills, communication skills, teamwork skills, self-monitoring abilities, responsibility, leadership skills.

1 INTRODUCTION

1.1 Statement of the Problem

Today, the arsenal of tools that translators use in their professional work is quite diverse. It includes not only automated and machine translation systems, terminology management systems and translation memory systems, but also a range of service programmes and translation support information sources. There is a clear tendency to focus not only on the use of information support predominantly from Internet resources, but also on the use of cloud services that duplicate traditional desktop systems and are accessed via network resources. This leads to the view that today it is not advisable to concentrate on mastering a single software product or information resource, but rather to form a cloud-oriented environment as a system of necessary tools and resources to carry out the full range of operations for translation projects. At the same time, an important aspect of professional training of translators is the development of their soft skills when working in a cloud-oriented environment, as this type of activity requires the ability to cooperate, lead or follow a leader, and meet deadlines for tasks or individual phases of a task. It is common for large tasks to be carried out by a team of translators in translation projects. This requires clear coordination of the work of individual project participants, monitoring of task progress, self-monitoring of deadlines by translators (time management), digital skills in a cloud-oriented environment, and remote communication skills.

1.2 The Purpose of the Article

The purpose of this paper is to explore the possibility of developing the soft skills of prospective translators when completing training projects in a cloud-based environment using the Memsource system.

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1.3 Literature Review

The popularity of cloud technologies is growing rapidly in all fields of application. The translation industry is no exception. Researchers in the field of language technology attribute the increasing use of cloud systems to their greater independence from operating systems and locations, easier conditions for collaboration, savings through operation without installation, and the offer of flexible licensing models (Imhof, 2014).

The last two decades have seen a dynamic of scholarly attitudes that correlate with the development of information technologies. In particular, whereas previously only the main benefits of information technology learning for translators were considered, with suggestions for rethinking the teaching of translation (Bowker, 2002), the translation process as a whole is now understood as an interaction between translator and computer (Bundgaard et al., 2016; Chan, 2015; O'Brien, 2012; Tarasenko and Amelina, 2020; Tarasenko et al., 2020). The proliferation of information technologies in the translation industry, in particular cloud-based technologies, is illustrated, for example, by data from TAUS, a think tank whose mission is to automate and innovate in the translation industry (Choudhury and McConnell, 2013).

According to Gambín (Gambín, 2014), one of the most important changes over the last ten years has been the proliferation of solutions with a clear trend towards cloud solutions. The use of cloud technologies in translation, according to the scholar, promotes competition, which in turn means lower and more flexible prices. This is particularly relevant for the activities of small groups of translators who do not have the infrastructure and finances that large corporations do, but thanks to cloud platforms, they will be able to compete with them in some way. At the same time, Gambín (Gambín, 2014) notes that the level of technologies on offer today is very different, but that high-quality solutions are becoming more affordable over time than they used to be. DePalma and Sargent (DePalma and Sargent, 2013) holds the same view and argues that the field of translation services will undoubtedly move to cloud-based solutions in the near future. Practitioners say the most popular translation management systems (TMS) on the market include SDL WorldServer, Memsource, GlobalLink, Across (Choudhury and McConnell, 2013; Tarasenko et al., 2020; Ultimate Languages, 2018). The availability of a choice of cloud offerings is emphasised by Muegge (Muegge, 2013), noting their wide range, e.g. Wordfast Anywhere, Lionbridge Translation Workspace, Memsource Cloud, Wordbee, XMT Cloud. Based on the experience of teaching a master's course for translators, Muegge (Muegge, 2013) concludes that cloud-based systems are easy to use, because all a translator needs is an Internet connection and a login. Since the "heavy" processes (segmentation, TM and glossary search, etc.) in all cloud-based systems take place on the server, there are no multi-step installation procedures required as for desktop systems.

As we can see, from a scholarly perspective, the professional activity of translators is rapidly shifting towards working in a cloud-oriented environment and is carried out through the execution of a translation project by a team of translators. This form of work assumes that translators have a number of soft skills, primarily related to organisational and communicative aspects. Soft skills are classified as "a broad set of skills, competencies, behaviors, attitudes, and personal qualities that enable people to effectively navigate their environment, work well with others, perform well, and achieve their goals. These skills are broadly applicable and complement other skills such as technical, vocational, and academic skills" (Lippman et al., 2015). Recently, employers have been focusing on these skills, stating that university graduates lack them (ManpowerGroup, 2013).

Employers consider soft skills to help professionals succeed in the labour market as: social skills, communication skills, higher-order thinking skills (problem solving, critical thinking and decision-making), self-control skills and a positive self-concept (Lippman et al., 2015). In the context of our study, we should focus on some of these skills. Social skills are understood by scholars as the ability to get along with other people, to avoid conflicts and to find ways to resolve them when they arise. For the translators involved in the project, the ability to work as part of a team and to cooperate with other team members in a conflict-free manner are important. From this perspective, the communication skills of project participants are extremely important, which can be realised verbally or in writing, in particular in the form of communication within the project.

The broadest coverage of the list of soft skills necessary for the successful career of young professionals is presented, in our view, in the U.S. Secretariat's detailed analysis of the U.S. Commission on Achieving Required Skills (SCANS). The thinking skills cover creative thinking, decision making, problem solving, reasoning, and the ability to learn. SCANS specifies that personal qualities include responsibility, self-esteem, sociability, self-management, integrity, and honesty. SCANS identifies five groups of workplace competencies: the ability to allocate resources (time, money, facilities), interpersonal skills (such as teamwork, teaching others, leadership), the ability to acquire and to use information, the ability to understand systems, and the ability to work well with technology (Kautz et al., 2014).

Given that the vast majority of publications on the subject of soft skills development also point to the importance of digital skills for professionals, we think it is worth considering the possibility of developing the soft skills of prospective translators precisely in the cloud-oriented environment in which they will have to work in the future.

2 RESULT AND DISCUSSION

2.1 Memsource as a Key Component of a Cloud-Based Environment in Which to Develop Translators' Soft Skills

The Memsource cloud-based system for mastering the principles of translation projects is a good choice as the basic component of a cloud-based training environment for translators. The following arguments can support this decision:

- although this CAT system offers proprietary software, Memsource provides the opportunity to take advantage of free software demos for 30 days, subject to registration and compliance with the relevant conditions,
- the software interface is clear and easy to master,
- the demo versions are functional on all the main operations of translation projects,
- ability to integrate with other cloud-based translation tools,
- there is a wide choice of interface languages during the registration process,
- the possibility of supplementing the functionality of the system by connecting terminology resources via terminology and translation memory databases.

An equally important argument in favour of using Memsource as the base element of a cloud-based system is its widespread use and study in the world's leading universities training translators (figure 1).

2.2 Selection of Memsource Version for Creating a Cloud-Oriented Environment From the Perspective of Translators' Soft Skills Development

The official Memsource website offers different versions of the programme, structured according to need and the level of work to be performed. In particular, offers are presented in different packages: for freelancers, small translation structures and powerful translation structures in four separate packages: Team Start, Team, Ultimate, and Enterprise.

Each of these packages can be used to form a cloud-based environment for translator training. However, we have chosen Team to model, as closely as possible, the organisation of the workflow and the automation of its stages with a multi-level management structure and control of the conditions of translation services according to the ISO 17100:2015 standard.

Of course, its potential for soft skills development in prospective translators also played an important role in the choice of the Team package. Having analysed the functional aspects of the package, we concluded that by using it, students can develop a number of soft skills necessary for their future professional activities, namely:

- the ability to work in a team, fulfilling a specific role assigned by the project administrator,
- the ability to communicate with other project participants based on the needs of the project,
- the ability to exercise self-monitoring in the performance of tasks within a translation project.

Another important condition for using this package was that we received an annual licence to use it under the academic programme (figure 2).

This is necessary, given that building a cloud-based environment based on this Memsource package is a painstaking and time-consuming job, and its use should provide training for students throughout the academic year, which unfortunately cannot be fully realised using the demo.

2.3 Developing Teamwork Skills in Implementing Translation Projects in a Cloud-Based Environment Using the Team Version

As mentioned earlier, the Team package is best suited to meet the needs of translation structures operating

Figure 1: Geography of university use of the Memsource cloud system.

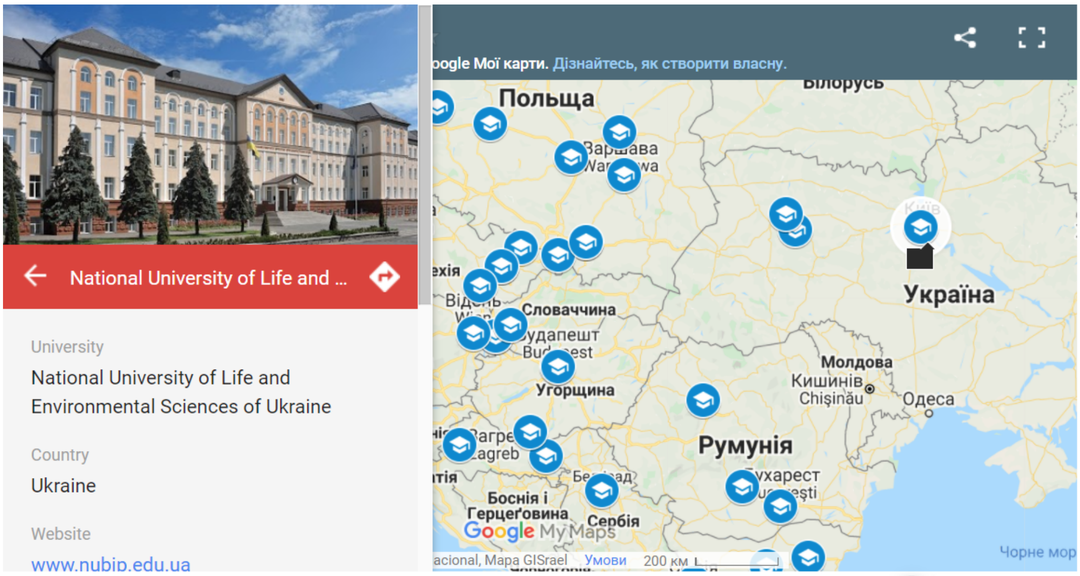

Figure 2: Marking on the Memsource cloud system website that the licence has been granted.

under a defined management hierarchy and practising a team approach to delivering translation projects. Mastering the Team suite will enable students to acquire skills in the administration of translation projects, management of human resources, terminology management, automated task preparation and distribution, analytical evaluation of project tasks, and performance evaluation of each individual participant in project implementation.

In order to use the Team package, a number of additional steps need to be taken to form a team of translators, managers and task distribution.

As the Team package allows the organisation of a hierarchical management system, a cadre of performers was formed from the students and given different statuses. In particular, the system provides four different statuses that can be given to enrolled performers, namely: “Administrator”, “Project Manager”, “Linguist” and “Guest”. Depending on their status, each performer had different opportunities and rights of access to carry out certain actions.

The administrator provided by far the highest level of functionality. In particular, he or she could create translation projects; enroll new performers; set and change performer statuses; assign tasks to performers within a project; monitor the status of each individual performer and the whole project team; and create, edit and populate translation memories and terminology databases.

The immediate work of the administrator, which started at the applicant enrollment stage, was the process of forming the project team, giving them appropriate statuses and distributing tasks among the participants. This enrollment could be done in two ways. One is to fill in the relevant form for each applicant and the other is to enroll applicants comprehensively by importing data from a pre-filled table in XLSX format (figure 3).

Once Memsource has enlisted people with different roles in translation projects, it is necessary to form teams of performers for individually defined projects. In this case, a project manager is selected, who in turn distributes tasks between translators within the project, either alone or together with the administrator. Of course, all the steps involved in creating projects and allocating tasks to projects need to be completed before the tasks can be allocated.

In order to master other roles as participants in a translation project, students could be given the statuses of "Project Manager" and "Linguist", which changed over the course of their work on different projects.

Students with Project Manager status mastered management skills. The range of functionality of the system manager depended largely on the settings set by the administrator. One of the main functions of the manager was to work out the distribution of tasks between the projects implementers (figure 4).

However, it should be noted that by activating all the possible options for manager status, the range of his capabilities will come close to those of an administrator. If partial options are activated, his/her powers will usually be limited to access to a specific project only, managing the executors of that project as a team of translators (linguists), managing translation memories and terminology databases. By observing the activities of the students in the implementation of training translation projects, we have in some cases raised the status of project participants to managerial status, giving them the opportunity to exercise their own abilities at this level.

The settings established for this status also allowed for the creation and maintenance of terminology and translation memory bases within a single project, the management of its executing team, and the monitoring of the project's progress status (figure 5).

The project administrator can obtain information on the level of implementation of the individual tasks within a certain project, in particular the number of translated and confirmed segments as a percentage, the status of the task as a whole, the name of the performer, etc. (figure 6). In addition to this information it is possible to perform various actions on the analysis of individual tasks. The use of these functions enables the development of critical thinking skills in the performers of the project. In particular, it is possible to see statistical indicators relating directly to the translation aspects of a particular task. In the structure of the window, a separate block called "Analysis" will be formed under the list of tasks. In this block, entries for the analysis of a particular task will be placed in separate lines.

To perform the analysis, it is possible to directly activate a table with a number of indicators (figure 7) related to the translation of the task for which the analysis is performed. These indicators will provide information on the total number of segments into which the system automatically divides the whole document, the number of pages in it, the number of words and characters. An important aspect of such an analytical table is also the information about the number of matches of these indicators against the translation memory, if such a database is connected to the project. In this case, the table contains detailed information even in terms of percentage matches between the words or segments present in the text and the corresponding words or segments in the translation memory database.

It is worth noting that the project participants, who were given the roles of administrator and manager, were able to demonstrate and develop their leadership skills through these roles. They were given full responsibility for the implementation of the project, so they coordinated the work of the entire team of translators.

The vast majority of the students in each individual project had the status of "Linguist". They were engaged directly to carry out the translation by performing a specific task. Students who acted as editors also held this status. The students who acted as editors also had this status. There can be any number of such performers in a project, but each of them must be assigned a separate task to perform. Both the administrator and the project manager can define such a task and monitor its progress. A translator with Linguist status also has a range of settings, which can restrict or expand the range of possible actions. These settings are usually made by the project manager. In particular, the settings can give the translator access to edit entries in the terminology database, edit entries in the translation memory, use machine translation, etc.

Before the translation started, the manager ensured that a specially created terminology and trans-

1	Last name	Email	Username	Role	Active	Receive newsletter	Note
2			Must be unique.	LINGUIST or PROJECT_MANAGER or ADMIN or GUEST	TRUE or FALSE	TRUE or FALSE	
3	Doe	alice.doe@company.foo	alice.doe	ADMIN	TRUE	TRUE	
4	Гаценко	megakiti@ukr.net	Catherine!!	LINGUIST	TRUE	TRUE	
5	Дещенко	mdeshchenko@ukr.net	Maria!!	LINGUIST	TRUE	TRUE	
6	Єрема	Ponomarenko320@ukr.net	Anna!!	LINGUIST	TRUE	TRUE	
7	Єрченко	oleksandrayerchenko@gmail.com	Alexandra!!!	LINGUIST	TRUE	TRUE	
8	Жеребченко	yanaolegivna93719@gmail.com	Yana!!	LINGUIST	TRUE	TRUE	
9	Коваленко	jambogirl666@gmail.com	Alexandra!!	LINGUIST	TRUE	TRUE	
10	Багацький	al3xc00ntcrush3r@gmail.com	Alexander!!	LINGUIST	TRUE	TRUE	

Figure 3: Enrollment of participants by the administrator and assignment of their respective roles.

Задания
Новые Редактировать Скачать Анализировать Предварительно перевести Инструменты Удалить

#	Подтверждено	Файл	Статус	Перевод
1	100%	До_Лр_10_Memsourse_завдання (1).docx	Завершено	UK^UA
2	0%	Текст_1.docx	Новые	UK^UA
3	0%	Текст_8.docx	Принято	UK^UA
4	100%	Текст_9.docx	Принято	UK^UA
5	0%	Текст_10.docx	Новые	UK^UA

Figure 4: Distribution of tasks between project implementers in the Memsource system.

lation memory database was connected to the project. This was done with the aim of having students with Linguist status practise the overwhelming number of possible features implemented in the Memsource system. In particular, provided the original segmented text was presented in a special window, the student was able to fill in variants of the target text in different ways (figure 8). These included: writing the target text manually from the keyboard; substituting a suggested translation variant based on the translation results in the selected machine translation system; substituting a suggested translation variant based on the results of a match with a segment in the connected translation memory, selecting the corresponding individual term suggested from the terminology database.

2.4 Developing Self-Monitoring Skills Based on Translation Quality Management in a Cloud-Based Environment Using the Memsource System

The large volume of material cannot be translated by using even highly qualified translators without the latest information technology-based tools. Experience has shown that the traditional approach to translating large volumes of documentation in the education sector by a team of translators has a number of negative consequences:

- low productivity due to the need for each translator to translate the same terminology several times in isolation,
- lack of uniform terminology used by each translator in a particular academic and scientific field, which leads to difficulty in understanding the content of the translated text by users,
- the difficulty of coordinating the activities of a group of translators,
- the difficulty of coordinating the activities of a group of translators,
- a high degree of dependence of the successful completion of a translation on the individual translator as the individual owner of the terminology resource.

With this in mind, it is advisable to train translators with the understanding that their future professional activities will involve them mainly in teamwork in translation projects with the obligatory use of the latest information technologies. Cloud-based systems are promising in this regard and have a number of advantages, as already mentioned in this paper.

The execution of translation projects enables a team of translators to coordinate their work, distribute tasks and get results, thereby achieving the goal of translating large amounts of textual material.

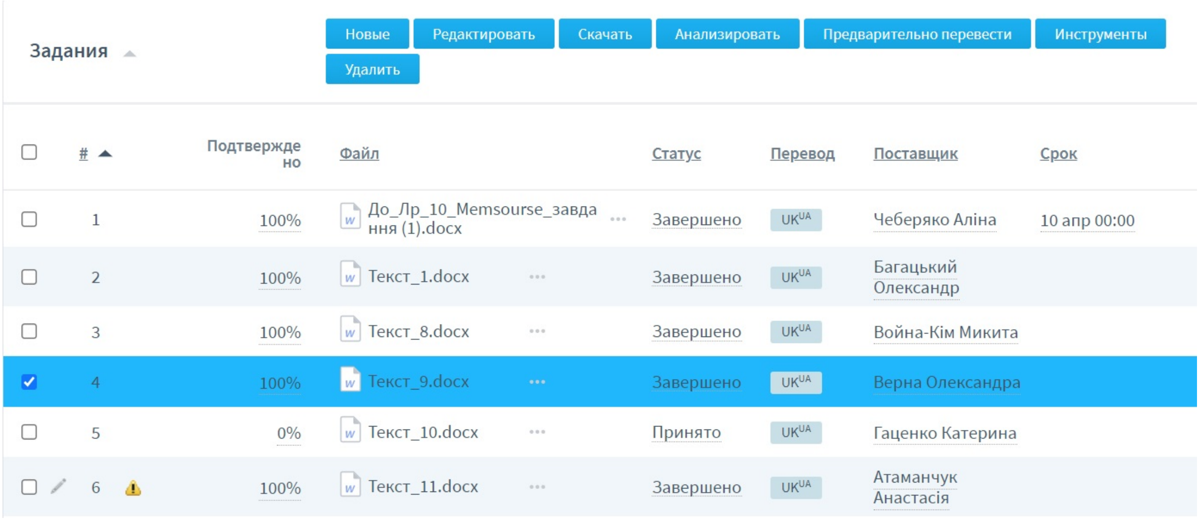

Figure 5: General monitoring of the status of projects and tasks in the Memsource system.

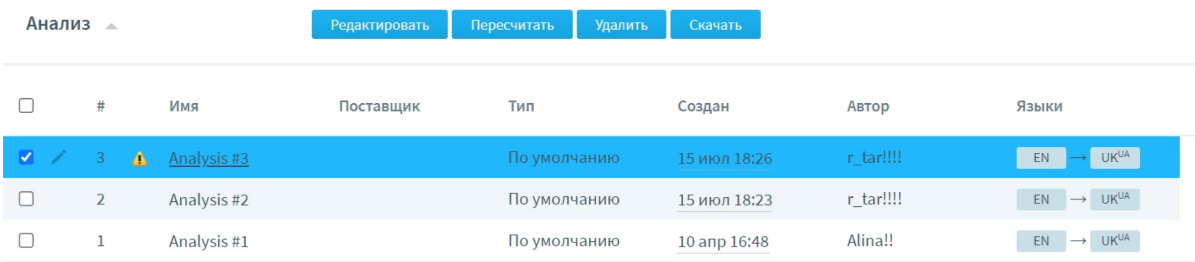

Figure 6: Monitoring the level of implementation of the individual tasks within the project.

The execution of translation projects enables a team of translators to coordinate their work, distribute tasks and get results, thus achieving the goal of translating a large volume of textual material.

At the same time, however, there is also the issue of ensuring the quality of the translated material, since losses in translation quality can be due to various types of errors, ranging from minor ones that do not make the target text difficult to understand to important ones that can lead to future misunderstandings or even losses due to incorrect or inaccurate translation. Particular attention is required to ensure that translators working on the same project use consistent terminology in order to avoid disagreements when translating parts of the same text.

In this aspect, it is valuable for training future translators to learn to apply the QA (Quality Assurance) management processes built into Memsource after the translation has been completed, or even in the intermediate stages of completion. This gives the translator a powerful tool to see what spelling mistakes have been made, identify missing elements in the translated segment in relation to the source segment, and ensure terminology consistency based on a connected terminology database, and so on (figures 9, 10).

In order to successfully master the QA processes, students learned a sequence of actions, namely:

- activate the tab of the same name in the window, which, by default, displays the suggested translation options. In this case, a list of errors detected by the system will be displayed with the number of the segment in which they occurred,
- make the necessary changes to the target text in those segments where the system has detected errors.

Once the translation of the file had been completed, the students’ next steps were to receive the translation results as a file in the format in which the original file was also posted, or to submit the results to the editor for review.

In the first case, they activated the browser tab with the translation project window, highlighted the task whose translation results were to be received as a file and selected the finished file for downloading via the context menu. Because of these actions, the student received on their own computer a downloaded

Базы памяти переводов: База_1, lad10

Файл: Текст_10.docx

		Сегменты		Страницы		Слова		Символы (без пробелов)		%	
Все		1387		29.68		8138		46683		100	
Повторы		31		0.23		61		385		0.7	
101%		7		0.16		47		249		0.6	
− 100%	Память переводов	96	39	0.21	0.07	104	43	366	119	1.3	0.5
	Непереводимые элементы		57		0.14		61		247		0.7
	Машинный перевод		0		0		0		0		0
+ 95%–99%		46		0.47		133		761		1.6	
+ 85%–94%		7		0.13		27		220		0.3	
+ 75%–84%		16		0.35		75		568		0.9	
50%–74%		177		3.99		986		6375		12.1	
0%–49%		1007		24.14		6705		37759		82.4	

Figure 7: Table with indicators on the translation of the individual task.

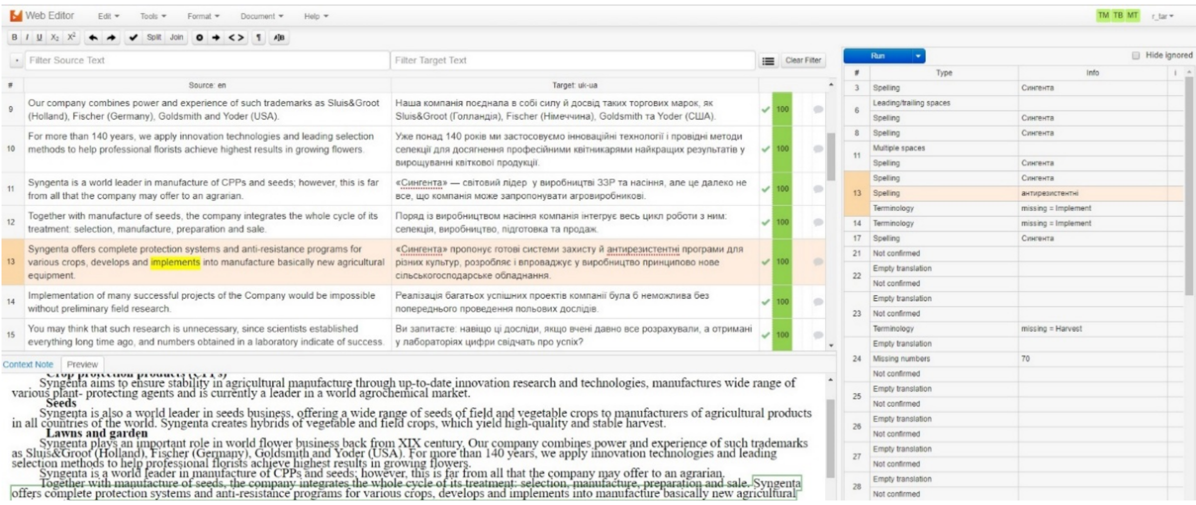

Figure 8: Example of translation in the Memsource system.

file with the target text, created based on the results of the translation and quality assurance activities.

In the second case, when editing is necessary before uploading the final translation results, students are reminded to select the DOCX option in the context menu. This will allow uploading the translation results by means of a bilingual text whose segments are placed in a table.

This option is useful if the person editing the translated text prefers to work with a text file in a text editor. It is also possible to check spelling when working with such a file, using the appropriate features of a text editor.

In general, in terms of translation quality assurance, a cloud-based translation memory system is better suited to cooperation between distributed teams of translators. By storing the linguistic resources (TM, TB, and bilingual MXLIFF) on one central server, translators can easily access the resources together and simultaneously. This allows already translated segments and created terms to be shared during the translation process. In addition, the workflow feature allows different project participants, such as translators, editors and proofreaders, to work on a document simultaneously, which can significantly reduce the turnaround time of a translation project.

3 ANALYSIS OF THE FEASIBILITY OF USING MEMSOURCE TO DEVELOP TRANSLATORS' SOFT SKILLS WITHIN A CLOUD-BASED ENVIRONMENT

In order to determine the feasibility of using Memsource in translator training as the main component of a cloud-based environment that can be used to form and develop soft skills, we asked students who had gained experience with this cloud-based automated translation system while studying "Information Technology in Translation Projects" (67 people) first to rate the usefulness of individual functions of the system on a 5-point system, and second to identify the

Run | Hide ignored

#	Type	Info	i
3	Spelling	Сингента	
6	Leading/trailing spaces		
	Spelling	Сингента	
8	Spelling	Сингента	
11	Multiple spaces		
	Spelling	Сингента	
13	Spelling	Сингента	
	Spelling	антирезистентні	
	Terminology	missing = Implement	
14	Terminology	missing = Implement	
17	Spelling	Сингента	
21	Not confirmed		

Figure 9: Checking spelling in Memsource.

ID	#	Source (en)	Target (uk-ua)	
	1	**Changes in Water-Extractable Organic Carbon with Cover Crop Planting under Continuous Corn Silage Production**	**Зміна водо-екстрагованого органічного вуглецю при посадці покривних культур при безперервному виробництві кукурудзяного силосу**	75
	2	The conversion of natural wetland and prairie habitats to row crop agriculture lands has led to long-term reductions in organic carbon (DOC) in soil.	Перетворення природних водно-болотних та прерійних середовищ існування ряду сільськогосподарських земель призвело до довгострокового скорочення органічного вуглецю (DOC) у ґрунті.	75
	3	The availability of soil carbon is an essential component of soil health that influences soil microbial activity, nutrient availability, water holding capacity, and water filtration.	Наявність ґрунтового вуглецю є важливим компонентом здоров'я ґрунту, який впливає на активність ґрунтових мікробів, доступність поживних речовин, водоутримуючу здатність і фільтрацію води.	75
	4	Thus, practices to restore soil carbon and organic matter are being investigated globally to increase the sustainability of row crop agriculture.	Таким чином, практики відновлення ґрунтового вуглецю та органічної речовини досліджуються в усьому світі для підвищення стійкості сільського господарства.	75

Figure 10: Checking the correctness of the translation by comparing segments of the source and target texts.

soft skills that they were able to improve when carrying out translation projects using the Memsource system.

The list of functions include: source text review during translation, display of full matches, display of fuzzy matches, integration with the MT system, merge/divide segments, use of repetitions, spell check on input, automated search for terms in the database, confirmation and saving of a segment, formal criteria check with error message, spell check of all translation units, export of target text, editing of source text, comments, automatic completion of the target segment based on MT translation results, copying a segment of source text into a segment of target text.

The results obtained (number of responses with a score to each function) are presented in table 1.

The responses received indicate that the following Memsource features received a 100% positive rating (a positive rating was taken to mean a score of 4 and 5):

- display of full matches (26+41),
- display of fuzzy matches (30+37),
- integration with the MT system (8+59),
- use of repetitions (23+44),
- spellcheck on input (11+56),
- automated search for terms in the database (26+41),
- confirmation and saving of a segment (18+49),

Table 1: Comparison of selected mobile language learning applications (paid).

Function	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Evaluation 5
Source text review during translation	0	0	4	18	45
Display of full matches	0	0	0	26	41
Display of fuzzy matches	0	0	0	30	37
Integration with the MT system	0	0	0	8	59
Editing of source text	3	6	7	48	3
Automatic completion of the target segment based on MT translation results	0	0	12	38	17
Copying a segment of source text into a segment of target text	0	0	17	35	15
Merge/divide segments	0	0	18	27	22
Use of repetitions	0	0	0	23	44
Spell check on input	0	0	0	11	56
Comments	5	7	35	9	11
Automated search for terms in the database	0	0	0	26	41
Confirmation and saving of a segment	0	0	0	18	49
Spell check of all translation units	0	0	0	13	54
Formal criteria check with error message	0	0	0	29	30
Export of target text	0	0	0	21	46

- spell check of all translation units (13+54),
- export of target text (21+46).

This high score for a significant number of functions indicates that the students have understood their benefits and usability, have mastered their skills and realised their effectiveness.

At the same time, several functions received a lower proportion of positive ratings, in particular:

- source text review during translation (94%),
- formal criteria check with error message (88%),
- automatic completion of the target segment based on MT translation results (82%),
- copying a segment of source text into a segment of target text (75%),
- merge/divide segments (73%).

This is, in our opinion, primarily because these functions are not quite typical in the translation process and the students have not fully understood their meaning and necessity.

The two functions that received the most varied evaluations were editing of the source text and comments. It is likely that some students did not appreciate their role in the translation process.

Overall, the vast majority of students who participated in the experiential learning, positively evaluating most features of the system, confirmed our assumption about the use of Memsource as a core component of a cloud-based environment.

At the same time, students were also generally positive about the possibility to develop soft skills when performing translation projects in a cloud-based environment based on Memsource. Table 2 presents a rating list of the skills highlighted by the students.

Table 2: List of soft skills developed in translation projects using Memsource.

Skills/Abilities	Number of responses
Digital skills	67
Ability to work in a team	64
Communicative skills	55
Ability to self-control	38
Responsibility	32
Leadership skills	5

As shown in table 2, all students improved their digital skills. It should be noted that at the same time during the verbal communication with the participants of the experiment they stated their understanding of the importance of these skills for their future professional activities. Almost 100% indicated the ability to work in a team, because without this ability of each team member, the project would not be possible. About half of the students highlighted the capacity for self-control and responsibility, which encourages us to increase our focus on developing these personal qualities in the future. Quite a small number of participants in the experiment stated that they had improved their leadership skills. This is explained by the fact that the respective roles (administrator and manager) were played by a small number of students, as it actually happens in real professional activity.

4 CONCLUSIONS

The use of Memsource in the training of translators contributes to the development of a number of soft skills necessary for their future professional career, namely:

- the ability to work in a team, fulfilling a specific role assigned by the project administrator (manager, linguist) and to practise relevant skills,
- leadership skills (in the case of the role of project administrator or manager),
- the ability to communicate with others involved in the project, which passes through the Memsource system and requires the development of digital skills,
- the ability to carry out self-monitoring of tasks within a translation project consisting of time management, meeting deadlines for a task or part of a task, checking the quality of one's own translation using the system functions, etc,
- the ability to make decisions at the level of their role (e.g. to allocate tasks),
- responsibility for their part of a translation project based on the awareness of the importance of their own contribution to the common cause,
- digital skills as part of the technological training of translators for professional activities in a new environment using information technologies.

The use of the Memsource system as the main component for creating a cloud-based environment for training translators has shown that it can be used in the educational process due to a number of significant advantages, which include:

- accessibility through the offer of a demo and an academic programme,
- easy for students to master, especially in cases where they have already studied one of the desktop translation systems,
- the user-friendly interface, which greatly simplifies working with the system,
- a wide functional range, allowing prospective translators to practise the different roles of participants in a translation project with relevant skills and abilities,
- the prospect of applying the experience gained with the system to future professional activities.

The cloud-based environment built using the Memsource platform ensures that prospective translators are systematically equipped with the tools and resources they need to carry out a full range of translation projects and, just as importantly, develop their soft skills.

The creation of a cloud-based environment will also optimise the structure and components of translation projects in the educational process of higher education institutions that train translators. This involves the justification, selection and enhancement of translation project tools, the basis of which will be cloud-based automated translation systems integrated with translation memory systems and systems for the creation and maintenance of educational and scientific terminology databases.

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Raising Students' Motivation in Terms of Blended Learning: The Example of Interface Design Mastering

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Keywords: Learning Motivation, Blended Learning, Blended Learning Activities, Interactive Methods, User Interface Design, Pre-Service Specialists' Training.

Abstract: The problems of raising students' motivation in terms of blended learning implementation at national universities are discussed in the paper in the context of interface design mastering by the students of various specialties. In the progress of work, there were analyzed the core features and challenges of blended learning, and covered the ways of enrichment of the blended learning techniques (flipped learning, gamification, digital storytelling, cooperative learning etc.) with interactive methods and forms of work. The experience of interactive methods practical realization in the process of the user interface design mastering by university students is presented. It is also covered the preparation stage of the survey on the estimation of the students' motivation. The survey was designed to evaluate whether the interactive methods introducing into the blended learning activities is in line with the aforementioned rules and detect what students' motivation levels are. The results of the survey, according to the levels of students' motivation are presented and discussed. The prospects of the research are outlined.

1 INTRODUCTION

According to recent studies, there is an increasing focus on the students' retention at university and accomplishing their higher education. For instance, the percentage of the university dropouts is pointed out as quite high (40% in USA, and about 10% in Europe) (Eur, 2023). Consequently, it raises the urgency of identifying factors that can cause decreasing the students' dropouts. Among the reasons for students leaving higher education (Bonfield et al., 2020; Eur, 2023; Hanson, 2022), there were identified some factors as affecting student's retention and their educational success: (1) trainee's characteristics including their motivation and cognitive abilities; (2) university surrounding comprising teaching quality, learning strategies and interactions with peers and educational staff; and (3) external factors connected with non-academic external problems (current job market situation, family responsibilities).

According to a psycho-educational dimension, motivation to learn is understood as a student's energy and drive to learn, work efficiently and realize their potential (Islam et al., 2018; Ibrahim and Nat, 2019). In numerous works motivation is considered as an important contributor to trainee's academic success and essential for their retention in higher education.

The issues of student's motivation boosting in terms of blended learning are widely discussed by the researchers. Especially urgent this problem is seen for the blended learning models with the focus on distant learning which are currently getting more common due to pandemic and war conflict situations. Despite the great advantages of the blended learning versus conventional classroom education, there are serious drawbacks and challenges of its successful implementation in the university studying pointed out by the researchers and practitioners.

In particular, it is stressed not satisfactory didactic and methodological provision in the context of current educational process. In addition, it is pointed out that in order to succeed, the correct blending of the conventional and online educational delivery needs to be realized. Conventional approaches to the learning

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aids creation, educational content design, and techniques of tutoring do not totally suit blended learning paradigm and do not enable to involve students properly into active learning process. One more problem in this context is associated with the fact that university curriculum is recently guided mostly by cognitive approaches rather than by motivation theory, therefore learners' motivation to study is undervalued (Islam et al., 2018; Ibrahim and Nat, 2019).

The said problems cause students' passive position at blended learning, lack of classroom atmosphere and interactivity, losing their cognitive interest, not satisfactory academic results, which finally leads to decreasing of students' motivation to master educational content and obtain top level professional expertise.

Thus, it is essential to find out the approaches to motivation boosting based on the involving students into the blended learning activities enriched with interactive methods.

The aim of the paper is to elaborate and cover the ways of raising students' motivation at blended learning and to probe them at user interface mastering in the progress of the university students' training.

2 THEORETICAL BACKGROUND

Theoretical framework of the research is made by the analysis of the (1) fundamentals of motivation theory; (2) main characteristics of blended learning and its typical learning techniques used in the practice of blended learning; (3) basic approaches to the mastering of the fundamentals of user interface design in the training of different specialists.

According to motivation theory and its educational dimensions, motivation to learn is defined as the personal efforts which encourage to learning activities, ensure their continuity and point direction to the activities with the aim at achievement of student's desired goals (Puspitasari, 2012). Learning motivation is seen as a psychological factor that plays a role in raising the spirit of learning for individuals. Motivation to learn is characterized as a drive of the tutorial process and significantly contributes to reaching the goal of taking the benefit from the learning, what is especially essential for professional university education.

It is also underlined by the researchers the tight connection between motivation and academic results of a student. It is recommended to analyze the factors which influence the learning outcomes in the context of learning motivation that is considered as a necessary requirement for studying, providing enthusiasm in overcoming leaning difficulties (Alderfer, 1969). Some experts also look at learning motivation as at the student's eagerness to do the learning activities driven by the desire to achieve the best achievement and academic results (Sofyan and Uno, 2004).

According to Keller (Keller, 1987), the most common factors that affect motivation in the process of learning are: attention, appealing to learner's past experience, positive attitude, and satisfaction. It is argued that provision of all these ingredients may promote and sustain motivation throughout the learning process (Keller, 1987, 2010). It is also formulated core rules that have to be met in the progress of tutoring to provide these components (Huang and Hew, 2016).

According to the first rule, a variety of learning strategies should be implemented to attract and retain learners' attention. The second rule recommends to set clear instructional goals and provide learners with educational content which refers to learner's past experience (academic or working one). The third rule which is responsible for shaping student's confidence says that learning environment should promote learners' positive attitude to the tutoring process and suggest focusing towards success. According to the fourth rule, it is essential to help students gain satisfactory feeling.

It is also pointed out that on condition the first three rules are met, students' overall satisfaction will be enhanced accordingly (Keller and Kopp, 1987; Keller, 2010). According to studies (Petsche, 2009; Ormrod et al., 2019) motivation may have different kinds of influence on the student's learning and their behavior toward subjects mastering. For instance, the motivation can: (1) direct learner's behavior toward proper aims; (2) lead to increased effort and energy; (3) raise initiation and persistence in doing learning activities; (4) strengthen cognitive processes; (5) lead to better performance.

There are distinguished two kinds of learning motivation: internal and extrinsic motivation (Petsche, 2009; Ormrod et al., 2019).

Intrinsic motivation typically arises without obvious reward. As an own reward, a person takes accomplishing the task or achieving their goal. Internally motivated behavior is said to be natural, and is considered to result in creativity and flexibility, experience of interest and enjoyment, and in feelings of being competent and self-determined.

Extrinsic motivation arrives from the outside a learner, and is driven by the apparent rewards or reinforcements for learners to engage them in the activities. The motivational rewards may include verbal praise, higher points, special beiges that can lead to academic privileges, certificates etc. The external motivation factors provide student's satisfaction and joy which the activity itself and their results may not give to a learner. Thus, it can be a challenge for educational staff to find out special stimulus as external motivation factors to provoke student's cognitive interest which can lead to raising his internal motivation and taking pleasure of learning activities and obtained results.

The process of students' motivating to learning is seen as a way of their encouraging to productive cognitive activities and active mastering of the educational content. This process has the features of a certain cycle which is repeated at each segment of learning on higher level. Therefore, educational staff have to provide each stage of motivational cycle with the help of special methods and techniques. Among them experts distinguish such stimulation techniques as communicative attack, suggestion, overcoming difficulties, positive expression shaping etc., and emphasize the increasing role of communication and interaction during learning. In particular, it is recommended to develop and apply the interactive forms of learning focused on the provoking students' cognitive interest and involving them into productive cognitive activities. In lots of works it is proved the connection of motivation with students' engagement and interactive strategies of learning which is coordinated perfectly well with the stimuli both for intrinsic and extrinsic motivation. It is pointed out, that interactive forms of learning are able to demonstrate students their personal role in common productive discussion, to make them understand the importance of their own contribution into common result, to feel pleasure of learning, which finally can influence on their learning motivation.

For successful blended leaning implementation, the introducing of interactive methods is seen also beneficial (Vakaliuk et al., 2021; Vlasenko et al., 2021; Dellatola et al., 2020). Thus, it is possible to anticipate the positive impact of enrichment of blended learning techniques with different kinds of relevant interactivity on students' motivation.

Covering main characteristics of blended learning and current challenges of its implementation in national higher educational practice, we would like to emphasize the following aspects.

Blended learning is considered as a combination of face-to-face and virtual learning, when educational content is presented and worked out online but with some features of typical classroom studying. According to Wear and Levenson (Wear and Levenson, 2020), the core goal of the virtual learning is to provide the access to education with technology support and enable a learner to achieve their personal educational targets. The final outcome of virtual learning is a distant learning provided by an online learning management system. These online systems enable trainees to get access to the necessary materials and trainers' responses at their outworking from any point with the Internet access. This model of blended learning is called online driver. However, it is concluded that the model is not effective enough, because the students' learning activity is not managed by the educational staff.

Researchers and practitioners find more appropriate for higher education two other blended learning models: flex model (mostly focuses on the online learning with trainers' support during online studies on a flexible basis) and rotation model (provides interchanging of in-person and online tutorial process). Their main benefits are sufficient levels of the control over the students' learning, and of flexibility, as the learners are provided with tailored learning techniques and platforms designed regarding blended learning strategy. In particular, the researchers and practitioners (Adel and Dayan, 2021; Wear and Levenson, 2020) point out that the learning systems in flex and rotation models are ought to be designed taking into account core features of the national educational systems, current peculiarities of tutoring process, trainees' needs etc.

In this connection, it is also emphasized that within any model of blended learning, it is essential to pick up proper learning techniques, which causes necessity to analyze common ones, available in the practice of blended learning. There are described some attempts to create the system of blended learning activities which might provide trainees with a total learning model, successfully using digital technologies and blending them with conventional learning techniques (Wear and Levenson, 2020). In the terms of blended learning, in particular, it is pointed out the benefit of using the system of the learning methodologies such as flipped learning approach, gamification strategy, digital storytelling, team work, cooperative learning and others. However, other researchers argue that these kinds of learning activity systems are not efficient enough for students' motivation raising, and must be improved in the lines of attracting rather interactive methods into said blended learning techniques regarding the challenges in terms of efficient communication (Dellatola et al., 2020).

Among the influential factors of successful elaboration of blended learning in higher education, it is also relevant to include the factor of regarding the specifics of the subject area and the features of exact academic subject due to the great variety of majors and difference of the curriculum disciplines. Therefore, the blended learning of the specific subject has to involve the trainees into special kinds of learning activities which are able to influence on their motivation to master exactly this subject domain and for the trainees of the exact major. The said learning activities must be selected in accordance with the proper educational content, also designed regarding the peculiarities of training the specific pre-service specialists.

Here we would like to cover authors' approaches to the mastering of the fundamentals of user interface design in the training of different specialists, partially based on our previous works (Bilousova et al., 2021b,a).

The focus on the educational challenges in this field is caused by the evidence of the national course on the digitalization of economy which raises the urgency of the training high level specialists in different areas who have advanced digital skills. Among such skills there is a competence in the field of user interface and user experience design (UI/UX design) which is essential today for a wide range of professionals from pure IT specialists to the experts in digital products development, marketing and human-computer interaction.

In our earlier works we presented special approach to the curriculum building for students' training in this area which was elaborated with understanding that UI/UX design is complicated subject domain that integrates the set of related areas, like graphical design, software development, digital products promotion, psychology, engineering, ergonomics and others. Thus, a designer is expected to master special inter-discipline knowledge and skills.

Characterizing our approach to the curriculum and educational content building for potential specialists' learning of the basics of UI/UX design, we would point out that it was also created based on the analysis of the essence of the UI/UX design and role of its mastering in the vocational training of different specialists.

In fact, the UI design rather focuses on the product appearance and supplies exactly interaction functions (Bilousova et al., 2021b). UI design is developed on some core regulations shaped regarding mostly the psychological features of the human perception of information, influence of visual language on this process, peculiarities of human interaction with devices and their software (Mikhnova, 2019). UX design differs from UI type of design. It is understood by the experts as a tool for provision of the best user's impression, practice and satisfaction of the interaction with the product of any kind (Platonova, 2019). It rests on the deep understanding of the user's profile, their needs and requirements; functionality of the product; possible user's behavior etc.

However, the both types of design are two sides of the same process and serve the same purpose of the best final marketing result, using different means. Hence, the mastering of the UI/UX fundamentals by the students of different branches should rest on understanding of some unique postulates and common instruments, and at the same time reflect the state-of-art tendencies in design shaped in different branches.

Thus, it was offered the practically-driven approach to the building of educational content for learning of UI/UX design basics which expects separation of the two parts (stable and varying) in the curriculum of the potential specialists' training.

The stable part includes the modules covering general fundamentals of the design that rest on common principles and must be mastered by the designers in any sphere. It was justified (Bilousova et al., 2021b) the structure and content of three academic modules of the stable part of the curriculum. The first module "Psychological base of visual perception" is aimed at forming the students' knowledge for realizing the psychological mechanisms and features of visual information perception. In addition, in the module it is discussed widely the psychological significance of the graphical image semantics due to the involvement of various information channels (logical, aesthetic, semantic) and their roles in the shaping of visual image in human mind (Mikhnova, 2019; Platonova, 2019).

Next module "Graphic interface design" of the stable part is dedicated to mastering basics of the graphical interface creation based on the principles of visual language application. Here it is learnt how to create and render the interface ideas using colors, typography, imagery, bootstraps etc., how to add visual anchors, and how to make interface function smoothly and in user-centric way. Thus, the module gives the trainees understanding of the peculiarities of both types of design and at the same time, their joint role in the successful interface creation. The final module "Tools for interface design" of the stable part of the UI/UX design university curriculum is expected to focus on practical work in one of the common environments (for example, in Figma) for the interface development. In fact, Figma is known an online design tool which enables to make mockups, interactive animations, and efficient apps prototypes (Bilousova et al., 2021b; Mikhnova, 2019). Figma environment also arranges version control, joint work opportunities, code generation and other essential features. In such a way, regarding Figma facilities, the process of the clickable prototype design is greatly coordinated with the multi-step process towards the software development, demonstrating the role of both UI and UX design at each stage of this practice. This promotes cultivating of the best experience for potential designers in any sphere. Thus, Figma is seen to be a state-of-art universal instrument of a designer and it is really beneficial for the trainees of different majors to master basics of UI/UX design on Figma platform. Finally, resting on the psychological knowledge and design skills obtained in the previous modules, the students will apply this methodology within the third module to produce a digital prototypes of their apps, working out the UI/UX design mastery.

The stable part of the UI/UX design curriculum of the potential specialists' training, according to our approach to the building of educational content, must be extended by the modules of varying part. They are recommended to concentrate on the learning other special tools appropriate for solving interface design problems in different subject domains including the facilities of a number of environments (such as Adobe Photoshop, Adobe XD, InVision, Sketch, Adobe Illustrator etc.) (Bilousova et al., 2021b).

Thus, the theoretical framework depicted above served a basis for our research covered in the following up chapters.

3 RESULTS AND DISCUSSION

3.1 The Ways of Enrichment of the Blended Learning Techniques with Interactive Methods

Basing on the provided theoretical framework, we are going to present distinguished learning methodologies (flipped learning approach, gamification strategy, digital storytelling, cooperative learning etc.) within the flex model of blended learning, and to offer the ways how to enrich them with interactive methods, which can make them more efficient in terms of improving students' motivation.

Flipped learning is seen by researchers as an educational approach where the conventional outlook of classroom-based studying is inverted in the lines of offering trainees to master the certain educational content before the classroom time (Dellatola et al., 2020). Therefore, the learners come to class being ready to discuss the familiar content with their peers and teacher that enables extended understanding through debating and problem-solving activities arranged by the educational staff. In terms of blended learning, flipped classroom seems to be commonly applicable and organic. Nevertheless, its implementation takes special teacher's efforts to arrange and facilitate students' interaction (discussion, efficient feedback, collaborative problem-solving, etc.) during online classes on the interface design mastering.

Different productive methodology which is available in blended learning is gamification strategy that allows to apply game-playing practices used in non-game contexts. It is emphasized, that attracting game elements into educational area provokes students' essential needs for their motivation (in particular, the needs to communicate, interact and cooperate with others, to feel own expertise in a certain area, and to control their own actions). According to studies, gamification techniques implementation is able to promote collaboration and raise communication, which is significantly important for flex model of blended learning. Some researchers also emphasize the essential feature of the strategy to apply game-based mechanisms and game thinking to diversify learning, to raise students' eagerness to study, and solve offered non-conventional problems (Zainuddin et al., 2020).

Besides the common application of the gamification methodology, for blended learning there might be also beneficial to use a gamification variant in the lines of the encouraging students to design a gamified product. Such an activity enables to trigger off gamification mechanisms, on condition of having enough importance for the trainees, involved into the creation of the gamified product, which can stimulate their sense of discovery and encourage them to master challenging material to develop a good product. At the same time, according to the theoretical background of the gamified products development (Dichev and Dicheva, 2017), the trainees have to follow some principles which are significant in the context of the user interface design mastering. In particular, it is essential for a potential user of the gamified product to feel that the game has a feasible goal exactly for him. Therefore, the product must have clear reward system and demonstrate individual user's progress along with its identification within other players who try to achieve the same target. It should make both competition and a feeling of belonging to a similar minded community. In addition, it is necessary to mind at the design of a gamified product that its main aim is to stimulate users to play the game trying to overcome difficulties in order to raise their scores. Thus, gamification strategy using in blended mastering of user interface design may be beneficial on condition of its didactically correct application.

Besides flipped learning and gamification strategies, it is also recommended to apply digital storytelling as a productive blended leaning technique. Digital storytelling is understood as a practice when people apply digital tools to tell and share their narratives which have a special purpose and devoted to important topic, presented in emotional way, and can be interactive. A digital story can be determined as a multimedia presentation that comprises a variety of digital components to convey the target audience a narrative. Besides, digital narratives may be presented as web-based stories, interactive stories, narrative computer games and other types of multimedia products (Rutta et al., 2021).

According to studies and evidence (Rutta et al., 2021; Sagri et al., 2018), the digital storytelling approach has also been introduced in education. Merging images, sounds and plot within digital story enables to reinforce concepts being appropriate to different learning types of trainees. It is pointed out that digital storytelling can be used by educators with different didactic purposes: to introduce new learning material, to facilitate its discussion by students, to help them get a deeper understanding of complicated concepts etc.

In addition, students can be also encouraged to create their own digital stories devoted to some learning elements and pursuer a certain pedagogical aim. Such learning activity can provide important benefits for the students. Through the stories making they have to analyze, synthesize, and finally to take ownership of the information they are presenting. These things provoke higher-level thinking and raise responsibility. In this context, comic-based digital storytelling can play significant role. In particular, it is underlined that student-generated comic-based digital story is a learning technique when trainees create personalized comics to achieve a didactic purpose. This activity can facilitate mastering difficult (or controversial) academic material and work out their research skills. Finally, created by the students digital stories of any type may be used as efficient learning aids and curricular resources.

Among different activities applicable to blended learning, group work plays special role. Group work (or cooperative learning) is characterized as an instructional strategy when groups of trainees work together upon a common assignment. Usually, each group participant is individually responsible for a part of the task and has to contribute into the common result. There are some key points which ensure the success of the group work: students should feel responsibility for their share of work and interdependence on the results of other peers; the group should be accountable for achieving its goal; face-to-face students' interaction and mutual support; group participants should obtain instructions in the interpersonal, social, and collaborative skills necessary to work with others.

It is clear that some of the mentioned key points are really challenging in terms of their realization at blended learning. Some challenges also include assessing of the each person's contribution, resolving conflicts etc., which demands development of special learning strategies. Carefully prepared activities can help students obtain the skills to work together successfully, structured discussion and reflection on group work can predict and avoid some problems.

Thus, as it was mentioned above, the discussed kinds of blended learning activities should be innovated with the help of introducing interactive methods of learning to raise the level and quality of communication. According to Edgar Dale's cone of experience, we can conclude in favor of interactive methods, that after two weeks we tend to remember 50% of the material that we see and hear (option of passive learning) and up to 90% of what we say and do ourselves (option of active learning) (Dellatola et al., 2020).

In contrast to just active learning, interactive approach provides trainees' interaction not only with the teacher but with each other as well. It is characterized by the researchers as a form of learning and communicative activities in which trainees are involved into contemplation on their own knowledge, estimation of their own abilities, skills etc. in comparing with their peers. Teacher's role changes drastically, as the interactive learning concentrates rather on the trainees' interests, needs, and abilities. Learners become active participants of the tutoring process and not only perceive information. Being engaged by the learning activity and based on their experience, students have to activate their knowledge and abilities, earn new skills, shape their attitude towards learnt material, and express their opinions.

The teacher's mission in interactive learning is shifted towards achieving the students' goals. The teacher has to arrange interactive forms of work and tasks, working upon which students receive new information, and an individual assignment is transformed into a group task where each member of the group contributes to the whole group's success.

Some basic types of interactivity are distinguished by the researchers: (1) individual interaction of the trainee and the learning content; (2) interaction between the trainee and the teacher who encourages trainee's motivation via offering them exciting learning material and stimulating to apply knowledge for solving specific tasks; (3) interaction between peers and teacher that expects involving the students into the interaction among themselves, an individual trainee with other students in the group (with or without the teacher) (Dellatola et al., 2020).

The last type of interaction seems to give the highest degree of the students' involvement in to the learning activity, which may cause the raise of the students' motivation to the subject learning. However, it is expected to be the most challenging to achieve, especially in terms of blended learning focused on remote mode. Thus, it is essential to apply certain interactive teaching methods that can guarantee efficient involvement of students in the interactive learning process. In fact, there is no general classification of such methods. However, it is possible to distinguish some of them which have special meaning in the context of their using in terms of blended learning in higher education. These methods may include lectures of selected kinds (inquiry-based, with deliberate errors, with the analysis of the specific situation etc.); game methods (business games, imitations, role-playing); debate methods (mini-conferences, seminars, Socratic dialogue, case studies); group solution method; project making.

3.2 Probation in Terms of User Interface Design Mastering

This subsection intends to demonstrate how the said activities (flipped learning, gamification, storytelling etc.) were enhanced with interactive methods in the process of blended learning of the course "User interface design basics" within the curriculum modules presented above in the progress of training of the university students' of different specialties.

Blended learning was implemented in its flex model when all the course materials were available for the students on the distant learning platform and there were delivered online (via Zoom, Google Meet etc.) lectures and practical studies according to common schedule including online consultations.

In the progress of going through the first course module dedicated to psychological fundamentals of visual perception that makes essential basis for user interface design there were applied mostly flipped learning and gamification strategies which were enhanced by different interactive methods.

For example, one of the flipped learning lectures on the topic of psychological mechanisms of data perception was held as an online mini-conference. There were assigned (in advance) different tasks to the pairs of students to learn proper theoretical material on the features of different data perception, to find out proper examples which illustrate peculiarities of human vision and their connection with interface design, and to elaborate presentation to take part in the mini-conference both as presenters and listeners.

For instance, one of the students' pairs had to learn physiological background of human perception of printed information. The students worked independently with digital sources to understand how our velocity of reading depends on the number of characters available for perception by our vision, and how this feature can be accounted at the interface design. During the flipped learning lecture hold in the form of online mini-conference which aimed at the exchange of results of the tasks assigned to different pairs of students, this pair gave a presentation on the results of their findings. In particular, they explained that the efficiency of reading depends in linear way on the amount of characters visible by eyes, and covered the reason of this fact based on psychological underlying of human eyes' parabolic movements similar to discrete leaps between words during reading. They also attracted the listeners' attention to the paradox of this cognitive and psychological phenomena, because despite their non-smooth nature, our eyes jumps improve our reading abilities, as we use the sense of skipped adjacent context to decrease the time of our comprehension of the read information.

The rest of the students who were listeners at the moment, were encouraged by the presenters and the teacher to discuss the connection of these findings with the problems of efficient interface. In particular, the listeners were attracted to speculation and making conclusions on the (1) efficiency of perception of isolated words and words connected into the long phrase; (2) the difference between task-driven and content-driven user interface; (3) the dependence of the efficiency of text comprehension in these types of interface; (4) the typographic decision-making at the interface design etc. In the end, the students-presenters supported the prepared discussion with the visual examples of the both types of user interface illustrating fruitful and non-fruitful using of these psychological peculiarities.

In similar way there was also arranged presentations of the results of the flipped learning tasks by the rest of the students' pairs with involvement other listeners into similar interactive debates. The group solutions finding during these mini-conferences within the first module were productively used by the students while their mastering subsequent modules.

For instance, in the progress of the interface design of potential web-application prototypes worked out at the workshops of the second module, there was used specially created interactive card game, focused on the involving the trainees in the analysis of applying various psychological techniques. Original card deck Mental Notes, suggested by Anderson (Anderson, 2009) presents over 50 insights from psychology, and can be used as an efficient brainstorming tool. Each card depicts an insight into human behavior and represents ways to apply this one to the user interface design. Selected samples of digital cards with insights are presented in figure 1.

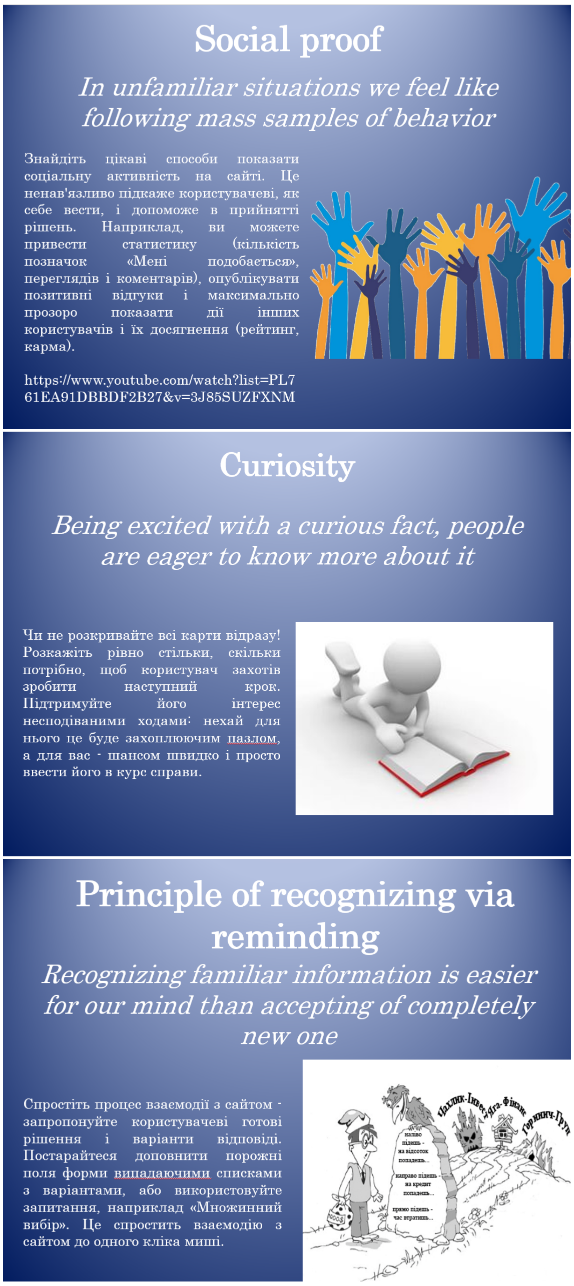

Figure 1: Selected samples of digital cards with insights into human behavior, representing the ways how to apply them to the user interface design.

The original card deck was transformed into interactive didactic game with digital "cards" and was virtually played during online workshop. At the initial stage of the game the students were assigned the topics of their potential web-application to speculate over its probable users, their targets, tasks, application functions etc. As the game starts, the participants "choose" in turn a card from the deck, which presents a psychological technique (insight) used in the current practice of user interface design such insights as: curiosity, social proof, reciprocity, regularity establishing and others.

The participants (individually or in pairs) analyze the insight presented in the card, then they explain and prove their decision as for how they can use this insight at the interface design of their potential application: which elements of visual language and how it is relevant to apply; what means of typography, color, and graphical images and why will be right to use; the insight is going (or is not going) to be successful exactly for their application, according to the results of their initial speculations. The rest of the players are involved by the teacher into active discussion of the presented solutions and into collective decision making.

In terms of motivation raising, such a game playing provoked students' cognitive interest to the topic; facilitated their understanding of effective psychological techniques and benefits of their using in interface design; promoted fluent communication on the professional topic, which finally led to joy feelings of the students and motivated them to be active participant of the tutorial process.

After the game the trainees may use the whole deck of the mental cards with variety of psychological techniques. As a game extension, the students are encouraged to apply at least five of the insights in the design of their interface prototype with their sequential presentations for the group.

In addition, the whole tutorial process on interface design mastering was immersed into the game online environment Classcraft, which enabled us to apply successfully gamification strategy. The environment allows to maintain gamification approach during any academic period, and encourages a trainee to go through the course sections individually or within the group, solving practical tasks, tests, and quests, deliberately created by the teacher for all the course modules, and earning game bonuses of different kinds.

In order to add interactivity into this gamified blended learning, we arranged the role playing game within Classcraft and involved individual students into the team role game, when each student should choose a character (a role of a Wizard, Warrior, Healer etc.) with proper skills, and cooperatively learn a topic via doing quests. The quests were prepared regarding the educational content and didactic purpose of the module.

For example, during the work within the second module "Graphic interface design" there were prepared the quests on the number of topics. One of them was the quest "Brief creation for UI design" which encouraged students to go through some quest stations. To overcome "Avatar" station, it was necessary to identify a character (in fact, a potential user) who is a target audience for the designing interface. The second station "Competitors" involved the students into analysis of the possible competitors of the interface design for potential user and sphere of their activity. Next quest station expected students to develop a chart of basic use cases for the developing interface. The final quest station "Visualization" encouraged students into determination of proper color palette and fonts as well as into picking up certain tools for the realization of different stages of the interface design regarding the analysis results obtained in previous quest stations.

At each quest station the students received specified tasks with exact scheme of actions. For example, at "Competitors" station (figure 2) the trainees' were focused on the analysis of strong and weak points of the competitors' interface design with subsequent concentration on successful and non-fruitful design solutions which led students to their unique design outlook for the identified user.

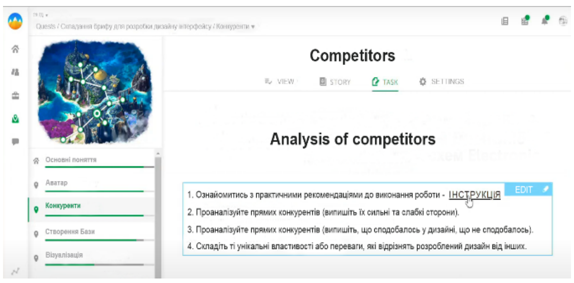

Figure 2: The episode of work at the quest station "Competitors" in the team game "Brief creation for UI design".

While overcoming the learning quests in the team, each participant used their skills according to their role and tried to contribute the best into the common results, doing quest tasks and earning different bonuses (Experience Points, Gold Pieces, Crystals, and Health) which gave them various additional opportunities and helped their team to achieve best learning results in the most effective way. Thus, the awareness of their personal responsibility for the team final success definitely raised the students' motivation to learn more and contribute more to feel the pride of the common academic result.

The trainees were also encouraged to solve the Boss Battles tests in the Classcraft game environment with the option of both individual and team work, which is the most beneficial in terms of raising motivation at blended learning. Doing the tests by the whole team prompted the students' interactivity, as only the joint and well thought efforts of each participant could bring the success to the team. In addition, Boss Battles option enables team members to give and get mutual help while test doing, which raised common responsibility and team spirit.

On the Classcraft gamified platform it was also organized students' group work upon real-life tasks. For instance, within the third module focused on mastering Figma tools for interface design, the students were assigned to build a dynamic prototype of the site with landing pages in Figma environment. The full assignment was formulated as follows.

Let us imagine, that you are a marketing director of a company which is a new player in the coffee trade market. The company buy coffee beans from Latin America, fry, blend, and mix them ourselves. Currently, there are three blends that are available for selling, and the company are working on adding three new ones. The company is concentrated rather on the retailers, but there is also have an offer for specialized retail chains, restaurants and other wholesalers. The company need to develop a site to talk about the company (services, offers etc.) and about coffee in general. In addition, the company is going to sell prepared blends via the site.

To solve this real-life problem and make a full-functioning dynamic site prototype in Figma, we offered students to create three groups, according to the roles which are typically fulfilled by interface designers at the different stages of the prototype developing. Therefore, there were selected the groups of Analytics, Developers, and Testers.

The didactic benefit of such group work on Classcraft platform in terms of blended learning is seen in following. Each group has to realize perfectly well the aim and essence of work at each stage of the prototype creation, and to allocate the roles inside the group correspondently. Thus, the students (with the teacher's help) have to interact with each other within the group in order to discuss and understand its specific task, final goal of the whole group, and the importance of their results for the success of other two groups who realize their own mission in the iterative process of the dynamic prototype development.

For example, the group of Analytics was encouraged by the teacher to hold debates with the help of, for instance, Socratic method of discussion as a kind of cooperative argumentative discussion based on asking and responding questions to provoke students' critical thinking and come with fruitful ideas. In particular, the set of issues for discussion by the Analytics for the understanding of their group mission included the following questions:

1. Who are our potential users?
2. What may be their age, education, needs, preferences etc.?
3. What tasks do the users want to solve via the site?
4. How are they going to solve their problems?
5. Which benefits from the users' standpoint can the site interface provide?
6. How to collect the said data from the users?
7. How can the collected information about users and their potential behavior on the site help the group of Developers? Is it essential also for Testers group? and others.

As a result of these argumentative debates, the group can obtain comprehensive understanding of their role in the whole iterative process of the prototype design, and can easily allocate the roles within the group with understanding by each member their own duties, responsibilities and scope of necessary interaction with members of other groups.

Similar debates were prepared and held in the groups of Developers and Testers. At some stages of work, it was initiated by the teacher interaction all the groups together in order to analyze the middle results of group work, such as Use Case diagram, Sequence diagram, mockups etc. built by the Developers group basing on the recommendations of the Analytics group. It helped to correlate the previous Analytics work, improve the Developers work immediately and avoid drawbacks and mistakes which may be revealed by the Testers group.

Analyzing the progress of the presented group work upon real-life tasks which also had a character of a role playing game, we would conclude the following. This form of work brought obvious interest and joy both to students and teacher, which caused a fruitful influence on the students' attitude to learning process and its results.

In particular, we could monitor appearing true incentives to learning, and arising motivation to classes preparation as well as to active participation in common work.

Emotional involvement into the group game according to their personal role and practical value of the tasks, made students keep educational content longer in their memory, speculate on it before and after classes, which provoked their inquisitiveness and enhanced their cognitive interest.

Therefore, it is possible to anticipate that such kind of blended learning technique enriched with interactive methods can have a positive impact on the students' motivation.

Digital storytelling as a common blended learning technique was also implemented in the process of interface design mastering within all the modules. We would like to demonstrate the example of creation of student-generated comic-based story in the progress of learning psychological basics of interface design which had a didactic purpose to investigate the influence of color pallet on the emotional stay of a user and implementation of its impact in the interface development.

At the preparation stage of the comics' creation the trainees were stimulated to discuss in group the issues which could help direct them during this creative task:

1. What is the goal of telling your story?
2. Who is the target audience of your digital story?
3. What feelings, emotions and ideas would you like to convey to the target audience?
4. What are the steps of your plot? How can you sequence the story with a beginning, middle part and final?
5. Which tools could be used to create your digital comic-based story? Which of them fit better for your idea and why? etc.

After this group solution findings, the students came to the core stage of the digital story making, according to their plot, and applying some of the graphic design tools on their choice.

Then, the groups of students demonstrated their comics and "told" their digital stories on the said topic during online practical classes.

Other trainees were engaged in the critical watching of their peers' digital stories. Therefore, at this stage student-generated digital stories served as cases that allowed involving all of the trainees into effective case studies, which added interactivity in the storytelling learning approach, raised the degree of students' participation in the tutorial process, which obviously affected their motivation.

In addition, the students were informed that their digital stories will be implemented as learning aids for further generations of trainees in the relevant interface design courses, which had a positive impact on the students' self-estimation, raised their responsibility, provoked their desire to contribute the best, and finally influenced on their learning motivation.

Episodes of one of student-generated comic-based digital stories where trainees expressed their ideas (in

Ukrainian) for associated meaning of different colors are given in figure 3(a)-(c)). In particular, in their digital story the students tried to render the associations of colors with our feelings and emotions: white – horror, black – grief, green – envy, pink – pleasure, purple – evil, light – happiness.

(a)

(b)

(c)

Figure 3: (a-c) Episodes of the student-generated digital stories on associated meaning of different colors (the explanations are given in the text above).

3.3 Preparation of the Survey on the Estimation of Students' Motivation

In order to estimate the level of the students' motivation to learning it is necessary to elaborate its criteria, develop their indicators, and determine the levels of their revealing.

As it was mentioned above, according to psychological background of motivation theory and its educational aspects, motivation to learn is defined as the personal efforts which encourage trainees to learning activities, ensure their continuity and concentrate a trainee on the activities with the aim at achievement of their desired goals. Among the most influential factors which affect student motivation are called attention, appealing to learner's past experience, positive attitude, and satisfaction.

Resting on this understanding of the learning motivation, and minding core rules for design of tutorial process and environment regarding motivation raising, we managed to elaborate several indicators and their levels. The core rules were presented in the theoretical framework chapter and can be formulated in brief as follows:

1. to apply methods for attraction and retaining learners' attention;
2. to set clear instructional goals and provide learners with educational content which refers to learner's needs and experience (academic and/or working one);
3. to shape student's confidence, creating learning environment which enables to promote learners' positive attitude to the tutoring process and suggest focusing towards success;
4. to create conditions to help students gain satisfactory feeling.

The survey was designed to evaluate whether the interactive methods introducing into the blended learning activities is in line with the aforementioned rules and detect what students' motivation levels are.

The survey consists of 20 items comprising 4 subsections corresponding to the amount of the rules. Each subsection included 5 items to get a feedback from the students on each motivation dimension. It measures learners' motivation level by applying a 5-point Likert-type scale (1 is strongly agree; 5 is strongly disagree).

Subsection 1 (*attention*) included the following questions.

Q1 There was some thought-provoking content of the course that got my attention.

Q2 I attended online classes with desire because there were used variety of gripping activities.

Q3 Communication with other students during debates and discussion helped hold my attention.

Q4 I was eager to attend classes because there usually were some things that were surprising or unexpected.

Q5 This course has things that stimulated my curiosity and I speculated about the learning material after classes.

Subsection 2 (*appealing to learner's needs and experience*) included the following set of items.

Q6 It is clear to me how the content of this course is associated with the things I already know.

Q7 I was involved into the work upon the tasks that demonstrated me how this course material could be useful to me and some other people.

Q8 Completing this course successfully was essential to me.

Q9 The content and style of the course material mastering is relevant to my needs and interests.

Q10 There are explanations, examples, cases etc. of how to use the competence from the course in daily professional activity.

Subsection 3 (*positive attitude*) included the following items.

Q11 The tutoring process within the course was entertaining.

Q12 Team interaction during material mastering suggested me confidence in my abilities to succeed in the course.

Q13 When I had learning difficulties, I felt confident that I could overcome them with my peers' help.

Q14 During online classes I felt myself happy as if I learnt material with my peers in real classroom.

Q15 As I worked on this course, I was confident that I could learn the content.

Subsection 4 (*satisfaction*) included the following items.

Q16 Completing the tasks and presenting my results in front of the group during online classes gave me a satisfying feeling of accomplishment.

Q17 I enjoyed this course so much that I would like to know more about this topic.

Q18 I really enjoyed when I contributed my expertise into the common result of my team going through the course material.

Q19 The sounding of feedback during and after the exercises in this course helped me feel rewarded for my effort.

Q20 It was a pleasure to work on the course in such a friendly and cooperative atmosphere.

To obtain preliminary results and test the designed survey reliability, it was conducted in one of the groups of pre-service IT specialists who completed the course "User interface design basics" in terms of blended learning activities enhanced with interactive methods and built according to our modules depicted above. In total, 27 students took part in the survey.

The scale reliability test was conducted to estimate the result. The reliability of all the four scales (for each motivation dimension) on standardized Cronbach Alpha was 0.75 ($n = 27$ on 20 items), which proved an acceptable reliability of the obtained result (Glen, 2023).

3.4 Discussion of the Preliminary Results

The average score of the students' motivation level as for all motivation dimensions, detected during the survey is presented in table 1.

Table 1: The average score of the students' motivation level ($n = 27$)

Motivation dimensions (5 items each)	Average score
Attention	3.42
Appealing to learner's needs and experience	3.61
Positive attitude	3.65
Satisfaction	3.63
Overall (20 items)	3.57

According to the score intervals, we distinguished four levels of motivation:

- High level (4.0-5.0),
- Intermedium level (3.5-3.99),
- Pre-intermedium level (3.0-3.49),
- Low level (lower than 3.0).

The results of the survey, according to the levels of students' motivation are shown in the table 2.

Table 2: Range of students' motivation level as a result of the survey.

Motivation level	Scores	Total $N = 27$	Percent
High	4.0–5.0	13	48.15%
Intermedium	3.5–3.99	6	22.22%
Pre-intermedium	3.0–3.49	4	14.81%
Low	<3.00	4	14.81%

As far as we can judge from the table 2, 13 (48.15%) out of the 27 respondents demonstrated high motivation level, 6 students (22.22%) had intermedium motivation level, 4 respondents (14.81%) revealed pre-intermedium level, and 4 respondents (14.81%) demonstrated low motivation levels. Thus, it was found out that the survey participants were mostly satisfied with the course material and blended learning techniques enhanced with interactive methods, with almost half of the respondents who had high level of motivation, and over 22% of them who revealed intermedium level of motivation to learning.

In addition, characterizing roughly the students' answers of the survey questions (Q1–Q20), we would like to emphasize the following.

About 70% of the trainees admitted that they attended online classes with desire because there were used variety of gripping activities; communication with other students during debates and discussion helped hold their attention; the course stimulated their curiosity and they speculated about the learning material after classes.

Over the half of the students said that during the course doing, they were involved into the work upon the tasks that demonstrated them how this course material could be useful to them in their potential professional life.

About 63% of the course participants revealed positive attitude to learning admitting that the tutoring process within the course was entertaining; team interaction during material mastering suggested them confidence in their abilities to succeed in the course; during online classes they felt myself happy as if they worked with their peers in real classroom.

Finally, about 72% said that they were pleased to work on the course in such a friendly and cooperative atmosphere.

The obtained survey results are complemented with our own observations. It was prepared by us special program of monitoring the students' attendance and behavior at online classes during different stages of the course. Our monitoring, according to this program, testified raising the percentage of students' attendance by 20% in comparing between beginning and end of the course.

In addition, our observations as for the students' cognitive behavior allowed to conclude that applied methods were productive in terms of encouraging motivation. They helped students feel the classroom atmosphere during online classes, promoted their cognitive eagerness to work with remote digital resources, contributed into effective learning communication, which helped overcome the feeling disconnection between the students inherent to blended learning in its flex model.

It was also monitored the growing of students' desire to take part in group activities, to reveal their knowledge and contribute best into the common group result. It was really pleasant to notice also some students' increasing tendency to find out additional learning materials and eagerness to do the tasks of higher complexity. It was also detected the raising of overall academic achievements of the group.

Thus, the obtained results of the conducted survey and our monitoring program may be taken as a basis for holding the full empirical research for the verification of the impact that made the offered blended learning activities enriched with interactive methods on the level of students' motivation and the results of pre-service specialists' training. It is planned to widen respondents' range to generalize the survey results and to expand it by clarifying and specifying the changes made in the research, which makes a prospect of our work.

4 CONCLUSIONS

The problems of raising students' motivation in terms of blended learning implementation at national universities are discussed in the paper in the context of interface design mastering by the students of various specialties.

Based on the recent studies review and educational practice analysis, it is revealed the urgency of our research connected with the problems of dropping students' motivation to study and to accomplish university education in general (students very often are eager to. It is analyzed that the situation is getting even worse in terms of blended learning with the focus to remote tutorial process. Retaining students' motivation to attend online classes, to earn knowledge and skills and work them out via different typical learning activities becomes really challenging task for educational staff.

It is also revealed that the using of the specially developed learning activities and methods is underestimated by the researchers and practitioners of blended learning implementation. It underlined the urgency of enhancing typical blended learning techniques with interactive methods in order to overcome the core challenges of the blended learning implementation, and to raise students' learning motivation in terms of current online studying.

Theoretical framework of the research is made by the analysis of the (1) fundamentals of motivation theory; (2) main characteristics of blended learning and its typical learning techniques used in the practice of blended learning; (3) basic approaches to the mastering of the fundamentals of user interface design in the training of different specialists.

In the progress of work, there were analyzed the core features and challenges of blended learning, and covered the ways of enrichment of the blended learning techniques (flipped learning, gamification, digital storytelling, cooperative learning etc.) with interactive methods and forms of work.

The experience of interactive methods practical realization in the process of the user interface design mastering by university students is presented. It was demonstrated how the considered leaning techniques which are typically used at blended learning in its flex model can be enhanced and enriched via using different interactive methods. Exact examples of their applications in real blended learning process are given.

It is also covered the preparation stage of the survey on the estimation of the students' motivation. The survey was designed to evaluate whether the interactive methods introducing into the blended learning activities is in line with the aforementioned rules and detect what students' motivation levels are.

The survey consists of 20 items comprising 4 subsections corresponding to the amount of the revealed motivation dimensions (attention, appealing to learner's past experience, positive attitude, and satisfaction).

To obtain preliminary results and test the designed survey reliability, it was conducted in one of the groups of pre-service IT specialists who completed the course "User interface design basics" in terms of blended learning activities enhanced with interactive methods and built according to our modules depicted above. The acceptable reliability of the scales was proved.

According to the score intervals, there were distinguished four levels of motivation. The results of the survey, according to the levels of students' motivation are presented and discussed. There were also given and discussed the results of the authors' observations according to the monitoring program.

It was concluded that the obtained results of the conducted survey and our monitoring program may be used potentially as a basis for holding the comprehensive empirical research for the verification of the impact which made the offered blended learning activities enriched with interactive methods on the level of students' motivation and the results of pre-service specialists' training. It is planned to widen respondents' range to generalize the survey results and to expand it by specifying the changes caused by the introduced methods, which makes a prospect of our work.

The prospects of the research also can be focused on finding out the most effective combinations of blended learning techniques and interactive methods in the process of interface design mastering by the students of different fields.

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The Use of ICT of Educational Purposes in the Independent Work of Students in the Study of the Basics of Programming by Future Software Engineers

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Abstract: The article describes the author's experience of using a number of information and communication technologies of education in the independent work of students in teaching the discipline "Fundamentals of Programming" to future specialists in software engineering. The content of studying the discipline "Fundamentals of Programming" and the number of hours allotted for its study in institutions of higher education in Ukraine is analyzed. When studying the discipline "Fundamentals of Programming" at the Zhytomyr Polytechnic State University, the study of the corresponding course on the platform of massive open online courses Sololearn is submitted for independent work, and use of other ICTs of educational purposes. A description of the possibilities of using this Massive Open Online Course (MOOC) in teaching the discipline "Fundamentals of Programming" for future specialists in software engineering is presented. In addition, using a pedagogical experiment, the effectiveness of using a number of information and communication technologies of education in the independent work of students in teaching the discipline "Fundamentals of Programming" to future software engineering specialists was tested. The results of the pedagogical experiment showed the effectiveness of using a number of information and communication technologies of education in the independent work of students in teaching the "Fundamentals of Programming" to future software engineering specialists.

1 INTRODUCTION

In the process of professional training of students of specialty 121 "Software Engineering", some professional disciplines are required to study, in particular, "Fundamentals of Programming", "Object-Oriented Programming", "Web Technologies", etc. All disciplines are studied in the manner prescribed by the educational professional program and provide for a certain "basic" level of knowledge for the preliminary study of the subject.

Analysis of the curricula of higher education in Ukraine (National University of Life and Environment Sciences of Ukraine, Zhytomyr Polytechnic State University, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Odesa Polytechnic National University) showed that the study of the discipline "Fundamentals of Programming" is given from 150 to 330 hours. Note that in some universities this discipline is divided into two Programming and Fundamentals of Software Engineering.

A sufficiently large number of hours predetermines the need to submit part of the material for independent study (usually from 30% to 60% of the

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material is submitted for independent study, and universities themselves operate on this). A variety of additional learning tools becomes useful here for both teachers and students (Seidametova et al., 2022; Vakaliuk et al., 2021; Kovalenko and Palamarchuk, 2018; Semerikov et al., 2020).

Massive Open Online Courses (MOOCs) has already gained popularity in the first quarter of the 21st century, so there are a lot of articles concentrated on that topic, even more, there are books, that are devoted to the disclosure of this topic from different angles. For example, we can see a demonstration of the historical perspective on various stages of development of these courses and how their value changed, depending on the stage (Waks, 2016), advises on optimizing the process of their implementation and use according to the type and stage of development of the information infrastructure of the educational institution advice on optimizing the process of their implementation and use respectively the type and stage of development of the information infrastructure of the educational institution (Mesquita and Peres, 2015) or just perspective of its evolution from a higher education point of view (Bennett and Kent, 2017).

Speaking about the latest research results, which undoubtedly appeared more due to the growing popularity of distance learning as a result of the pandemic, it is worth paying attention to Scopus as one of the most reliable sources of verified information. There are currently 48 articles available in this source that focus on this topic part of them are concentrating on the adaptation of the course to the general type and specifics of the country's study conditions or just on solving some specific problems universities are forced to face too, like overcrowded universities on the impossibility of organizing real-time face-to-face lessons (Naji et al., 2020). However, one of the most important and interesting aspects of the Massive Open Online Courses study is its use in teaching students a specific subject, for example, mathematics (Vagaeva et al., 2021), international relations (Kaempf and Finn, 2019), geography (Syvyi et al., 2020), physics (Huangqing and Yanping, 2021) or languages (Lebedeva, 2021). Still, we have to remember about digital barriers (Ling et al., 2020) that students might have while studying that way. Those barriers could make effect data results and lead to a distortion of information about the prospects for the development of the MOOC industry in education since every year students are better versed in digital technologies. The best way out of the situation is to test such courses on subjects that are studied by students of specialties related to information technology. A good example of such subjects could be computer networks (Vakaliuk et al., 2020) or software engineering.

A review of various MOOC platforms showed that they mostly contain theoretical material, test tasks; the possibility of communication between other participants, and, in the case of learning programming languages, a compiler is built in to train the acquired skills.

In the professional training of future software engineering specialists in the context of a pandemic and the Russian-Ukrainian war, a combination of traditional, distance, and blended learning opportunities, as well as the use of various additional tools, including massive open online courses, are becoming increasingly important, which allows increasing motivation and student interest.

2 LEARNING THE FUNDAMENTALS OF PROGRAMMING WITH MOOCs

The purpose of studying the discipline "Fundamentals of Programming" is to form students' theoretical basis necessary for further work, obtaining theoretical knowledge and practical skills in the algorithmization of computational processes, the basic principles of software development in the C programming language.

The objectives of studying the academic discipline "Fundamentals of Programming" are:

- providing students with the necessary knowledge on the theory and practice of using algorithmic programming languages;
- to form an idea among students about the main stages of solving a computer problem;
- the sequence of actions, skills, and abilities to work with modern software, program debugging;
- providing students with basic knowledge and skills with basic algorithmic structures;
- mastering by students of basic knowledge and skills in working with arrays;
- mastering by students of different methods of sorting arrays;
- providing students with basic knowledge and skills for working with functions, as well as the ability to implement recursive functions;
- mastering students the ability to work with structures, string values, pointers;
- mastering by students the basic skills of working with repositories.

Let us give an indicative topic for studying this discipline (as an example, the program is given, according to which they study at the Zhytomyr Polytechnic State University).

Content module 1. Introduction to programming. Basic construction methods.

Topic 1. Introduction to programming. Basic concepts. The concept of a method. Ways of representing algorithms. The alphabet of the C programming language. Directives. Connecting libraries. Data types. Constants and variables. Declaring variables. Operations of the C programming language. Data input-output operators. Formatting specifiers. Arithmetic operations. Features of working with them. Increment, decrement. Math functions. Block diagram. Basic elements of flowcharts. Basic algorithmic constructions.

Topic 2. Branching. Comparison operations. Logical operations. Boolean expressions. Simple and compound logical expressions. The if branching statement. Ternary operation. Switch statement.

Topic 3. Introduction to the Git version control system. The concept of a repository. Existing version control systems. Introduction to the Git version control system.

Topic 4. Loops. The concept of a loop. Loops with while condition. Loops with "for" parameter. Break and continue. Loops with postcondition "do ... while". The comma operation. Nested loops.

Content module 2. Arrays.

Topic 5. Setting up the program. Testing. Basic concepts. Setting. Error types. Test types.

Topic 6. Arrays. Array concept. One-dimensional arrays. Declaring and calling in one-dimensional arrays. Generation of pseudo-random numbers. Operations with one-dimensional arrays.

Topic 7. Sorting arrays. Sort by the exchange. Sorting by the selection method. Insertion sort. Shell sorting. Pyramid sort.

Topic 8. Multidimensional arrays. Declaring and accessing multidimensional arrays. Two-dimensional arrays. Operations with matrices.

Content module 3. Functions, pointers, structures.

Topic 9. Functions. The concept of a function. Function prototype. Passing parameters. Functions with a changing number of parameters. Passing an array to a function. Recursive functions.

Topic 10. Pointers. Local and global variables. Variable address. The concept of a pointer. Declaring a variable of pointer type. Basic operations on pointers. Features of the scanf function. Pointers and arrays.

Topic 11. Character variables. Working with string and character variables. String functions.

Topic 12. Structure. The concept of structure. Arrays of structures. Programming with structures.

When studying the discipline "Fundamentals of Programming" at the Zhytomyr Polytechnic State University, students are recommended to study the materials of massive open online courses as part of their independent work. Students can take the course offered on the MOOC platform Sololearn (Sololearn, 2023). This course provides an opportunity to study individual theoretical blocks, and perform individual test tasks and certain final works.

Let us consider the possibility of using MOOC Sololearn when studying the course "Fundamentals of Programming" as part of additional independent work. The first thing to point out is that this course is in English, and since this platform does not provide for any actions of teachers or instructors, it is not possible to localize in another language.

This course involves studying the material and improving skills in the basics of programming in the following sections: basic concepts of the C programming language; conditional expressions and loops; functions, arrays, pointers; strings and function pointers; structures; memory management; file and error handling; preprocessor.

These topics fully cover the topics for study in the main course "Fundamentals of Programming" and are their logical addition. Another feature of this MOOC platform is that the courses are freely available and anyone can take them. Yes, not all features of the platform are freely available, but if you wish, you can purchase the full version for an in-depth study of the material. Another feature of this platform is that each course is provided with a separate address where you can enter the course without wasting time searching for the course.

When you log into your account at the address of a specific course (Sololearn, 2023), the user opens his profile of passing (studying) the course (figure 1).

Each section (study topic) in this MOOC includes theoretical information (figure 2), containing material for repeating what was learned in the classroom.

This MOOC can leave comments on all activities of each topic. Such a section is located in the upper right corner, by entering which a registered user at the stage of viewing theoretical material can communicate with other registered users through comments (figure 3).

However, it should be noted that not in all sections of the MOOC data, such an opportunity is open immediately. In addition to theoretical material, users are allowed to view examples of program execution and try to work with them on their own, making cer-

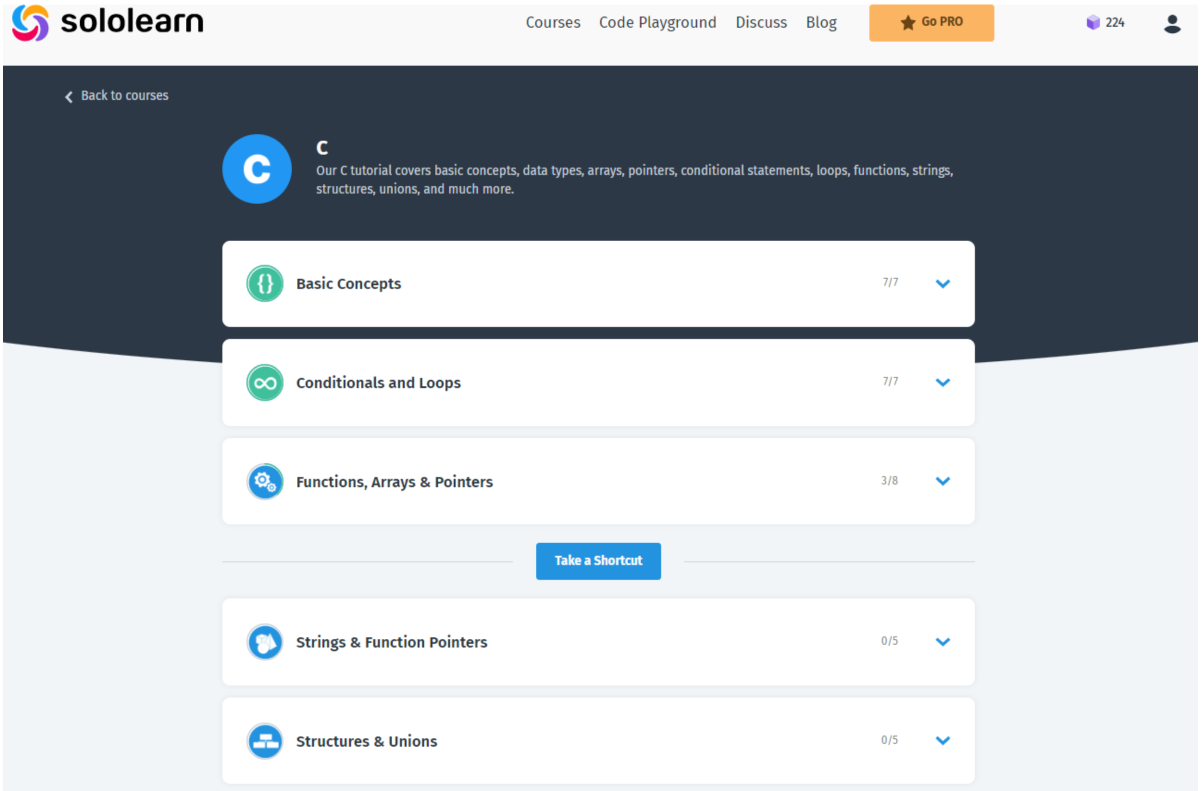

Figure 1: Personal account for studying the course.

tain changes (figure 4 and figure 5).

This platform MOOC also provides a task for testing knowledge of various forms, for example, choosing 1 answer from several proposed ones (figure 6) and entering your answer (figure 7). At the same time, it should be noted that the section of communication through comments in such tasks becomes available only after checking the answer. For each topic, up to 10 tasks of this type are given to consolidating knowledge.

After passing the module, the user is presented with a final test (figure 8), which consists similarly of several questions (from 5 to 10), and according to the result, it is set whether the module was enrolled to him.

It should also be noted here that the next module will not be opened to the user until he completely completes the previous one (figure 1).

If we consider each topic offered in this MOOC, then in section 1 "Basic concepts" there is a repetition of the base of the C programming language, namely: data types, arithmetic operators, comments in the code, working with the console (input and output). In section 2 "Conditional statements and loops", conditional statements were considered, such as: if, else, switch, three types of loops: for, while, do. . . while. The section also included theory on logical operators, which are &&, which means "and", and ||, which means "or".

Section 3 "Functions, Arrays, and Pointers" provides material that is completely repetitive to the classroom material. As a result, in this section, there is only a repetition of the studied material, as well as the consolidation of the necessary skills for working with arrays, functions, and pointers.

Section 4 "Strings and Function Pointers" has a new topic that doesn't overlap with the classroom material. This is the "Pointers to Functions" topic, which explains in detail how to declare and access functions using pointers. The next section is "Structures and Unions". It should be noted here that again students were offered a new topic for study – this is the topic "Union", in which students can learn about unions, which allow storing different types of data in the same place in memory, accessed through the dot operator located between the name of a variable and the name of a particular union member.

In Section 6 "Memory Management", the following functions were considered for memory allocation on dynamic array memory (malloc, calloc), array expansion (realloc), and freeing (free). This material is not new to the student, since this topic completely

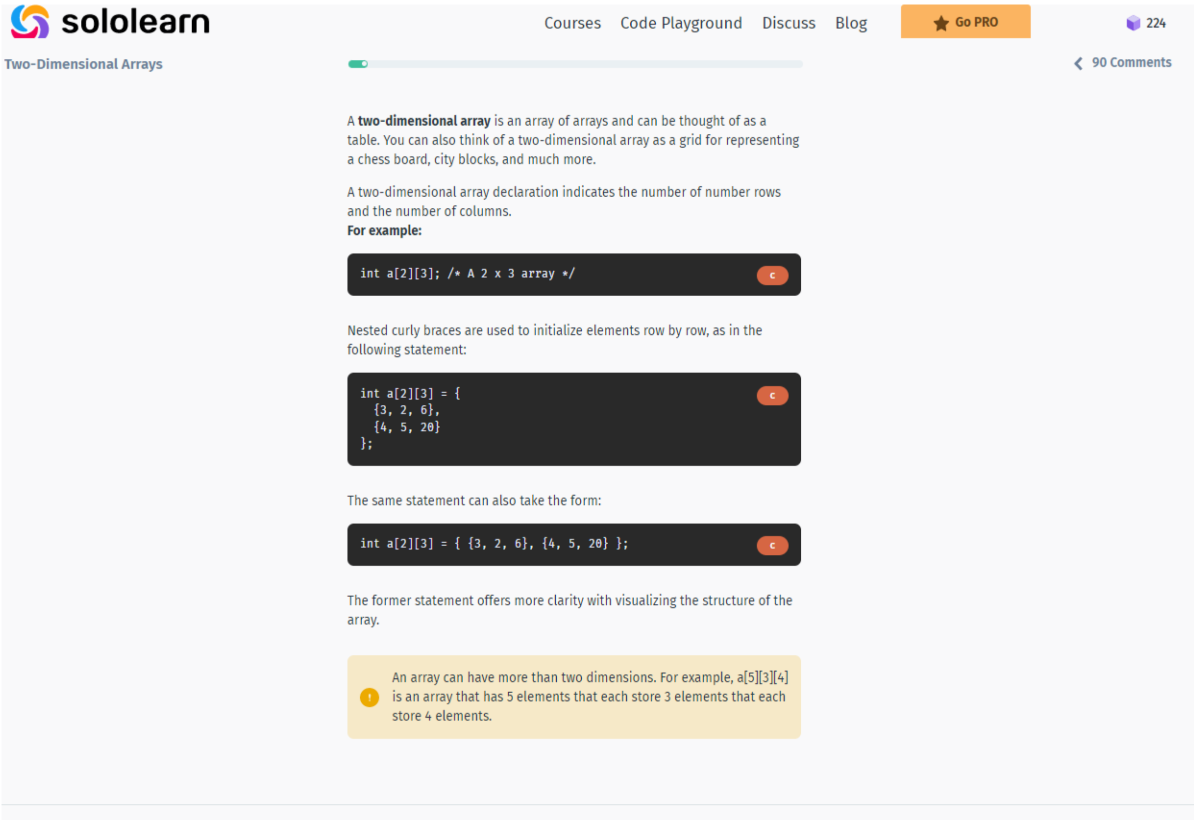

Figure 2: Theoretical material in the MOOC Sololearn.

overlaps with the topic for studying in the classroom, so students in this section only consolidated their knowledge and skills.

Section 7 "File and error handling" is the largest section in terms of the amount of new material that is submitted for independent processing. By studying the topics in this section, students can learn how files are handled in the C language, which is used for this function, what binary files are, and how to handle errors.

Section 8 "Preprocessor" contained some of the material that students studied in the classroom and some of the new. The topics covered in this section are preprocessor directives, conditional compilation directives, and preprocessor statements.

Note that the advantage of such MOOC is that all the material is structured, and for each topic, there is theoretical material, attempts to work with the program code, and knowledge testing.

The use of this MOOC for self-processing by students within the framework of the course "Fundamentals of Programming" contributes to the consolidation of the mastered theoretical material, since the course contains a repetition of the theory presented to students in lectures on this discipline, as well as the development and improvement of skills in programming in the C language.

During the course, students can view the progress bar (figure 9), and after successful completion of the course, students receive a certificate (figure 10).

Note that the MOOC Sololearn is adaptive for various systems and, accordingly, devices, so the user has the opportunity to use it from any device.

The use of MOOCs in the educational process of higher education contributes to the assimilation of the material through one's own practical experience, mostly independent. After all, students can get acquainted with additional theoretical information, view various examples with solutions in the C language, and at the same time they can also try to change a fragment of the program code using the knowledge gained; perform a separate task by writing code fragments in the answer, and, of course, take a test to test your knowledge.

The use of such a MOOC provides 100% coverage of the topics provided by the training program for studying the discipline "Fundamentals of Programming". Note that MOOC is not the main one in the study of the course "Fundamentals of Programming". It is only an auxiliary tool for consolidating knowl-

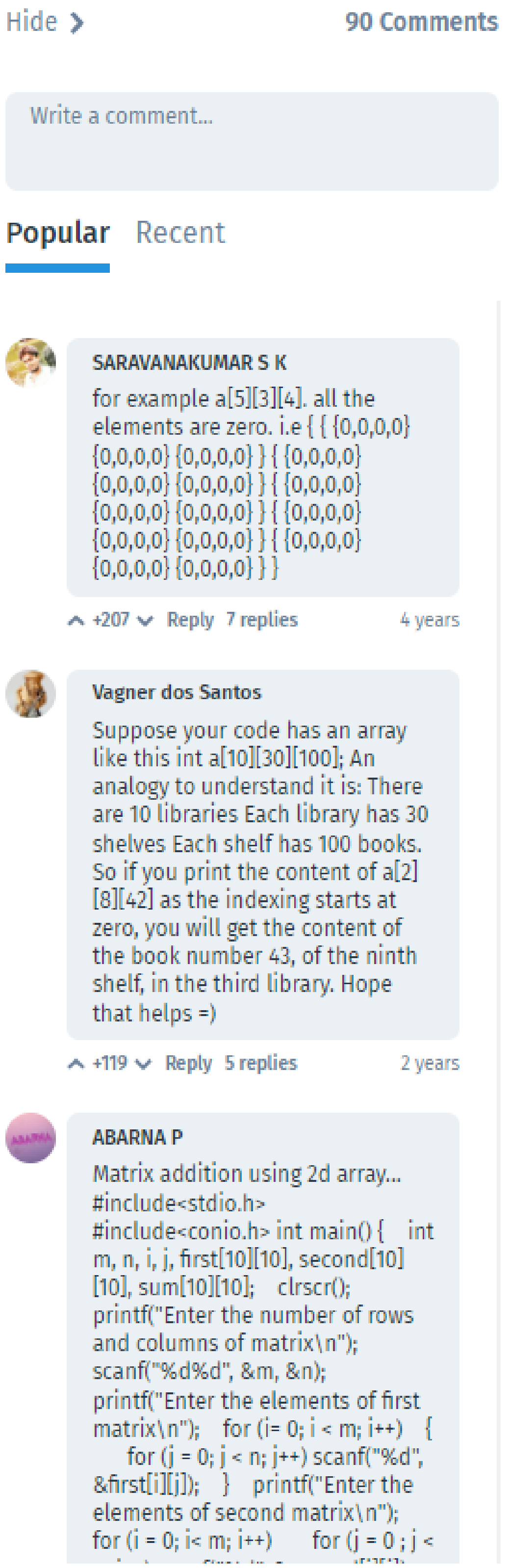

Figure 3: The ability to communicate through comments in the MOOC Sololearn.

edge and skills during lectures and practical exercises.

In particular, to study the basics of programming, students are also offered the following MOOC for independent study:

1. C programming (https://moocfi.github.io/courses/2016/aalto-c/en/)
2. Learn the Basics of C Programming Language (https://www.eduonix.com/courses/Software-Development/Learn-the-Basics-of-C-Programming-Language)
3. Programming Fundamentals (https://www.coursera.org/learn/programming-fundamentals?specialization=c-programming)
4. Writing, Running, and Fixing Code in C (https://www.coursera.org/learn/writing-running-fixing-code?specialization=c-programming)
5. Pointers, Arrays, and Recursion (https://www.coursera.org/learn/pointers-arrays-recursion?specialization=c-programming)
6. Interacting with the System and Managing Memory (https://www.coursera.org/learn/interacting-system-managing-memory?specialization=c-programming)
7. Learn C (https://www.learn-c.org/)

The listed MOOC are offered for additional study of the basics of programming, their content covers the topics of studying the course "Fundamentals of Programming". However, to fully study the course, for example, on the MOOC Coursera, you need to complete 4 courses.

Note that within the framework of studying the discipline "Fundamentals of Programming", students have the right to choose any similar course that fully covers the study of the topics of this discipline, of course, by the decision of the teachers.

It should be noted that in order to motivate students to use additional means, including MOOC, the Zhytomyr Polytechnic State University decided to count certificates of certain courses as separate components of the study of the subject (as part of the study of individual topics). To enroll as a separate topic or within the subject is decided by teachers who teach the basics of programming to collective solutions. In addition, at the discretion of the teachers, the completion of such courses is counted as a separate part of the number of points for the overall rating. This helps to motivate students to successfully complete the full course.

It should be noted that most of the proposed MOOCs are in English, which, along with mastering certain programming knowledge, helps to im-

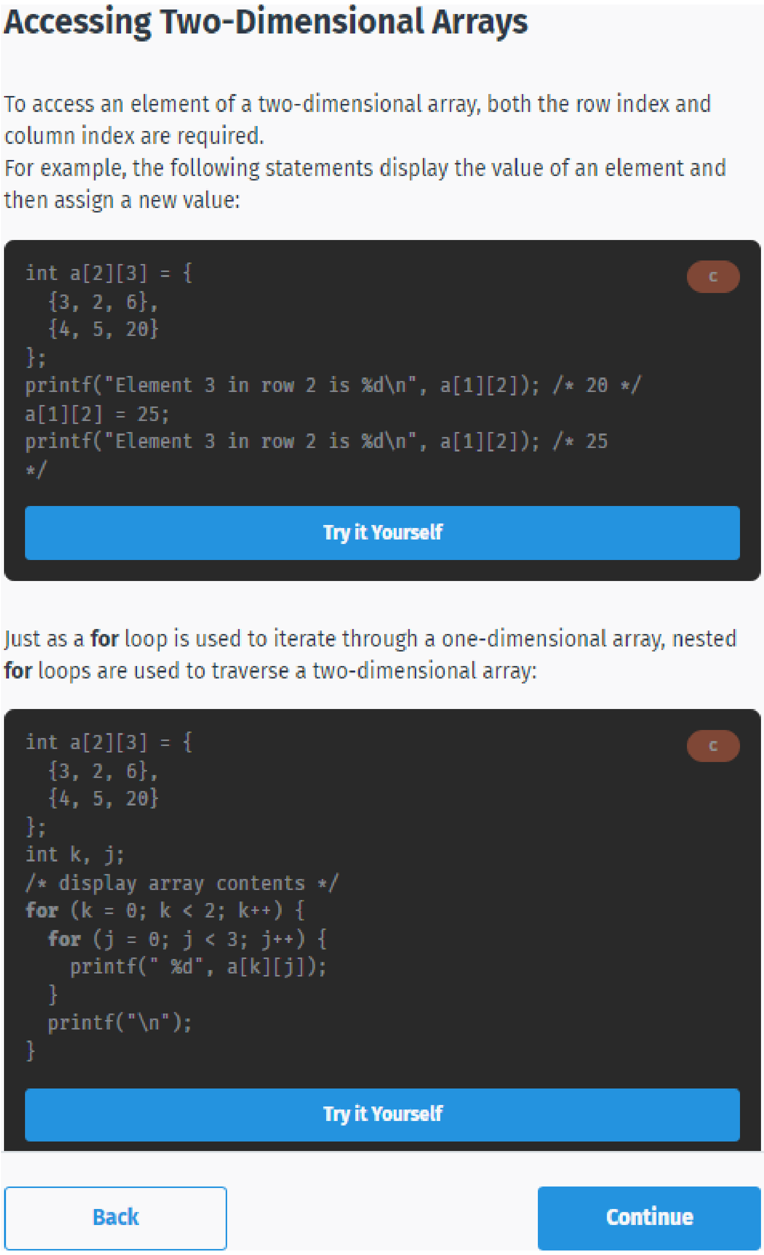

Figure 4: Ability to work with program code in Sololearn.

Figure 5: Working with program code in Sololearn.

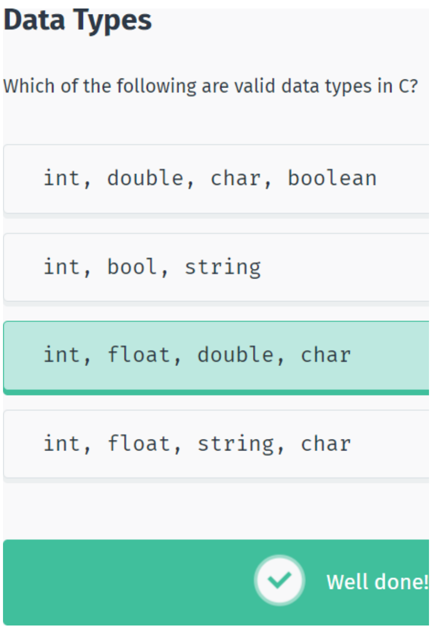

Figure 6: Choice of 1 correct answer.

prove the level of foreign language proficiency, which is a mandatory requirement for future programmers, testers and project managers when applying for a job.

We also note that once a year, before the start of a new academic year, it is necessary to check the available new MOOC for a qualitative update of the proposed list.

Students are encouraged to master these materials on their own as an additional source of study of a particular subject.

These courses were chosen in accordance with the subject "Fundamentals of Programming", as well as in accordance with the competencies that students have at the end of the course. The experience of teachers working with international software companies will also play a role in choosing a course.

The work of students with MOOC provides:

- study of theoretical material on a particular subject;
- implementation of scientific projects using acquired knowledge and skills;
- implementation of joint projects with their further presentation and defense in front of a group of students.

In addition, other teaching aids should be used for independent work of students. In particular, to get acquainted with theoretical information, we offer for use a number of electronic textbooks on the basics of programming in the C language:

1. https://metanit.com/cpp/c/1.1.php
2. https://www.codesdope.com/c-lets-start/ (figure 11)
3. https://www.codingeek.com/c-programming-tutorials/ (figure 12)
4. https://www.codingeek.com/tutorials/c-programming/beginning-with-c-programming-language/
5. https://www.geeksforgeeks.org/c-programming-language/

It should be noted here that all but the first two resources are in English. These electronic manuals are clearly structured, freely available, and offered to a wide range of users. The second service is quite popular because it contains not only theoretical information but also specific examples for each topic.

Such online resources allow not only to get acquainted with theoretical material, but also to communicate with each other through comments on relevant topics. Often, the authors of such resources support feedback and provide users with comprehensive answers.

Teachers offer students for preliminary acquaintance with theoretical material and subsequent discussion of problematic issues of individual topics in the classroom. In addition, at the discretion of the teacher, the material can be taken out for independent study by students, and then the presentation of the material at lectures by the students themselves in front of their fellow students for additional points.

In addition, students are encouraged to use freely available videos, in particular, the free online programming course in C for beginners (https://www.youtube.com/playlist?list=PL76809ED684A081F3). This course is logically divided into lessons, where the author offers his own vision of learning the C programming language. So, for independent work, and familiarization with the material, this is a fairly useful resource that clearly shows all the possibilities of the C programming language.

The listed means contribute to the consolidation of theoretical knowledge on the basics of programming, as well as self-learning and self-development.

In addition, to consolidate practical programming skills, the authors offer a number of available tests to test knowledge and programming skills:

1. C Programming Online Test https://www.tutorialspoint.com/cprogramming/cprogramming_online_test.htm
2. C Programming Test https://www.indiabix.com/online-test/c-programming-test/
3. C Online Test https://www.testdome.com/tests/c-online-test/62

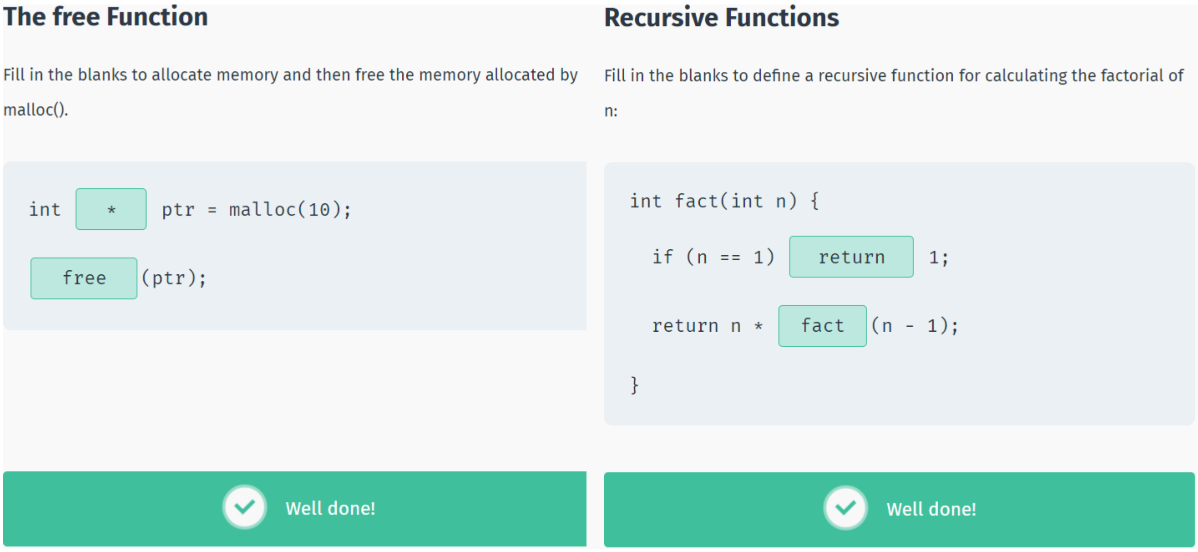

Figure 7: Entering your answer.

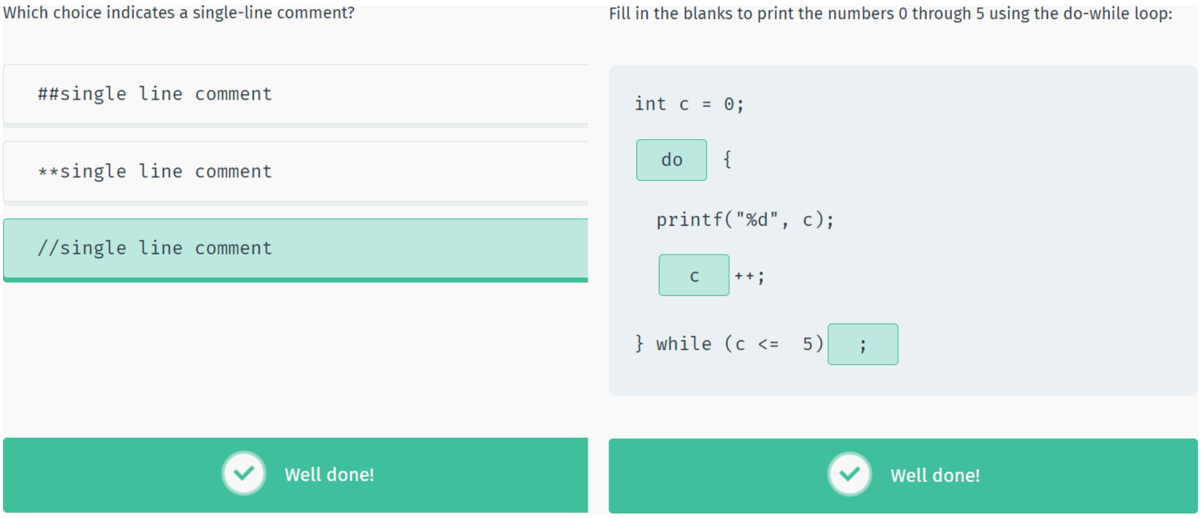

Figure 8: Module test.

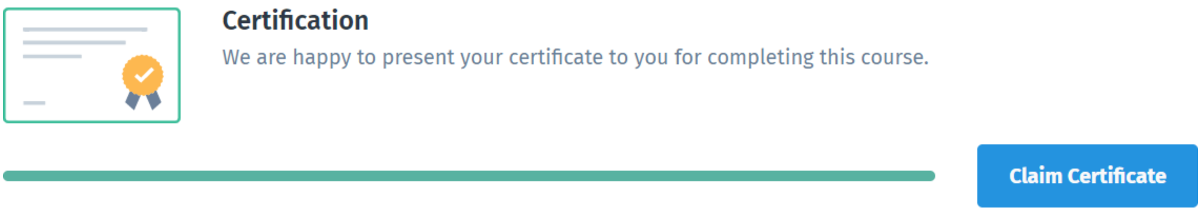

Figure 9: Course completion scale.

4. C Quiz | C Online Test https://www.javatpoint.com/c-quiz (figure 13)
5. C Online Test http://www.pskills.org/c.jsp (figure 14)
6. Online C Programming Test – Free MCQ's to test your C Skills https://data-flair.training/blogs/online-c-programming-test/
7. C Online Quiz Test https://codescracker.com/exam/showtest.php?subid=2 (figure 15)
8. C Programming Online Test https://www.jobstron.com/c-programming-online-test

It should be noted here that some of the tests are

Figure 10: Certificate.

generalized for the entire course C (1, 3 – hereinafter, respectively, the number of the means for testing), and the other part is a set of tests on topics (2, 4, 5, 6, 7, 8). Note that these tests are divided into topics in different ways. Some services offer detailed breakdowns into topics (2, 4, 5, 6), while others are superficial and cover only selected topics.

Here it should be noted that, again, the decision of teachers, to pass tests covering most topics, may be accompanied by additional motivation in the form of additional points instead of lost ones (for late delivery, for example, laboratory work).

In addition to all of the above for independent work, students are offered a parallel study of various programming languages. To do this, students are offered the same resources, only with an emphasis on a different programming language. Also, dual education started this year at the Zhytomyr Polytechnic State University. Its essence lies in the fact that in the course of studying the basics of programming in the 1st semester, students can study object-oriented programming in courses from ISM Ukraine. As a result of taking these courses, students were asked to have an interview on theoretical material with the course teacher and subject teachers at the university, and as a result, receive an appropriate grade in the next subject. This contributes to the development of the self-organization of students, the organization of their employment, and usually the use of various additional means for self-study.

It should be noted that the list of proposed ICTs for teaching the basics of programming was formed by the authors as a result of their many years of experience (Vakaliuk et al., 2020, 2021) and other their works, as well as preliminary scientific research on the selection of appropriate learning tools. Therefore, the each teacher can choose the range of information and communication technologies for teaching independently. In particular, as you know, now there

Table 1: Comparative distribution of students from the CG and the EG by the level of educational achievements in the fundamentals of programming at the beginning and end of the pedagogical experiment.

Level of academic achievement	Before		After	
	CG	EG	CG	EG
Beginner (1-59)	10	10	9	5
Average (60-73)	25	27	21	10
Sufficient (74-89)	21	19	24	33
High (90-100)	9	8	11	16
Total	65	64	65	64

are many games and simulators for learning programming languages. The only drawback in our case is that there are no such tools specifically for learning the C language. However, if the basics of programming in some higher education institutions are studied on the example of another programming language, the use of such games contributes to even greater interest and motivation of students.

In addition, another tool for effective independent work of students we see Gitlab, which on the basis of the Zhytomyr Polytechnic State University is used not only in classroom work, but also in extracurricular activities. Thus, in cooperation with ISM Ukraine, on the basis of this institution of higher education began to implement the so-called program “Code Review”, in which employees of IT companies provide their recommendations to students to successfully improve their own laboratory work. All this is done within the framework of using the Gitlab service for successful communication of all members of the educational process.

To test the effectiveness of the implementation of a number of information and communication technologies of education in the independent work of students in the study of the discipline “Fundamentals of Programming”, a pedagogical experiment was conducted based on the Zhytomyr Polytechnic State University, which consisted in comparing the learning outcomes according to the traditional method of teaching the basics of programming and the author’s using a number of information and communication technologies of education in the independent work of students.

For this, the applicants for the education of 1 year of study were divided into the EG and the CG (experimental and control groups, respectively). In the CG, training was carried out according to the traditional method, and in the EG – using a number of information and communication technologies of education in the independent work of students.

Statistical data of the EG and CG before and after the experiment are presented in table 1 and figure 16.

To test the statistical equivalence (to the exper-

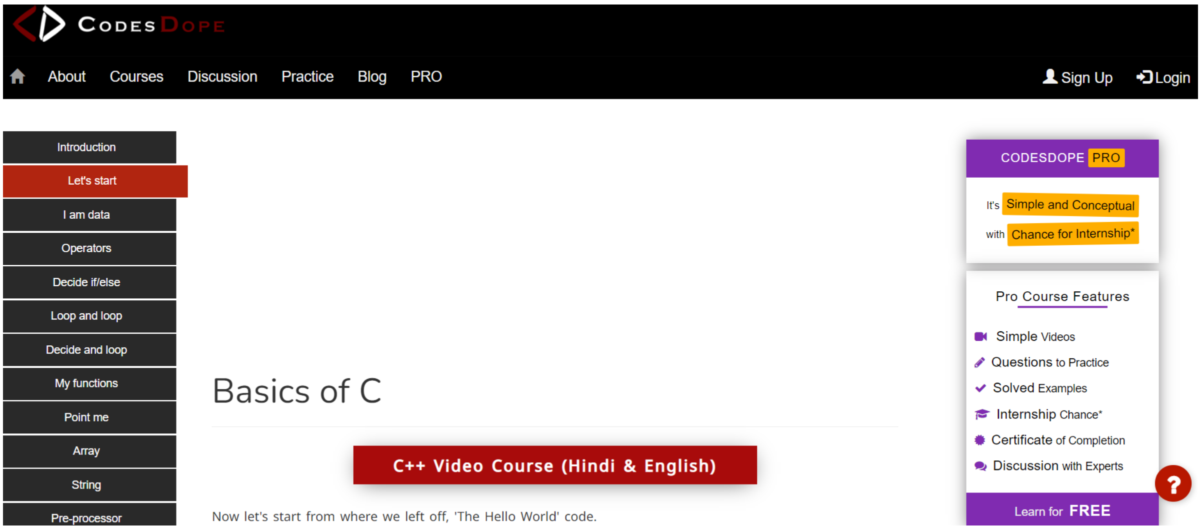

Figure 11: https://www.codesdope.com/c-lets-start/

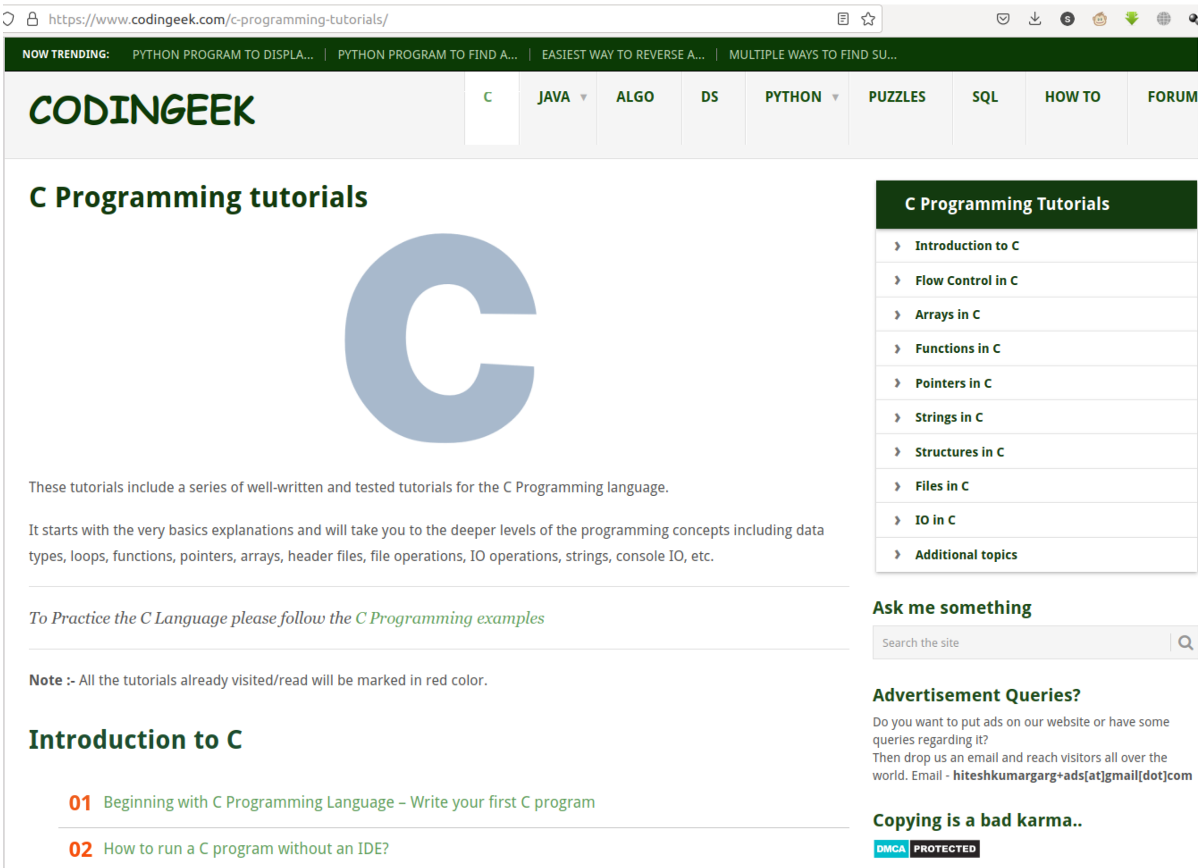

Figure 12: https://www.codingeek.com/c-programming-tutorials/

iment) and statistical non-equivalence (after the experiment), the Pearson test was applied, the result of which was found:

- at the beginning of the pedagogical experiment, it was found that $\chi^2_{emp} = 0.36, \chi^2_{emp} < \chi^2_{0.05}$, therefore, the samples do not have statistically significant differences, and this means that the composition of students in the EG and CG is approxi-

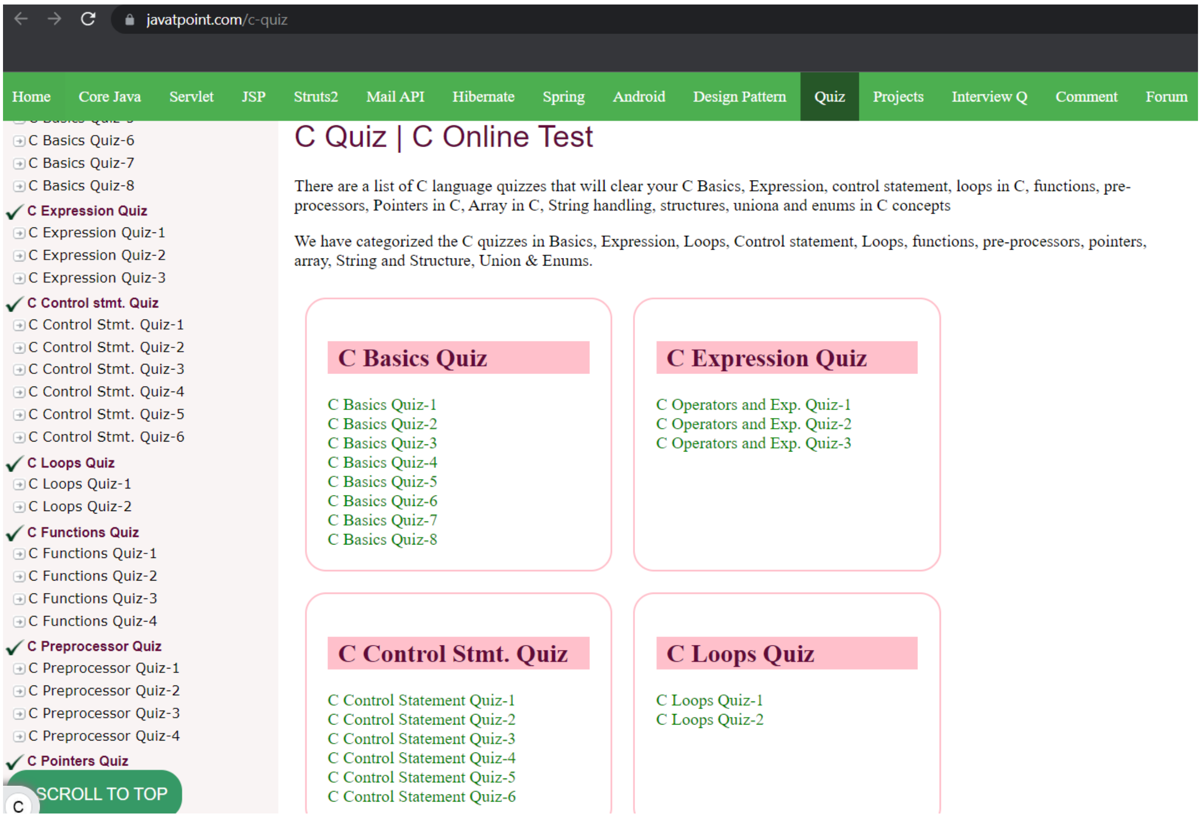

Figure 13: C Quiz | C Online Test.

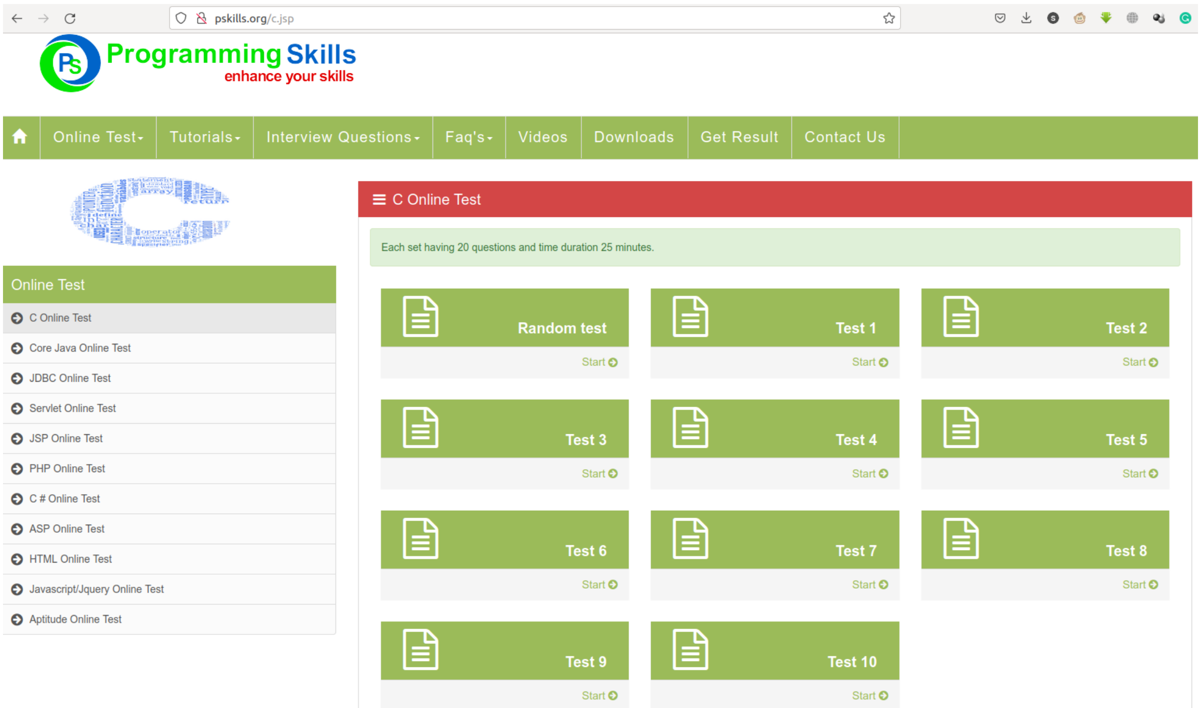

Figure 14: C Online Quiz Test.

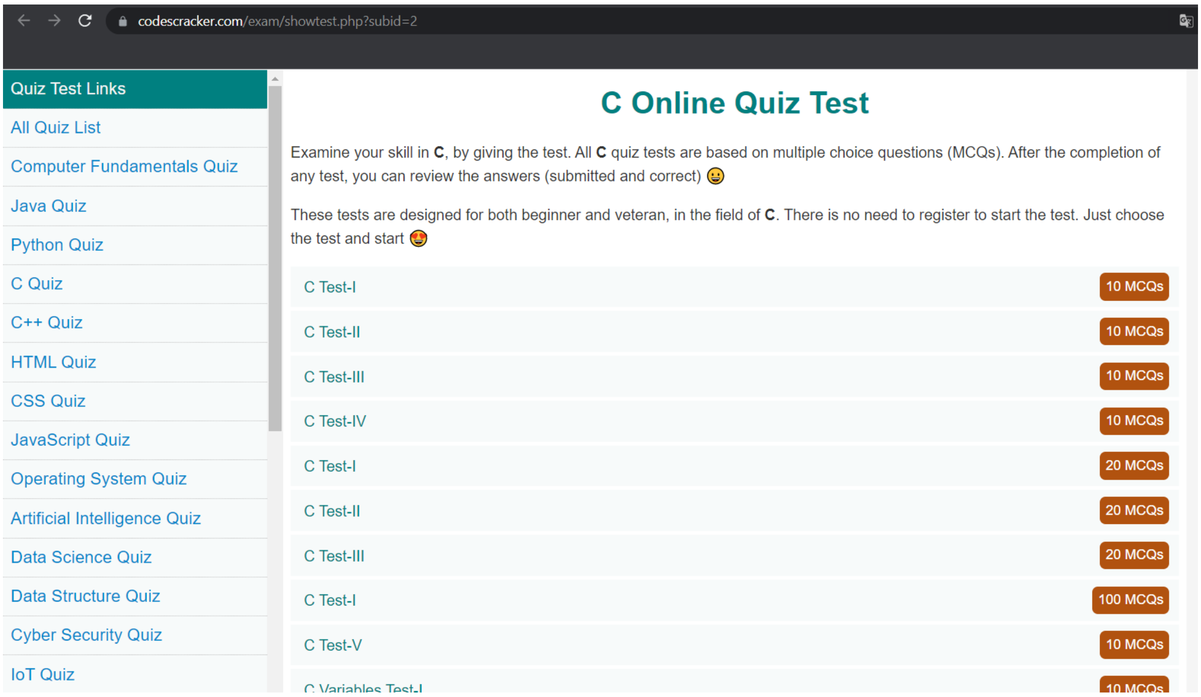

Figure 15: C Online Quiz Test.

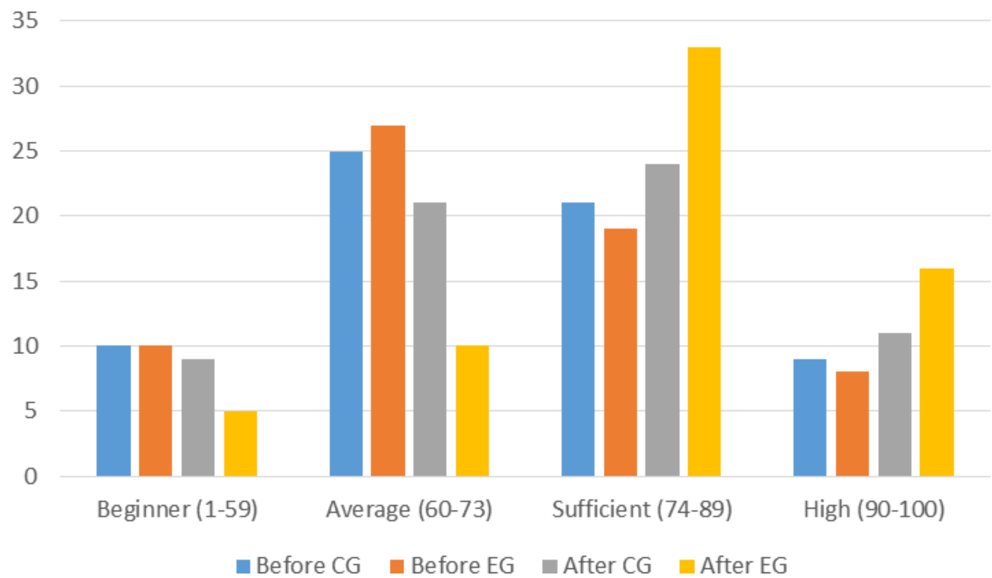

Figure 16: Comparative distribution of students in CG and EG according to the level of academic achievements in the fundamentals of programming at the beginning and end of the pedagogical experiment.

mately equivalent;

- at the end of the pedagogical experiment, it was found that $\chi^2_{emp} = 8.48, \chi^2_{emp} > \chi^2_{0.01}$ and this indicates that the samples have statistically significant differences at this stage.

Since the statistical data testify to the positive dynamics of a sufficient and high level of educational achievements in the experimental group at the end of the pedagogical experiment, which is confirmed experimentally, we can conclude that the experimental methodological system of teaching “Fundamentals of Programming” using a number of information and communication technologies of education in the independent work of students is more effective than the traditional one.

3 CONCLUSIONS

When teaching the basics of programming to future software engineers, changes should be made to the curriculum of the discipline with the addition of a number of information and communication technologies of education for independent work. As the conducted pedagogical experiment showed, the use of a number of information and communication technologies of education in the independent work of students in teaching the basics of programming to future bachelors in software engineering helps to increase the level of student's educational achievements. In addition, as the students themselves point out, the use of various tools in the educational process contributes to their self-development, motivation, and interest, and helps to consolidate the acquired knowledge and skills. As for the prospects for further research, the authors see them in the search and development of new qualitatively new learning tools for the basics of programming.

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The Modern STEM Center as a Perspective Educational Resource for Undergraduate Science and Mathematics Training

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Abstract: The development of education in the field of STEM as an innovative direction of science and mathematics education in Ukraine is carried out through the effective use of STEM methods as tools for learning, career guidance of pupils/student youth, training, retraining or advanced training of scientific and pedagogical workers. The article analyzes trends in the development of education in the field of STEM as one of the key fields of research worldwide from the point of view of geospatial focus, main disciplinary areas, methodological and theoretical assumptions in the formation of research and STEM education practices. The regulatory and legal field of the implementation of the state program of the STEM field in Ukraine has been studied. The article focuses on effective pedagogical strategies of STEM education from the standpoint of creating a STEM center as a perspective educational resource for undergraduate science and mathematics training at the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University. The key performance indicators of the STEM center "Educational and Scientific Training Center for Computer Science and Computer Mathematics" have been determined. The popularization of STEM education among young people, teachers of general secondary education institutions and teachers of higher education institutions thanks to holding meetings in the direction of STEM education with leading specialists of Delphi Software, an expert of Panasonic is described. The experience of the functioning of the STEM center based on the Department of Mathematics and Computer Science is highlighted. Innovative forms of implementing STEM education to attract young people to educational, practical and scientific research activities are considered. The effectiveness of the work of the "Educational and Scientific Training Center for Computer Science and Computer Mathematics" is evidenced by the achievements of university students in various Olympiads, competitions, and presentations at conferences. Pedagogical research on the perception by respondents of the functions performed by the STEM center was analyzed using factor analysis. Factor analysis was performed using principal component analysis and varimax rotation (Varimax Normalized). The optimal number of factors and their statistical significance were checked according to the Kaiser criterion.

1 INTRODUCTION

Ukraine, integrating into the European and world educational space, strives to reform the modern education system for the versatile training of highly competent education seekers who are able to demonstrate relevant learning results of theoretical and applied content. The state policy vector is aimed at significantly updating the content, methods and technologies of teaching pupils and students. Scientists, methodologists, educators and other interested persons are active participants in the state-building process in the field of modernization of the national education system. Therefore, relying on the experience of such countries as Australia, Great Britain, Israel, China, Korea, Singapore, the USA and others, Ukraine joins the world practice of introducing education in the field of STEM as an innovative direction of the development of science and mathematics education.

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Note that the acronym STEM is used to denote a popular direction in education, which includes natural sciences (Science), technology (Technology), technical creativity (Engineering) and mathematics (Mathematics) (IMZO, 2018a). Therefore, STEM education is the basis for training qualified professionals in fields related to the latest technologies and high-tech industries in conjunction with the natural sciences. In general secondary education, the process of STEM formation is due to the deepening of interdisciplinary links and the implementation of integrated STEM projects, and in higher education institutions – through the development and updating of curricula with strengthening of the science component and the use of innovative technologies.

Developed countries have been implementing government programs in the field of STEM education for many years. In Ukraine, the Institute for Modernization of Educational Content has established a department of STEM education in which the following sectors (IMZO, 2018b) operate: innovative forms and methods of teachers, scientific and methodological support of STEM education, research of educational processes. Specialists of the department deal with practical issues of analysis of the process of development and dynamics of development, identification of problems and forecasting of further trends in the implementation of STEM education; providing scientific and methodological support for experimental innovation activities, providing practical assistance to educational institutions implementing STEM majors; carrying out various activities to train and improve the skills of teachers in educational activities in the field of STEM education, providing them with professional methodological assistance in the organization of STEM training; coordinating the activities of working groups of scientists, educators and specialists in STEM education and establishing communication links with the structures of the education sector, stakeholders and other institutions in the regions; initiation, attraction of resources and funds, coordination, organization of educational projects, publications, presentations during educational events of various levels aimed at promoting STEM learning and career guidance among students, dissemination of experience and achievements of STEM education and other important tasks, absent which a systematic approach to the implementation of STEM education is difficult to imagine.

The legal field for the development of STEM direction in domestic education includes Orders of the Ministry of Education and Science of February 29, 2016 № 188 “On the establishment of a working group on the implementation of STEM education in Ukraine” (Ministry of Education and Science of Ukraine, 2016), of May 17, 2017 № 708 “On research and experimental work at the national level on the topic: “Scientific and methodological principles of creation and operation of the All-Ukrainian scientific and methodological virtual STEM center” for 2017-2021” (Ministry of Education and Science of Ukraine, 2021) and from April 29 2020 № 574 “On approval of the Standard list of teaching aids and equipment for classrooms and STEM laboratories” (Ministry of Education and Science of Ukraine, 2020), Order of the Cabinet of Ministers of Ukraine of August 5, 2020 № 960-r “On approval of the Concept of development of natural and mathematical education (STEM education)” (Cabinet of Ministers of Ukraine, 2020) (hereinafter – the Concepts), the implementation of which is scheduled for 2027, and a number of orders and letters of the Institute for Modernization of Educational Content, other official documents and guidelines, collegial decisions and responses measures regulating the provision of educational services in Ukraine.

In particular, the main goal of the Concept is “to promote the development of natural sciences and mathematics education (STEM education) as a basis for competitiveness and economic growth of our country, the formation of new competencies of citizens, training new generations capable of learning and developing and using new technologies”. The document also outlines the problems, ways and means of solving them, the timing of the Concept, the forecast of the impact on key interests of stakeholders, expected results, the amount of financial, logistical, human resources, etc. Accordingly, the following are defined: the purpose of natural sciences and mathematics education (STEM education) and current competencies in the labor market, which should be formed through the development of appropriate teaching methods and training programs; principles, main tasks and priority directions of its development at the levels – primary (preschool, out-of-school, primary education), basic (basic secondary, out-of-school education), profile (profile secondary, out-of-school, professional (vocational) education), higher / professional (Higher Education). “Natural sciences and mathematics education (STEM education) in Ukraine can be implemented through all types of education, namely: formal, non-formal, informal (on online platforms, in STEM centers / laboratories (including virtual), by conducting tours, quests, tournaments, competitions, Olympiads, festivals, workshops, events, during which specialists in the field of software development work on solving a problem, creating new computer programs)” (Cabinet of Ministers of Ukraine, 2020).

Thus, an integral component of science and mathematics education (STEM education) is the creation of a network of modern STEM centers as promising educational resources (including virtual ones), the activities of which should be aimed at: organizing science-oriented project and research activities of education seekers with the use of high-tech teaching aids, innovative education models, their development and approval; popularization of the results of inventive, science-oriented activities and development of pupils/students creativity, critical thinking skills; professional improvement and growth of scientific-pedagogical and pedagogical workers, deepening of their professional training in a way acceptable to them, including using distance learning technologies.

Because STEM centers can be equipped with “general secondary education institutions, as well as vocational (technical) and professional higher education institutions that provide complete general secondary education, as well as higher education institutions that train teachers” (Ministry of Education and Science of Ukraine, 2020). Therefore, in the framework of the Concept we consider it expedient to create a STEM center as an educational resource for training in the context of the development of natural and mathematical education (STEM education) on the basis of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

The goal is to determine the key functions and effectiveness of the STEM center on the basis of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

Main tasks:

- to carry out an analysis of trends in the development of education in the field of STEM based on the practical experience of scientists from different countries;
- to investigate the regulatory and legal field of implementation of the state program of the STEM field in Ukraine;
- to popularize STEM education among young people, teachers of general secondary education institutions and teachers of higher educational institutions thanks to the experience of the operation of the STEM center “Educational and Scientific Training Center for Computer Science and Computer Mathematics” on the basis of the Department of Mathematics and Computer Science of the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University;
- to determine the purpose of the operation of the STEM center for junior year students and pupils, teachers of general secondary education institutions, to determine the key indicators that affect the development of education in the field of STEM as an innovative direction of the development of science and mathematics education in Ukraine;
- conducting events in the direction of STEM education to attract scientific and pedagogical workers to the use of new technologies, as well as their training, retraining or advanced training for the effective use of STEM methods as tools for training and career guidance of pupils/students;
- to verify the pedagogical research on the perception by respondents of the functions that will be performed by the STEM center, based on the results of the scientific experiment by means of factor analysis;
- to describe the prospects of further research of the STEM center “Educational and Scientific Training Center for Computer Science and Computer Mathematics” on the basis of the Department of Mathematics and Computer Science of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

2 LITERATURE REVIEW

The analysis of trends in the development of STEM education based on practical experience shows that STEM education is one of the key areas of research worldwide. A critical review of the transdisciplinary point of view on geospatial focus, main disciplinary areas, methodological and theoretical assumptions in the formation of research and practice of STEM education is presented in the article (Takeuchi et al., 2020). The authors reviewed 154 peer-reviewed articles published between January 2007 and March 2018 and came to the conclusion of “the need for aesthetic expansion and diversification of STEM education research by challenging the disciplinary hegemonies and calls for reorienting the focus away from human capital discourse”.

In the world educational practice there is a serious problem of inconsistency of indicators for STEM programs in higher education in different countries of the world. Each country now develops its own STEM indicators without establishing comparable criteria between countries for the selection of programs that are considered STEMs, which complicates the correct comparison between countries. Maldonado et al. (Maldonado et al., 2020) propose a criterion for selecting STEM programs to create internationally comparable data through a conceptual and contextual socio-historical review of the STEM movement.

There is considerable interest in STEM education and major projects in the development of STEM curricula around the world. Therefore, efforts should be made to increase the number of STEM teachers through the proper and effective professional development of teachers. Jong et al. (Jong et al., 2021) propose to enable researchers and practitioners in the field of STEM education to implement a scientific platform to reflect on the problems and obstacles faced by STEM teachers, as well as to share new theoretical and practical knowledge gained from empirical research on program design, implementation and evaluation, professional development to develop the potential of teachers in STEM education.

Exploring the mentoring model for teacher education, Yabaş and Boyaci (Yabaş and Boyaci, 2022) considered the STEM program for young researchers and practitioners, which aimed to integrate STEM integrated learning knowledge into the teacher training process. Content analysis showed that awareness of STEM education, development of integrated learning skills and program elements were relevant topics in the program experience.

Toma and Retana-Alvarado (Toma and Retana-Alvarado, 2021) considered the issue of improving teachers' perceptions of STEM education. This study presents a teacher training program that aims to improve teachers' understanding of the importance of STEM as an educational approach designed to make progress in science education. The results of the implementation of six different STEM models are presented, ranging from the simplest (for example, STEM as an abbreviation) to more developed models that meet current definitions (for example, STEM as an educational integration of four disciplines).

Santangelo et al. (Santangelo et al., 2021) described a multi-institution, multidisciplinary approach to transforming undergraduate STEM education. "It is founded upon three strong theoretical frameworks: Communities of Transformation, systems design for organizational change, and emergent outcomes for the diffusion of innovations in STEM education... While the systemic transformation of STEM higher education is challenging, the (STEM) Network directly addresses those challenges by bridging disciplinary and institutional silos and leveraging the reward structure of the current system to support faculty as they work to transform this very system".

Dare et al. (Dare et al., 2021) show that all teacher participants viewed STEM education from an integrative perspective that fosters the development of 21st century skills, using real-world problems to motivate students; that teachers have varying ideas related to the STEM disciplines within integrated STEM instruction, which could assist teacher educators in preparing high-quality professional development experiences. Findings related to real-world problems, 21st century skills, and STEM careers provide a window into how to best support teachers to include these characteristics into their teaching more explicitly.

The study by AlMuraie et al. (AlMuraie et al., 2021) aimed to recognize upper-secondary school science teachers' perceptions of the meaning, importance, and integrating mechanisms of science, technology, engineering, math (STEM) education, taking into account the differences between the science teachers' perceptions according to their specialties, years of experience, and degrees. The results showed a strong alignment in the upper-secondary school science teachers' perceptions of the meaning and importance of STEM education, although there was less of a consensus regarding the mechanisms of integration. Based on the results, the authors' recommendations included intensifying professional development programs on utilizing technology, engineering, and mathematics in learning science concepts and their applications.

Carmona-Mesa et al. (Carmona-Mesa et al., 2020) shows the experience of integrating mathematics with physics and technology through mathematical modeling. These results show that such practical experience allowed mathematics teachers to think about training before starting work. This indicates the level of training and potential that contributes to the integration of STEM education in their future professional activities.

There is a broad consensus on the need to promote scientific literacy and promote the full development of students' competence in education. The toolkit for this is interdisciplinarity, the continuous questioning of traditional teaching methods due to their ineffectiveness. Ortiz-Revilla et al. (Ortiz-Revilla et al., 2022) proposed a theoretical basis for integrated scientific, technical, engineering and mathematical (STEM) education, built a consistent model that can contribute to the development of coherent integrated education STEM, gave an example of real application of this theoretical framework in developing, implementing and evaluating didactic block STEM.

Using the cognitive neuroscientific paradigm of spatial navigation, Li and Wang (Li and Wang, 2021) investigate the spatial cognitive process in STEM students and its role in STEM education is studied. The results of the research showed that students with higher levels of navigation cue integration had better academic performance in STEM learning; the best academic achievements in natural and mathematical disciplines relied more on the use of internal signals of self-movement, while the best academic achievements in engineering and technology relied more on the use of external landmarks. Research sheds some light on the spatial cognitive process and its role in STEM education from the cognitive neuroscience perspective, thus deepening the functional understanding of spatial ability as a systemic source of individual differences for STEM education, and provides an empirical reference point for interdisciplinary studies on the role of cognition in the context of STEM education.

Research by Yıldırım (Yıldırım, 2022) investigated teachers' views of Massive Open Online Courses (MOOCs) in STEM education. Participants use MOOCs because they are free of charge and have good content and high quality. MOOCs help them learn science, technology, engineering, and mathematics, gain professional knowledge, and develop skills, and positive attitudes and values. It is recommended that MOOCs be designed in such a way that they increase participants' motivation and allow for feedback.

Mella-Norambuena et al. (Mella-Norambuena et al., 2021) analyzed the use of smartphones by students studying science, technology, engineering and mathematics (STEM) during the COVID-19 pandemic. Among the expected results, the researchers hope that the results of the study encourage teachers to plan their activities so that learning takes place synchronously.

The connection between learning and group work is often seen as obvious, but today's conditions require further study of the social organization of group work. Group work is an arena of learning in STEM education (Rusk and Rønning, 2020). Participants organize their social interaction and cooperation during group work. Important factors that may affect group work include access to physical resources, participants 'expressed knowledge and focus on participants' expressed knowledge, and access to new knowledge.

Lasica et al. (Lasica et al., 2019) review the project Enlivened Laboratories in Science, Technology, Engineering and Mathematics (EL-STEM) and describe the possibilities of using augmented reality in STEM – education to attract students and increase their interest in EL-STEM, improve student performance in STEM – training. In addition, EL-STEM provides teachers with high-quality professional development opportunities to acquire knowledge and skills for the effective implementation of augmented and mixed reality (AR / MR) technologies in teaching and learning.

Rahman's results of the thematic analysis (Rahman, 2021) showed that the expected learning outcomes in robotics lessons are related not only to the educational achievements (content knowledge) observed in traditional learning, but also to the improvement of behavioral, social, scientific, cognitive and intellectual opportunities and abilities of students. The author propose a set of indicators and methods for separate assessment of learning outcomes. The results of the study of educators and teachers showed the approval of participants in the educational process, the effectiveness and suitability of indicators and assessment methods. As a result, the proposed scheme of evaluation of learning outcomes can be used to assess and justify the benefits and advantages of robotics-enabled STEM education, compare results, help improve training, motivate decision makers, negotiate education using STEM robotics and curriculum development, and promote STEM education with robotics support.

Chang and Chen's research (Chang and Chen, 2022) aimed to study psychomotor productivity and perception on the basis of practical STEM training in task-oriented educational robotics. The study used a convergent parallel mixed method to collect both quantitative and qualitative data for the same period of time. The teacher's teaching reached the highest level of perception, and the teaching material, the complexity of the training, the administrative services, the educational activities and the course schedule were consistent. Chang and Chen (Chang and Chen, 2022) has confirmed that a practical approach to task-oriented STEM learning is effective for teaching students educational robotics. Finally, the study offers values and recommendations for working in robotics.

Sarı et al. (Sarı et al., 2022) argue that there is a need for practical classes on how to develop algorithmic thinking and what activities and learning content can be used in lessons. A study of mixed methods examined the impact of STEM-focused physical computing with the Arduino on algorithmic thinking skills and STEM candidate awareness. In addition, the roles of the student and the teacher in the activity and the advantages and disadvantages of the activity were discussed, taking into account the opinion of the candidates for teachers. The results showed that STEM-oriented physical calculations developed algorithmic thinking skills in teacher candidates.

Kovtoniuk and Didovyk (Kovtoniuk and Didovyk, 2018) note that in modern conditions for the successful training of future teachers of mathematics and physics there is an urgent need to design and implement innovative methods and technologies in the field of management and education. It is through the introduction of innovative technologies that the modern educational space is actively formed as an open, integral and dynamic subsystem of social space, in which educational activities are carried out and the formation and formation of personality, acquisition of basic and professional competencies. Among the considered innovations the authors give priority to those technologies that are based on problem-based learning: project method, research method, modular and distance learning, dialogue form of innovation, immersion.

Training in STEM centers is becoming increasingly important to meet new educational needs, caused mainly by the high speed with which new technologies have been entering our lives in recent years. Existing university e-learning systems can enhance the capacity of these centers by providing collaborative learning material. Stoyanov et al. (Stoyanov et al., 2022) presents a distributed educational platform that supports the sharing of educational material at the university and in STEM centers in secondary schools. Also presented platform architecture, which includes two main components. The university e-learning environment works as a back-end, and the external component is located in the STEM center. In addition, Stoyanov et al. (Stoyanov et al., 2022) consider the implemented prototype of the platform. The use of the platform is demonstrated by two educational games. The platform is expanded with four educational robots to increase the attractiveness of the educational process.

Fedoniuk et al. (Fedoniuk et al., 2021) has shown that the process of STEM projects development requires solving many organizational, psychological-pedagogical, educational-methodical issues: development of appropriate educational-methodical support, formation of culture of research work, development of creative abilities, cognitive and creative activity of listeners, formation of individual style of their scientific activities. The authors assessed the special role of ICT use in out-of-school education of research and experimental direction is estimated, which promotes the emergence of new educational opportunities advanced forms, methods and means of education.

Rushton and King (Rushton and King, 2020) suggest that play has an important pedagogical role in informal STEM activities, including making, when it is grounded in free-choice exploration and imagination. Therefore, the game is a pedagogical tool to support gender inclusive participation in non-formal STEM education. They identify that play has three key affordances, namely: (1) play can provide structure, (2) play is considered to be synonymous with open-ended science inquiry, and, (3) play can enable gender inclusive STEM spaces through promoting free-choice (Rushton and King, 2020).

Zhu (Zhu, 2020) described effective pedagogical strategies for STEM Education from Instructors' Perspective. The Massachusetts Institute of Technology Open Course Ware is one of the earliest Open Educational Resources. The most effective pedagogical strategies used by teachers were active learning, personalization of learning, involvement of students, providing feedback, creating a learning community and clarifying the purpose of learning. Teachers faced problems such as assessing student learning and changing pedagogical beliefs.

Soia et al. (Soia et al., 2021) presents the general characteristics of mobile technologies and means of teaching STEM education in institutions of general secondary and higher pedagogical education. The model of using mobile educational environments in the process of teaching students of pedagogical institutions of higher education as a system combination of target, content, technological and effective structural blocks is presented. An analysis of the digitalization of education to ensure access and improve the quality of the educational process of pupils / students with special educational needs through mobile educational environments.

The overall aim of paper by Ortiz-Revilla et al. (Ortiz-Revilla et al., 2020) is to establish an initial framework for philosophical discussion, to help analyse the aims and discourse of integrated STEM education, and consider the implications that adopting any particular epistemological view might have on the aims for general education, and on the construction of science curricula oriented towards citizenship and social justice. Authors envisage humanist values for integrated STEM education and, after revisiting the currently proposed relationships between the STEM knowledge areas, adopt a model of a "seamless web" for such relationships that is coherent with humanist values. A few issues emerging from this model are addressed through the lens of the so-called "family resemblance approach", a framework from the field of research on the nature of science, in order to identify some potential central features of "nature of STEM".

Ross et al. (Ross et al., 2022) examined the responses of STEM academics in higher education to educational reform of the academic role using the theoretical construct of resilience and Bronfenbrenner's socio-ecological model. Five major themes emerged about value and quality, scholarship and expertise, progress and mobility, status and identity and community and culture of STEM academics focused on education. Therefore more attention on the direction and reciprocal relationships in the socio-ecological model of higher education is needed in order for educational reform in higher education STEM to be effective.

McGee (McGee, 2020) conducted research and critical analysis of structural racism in STEM higher education. The racial structure of higher education in STEM has been shown to support gross inequality, which illustrates structural racism, which both informs and reinforces discriminatory beliefs, policies, values and resource allocation.

Tandrayen-Ragoobur and Gokulsing (Tandrayen-Ragoobur and Gokulsing, 2022) investigated the presence of potential gender disparities in admission to higher education STEM. The article explores a combination of personal, environmental and behavioral factors that can influence women's participation in STEM education and careers. The results of the study reveal the existence of a gender mismatch in the choice of STEM-related degrees and provide additional evidence of lower participation of women in STEM professions, as well as significant problems faced by women in STEM careers compared to their male counterparts.

Kara et al. (Kara et al., 2021) assessed the impact of class size on the academic performance of university students, distinguishing between areas of STEM and non-STEM. The authors investigated the heterogeneity of the effect in terms of socioeconomic status, abilities and gender of students, finding that smaller classes are especially useful for students with low socioeconomic level, and within STEM areas for students with higher abilities and male students.

Davey et al. (Davey et al., 2021) considered individual-oriented approaches to accessibility in STEM education. "Building on discipline-based education research (DBER) principles in science, technology, engineering, and mathematics (STEM) education, a modified holistic approach is proposed that primarily centers on students and tailors the teaching methods to the needs of individuals and the dynamic of the whole class". Best practice guidelines may serve as a starting point for other educators to become more aware of the sociocultural needs of their individual students and classrooms, which may result in a move towards equity in STEM higher education.

Bittinger et al. (Bittinger et al., 2021) investigated the career aspirations of high school students, modeling the probability that students with individualized education programs (IEPs) aspire to a STEM career. The results did not show any differences in STEM career aspirations, lower math and science identities for students with IEPs, and proportionally more students with ADHD aspiring to STEM careers.

Through the analysis of scientific and methodological sources, it was found that the introduction of education in the field of STEM is relevant for Ukraine and is rapidly gaining popularity. This is evidenced by numerous studies and publications (Bilyk et al., 2022; Botuzova, 2018; Burak and Holovko, 2021; Hrynevych et al., 2021; Kramarenko et al., 2020; Lukychova et al., 2022; Martyniuk et al., 2021a,b; Mintii, 2023; Morze et al., 2022; Oleksiuk and Oleksiuk, 2022; Pylypenko, 2020; Shapovalov et al., 2019a,b, 2020; Valko et al., 2020). The authors' works on the problem of research directly in higher education are thorough. In particular, Balyk and Shmyher (Balyk and Shmyher, 2017) characterize the main approaches and features of modern STEM education, determine promising steps in the implementation of STEM training at Ternopil Volodymyr Hnatiuk National Pedagogical University through the creation of STEM center "Digital Scholars" at the Department of Computer Science and Teaching Methods; Botuzova (Botuzova, 2018) reveals competence and STEM approaches in the professional training of future teachers of mathematics; Tsinko (Tsinko, 2017) emphasizes that the training of teachers of the new format in higher pedagogical educational institutions should be carried out from the standpoint of the introduction of STEM education in Ukraine; Podliesnyi and Tarasov (Podliesnyi and Tarasov, 2019) describe the relevance of the use of STEM-STEAM-STREAM technologies in the field of engineering education.

3 METHODS

Theoretical analysis of research works and resources containing materials about current realities and promising areas of STEM center as an educational resource of STEM education contributes to the development and implementation of STEM center for training in the context of natural sciences and mathematics education (STEM education) on the basis of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

3.1 Theoretical Framework

In order for civil society to properly perceive the state initiative on STEM education, a number of efforts should be made to reduce obstacles to its successful development. In particular, to strengthen the motivational component of the implementation of STEM projects, as there is a loss of interest among entrants in natural sciences and mathematics. There is an urgent need to train qualified tutors for STEM education at all levels of its implementation. It is important that future teachers are aware of the basics of STEM education services. Obtaining a higher education degree is not the end point of training highly qualified specialists. Due to the rapid development of modern science and new technologies, graduate subject teachers are in a state of constant professional development and regularly need training in the field of science and mathematics education (STEM education), and novice teachers also need mentorship from experienced colleagues. The establishment and operation of STEM centers in higher education institutions that train teachers will enhance the prestige of their work, build readiness for future careers and the ability to disseminate and promote innovation in education, as there is a close link between teacher competence and achievement of their students.

One of the key factors influencing the development of STEM education as an innovative direction in the development of science and mathematics education in Ukraine is the lack of financial resources / funds needed to fully equip STEM centers – structural units of educational institutions established to provide science and mathematics education, organization and interaction of stakeholders (Cabinet of Ministers of Ukraine, 2020). Another lever that determines the possibility of STEM learning activities is the training of research and teaching staff to use new technologies, as well as their training, retraining or advanced training for the effective use of STEM tools as tools for teaching and career guidance of students. Directly in front of those who seek to create a STEM center as a promising educational resource in their educational institution, the problem arises of developing integrated educational methods and educational programs aimed at the comprehensive development of the personality of pupils and students, the formation of algorithmic thinking and digital literacy in them, scientific and research and other skills presented in the Concept (Cabinet of Ministers of Ukraine, 2020), as well as the organization of research-oriented activities of students using high-tech learning tools and innovative models of education, including for people with special educational needs.

The world is growing employment opportunities in science, technology, engineering and mathematics, ie in STEM areas. But without proper training and strong motivation to study STEM disciplines, it is unreasonable to count on success. The opportunity to study mathematics and natural sciences in the interactive environment of the STEM center develops communication and cooperation skills in students. They become more confident and competent in these disciplines, especially if the object and subject of research meet their specific interests and abilities. Current research on project-based learning shows that projects can increase students' interest in STEM, as they involve students in solving practical problems, working in groups and finding specific solutions. Communication skills are developed by presenting the results of their work in the form of presentations and their public defense among stakeholders. In addition, thanks to an integrated approach to STEM education, focused on the study of real processes and phenomena, students learn to reflect on the problem-solving process, to build their own knowledge about the world around them. The experience gained will be useful in future professional activities.

As an example, we offer the project "Mathematical modeling of real processes using differential equations". Training in our case is conditionally divided into 3 stages. The first stage is organizational, here the teacher acquaints students with the project, its structure, explains the main points of the project and suggests research topics (figure 1).

The second stage, in fact, is an independent work of the student. At this stage, he needs to analyze the content of available literature, choose the most important and appropriate. Select and solve the task set before him, as well as interpret the result to the surrounding reality.

The third stage is the design and defense of the results. Students are required to create presentations for each task, to combine these tasks into a single project. Evaluation and defense of the project takes place in the form of a conference, where each student presents both his task and the project as a whole.

The main novelty of this project is the acquaintance and application by students of the method of mathematical modeling.

Thus, mathematics gives us the apparatus that helps to explore as closely as possible the world around us, what we face every day, or what we can not explore with direct methods ("incomprehensible, unattainable"). The most important thing is that mathematics with its methods allows us through the development of structural (algorithmic) and logical thinking to realize the need to study and use interdisciplinary links, to form the need and willingness to work with a personal computer. Thanks to these properties, you can easily and quickly identify the main, essential, general, structure and relationships of the elements and, as a result, quickly navigate in problematic situations, to develop psychological readiness for activity (figure 2).

Since STEM education is an integration of several disciplines, it is necessary to develop an appropriate approach to their teaching and learning on the basis of STEM centers, to develop advanced training courses and professional skills through the coopera-

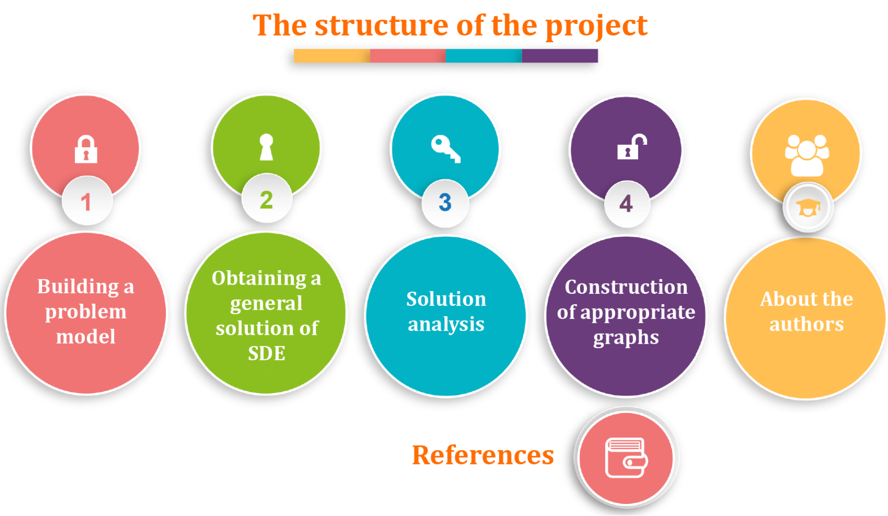

Figure 1: Structure of the project.

tion of university/school teachers and the involvement of specialists in high-tech industries in the educational process. Maximum efforts should be made to promote the expansion of scientific and research cooperation between educators, scientists, technologists, engineers and other stakeholders, which will contribute to the improvement of relationships and exchange of information between interested parties. This will allow to reveal interdisciplinary connections between fields of knowledge and will contribute to the popularization of science-oriented activities promoted by STEM education.

In order to get a new generation of highly skilled workers, it is necessary to update the content of natural, mathematical and technological educational fields. The Concept (Cabinet of Ministers of Ukraine, 2020) defines "the essential role of mathematics in the integrative approach to the implementation of natural and mathematical education (STEM education), consistent, thorough, high-quality teaching". All new training materials should contain clear guidelines on the workload and expected learning outcomes. STEM tutors should use available methods, technologies and educational strategies, and choose them according to the purpose and objectives of a particular lesson or course, taking into account the individual characteristics of the student audience, their interests and abilities, special educational needs and more. Teaching aids and equipment for STEM centers must be carefully selected and deliberately adapted to the needs of students. Only in this way will all students have the opportunity to succeed. Therefore, classrooms should be conducive to learning. If the necessary tools are available in Ukrainian educational institutions in sufficient numbers, it will strengthen the ability of teachers to facilitate students' learning activities and improve the educational achievements of students. Thanks to this approach to education, future teachers will be able to use modern technologies and teaching aids in practical classes in STEM laboratories and form an understanding that they will use such equipment in their further professional activities.

3.2 Research Results and Discussion

Introduction of methodical decisions of STEM education in educational process of educational institutions allows to form in pupils, students the most important competences of the modern expert: ability to see and formulate a problem, ability to suggest ways of its decision, flexibility as ability to understand a new point of view and stability in defending the position, originality of ideas, ability to abstract, concretize, analyze and synthesize. The implementation of STEM education approaches presupposes that students learn about technology, field of knowledge and acquire practical skills at the same time. Early involvement of pupils and students in STEM can support not only the development of creative, technical thinking, but also contribute to better socialization of the individual, because it develops such skills as: cooperation, communication, creativity.

Extracurricular STEM education in Ukraine is a variety of competitions, events, activities of the Small Academy of Sciences, clubs, centers and more.

One of the ways to develop STEM education is the creation of appropriate centers in institutions of higher pedagogical education, which contributes to increasing interest in the study of natural and mathematical sciences among pupils, providing opportu-

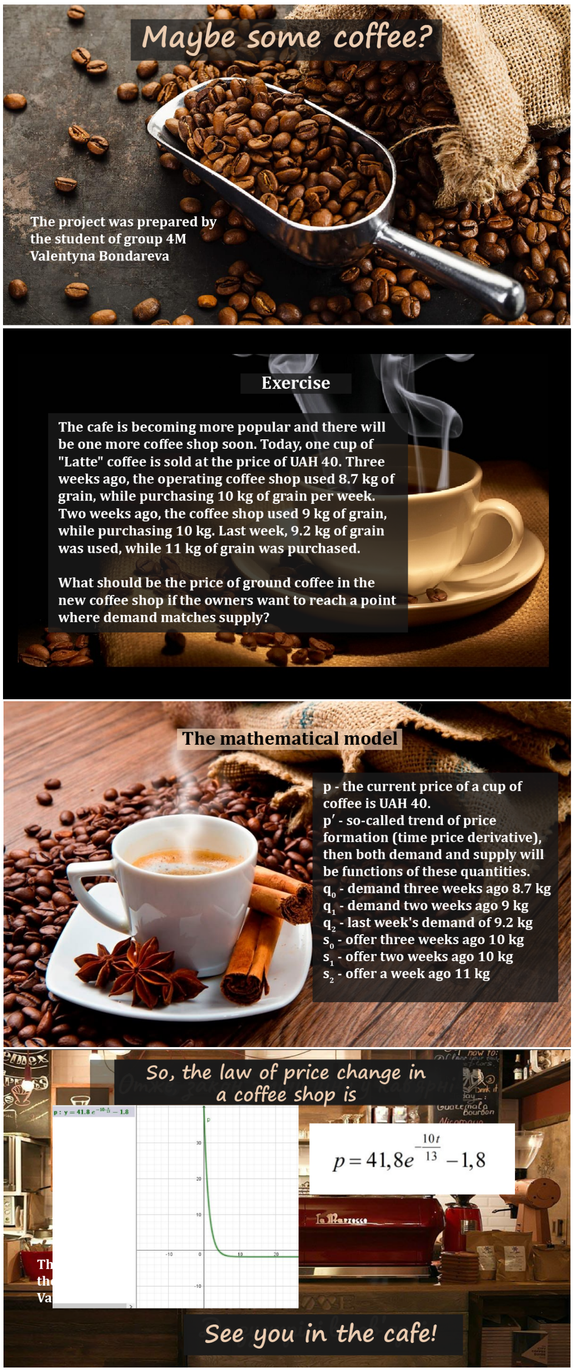

Figure 2: Research project.

nities for high school pupils and students to develop research potential on the basis of a specially created scientific laboratory at the university and attracting the best school graduates to the student ranks of this higher education institution.

Within the framework of STEM education at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University at the Department of Mathematics and Computer Science there is a STEM Center "Educational and Scientific Training Center for Computer Science and Computer Mathematics" for junior university students and school students, teachers of institutions of general secondary education. The purpose of the STEM center:

- motivation to study technical, natural and mathematical sciences;
- popularization of technical and natural science and mathematics specialties;
- training of a new generation capable of accepting the challenges of the future, transforming and producing new knowledge in any independent and group activity.

Classes in the STEM center are conducted using the educational technology "peer to peer" (students look at the experience of other students, and therefore more boldly and actively get involved in the work – "they did it and we will succeed too!").

The main objectives of the "Educational and Scientific Training Center for Computer Science and Computer Mathematics" are: involvement of young people in educational and practical and research activities; deepening the knowledge of pupils and students in technical and natural sciences; creating conditions for the development of creative activity of a young researcher; promoting students' professional self-determination; involvement of students in teaching activities, creation of creative research teams, preparation of the reserve of pedagogical university students, education of students' needs to constantly improve their knowledge of the chosen profession.

STEM center "Educational and Scientific Training Center for Computer Science and Computer Mathematics" on the basis of the Department of Mathematics and Computer Science has been operating since 2019. Classes are held twice a month for 2 hours on the basis of training laboratories of the Faculty of Mathematics, Physics and Computer Science of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University and are open to visitors. The main types of classes – lectures, practical and laboratory classes, meetings with specialists in the field of informatics, teachers of general secondary education, participation in scientific and practical activities. Individual educational and research activities are combined with participation in scientific and practical activities.

The program of work of the "Educational and Scientific Training Center for Computer Science and Computer Mathematics" is prepared in advance, all members of the department, as well as members of the STEM center of previous years take part in its formation. The topics of the center's classes are reviewed and updated at the beginning of the school year. The main principles that guide teachers and students in compiling the program are scientific, systematic, as well as personal approach. The high level of scientific knowledge is provided by the highly skilled scientific staff of the department, which has experience, its own traditions and history. Systematization is realized by the clear planning of group meetings, and individuality – in accordance with the content of group meetings to the interests of schoolchildren, students.

In 2019-2021 STEM center worked on the following modern areas of computer science: Python: tkinter library, Windows applications, Construct 2, game creation, Platformer, one-dimensional (multidimensional) arrays, modern methods of Web page layout, ways to use graphic images in applications with graphical interface (on Lazarus), Bezier and Hermit problems, practical application of knowledge and skills in mathematics and computer science to solve real problems on the example of Google, cryptography: Caesar cipher, Wiegener and RSA cipher, creating cyclic animation, importing images and audio.

It should be noted that the members of the STEM Center have repeatedly met with leading experts in the field of informatics. Thus, in 2019, an interesting report "Augmented Reality (Microsoft HoloLens)" was made by Matviishen, senior project manager of Delphi Software and demonstrated augmented reality with the latest developments in computer science. There was a meeting with the trainer of Intel "Learning for the Future", "Equal Access to Quality Education", Panasonic's interactive equipment expert, multiple winner and winner of the "Teacher-Innovator" competition, Microsoft trainer, Microsoft expert teacher Poida, who acquainted the members of the STEM center with the use of Microsoft services in educational activities.

In the modern realities of the forced transition to distance learning, members of the STEM center "Educational and Scientific Training Center for Informatics and Computer Mathematics" held a number of online classes in which schoolchildren and students participated. During the classes, the participants were provided with software for performing tasks on the subject of the corresponding class: "Actual trends in IT. Algorithms for solving problems"; "Creating loop animation. Import images and audio"; "Animation of particles"; "Python basics: one-dimensional (multidimensional) arrays" and others.

At the stage of empirical research, a questionnaire was used on the attitude of pupils/students to the main functions that should provide STEM-oriented educational environment to support the implementation of STEM-approach in the educational process.

In order to study scientific and research interests, expectations from classes, and to determine the priority functions of the work of the STEM center, questionnaires and surveys of the participants of the STEM center are systematically conducted.

In order to determine the priority functions that should be provided by the STEM center "Educational and Scientific Training Center for Informatics and Computer Mathematics", we used the online survey method. The online survey was conducted using the Google Form tool. Participants of the STEM center were the respondents of the online survey. Since the respondents were students of a senior specialized school and students of junior courses, the survey was conducted according to one form of the questionnaire. Respondents were asked to rate the functions of the STEM center that we highlighted on a scale of significance (1-5 points) (access to the initial data of the questionnaire: https://u.to/qetDHA).

As a result of the study for data analysis we have fully completed 82 questionnaires.

We used factor analysis to determine the question and structure of respondents' perceptions of the functions to be performed by the STEM laboratory. Factor analysis allows to classify survey data in the form of factors and determine the most significant of them for respondents. In our research the obtained factor structures made it possible to identify the most important functions of the STEM laboratory for the respondents. Interpretation of the results of factor analysis was carried out taking into account the contributions of the variance of functions in total variance factor.

Factor analysis allows you to identify a number of key factors that are the basis of the structure of the survey data. Factor analysis was performed by the principal components analysis and varimax rotation (Varimax Normalized). The optimal number of factors and their statistical significance were tested by Kaiser's test. According to the Kaiser criterion, it is necessary to leave only those factors whose eigenvalues are greater than 1.0; factor load is considered significant if its absolute value is greater than 0.5. To determine the stability of the resulting factors, a single factor must contain at least two components.

The result of the selection of factors indicates that the 3-factor solution is optimal for the study data at a significance level of p smaller than 0.05 (table 1).

Summarizing the results of factor analysis, we can conclude that the function "Ensuring the mobility of students" does not belong to any factor, which indicates that this function is not significant for respondents in the functioning of STEM center.

The percentage of the total variance of each of the identified factors is determined, the results are shown

Table 1: Factor loads of STEM laboratory functions.

№	Function	Factor		
		I	II	III
1	Ensuring learning mobility of pupils / students	-0.021	0.454	0.138
2	Participation in competitions	**0.789**	0.047	0.112
3	Assistance in conducting STEM research	**0.815**	0.091	-0.092
4	Participation in competitions of student scientific works / MAS	**0.697**	0.031	0.187
5	Development of algorithmic thinking of pupils / students	0.118	0.096	**0.909**
6	Development of creative thinking of pupils / students	0.130	0.224	**0.885**
7	Development of collective cooperation between pupils / students; teachers, professionals and employers	-0.314	**0.801**	0.068
8	Providing a combination of creativity and technical knowledge	0.239	0.201	**0.701**
9	Emphasis on the integration of academic disciplines	0.496	**0.751**	-0.034
10	Writing mathematical creative projects of applied direction	**0.729**	-0.016	0.153

in table 2.

From table 2, the first factor explains the 62.661% variance of the functions and includes the following functions:

- "Participation in competitions" (factor load – 0.789);
- "Assistance in conducting STEM-research" (factor load – 0.815);
- "Participation in competitions of student research papers / IAS" (factor load – 0.697);
- "Writing mathematical creative projects of applied direction" (factor load – 0.729).

Summarizing the content of the functions included in the first factor, we can highlight a common feature – all of them to some extent demonstrate the desire of respondents to participate in research and feel in the role of scientists.

The second factor explains 30.753% of the variance and includes the following functions:

- "Development of collective cooperation between pupils / students; teachers, specialists and employers "(factor load – 0.801);
- "Emphasis on the integration of academic disciplines" (factor load – 0.751).

For the functions included in the second factor, we can identify such a common feature – the deepening of cooperation between the parties to the educational process.

The third factor explains 49.819% of the variance and includes the following functions:

- "Development of algorithmic thinking of pupils / students" (factor load – 0.909);
- "Development of creative thinking of pupils / students" (factor load – 0.885);
- "Ensuring a combination of creativity and technical knowledge" (factor load – 0.701).

For the functions of the third factor we can identify such a common feature – the formation of innovative thinking, mastering the tools of a creative approach to solving innovative problems.

Thus, the results of the factor analysis allowed us to identify the structure of the main factors in relation to the functions to be provided by the STEM laboratory. The most important factor is the one that includes functions that demonstrate the respondents' desire to participate in research. Therefore, in the planning of the work of the STEAM center, considerable attention is paid to the participation of pupils/students in Olympiads, competitions of student scientific works, and the small academy of sciences.

The analysis of the internal consistency of the questionnaire on the main functions to be provided by the STEM laboratory was carried out by determining the correlation between factors and its components (table 3).

The level of correlation between the components varies from very weak to moderate (from 0.27 to 0.47), which indicates a high level of discriminant validity of the questionnaire.

During the research, we studied the expediency and effectiveness of the operation of the STEM center in relation to educational, economic and social indicators.

The effectiveness of the work of the "Educational and Scientific Training Center for Computer Science and Computer Mathematics" in terms of educational indicators is evidenced by the achievements of pupils/students in various Olympiads, competitions, and presentations at conferences. Thus, significant success was achieved by students who took part in the II stage of the All-Ukrainian Student Olympiad in Programming (quarter finals of the ACM

Table 2: The cumulative variance is explained.

Factor	Eigenvalue	Cumulative Eigenvalue	% Total variance	Cumulative %
I	1.284	6.266	6.266	62.661
II	3.075	3.075	30.753	30.753
III	1.907	4.982	4.982	49.819

Table 3: Correlation between the functions of the STEM laboratory.

Functions	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	№ 7	№ 8	№ 9	№ 10
№1	1.00	0.02	0.18	0.08	0.22	0.09	0.25	0.16	0.06	0.12
№2	0.02	1.00	0.61	0.47	0.12	0.25	-0.21	0.18	0.24	0.43
№3	0.18	0.61	1.00	0.42	0.12	0.00	-0.18	0.20	0.34	0.47
№4	0.08	0.47	0.42	1.00	0.23	0.20	-0.16	0.21	0.29	0.41
№5	0.22	0.12	0.12	0.23	1.00	0.71	0.10	0.14	0.12	0.22
№6	0.09	0.25	0.00	0.20	0.71	1.00	0.18	0.35	0.20	0.21
№7	0.25	-0.21	-0.18	-0.16	0.10	0.18	1.00	0.40	0.22	-0.14
№8	0.16	0.18	0.20	0.21	0.14	0.35	0.40	1.00	0.39	0.15
№9	0.06	0.24	0.34	0.29	0.12	0.20	0.22	0.39	1.00	0.38
№10	0.12	0.43	0.47	0.41	0.22	0.21	-0.14	0.15	0.38	1.00

ICPC World Championship) in the South-West region (2019). The VSPU-BreakOut team, consisting of Dmytro Boichuk, Svitlana Tkachenko, and Yuri Lyulko, took 1st place among the teams of pedagogical educational institutions and 2nd place among the teams of pedagogical educational institutions in the III (final) stage of the All-Ukrainian Student Programming Olympiad, Maria Levytska participated in the All-Ukrainian competition of student scientific works in mathematics and statistics and was awarded a diploma for significant achievements. Participant of the STEM center and student of the senior specialized school Iryna Turzhanska won the first place in the II stage and the III place in the III stage of the All-Ukrainian competition for the defense of research works of students who are members of the Small Academy of Sciences of Ukraine.

Using the method of surveying pupils/students, we have determined the competencies that, in their opinion, contribute to the formation of classes in the STEM center. According to the results of the survey, 96% of respondents chose the competence “development of technical culture”, “acquiring experience of own design activity” – 85%, “acquiring experience of inventive activity” – 56%, “acquiring experience of research and experimental activity” – 65%, “development of design abilities” – 86%, “development of logical thinking” – 96%; “development of creative initiative and self-realization” – 98%.

The STEM center is free for pupils/students, so from the point of view of the economic effect, it contributes to the optimization of financial expenses by parents for extracurricular education of children in the direction of STEM.

Among the social indicators related to the functioning of the STEM center, we single out the popularization of STEM education, increasing the prestige of science and mathematics professions.

4 CONCLUSIONS AND RECOMMENDATIONS

Introduction of methodical decisions of STEM education in educational process of educational institutions allows to form in pupils, students the most important competences of the modern expert: ability to see and formulate a problem, ability to suggest ways of its solution, flexibility as ability to understand a new point of view and stability in defending the position, originality of ideas, ability to abstract, concretize, analyze and synthesize. The implementation of STEM education approaches presupposes that students learn about technology, field of knowledge and acquire practical skills at the same time. Early involvement of pupils and students in STEM can support not only the development of creative, technical thinking, but also contribute to better socialization of the individual, because it develops such skills as: cooperation, communication, creativity.

As a result of the research, we highlighted the key performance indicators of the STEM center “Educational and Scientific Training Center for Computer Science and Computer Mathematics” at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University:

- for the university: promotion of STEM education among young people;

- for teachers: mastering modern technologies in demand in the labor market, awakening interest of students in the disciplines of the natural cycle, the disclosure of creative potential of youth, the search for talented youth, talents;
- for students: increasing competitiveness in the labor market through the mastery of modern technologies, participation in competitions, contests, competitions of student research papers;
- for teachers of general secondary education: providing methodological assistance on the implementation of STEM education in the educational process;
- for students of general secondary education institutions: participation in competitions, research contests of the Small Academy of Sciences of Ukraine, adaptation of future entrants to the conditions of student scientific activity; the opportunity to decide on the choice of a future profession, which will influence the choice of a higher education institution for further education and realization of a life trajectory;
- for parents: free participation of students in the projects of the STEM center will allow to optimize financial expenses from the family budget for extracurricular education in the STEM direction.

In the future, the STEM center plans to design and operate a laboratory for educational robotics.

It is planned that the main purpose of the laboratory of educational robotics will be:

- information and analytical work on topical issues of robotics in order to provide information to the educational process, strengthening its practical direction;
- use of software to control the electronics and mechanics of robots;
- collection of materials for research and preparation of publications in accordance with the scientific topics of the laboratory;
- 3D modeling and printing of prototypes and ready-made models of robots on a 3D printer;
- analysis of world practices in the field of robotics and information technology;
- organization and participation in scientific, educational and educational activities in the field of robotics.

On the basis of STEM laboratory in the future it is planned to conduct a training course on the organization of project-technological and interdisciplinary project activities, development of methods of STEM training, creation of interactive complexes for lessons, reports, lectures, laboratory and practical classes, presentations for studying natural sciences and mathematics.

The results of the pedagogical research on the perception of responders of the functions performed by the STEM center were analyzed by means of factor analysis. Factor analysis was performed using principal component analysis and varimax rotation (Varimax Normalized). The optimal number of factors and their statistical significance were checked according to the Kaiser criterion.

So, the goal has been achieved, the tasks of the scientific research have been successfully fulfilled, namely:

- the analysis of trends in the development of education in the field of STEM has been carried out based on the practical experience of scientists from different countries;
- the normative and legal field of implementation of the state program of the STEM field in Ukraine was investigated;
- thanks to the experience of the operation of the STEM center "Educational and Scientific Training Center for Computer Science and Computer Mathematics" on the basis of the Department of Mathematics and Computer Science of the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, the popularization of STEM education among young people, teachers of general secondary education institutions and teachers has been ensured higher educational institutions;
- the purpose of the operation of the STEM center for junior year students and pupils, teachers of general secondary education institutions, key indicators affecting the development of education in the field of STEM as an innovative direction of the development of science and mathematics education in Ukraine is defined;
- holding meetings in the direction of STEM education with leading specialists in the field of computer science to involve scientific and pedagogical workers in the use of new technologies, as well as their training, retraining or advanced training for the effective use of STEM tools as tools for training and career guidance of pupils/students;
- a questionnaire was conducted, interviewing respondents to study scientific research interests, expectations from classes, determining the priority functions of the STEM center, competences, the formation of which is facilitated by classes,

to analyze the structure and perception by respondents of the functions that the STEM center should perform, we used factor analysis;

- determined the prospects for further research.

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The Use of ICT Tools in Teaching Mathematical Modeling to Students

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Abstract: The study reveals that for the development of students' mathematical competency it is important to provide effective conditions for the formation of mathematical modeling skills. It is considered that methodologically balanced use of information and communication technologies (ICT) in the process of teaching mathematical models is a key means in the formation of students' mathematical modeling skills. In the article, the authors described the possibilities of using the electronic manual "Methodological Tool for Developing Students. Ability to Mathematical Modeling" and the mathematics teacher's website in today's conditions of forced distance learning. According to the results of the expert survey, it was elucidated that there was a request from the mathematics teachers for methodologically adapted and substantiated electronic manuals. For mathematics teachers, the most important aspects in such manuals were: methodologically successful selection of applied problems; modern, relevant content of tasks for students; methodological assistance to teachers in order to increase the effectiveness of teaching. The research on the effective use of ICT in the process of formation of students' mathematical modeling skills was based on the same principles as the development of computer-oriented methodical learning systems were based: the principle of interest in learning, the principle of adaptability to the individual characteristics of students, the principle of the student's search activity, the principle of self-evaluation and self-actualization, the principle of individualization of learning, and the principle of cooperation and mentoring. It is concluded that it is important to form skills of using ICT for creation and study of mathematical models to prospective teachers of mathematics.

1 INTRODUCTION

All recent Ukrainian educational documents on mathematics education emphasize that mathematical competency is the ability to see and apply mathematics in real life, understand the content and method of mathematical modeling, build a mathematical model and study it by using mathematical methods, and interpret the obtained results. We consider the ability to mathematical modeling as a direct feature of students' practical competency, which is formed in parallel with the formation and development of skills to use mathematical modeling in educational activities and practice.

The analysis of scientific and methodological publications shows that research on the problems of teaching mathematical modeling to students in different countries around the world has evolved from simple quality research cases to large research projects. The analysis of the Ukrainian scholars' pedagogical research reveals that special attention should be paid to the problem of providing the effective conditions for the formation of students' mathematical modeling skills. We completely agree with opinion of Semerikov et al. (Semerikov et al., 2010), formulated more than ten years ago, that "today it is no longer necessary to prove the obvious fact that increasing the effectiveness of the study of all school subjects is based on the systematic use of ICT". The intensive development of computer technologies is leading to the emergence of new approaches to the educational process. The quarantine requirements for COVID-19 have accelerated this process. The program of education reform

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activities developed by the Cabinet of Ministers of Ukraine provides the creation of modern electronic educational resources, in particular, electronic textbooks and manuals. In the context of this article, the particular interest is paid to the scientific heritage of Myroslav I. Zhaldak as to the methodological activities of teachers, in particular, "pedagogically balanced, theoretically and experimentally justified use of innovative ICT in the educational process harmoniously combining with the scientific-educational heritage of the past allow to form the knowledge that underlies many contemporary professions related to new information and production technologies" (Zhaldak, 2003).

The purpose of the article is an explanation of the methodologically balanced use of ICT by the mathematics teacher in the process of teaching mathematical modeling to students in the present-day forced conditions of distance learning.

2 LITERATURE REVIEW

The analysis of scientific publications has shown that the problem of formation and development of mathematical modeling skills is one of the most globally recognized problems in the study of mathematical education. The most important arguments for this conclusion are:

- Since 1983, the International Conference on the Teaching and Learning of Mathematical Modeling and Application (ICTMA) has been held every two years. The conference discusses the state and problems of teaching mathematical modeling to students in the form of an international discussion. The conference abstracts are regularly published in the series Springer's International Perspectives on the Teaching and Learning of Mathematical Modeling.
- At the CERME International Forum, organized by the European Society for the Study of Mathematical Education, one of the traditional sections is "Applications and Modeling".
- Springer search system issued 58,613 search results for "Mathematical modeling in secondary school". Moreover, these results are publications of recent decades, which address the problem of formation and development of mathematical modeling skills.

In order to obtain information about the areas of current studies and their results related to the use of ICT in teaching mathematical modeling, it is considered to observe some recent publications.

Tezer and Cumhur (Tezer and Cumhur, 2017) analyzed the results of research connected with the impact on mathematical achievement, problem-solving skills and students' views by means of the educational model 5E and the method of mathematical modeling in the process of studying the topic "Geometric Objects". The results of statistical analysis proved that learning with the 5E "Instructional Model" in experimental group 1 and the method of mathematical modeling in experimental group 2, improved students' academic achievements. However, the method of mathematical modeling was more effective for mathematical achievements and problem-solving skills.

Blum (Blum, 2011) and Kaiser (Kaiser, 2019), the most authoritative German researchers on the formation and development of mathematical modeling skills, founded the ISTRON group. Since 2014, the ISTRON group has published 20 volumes of publications to support teachers in solving real problems of teaching mathematical modeling to students at school. In all these studies, various aspects of the problem of modeling training were analyzed in complex. In particular, one of the learning environments, designed specifically for beginners in modeling, examined the KOMMA (computer learning environment). The KOMMA learning environment included four variants of heuristic activity samples. In these samples, two fiction characters solved simulation problems and explained their ideas, heuristic strategies, and tools. All samples were structured by means of a 3-step simulation cycle. The eight-grade students' competency of modeling (316 people) was tested before the experimental training, immediately after it, and four months after the experiment. The results of the research have shown a significant increase in the competency of modeling immediately after the implementation of the learning environment and a slightly lower long-term effect (Greefrath and Vorhölter, 2016; Blum, 2015).

In recent years, in Germany, the methodological activity of teachers in teaching mathematics (including modeling) has changed mainly due to the active development and implementation of digital technologies. Solving application problems, a computer or a well-equipped graphing calculator can be especially useful tools to support teachers and students. For example, Henn (Henn, 2007) suggested the use of digital tools, such as notebooks with algebra software, as it allows to incorporate complex programs and modeling into everyday learning.

One of the possibilities of using digital technologies is research and experiments (Hilscher, 2002). For instance, a real situation can be transferred to a geometric model, where one can experiment with dynamic geometry software or spreadsheet analysis that seems to be similar to experimental modeling. Modeling in the process of experiments is designed to provide an idea of the real system presented in the model (Greefrath and Weigand, 2012). Applied mathematical simulations performed by a computer can be perceived as part of a simulation cycle in which a numerical model, developed from a mathematical model, is tested and validated by comparing it with measurement results (Sonar, 2001). A common use of digital tools, especially computer algebraic systems, is to calculate or estimate numerical or algebraic solutions (Hilscher, 2002). Without the use of a computer, students would not be able to make these assessments, at least in a reasonable amount of time. In addition, digital tools can perform visualization of the studied object (Barzel and Hußmann, 2009; Hilscher, 2002; Weigand and Weth, 2002). Digital tools also play a useful role in controlling and testing the mathematical modeling skills (Barzel and Hußmann, 2009). If computers with Internet connections are provided for teaching mathematics, they can be used for research (Barzel and Hußmann, 2009), for example, in the context of programs.

German scientists state that there is currently little empirical knowledge about the possibilities of learning modeling and recommendations for working with digital tools in teaching mathematics. Only some case studies have been conducted, there are no large-scale experiments on the introduction of computer technology in the process of teaching mathematical modeling. Case studies (Greefrath et al., 2011; Geiger, 2011) note that digital tools can be useful for each step of the modeling process, especially for interpretation and validation. Open research questions can be found in the studies of Niss et al. (Blum et al., 2007; Niss and Højgaard Jensen, 2002): "How should digital tools be used in different classes to support modeling processes? What is the impact of digital tools on the range of modeling issues that need to be discussed? How does the use of digital technologies affect the learning culture? When do digital tools improve or hinder learning opportunities in the modeling process?"

Based on the mentioned analysis of teaching mathematical modeling in Germany, we indicate several current issues and tasks in formation of students' mathematical modeling skills for Ukrainian mathematics education:

- modeling activities can be significantly changed due to the development of digital technologies;
- the activity and role of mathematics teachers in the successful implementation of mathematical modeling in mathematics lessons is important;
- the focus should be on research of particular modeling lessons, as well as the entire modeling education environment.

In the article (Matiash and Mykhailenko, 2021) we analyzed the course of scientific discussions in terms of the International Forum CERME-2021 (we were lucky enough to be participants of it), which related to the use of information technology in the formation of mathematical competencies of students. Nowadays, the attention of researchers of mathematics education in the world is focused on problems: blended learning of mathematics students, blended learning in the process of professional training of mathematics teachers, and the developing tools, platforms and learning equipment for online mathematics education.

3 THEORETICAL BACKGROUND

Systematic application of the method of mathematical modeling at the process of teaching mathematics at school can be considered as a means of implementing the applied orientation of the school course of mathematics. In particular, it means: creating a bank of mathematical models that describe real phenomena and processes, have general cultural significance, and are studied in related courses; formation of students' knowledge and skills which are required for the study of these mathematical models; teaching students to build and study the simplest mathematical models of real phenomena and processes.

3.1 Mathematical Modeling

The essence of the concept of "mathematical modeling" is explained in different ways in many modern available sources:

1. Modeling is the study of knowledge objects on their models; construction of models of real objects and phenomena (living organisms, engineering structures, social systems, various processes, etc.). Mathematical modeling is the most modern comprehensive method of scientific research; it is the process of creating mathematical models. A mathematical model is a system of mathematical relations that describes the studied object, process, or phenomenon (Mathematical model, 2023).
2. Mathematical modeling or mathematical simulation is a research method of processes or phenomena by creating mathematical models and studying these models. Mathematical modeling allows

to replace a real object with its model and then study it (Mathematical model, 2023).

3. Mathematical modeling is one of the main modern methods of systems research. It usually involves the creation of a conceptual model of the studied object, its formalization and transformation into a mathematical or computer model, verification of adequacy and further study of the model by means of analytical or numerical methods and modern computer technology (Semenova, 2014).

4. Modeling is a process of real system research, which includes construction of a model, its research and transfer of the obtained results to the studied system. A model can be defined as an object that in some respects coincides with the prototype and is a means of describing, explaining and/or predicting its behavior. The mathematical model of the real system (process) means a set of relationships (formulas, equations, inequalities, logical conditions, operators, etc.) that determine the characteristics of the system depending on its parameters, external conditions (input signals, influences), initial conditions and time (Bakhrushin, 2004).

5. Modeling is the construction (or selection) and study of an object of any nature (model) that can replace the studied object (the original) and the study of model provides new information about the studied object. *Mathematical modeling* is the highest form of modeling. It contributed to the development of science and technology in industrial society, and the advent of electronic computing facilities led to the rapid development of contemporary – post-industrial society (Stanzhytskyi et al., 2006).

Thus, *mathematical modeling* is considered mostly as the study of the object properties in a mathematical model. Simultaneously, the mathematical model is an approximate description of a phenomenon or process of the external world, which is presented by mathematical symbolism. Mathematical modeling is one of the most up-to-date directions, which is closely related to the introduction of modern computer equipment and information technologies (Zahrai and Kotovenko, 2007).

From the pedagogical point of view, it does not matter where (mathematics, physics, computer science) students learn to model. It is important to understand that by means of modeling, the system-combinatorial thinking and the ability to solve real problems are formed (Teplytskyi, 2000). It is worth mentioning that modeling forms the world view and the scientific picture of the world not only for the student but also for the teacher. Modeling is the method, the most adequate to modern requirements for the education system, of including a computer in the learning process, which provides an active type of educational and cognitive activities (Morze et al., 2022). In particular, a computer model is a software environment for a computational experiment. Based on a mathematical model of a phenomenon or process, it combines tools of the experiment object analysis and information display. Using widely computer graphics, 3D modeling programs help to turn individual ideas into smart models and prototypes. 3D models are used in various fields: cinema, computer games, interior design, architecture, etc. Choosing software for modeling is a rather difficult process, as it is not easy to find a program that would have all the required functionality.

The use of computer modeling in the learning process (study of phenomena based on ready-made models, constructing models by students themselves) can increase the intensity of learning and the students' cognitive activity. The advantages of educational computer modeling are related to overcoming the formality of knowledge acquisition, the development of research and design skills, and the development of students' intellectual abilities (Morze et al., 2022).

Teplytskyi (Teplytskyi, 2000) proposed a methodological system for studying computer modeling and aimed to reveal the content of all school education through the introduction of the concepts of "model" and "modeling", which have developed both in specific sciences and in the methodology of science in general. The scholar considered the following definitions to be the most accessible to students: a model is a mentally imagined or materially realized system of reflecting or reproducing the studied object and the study of the model provides new knowledge about this object (Shtoff, 1963). Additionally, the model is considered as a system that does not differ from the studied object in some of its essential properties and differs in all other insignificant properties (Biriukov and Gutchin, 1982; Maliarchuk, 1997).

In our study, we reveal the content of the mathematical model as a set of mathematical relationships, equations, and inequalities that describes the basic laws in the studied process, object, or system (Kvietnyi et al., 2012). Modeling in the teaching of mathematics at school is understood as the process of building a model. Studying mathematics at school, students should realize that the process of any applied problem solving is divided into three stages: 1) formalization (transition from the situation described in the problem to a formal mathematical model of this situation, and from it to a clearly formulated mathematical task); 2) solving the problem within the constructed model; 3) interpretation of the obtained solution of the problem and its application to the initial situation.

3.2 Key Aspects of the ICT Use in Teaching Mathematics to Students

In the publications of Zhaldak (Zhaldak, 2003; Zhaldak and Hrybiuk, 2014), ICT in education are considered as a set of computer-oriented educational and teaching materials, software, and hardware for educational purposes, as well as a system of scientific knowledge about the role and place of computer technology in the educational process, the methods and forms of their pedagogically balanced, methodologically motivated, and appropriate use in order to improve the educational process.

There is awareness among mathematics teachers that the introduction of ICT tools can significantly help to create more effective conditions for students' cognitive activity and contribute to the formation of their competencies. "The basis of informatization of the educational process is grounded on the creation and widespread introduction of new computer-based teaching methods into everyday pedagogical practice based on the gradual and non-antagonistic principles, omitting destructive reforms. Embedding information and communication technologies in existing didactic systems is considered as a harmonious combination of traditional and computer-oriented learning technologies, without denying and rejecting the achievements of pedagogical science of the past, but, on the contrary, their improvement and strengthening by means of including the use of advances in computer technology and communications as well" (Zhaldak and Hrybiuk, 2014). According to Zhaldak (Zhaldak, 2003), the specific components of a teacher's information culture are the ability to use ICT for training, support, analysis, adjustment, and management of the educational process; the ability to choose the most rational methods and tools of learning, and take into account the individual characteristics of students, their requests, inclinations, and capabilities; ability to combine effectively traditional teaching methods with new ICT. At the same time, the use of ICT in the educational process (Zhaldak, 2003; Zhaldak and Hrybiuk, 2014) should not promote only the study of certain learning material, but, first of all, the comprehensive and harmonious development of students' personalities and their creative capabilities. Thus, in the conditions of active use of ICT tools in teaching mathematics, the requirements for the methodological competency of the teacher increase significantly.

Nowadays, in the era of mobility and globalization, there is an urgent need to use the Internet, social networks, and personal sites. Looking at modern students' level of informatization, it becomes clear that the teacher needs "to keep up with the times", as traditional teaching methods, in some way, lose their effectiveness. Currently, a mathematics teacher should have to some extent universal, fundamental and modern knowledge in order to be able to use ICT in a methodically competitive and effective way, and create conditions to develop students' inclinations and capabilities, meet educational and cognitive needs.

The study and justification of the required directions of ICT use in the educational process should be considered as one of the most important pedagogical problems. Zhaldak (Zhaldak, 2003) note that the problems of teaching mathematics in secondary schools by means of ICT are studied insufficiently. Despite a significant amount of research on this topic, there is a lack of computer-based scientific and methodological support for teaching school subjects in the context of systematic pedagogically balanced and methodologically motivated use of ICT, particularly, in mathematics. The methods of studying the effectiveness of computer use in education need to be improved (Zhaldak, 2003; Zhaldak and Hrybiuk, 2014). Studying the effectiveness of teaching mathematics to students by means of ICT, it is necessary to identify its criteria and reasoning factors. The teacher can achieve the set goals only if these goals are accepted and achieved by the students. Evaluating the possibilities and expediency of using ICT in teaching mathematics to students, it should be mentioned that a computer is only teachers and students' tool for educational activities.

It was remarked principally by Razumovsky et al. (Razumovsky et al., 2013) that with the introduction of computers in the educational process, the possibilities of many methods of scientific knowledge are increased, especially the method of modeling, which can dramatically influence the intensity of learning. While modeling, the essence of phenomena is singled out and their commonality is cleared up, i.e. scientific and theoretical thinking is developed. However, the fascination with the use of ready-made models threatens to prematurely disconnect between the studied phenomenon and reality. It often happens when students are asked to work with ready-made models without disclosing the process of model creation. Since the objects of study must still be real phenomena, their replacement, by abstract concepts and symbols with an insufficient base of observations and experience, often leads to pernicious formalism, when the pretended knowledge lacks the essence.

The issue of computerization of school education and the development of appropriate pedagogical software is the subject of constant attention of Ukrainian scholars (Zhaldak, 1989; Zhaldak et al., 2012, 2020; Zhaldak and Franchuk, 2020; Leshchuk et al., 2022; Kramarenko et al., 2019; Morze et al., 2022; Semerikov et al., 2021).

4 TEACHING MATHEMATICAL MODELING TO STUDENTS IN CONDITIONS OF ICT USE

4.1 Literature Review of Ukrainian Scientists' Research Results

The Ukrainian scientists study the problem of students' forming mathematical modeling skills in many ways. In particular, the content of teaching students the methods of mathematical modeling is determined; the main stages of constructing a mathematical model and their operational composition are highlighted; the functions of modeling in the educational process are described; some methodological recommendations for teaching mathematical modeling to students have been developed; the ways of using ICT in the process of teaching mathematical modeling to students are proposed. The main methodological fundamentals of teaching mathematical modeling to students are revealed in the studies of Vozniak and Vozniak (Vozniak and Vozniak, 2003), Gnedenko (Gnedenko, 2020), Slepkan (Slepkan, 1983), Shvets (Shvets, 2009).

Filimonova and Shvets (Filimonova and Shvets, 2010; Shvets and Filimonova, 2010) developed the main fundamentals of the methods of forming the middle-class students' knowledge, skills and abilities in mathematical modeling. Among them are the following aspects: the formation of mathematical modeling skills should be provided through successful use of organizational and methodological tools. In particular: a rational combination of traditional and innovative teaching methods. A special role should be given to interactive and project methods.

Panchenko and Shapovalova (Panchenko and Shapovalova, 2010), one of the goals of mathematical training of prospective mathematics teachers in higher education is teaching the basics of mathematical modeling and training students for the introduction of ideas and methods of mathematical modeling in the course of mathematics in secondary school. To achieve this goal, it is necessary to perform some tasks, namely: to teach students and pupils to use ICT in creating and studying mathematical models.

From the point of view of our research, the following position draws our attention: it is expedient to include elements of mathematical modeling in secondary school education to a somewhat greater extent and with greater penetration into the essence of models than it is done in many cases today. Obviously, it should be done in classes of an advanced study level of mathematics in secondary school. However, in classes with a general academic level of mathematics, physics or computer science, the appeal to mathematical modeling should be moderately dosed and balanced with the interests and abilities of students (Krasnytskyi and Shvets, 1997).

Since the method of mathematical modeling is a powerful tool for studying various processes and systems, according to many Ukrainian scholars, the concept of mathematical model and some general fundamentals related to it should be illustrated in one form or another at the learning process of the entire systematic course of mathematics in school. The samples of this method application for solving specific problems are presented in many well-known monographs and textbooks.

Ukrainian scientists' research emphasizes that for older adolescents it would be appropriate to organize the educational process with lessons-lectures, lessons-seminars, lessons-conferences, etc., involvement in writing research papers, and projects. Units of school curricula in various discipline courses related to solving problems for work, movement, interest, progression, application of derivatives and integrals can serve to develop the students' mathematical modeling skills. At the same time, Ukrainian researchers point out the current problems in the mathematical training of students, which often cause difficulties in the process of developing mathematical modeling skills. As for the method of mathematical modeling as a method of scientific research and learning cognition, in fact, it was not realized systematically and continuously in the school course of mathematics in the last three decades.

4.2 Methods of the Research

The Ukrainian and foreign researchers emphasize the need to use project technologies in the process of formation of students' mathematical modeling skills. We consider the organization of project activities of students at school as one of the priorities of modern education. Educational projects allow taking into account the individual characteristics of students that contribute to the formation of their active and independent position in learning, and readiness for self-development. The project method, as a component of the education system, creates personal motivation to solve an interesting problem. The project method is associated with active practical activities and teamwork. We assign a significant role to ICT in the organization of students' project activities. In particular, ICT (mathematics teacher's website, social network group, and the electronic manual) were actively used in the process of teaching mathematics to students of the 9th grade in order to improve the conditions for the formation of mathematical modeling skills.

We tested the students' implementation of a research project on the topic "Geometry and Football". A group of nine-grade students from the Regional Sports and Humanitarian Lyceum-Boarding School of the Municipal Higher Education Institution "Vinnytsia Humanitarian Pedagogical College" took part in the project. The designed project was awarded the third place at the Ukrainian Conference-Olympiad of Geometric Creativity named after V. A. Yasinskyi. As the participants of the project were students of the sports and humanitarian profile, the sports direction was chosen for the project. Out of one hundred students of the lyceum – 70 students were engaged in various kinds of sport at that time. The most number of lyceum students played football – 22 students (31% of all lyceum students). Therefore, the play of football was stressed in the project. Students learned with great enthusiasm that mathematical models can be used to solve certain practical problems in football, helping the team and coaches to achieve the best results. Our experience has shown, that solving football problems has increased interest, motivation, and as a result, the effectiveness of the study of mathematics, geometry in particular. Cooperation with students was established by means of the teacher's personal website and social networks. All students in the class were asked to solve geometric tasks about football. Each student sent the solution personally, hidden from other project participants. If the student solved the problem correctly, he received the next task, in case he did not solve the task, he received instructions about mistakes and tips on how to correct them. The students were motivated by the fact that they did not know at what stage (what task) the rest of the classmates were currently solving.

The project aim was not only to increase the motivation of sports students to learn geometry with the help of new technologies but also to show the importance and practicality of geometric knowledge in everyday life and future activities. It was important to ensure that students learned to come up with their ideas, were not afraid to express their opinions, and were able to think logically and critically.

In order to do this, students were offered a research task: to create problems in geometry, which would be directly connected to football and things related to it (football field, football goal, football ball, etc.). Surprisingly, but not only the students with the high level of academic achievements worked hard. As samples, the students used the problem tasks that they solved remotely in the first phase of the project.

We managed to ensure that students learned to come up with their ideas, were not afraid to express their opinions, and tried to think logically, in particular, critically. In the process of implementing the designed project, it became clear that we managed to create conditions with good opportunities to convince students that mathematics is the way to improve a lot of circumstances of the surrounding reality. For further diversifying the methods of motivation to master the method of mathematical modeling, it is important to select and accumulate effective teaching tools and techniques by mathematics teachers. Among effective teaching tools and techniques are applied tasks, methods of implementing interdisciplinary links, preparation and conduct of special practical work with an applied focus.

As we have already mentioned in this article, one of the main problems in the process of forming students' skills of mathematical modeling in Methodology of mathematics is the lack of methodological materials, especially for high school students. Therefore, in order to help mathematics teachers, we have developed and experimentally tested the textbook "Methodological Tools for Developing Students' Ability to Mathematical Modeling" (Matiash and Kateryniuk, 2019). In the textbook, it is presented and substantiated the theoretical aspects of students' ability to mathematical modeling, offered a system of applied problems for the formation of mathematical modeling skills (tasks to find the smallest or largest values; geometric problem-tasks; physical problems; stochastic problems; production problems; everyday and professionally oriented tasks), explained the methodological aspects of solving problems based on mathematical modeling. The methodological recommendations on the organization of independent cognitive activity of students in order to form the skills of mathematical modeling, students' project activities, and diagnostic tools for the formation of students' mathematical modeling skills were given. As a separate unit of the textbook, we have provided teachers with a list of publications on the development of students' mathematical modeling skills. Thus, we have systematized relevant material for practical use in mathematics lessons at school, and proposed authors' tasks. In the textbook, we have emphasized that at school, according to the learning outcomes identified in the mathematics curriculum, mathematics teachers must provide conditions for the development of students' mathematical modeling skills. The textbook is prepared for teachers of mathematics and prospective teachers of mathematics in order to provide methodological assistance in overcoming the problem of developing students' mathematical modeling skills.

Based on the printed textbook "Methodological Tools for Developing Students' Ability to Mathematical Modeling", we have developed an electronic manual. It is not just an electronic version of the printed textbook; it is also an electronic supplement to it. Simple and clear navigation allows turning pages quickly and easily. The use of an electronic appendix to the third section of the manual, which is devoted to the systematization of publications for further detailed study of materials on this topic, is of great practical value. It is much more convenient to use it as it contains all the publications we have mentioned, not just a list of them (as in the print version). They are available for viewing and downloading in *pdf* or *djvu* format. To download the e-manual, the following link can be used: https://drive.google.com/file/d/1K9B9VI6Yr12w0JHG4Y_aSOSJVsm3cuGd/view?usp=sharing.

According to the results of our research and experimental study aimed at finding ways to improve the effectiveness of forming the students' mathematical modeling skills, we can summarize that the personal website of the mathematics teacher is in great use. The personal website of a mathematics teacher should facilitate the exchange of experiences with colleagues, reduce the distance between teacher and parents, as well as between students and parents, and most importantly between students and teachers. The teacher's website allows implementing an individual approach, and focusing on the development of the personality of a particular student. With the help of the website, the teacher can distribute the required information in a short time, share important news, post educational and methodological hand-outs, creative work of students, their achievements, and much more. The personal website of the mathematics teacher has the opportunity to convey information to students in multimedia forms.

On the pages of the personal site, our teacher-experimenter (co-author of this article) added, edited and commented on materials, posted and analyzed test tasks, discussed various issues, and communicated with students. It is observed that modern students spend increasingly much time online and it is much easier for them to get the required materials online than to use libraries, books, reference books, and even writing home-assignment. According to most teachers' opinion, it is not very good. However, teachers should understand that they work with students of the new generation, and train them for life in a new society, which requires a modern personality, who is ready to live in a new information society. Out of 100 students (the survey was conducted at the Regional Sports and Humanitarian Lyceum-Boarding School of the Municipal Higher Education Institution "Vinnytsia Humanitarian Pedagogical College"), 95 have mobile phones (95% of respondents). 68% of students have mobile Internet access, and the rest students use Wi-Fi. After classes, 100% of respondents have access to the Internet. It confirms the ability of the mathematics teacher to communicate actively with students via the personal website.

During the experiment studying, the mathematics teacher's website provided an opportunity to draw students' attention by interesting learning materials, in particular, to the teacher's information competency. It expanded the possibilities of conveying interesting and important information to students and showing the wide application of the acquired mathematical knowledge in everyday life.

Such an environment allowed implementation of educational functions. The teacher, for example, placed the text of a problem task on the forum of the website and set the instruction: to construct a mathematical model. In the process of completing the task, students discussed, suggested their models, and when everyone expressed the opinion, the teacher corrected their steps, explained the incorrectness or inaccuracy of their reasoning, if a mathematical model did not correspond to the task in a result. On the contrary, the teacher could emphasize the right considerations, encourage further work, and summarize which model was still correct, or the most appropriate. The next step was the process of collective research of the mathematical model. Those students, who were not able to participate in the online discussion, had the opportunity to open the forum later and get acquainted with the discussion and the whole process of solving the tasks proposed by the teacher. Thus, we consider the function of the mathematics teacher's website "teacher-student interaction" to be quite effective. While experimental training, the question was put: "Why can't the teacher's personal website be replaced by communication with students on social networks?" According to the results of our research, we came to the conclusion that it is better to leave social networks for personal communication and entertainment, and everything that the mathematics teacher wants to convey to his/her students is better to post on the pages of the teacher's personal website. In our opinion, the modern mathematics teacher can create a personal website by him/herself with the help of a site designer, using a simple and free service Google Sites, as well as due to information competency which was formed in the process of professional training in a higher educational institution.

We created the mathematics teacher's personal website (URL: https://sites.google.com/view/kateryniuk/). Its content and effectiveness in improving the conditions for the formation of students' mathematical modeling skills were essential for us.

Thus, modern content management systems (CMS), the availability of free hosting, and free website designers allow teachers to create and develop their personal websites. The personal pedagogical website is not just a matter of time, but a necessity for the fruitful work of any subject teacher who cares about providing conditions for improving the effectiveness of teaching. Distance learning and external studies are developing extremely, so the exchange of tasks between a student and a teacher is rapidly moving into the ICT medium. In our opinion, the main tasks that are effectively solved with the help of the teacher's personal website are searching for new ways to interact with students and the organization of distance learning and project activities on the Internet.

5 RESULTS AND DISCUSSION

Different research and experiment methods allowed to construct an up-to-date method for the formation of students' mathematical modeling skills and to explain the place and role of ICT use in this method. In order to determine the attitude of the mathematics teachers to some results of our research (expediency and quality of the electronic manual "Methodological Tools for Developing Students' Ability to Mathematical Modeling"), we used the method of expert evaluation (Delphi method). The main stages of implementation of the method of expert evaluations in our study were: expert selection, identifying factors for the survey, conducting the survey, analyzing the results of the survey, and processing the results.

32 experts were chosen from a group of mathematics teachers of Vinnytsia and Vinnytsia region, who took courses of continuing professional development for teachers in-service based on the Department of Algebra and Methods of Teaching Mathematics at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University. Before the presentation of the electronic manual "Methodological Tool for Developing Students' Ability to Mathematical Modeling" to expert teachers, we found out the experts' preliminary vision of the importance of certain characteristics of the use of electronic manuals in teaching mathematics to students.

The survey suggested 10 factors:

(1) quality of the manual design;

(2) the presence of clear scientifically grounded recommendations for the formation of students' mathematical modeling skills;

(3) increasing the number of school mathematics lessons;

(4) modern, relevant for students the content of tasks;

(5) the conviction of the mathematics teacher in the need for special conditions for the formation of students' mathematical modeling skills;

(6) high teacher salaries;

(7) successful selection of applied tasks;

(8) the teacher's methodological competency;

(9) students' interest in learning material;

(10) teacher's knowledge and understanding of the criteria and indicators of the formation of students' ability to mathematical modeling.

The used methods of mathematical statistics were based on ranking. In our case, each factor was assigned a rank from 10 to 1 by each expert (in descending order to determine their relative importance). The required condition for the reliability of the collective assessment was sufficient consistency of opinions of the interviewed experts. To determine the consistency of group assessments, we used the concordance coefficient – a common rank correlation coefficient for a group of experts. Statistical processing of the results of the teacher survey allowed us to state that the most significant ranks were:

5. Conviction of the mathematics teacher in the need for special conditions for the formation of students' mathematical modeling skills;

7. Successful selection of applied tasks;

4. Modern, relevant for students the content of tasks;

9. Students' interest in learning material;

8. Teacher's methodological competency.

The consistency of experts' opinions was assessed by the concordance coefficient:

$$W = \frac{12}{m^2(n^3-n)} \cdot \sum_{j=1}^{n} \left[\sum_{i=1}^{m} x_{ij} - \frac{m(n+1)}{2} \right]^2,$$

where m – the number of experts, n – the number of factors.

In our case, $m = 32$, $n = 10$. The obtained value is $W = 0.64$, according to the scale for rank correlation coefficients, which falls into the interval $(0.6; 0.8)$. It demonstrates a good consistency of experts.

According to the results of the expert survey, it was found that the designed electronic manual contained the important characteristics of the use of electronic manuals in the teaching of mathematics to students that were relevant for mathematics teachers, and therefore would be useful for the formation of students' mathematical modeling skills. In order to identify the needs of mathematics teachers in printed or electronic manuals for the formation of students' mathematical modeling skills, the survey was proposed. The seventh question of the questionnaire was: "Would you like to have a manual in printed or electronic version?".

The response results of 500 surveyed teachers to the proposed question are presented in the following diagram (figure 1).

Analysis of respondents' answers to other questions of the proposed survey allowed to assert that 78% of mathematics teachers (out of 500 participants) need educational and methodological literature on the formation of students' mathematical modeling skills; 97.2% of teachers find it useful to develop a system of applied tasks; 66.4% of teachers need to master the method of solving problem tasks based on the mathematical modeling; 58.4% of teachers state that it is appropriate to develop lesson outlines for teachers oriented on the topic of mathematical modeling, and 30.8% of teachers admit the usefulness of such outlines. 90.4% of teachers are interested in diagnostic tools for the formation of students' mathematical modeling skills. 95.6% of respondents express a desire to get acquainted with the scientific and methodological publications on the formation of students' mathematical modeling skills. 58.6% of teachers want to have a textbook on teaching students mathematical modeling in the printed version and 68.3% of teachers – in the electronic version.

In the process of pedagogical experiment, and active communication with mathematics teachers, it was confirmed that "the use of ICT can significantly improve the efficiency of learning messages and data circulating in the educational process, due to their timeliness, usefulness, appropriate dosage, availability (intelligibility), noise minimization, and operational relationship between the source of educational information and the student, adapting the pace of presentation of educational material to the speed of its assimilation, taking into account individual characteristics of students, effective combination of individual and collective activities, teaching methods and tools, organizational forms that to some extent contributes to solving the problems of educational process humanization. Students and teachers remain the main participants in the educational process. Computers, software, and communication tools, are the only means of their activities. The effectiveness and efficiency of educational and cognitive activities of students depend on the teacher's awareness and skillfulness" (Zhaldak, 2003).

6 CONCLUSIONS

ICT and communication tools play an important role in the forming technology of students' mathematical modeling skills. Nowadays, it is important to teach prospective mathematics teachers to use ICT in the creation and study of mathematical models, and in the process of teaching mathematics to students. Due to forced conditions, distance learning development is accelerating, so communication between teachers and students is rapidly moving into the ICT medium. The results of teachers' surveys and the pedagogical experiment lead to the conclusion that the task of methodologically balanced use of ICT is complicated by the necessity to change the personal attitude of both teachers and students to self-education, self-development, and cooperation. Simultaneously, the Ukrainian scientists' ideas are confirmed that the readiness of mathematics teachers to use ICT depends significantly on:

- understanding the effectiveness of the use of ICT and communication tools in the educational process;
- ability to use modern computer equipment and tools of communication in professional activities;
- ability to competently assess the benefits, opportunities, and limitations of the use of ICT in the educational process;
- understanding the place and role of autonomous work of students using ICT;
- understanding the changes in the functions of the teacher in the organization of the educational process with using ICT (Zhaldak and Hrybiuk, 2014).

Our research on the effective use of and other methodological tools and techniques for forming students' mathematical modeling skills was based on the same principles as the principles of the development of computer-based teaching methodological educational systems were grounded by Zhaldak and Hrybiuk (Zhaldak and Hrybiuk, 2014): the principle of interest in learning; the principle of adaptability to

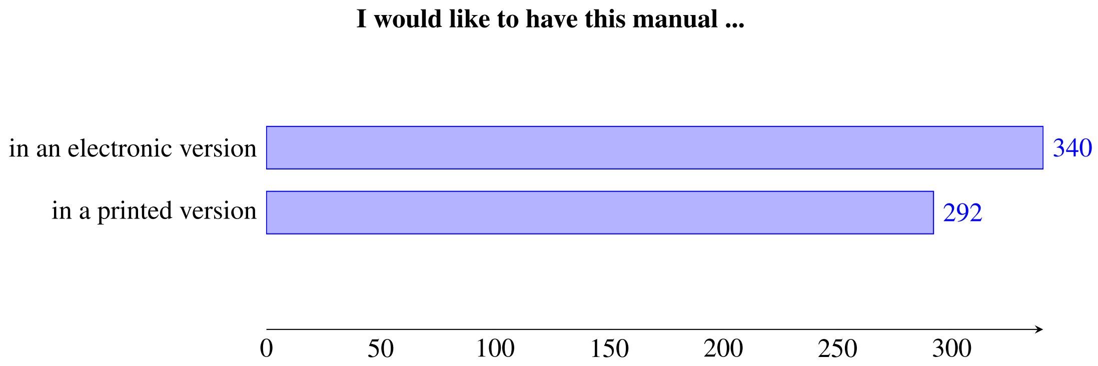

Figure 1: The results of the teacher survey.

the individual characteristics of students; the principle of the student's search activity; the principle of self-evaluation and self-actualization; the principle of individualization of learning; the principle of cooperation and mentoring. Thus, adherence to these principles in the process of formation of students' mathematical modeling skills is an important component of the methodological activities of mathematics teachers at school.

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Features of Using Mobile Applications to Identify Plants and Google Lens During the Learning Process

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Abstract: Students' motivation by providing personalized studies and using IT during classes is relevant in STEM. However, there is a lack of research devoted to justifying these approaches. The research aims to justify the choice of AR-plant recognition application, choosing to provide personalized experience during both the educational process at school and extracurricular activities. All apps have been analyzed and characterized by all interaction processes of the app with the user. In addition, the social environments of the apps and their usage during extracurricular activities are described. The didactics of the usage of AR-recognition apps in biology classes have been described. To provide usability analysis, a survey of experts on digital didactics was conducted to evaluate such criteria as installation simplicity, level of friendliness of the interface, and accuracy of picture processing. To evaluate the rationality of usage, apps were analyzed on the accuracy of plants recognition of the "Dneprovskiy district in Kyiv" list. It is proven that Google Lens is the most recommended app to use for these purposes. Considering the analysis results, Seek or Flora Incognita are both valid alternative options. However, these apps were characterized by lower accuracy. The use of mobile applications to identify plants is especially relevant for distance learning.

1 INTRODUCTION

The implementation of a mobile phone as a modern instrument into educational process has proven to achieve impressive results. Mobile phone usage during classes provides visualization of educational material, thus involving students in research and increasing their motivation for learning (Martín-Gutiérrez et al., 2015; Kinateder et al., 2014). Compared to computer approaches, mobile phone applications are characterized by the most promising advantages, including portability and the possibility to use both internal and external sensors (not commonly used). The modern educational directions include personalization and the research process, which may be achieved through the use of mobile phones (Marienko et al., 2020). However, it was proved that a general didactic approach led to a significant effect rather than using the device (mobile phone) for some separate aspects of education (Amelina et al., 2022). STEM/STEAM/STREAM technologies appear to be the most promising and relevant for the use of mobile apps.

1.1 Types of Software That Can Be Used During Education

All software that can be used during the learning process in the application of STEM can be divided into

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desktop applications, mobile applications, and web-oriented technologies. The most perspective of information and communication technology (ITC) in education are augmented reality (Martín-Gutiérrez et al., 2015; Marienko et al., 2020; Modlo et al., 2019a; Agustina et al., 2019; Nechypurenko et al., 2019, 2023; Kramarenko et al., 2019; Oleksiuk and Oleksiuk, 2022; Rashevska et al., 2020), virtual reality (Kinateder et al., 2014; Potkonjak et al., 2016; Joiner, 2018; Lee and Wong, 2014; Sala, 2014; Hussein and Nätterdal, 2015; Zantua, 2017; Antonietti et al., 2001; Park, 2014), providing digital environments of education, including computer modelling (Sarabando et al., 2014; Sahin, 2006; Sifuna et al., 2016; Khine, 2018; Clark and Ernst, 2008), providing of ontological educational networks (Tarasenko et al., 2021; Shapovalov et al., 2021; Stryzhak et al., 2019), mobile-based education (Modlo et al., 2019b,a; Nechypurenko et al., 2023), modelling environments (Dziabenko and Budnyk, 2019; de Jong et al., 2014; de Jong, 2019; Kapici et al., 2019), providing of education visualization by including YouTube videos (Chorna et al., 2019), 3D modelling, and printing, smart physiological tools (Shapovalov et al., 2022) etc. A comparison of the most used software in the education process is presented in table 1.

Using mobile phone apps during the educational process is characterized by advantages such as multi-capabilities, interaction with students in their research, and visualization of the educational process. Mobile apps can be classified as measuring apps, analyzing apps, image recognition, and classification apps, course platforms, and VR/AR-based apps. Based on the functions of apps, they can be divided into the following categories:

- training (course) platforms;
- measuring apps;
- measuring apps;
- video analysis apps;
- applications that analyze images and classify them;
- augmented and virtual reality (AR and VR) apps.

A comparison of different mobile apps categories is shown in table 2.

Apps-identifiers are characterized by the high potential, especially in biology classes, due to their capability to provide personalized studies. Nowadays, there is an entire range of mobile applications for identifying wildlife. Such apps may help identify insects (for example, Insect identifier Photo), animals (Dog Scanner), mushrooms (Fungus) and plants (Flora Incognita, PlantSnap, Picture This). In addition, some apps (such as Seek) provide identification of a few types of nature (both plants and animals). Nonetheless, in our opinion, the most promising applications provide analysis of the static objects of nature (plants and mushrooms). It is dependent on lower requirements for image quality, meaning that one does not require a high-end expensive smartphone to use the app effectively. Therefore, Inclusion of most students in most schools is not guaranteed.

1.2 The Problem of Plants Identification

There are about 27,000 species of flora in Ukraine. Such biodiversity requires detailed description and study. Natural conditions are constantly changing, causing changes in the species composition of biocenosis. Both aspects indicate a problem with plant identification. One of the basic principles of pedagogy is the principle of a natural experiment. For a modern child, a mobile phone with Internet access is a natural environment. So, training should be carried out within the environment where a mobile phone should become a full-fledged learning tool.

Some apps can be installed on a student's mobile phone free of charge while still allowing to determine the species of plants, their morphology, the range of distribution, and more.

There are about ten applications that can be used to identify plants. Most common of them are LeafSnap, Seek, PlantNet, Flora Incognita, PlantSnap, Picture This, Florist-X (in Russian), What is a flower (in Russian), Manager of houseplants (in Russian).

These applications can be divided into three groups:

1) plant identifiers that can analyze photos (for example, Google Lens, PlanNet, Flora Incognita, PlantSnap, Picture This);
2) plant identifiers with the function of classification allow to identify plants manually. The plant's classificatory commonly contains pictures and information about plant species. However, the quality of analysis, in this case, will depend on the user's knowledge and skills, which may cause difficulties for both teachers and students. Their use in biology lessons within the STEM approach has considerable potential because it allows them to learn plant morphology. However, its efficiency depends on the user's knowledge, which may be lacking in the case of pupils (for example, Florist-X and What is a flower);
3) plants-care apps that remind to water a plant or change the soil, characterized by a lower potential

Table 1: Comparison of the most used in the education process software.

Type	Web-oriented	Mobile applications	Desktop applications
Installation	Not required	From official stores or using application file	From official stores or installation files
General requirements	Compatible Internet browser for all features support	A compatible version of Android, iOS or another mobile operating system	A compatible version of Windows / macOS /Linux or another desktop operating system
Facilities	Modelling, calculation, visualization, video presenting	Modelling, calculation, visualization, video presenting, AR, measuring with both internal and external sensors, photo analysis, AR, VR	Modelling, calculation, visualization, video presenting, using additional external sensors
Main advantages	Cross-platforming, no installation required, low device space usage	Huge possibilities, portability	Stability and variation of applications
Main disadvantages	Limited opportunities, may not start correctly depending on the platform, lack of individualization	Needs technical updates, which may be expensive (a new phone purchase may be required each two or three years)	Lack of individualization, the lesser effect of increasing motivation during STEM-education

Table 2: Comparison of different mobile apps categories.

Type of application	Description	Examples
Education platforms	These platforms allow the teacher to create instructional content, communicate with students, give them assignments and check them out automatically	Google Classroom, Prometheus, Coursera, Microsoft Office 365 for Education
Measuring applications	These sensors and their software are already built into mobile phones	Measure, AR-ruler, Smart Measure, Lux-meter, Accelerometer, Magnet Field Meter
Image analysis apps	It allows you to measure distances, angles, perimeters, areas, and calculate with this data.	ImageMeter
Image recognizing and it's classification applications that analyze images and classify them	These mobile applications allow you to identify species of plants and animals using photos	Identification, Mushroom, Identify, Shazam, Dog Scanner, Identify
VR and AR-based apps	Allow virtual travel, get a spatial image of the training material.	Minecraft Earth, IKEA Place, Ideofit, Lego Hidden Side

than other application types (for example, Manager of houseplants).

Considering all advantages of plant identifiers, they were used as an object of the research. It was proven that Google Lens provides high efficiency in plant type and species identification (Bilyk et al., 2022). Furthermore, Google Lens can analyze real-life objects in AR and provide additional information using neural network algorithms. A few articles have been devoted to Google Lens that prove its relevancy and usability (du Plessis, 2015; Bilyk et al., 2020; Devi and Gaurav, 2018). However, some apps-identifiers may be more specialized and may provide better identification efficiency.

Despite the greater specialization of other applications, the research hypothesis is that Google Lens is the best plant analyzer because it may use a more extensive database, better algorithms or analysis and teaching AI using the Google crowdsource app (500 000+ installation).

Therefore, this article aims to analyze existing applications that can be used in teaching biology both in the classroom and in the field.

1.3 New Features in Google Lens

Interest in learning Google Lens capabilities usage for the learning process is growing. This is due to the development of both the technology itself and the pedagogical and psychological aspects of its application. For example, Google Lens can be installed on a desktop computer via Chrome. In this version, Google

Lens allows you to not only search for similar images, but also to perform operations with text on images.

Google Lens announces the emergence of a new search algorithm Multitasking Unified Model (MUM). At the presentation, they demonstrated how it works by searching for "Socks with this pattern". As a result – a list of stores selling socks with a similar pattern was shown. There is another way to use it for other purposes, for example looking up how to fix a speed shifter on a bicycle. Simply by pointing the lens on the object and asking "How to fix it", MUM would show a video with the necessary timecode.

At a first glance, the above example with the sock pattern resembles a successful marketing move, but it also involves the moment of finding information and clarifying its proper use. For example, bicycle repair is a classic STEM project. There is a problem statement and its practical solution by way of the engineering method.

An interesting aspect of Google Lens use is facial recognition of employees working for large enterprises. The developers of Google Lens are also working hard to implement the translation feature. Photographing text in one language provides automatic translation into another. Such technology would be especially relevant for teaching deaf and dumb students.

Yue's work has shown that the use of Google Lens significantly expands the vocabulary among English for lower primary pupils (Sergeeva et al., 2021) examined the possibility of utilizing Google Lens in teaching foreign language. These studies reported that Google Lens can be applied in foreign language classes as it contributed to the optimization of the educational process by filling it with information, involving students, and successfully influencing the process of development.

Psychological and pedagogical aspects of the Google Lens application are currently being actively studied. The study results (Nguyen, 2021) showed that performance expectancy, utilitarian value, and social influence had a statistically significant and positive impact on behavioral intention, but the perceived risk had a statistically significant and negative effect on behavioral intention.

Nowadays, some aspects of Google Lens use in marketing, in learning foreign languages with students of all ages, and in biology lessons are explored. However, the effectiveness of Google Lens in recognizing living objects requires further study and comparison with other mobile applications.

2 ANALYSIS METHODS

To analyze the plant identification apps' usability, a survey of experts on digital didactics was provided. The main criteria were installation simplicity, level of friendliness of the interface, and accuracy of picture processing. Each criterion was evaluated from 0 to 5 (the higher the better). Those applications which were characterized by an average evaluation grade of more than four were used to further analyze quality of identification taking into account the condition that the application may be used by both students and teachers with a low level of ICT competence.

Analysis of quality of identification was provided by a simplified method compared to our previous research (Sala, 2014) due to the aim of this paper to obtain a general state on application plant identification accuracy. 350 images from the list of plants of the catalog "Dneprovskiy district of Kyiv" were taken to analyse the identification accuracy. The key from the "Dneprovskiy district of Kyiv" plant classification was used as a control. The vast majority of photographs of plants on this list contain distinct vegetative organs (shoots with stems, leaves, buds) and generative organs (flowers or fruits). The presence of the latter is necessary to accurately determine the species.

To analyze the data, tables with names of the plant as lines and as names of the app in columns have been created. Each successful identification was evaluated as 1 and unsuccessful as 0 (see an example in table 3).

Table 3: Example of the table of apps analyzing.

The name of the plant	Flora Incognita	PlantNet	Seek	LeafSnap	Picture This
Prunus armeniaca (Apricot)	0	0	0	0	1
Jasione montana	0	1	1	1	1
Ageratum houstonianum	0	1	0	1	1
Chaenomeles japonica	0	0	0	0	0
Amaranthus	1	0	1	1	0
Ambrosia artemisiifolia	0	1	0	1	1
Amorpha fruticosa	0	0	1	1	0
Anemone sylvestris	1	1	1	1	0
Anemonoides ranunculoides	1	0	0	0	1
Anisanthus tectorum	0	0	1	0	0

Finally, all obtained results, including general usability evaluation (survey) and results on identification quality, were compared with results on Google Lens to summarize information.

3 RESULTS

3.1 Analysis of the Interaction with Apps

General characteristics of the apps. The apps' databases are significantly differing. For example, the lowest number of plants in the database is in Flora Incognita (4800 species), and the highest is in PlantSnap (585,000 species).

In addition, the app's databases differ in the presence of species based on geographical locations. For example, Flora Incognita's database is very limited geographically and contains only German flora; Conversely, PlantNet's data is geographically vast and contains flora of Western Europe, USA, Canada, Central America, Caribbean islands, Amazon, French Polynesia, including, medicinal plants, invasive plants, weeds.

Login procedure and instruction. For education, the login procedure is significant because it is related to the safety of students' personal data. On the other hand, login possibility is vital to save achievements, progress, and communications which motivates the student.

Only LeafSnap does not use the additional account at all (it automatically connected to the Google account). However, almost all apps request their own account. For example, Seek requests Inaturalist account (to connect with Inaturalist social network). Apps such as FloraIncognita start with the account creation page; PictureThis starts from the page with subscription plans, which may be a disadvantage when used by students. The login process into Flora Incognita, PlantNet, PlantSnap, Seek, PictureThis, and PictureThis's is accompanied by aggressive advertising illustrated in figure 1.

The feature of detailed video instructions is available via e-mail only in the PlantSnap app (English audio and Russian subtitles available). Other apps provide instructions within themselves. PlantNet does not feature any instructions whatsoever. Instructions of PictureThis are very simple. LeafSnap's help section is not displayed with the first launch confined to a specific tab. Instructions presentation in Flora Incognita (a), PlantSnap (b), PictureThis (c) LeafSnap (d) and Seek (e, f) apps is presented in figure 2.

Data and photo input process. According to botanical science, the algorithm for determining a plant includes: establishing the life form of the plant (tree, bush, grass); studying the vegetative parts of the plant (leaves, stem). In addition, generative organs (flower or fruit) analysis is helpful to determine a specific species name. Flora incognita and LeafSnap request the addition of different parts of the given plant's pictures. The mechanism of processing can differ. For example, Flora incognita processes photos of different parts of the plant; PlantNet provides photography and then choice of the plant part (analysis of only one photo)

Geographic location is significant to identify many species. For example, Picea omorika and Picea abies are very similar species, but Picea omorika is only found in Western Siberia and Eastern Bosnia and Herzegovina. Seek, Flora Incognita, LeafSnap, PlantNet request geolocation access during the first launch. If the algorithm for determining the plant in the application includes the definition of life form, photographing the vegetative and generative organs, and the geographical location of the object, such algorithm has been evaluated as entirely correct. If the application of the plant is based on the analysis of one image in a single click, the algorithm has been evaluated as simple. The interface of different apps' photo and data input is presented in figure 3.

apps are free, but PlantSnap limits the quantity of identifications by 25 plants per day per account. The mobile application PictureThis has the biggest amount of advertising. This mobile application also allows you to identify only 5 plants per day for free. Therefore, the use of PictureThis during the learning process is quite limited. The programs can request a single photo of the plant or photos of different parts of plants (PlantNet). In addition, LeafSnap provides automatic detection of the part of the plant presented in the photo. In general, all programs allow both making a real-life photo or uploading the photo made before.

Identification results. All apps (except PlantNet and Seek) provide information on the determined plant. All data on the plant is very structured in all apps and displayed, for example, in the manner: "Genus: Fucus".

FloraIncognita, PlantNet, PlantSnap provide interaction with other sources. Both public sources such as Wikipedia and more specialized sources, such as Plants for a Future, are used for interaction. The most interactive app among them is Plant net. It provides links to Catalogue of Life, Plants for a Future, and Wikipedia Flora Incognita. When used with the Russian interface, it provides the additional link to the site https://www.plantarium.ru (figure 4). Comparison results of mobile applications that can analyze plant photos are presented in table 4.

There are some spesific functions available during identification:

- PictureThis can provide an auto diagnosis of plant's problems with pests and determination of their diseases (figure 5);

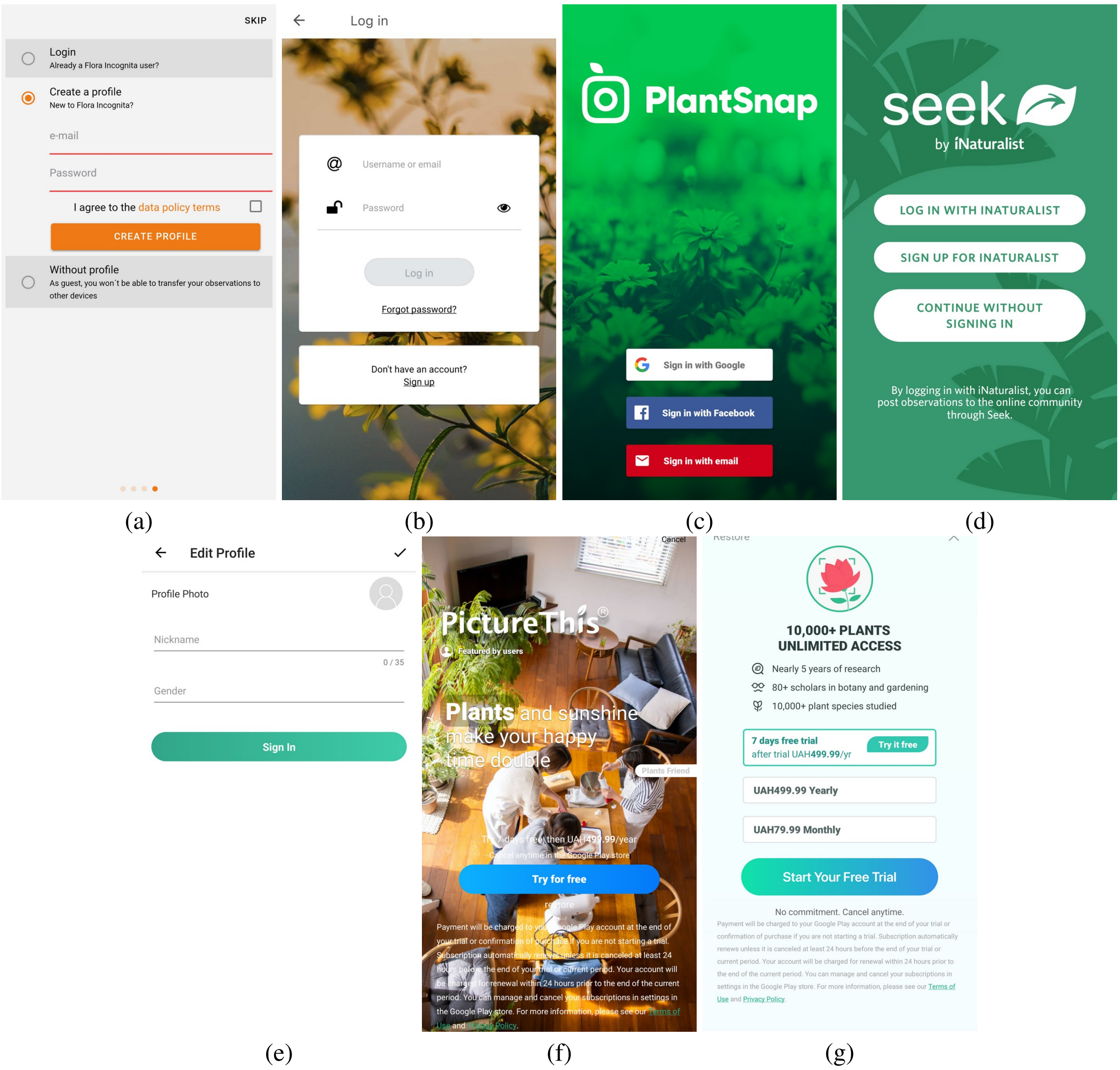


Figure 1: Login process of Flora Incognita (a), PlantNet (b), PlantSnap (c), Seek (d), Picture-This (e), and PictureThis's aggressive advertising (f, g).

- PlantSnap finds the plant on amazon and provides an infographic on solar activity, water usage and activation temperature.

3.2 Infrastructure and Social Environment

Some applications have their own approach to providing complex research of nature. Those features are useful forincreasing students' motivation to research nature. However, it is worth noting that the most developed environment is in Seek used iNaturalist application (developed by California Academy of Science and National Geographic), which delivers robust systems of different instruments to students and teachers.

Photo sharing and communications. PlantNet provides the feed of photos to identify plants shared by other users of PlanNet. The information in the feed is divided into classes "identified", "unidentified", and "All" filter (displays both identified and unidentified). The items in the feed with an "identified" filter will display already identified plants by users, and "unidentified" filter will display unidentified pictures updated by users. The most promising approach is to use an "unidentified" feed which may be helpful in a few cases:

- To help with identifying the plant
- To train own identification skills by providing

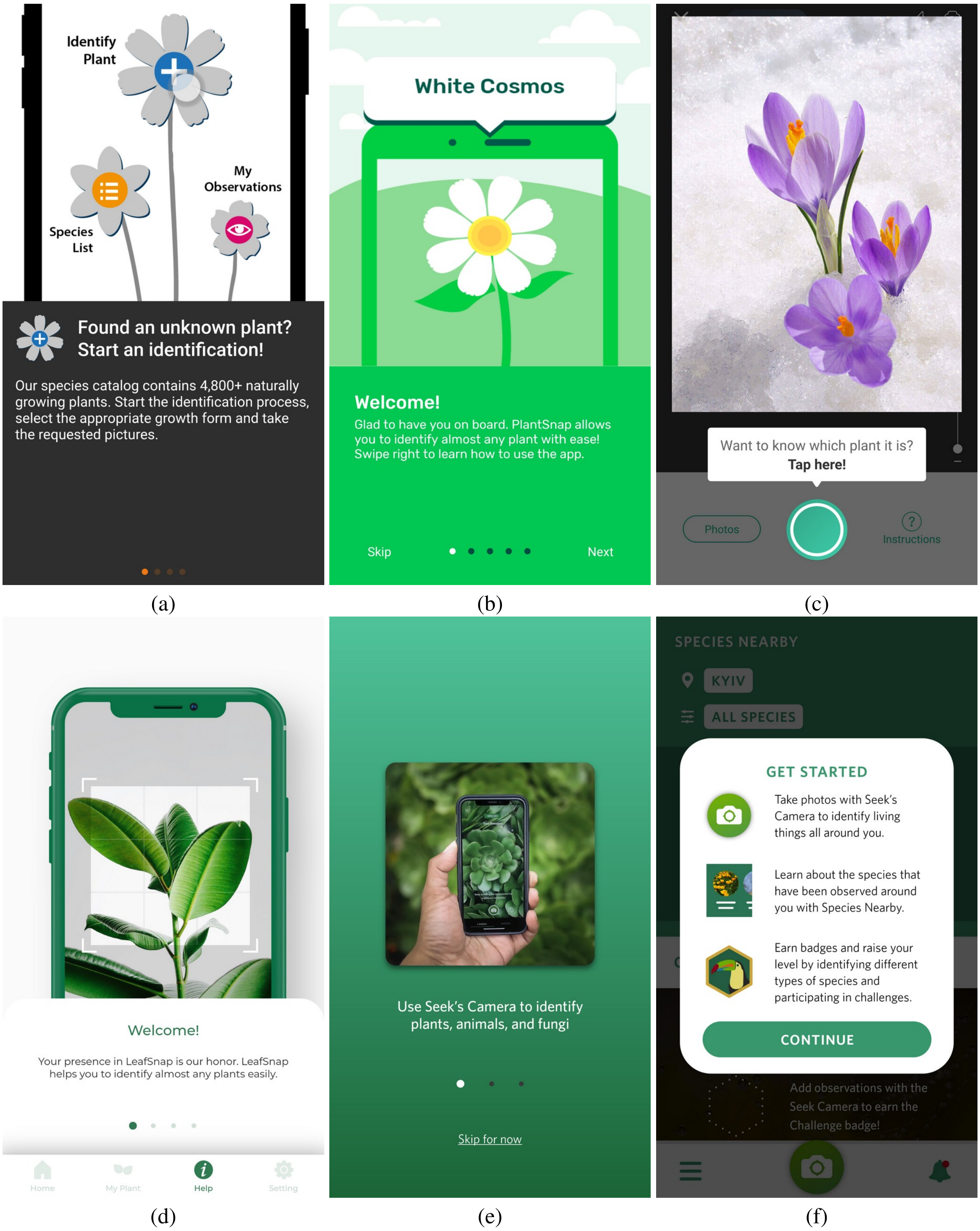


Figure 2: Instructions in Flora Incognita (a), PlantSnap (b), PictureThis (c) LeafSnap (d) and Seek (e, f) apps.

identification of pictures of others

- To share thoughts in the field of botanic, communicate with other researchers, and provide social science networking.

Personal journals. The first instrument to motivate a young researcher is providing a personal journal of observation and identification. It is a widespread feature. For example, Flora Incognita has

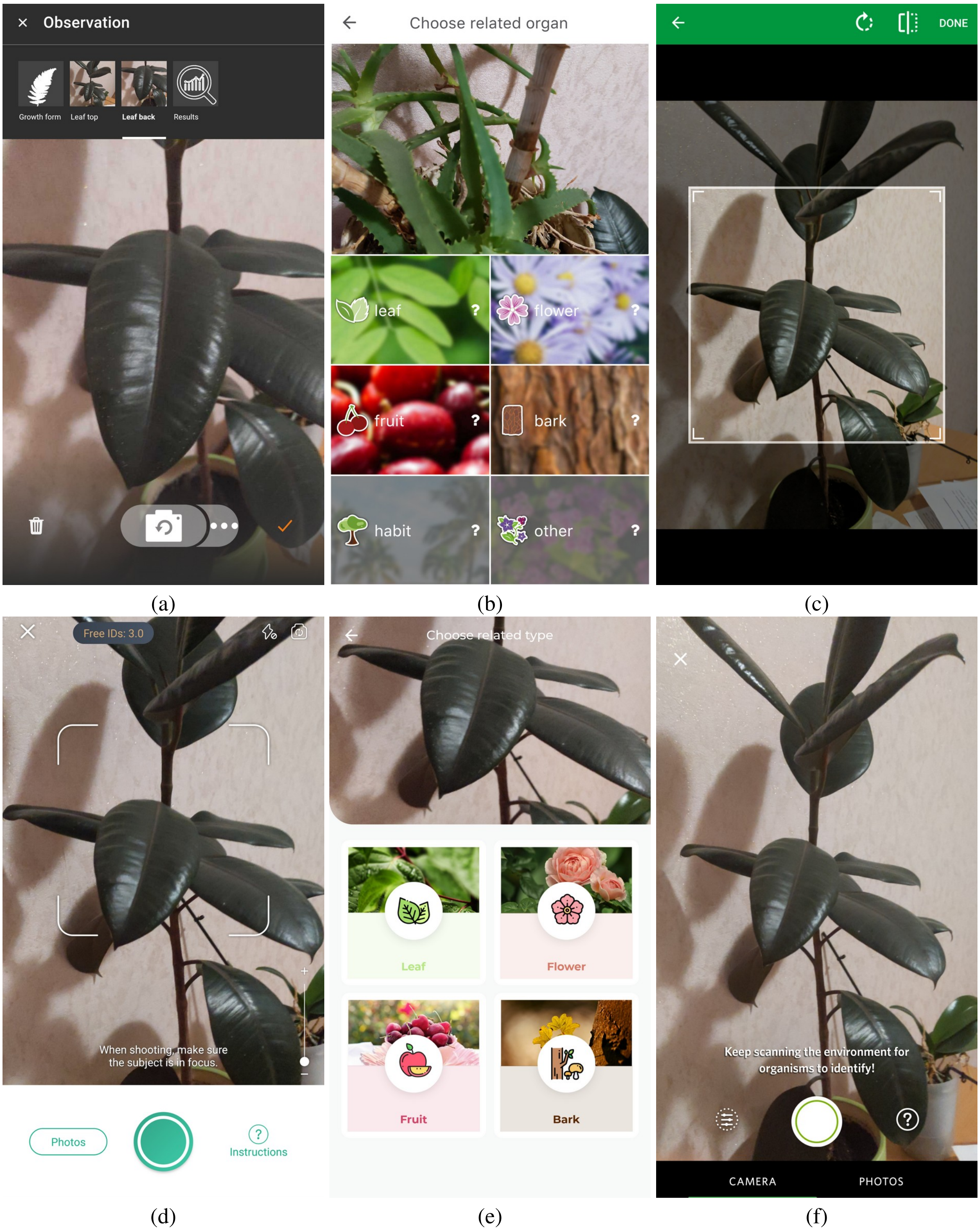
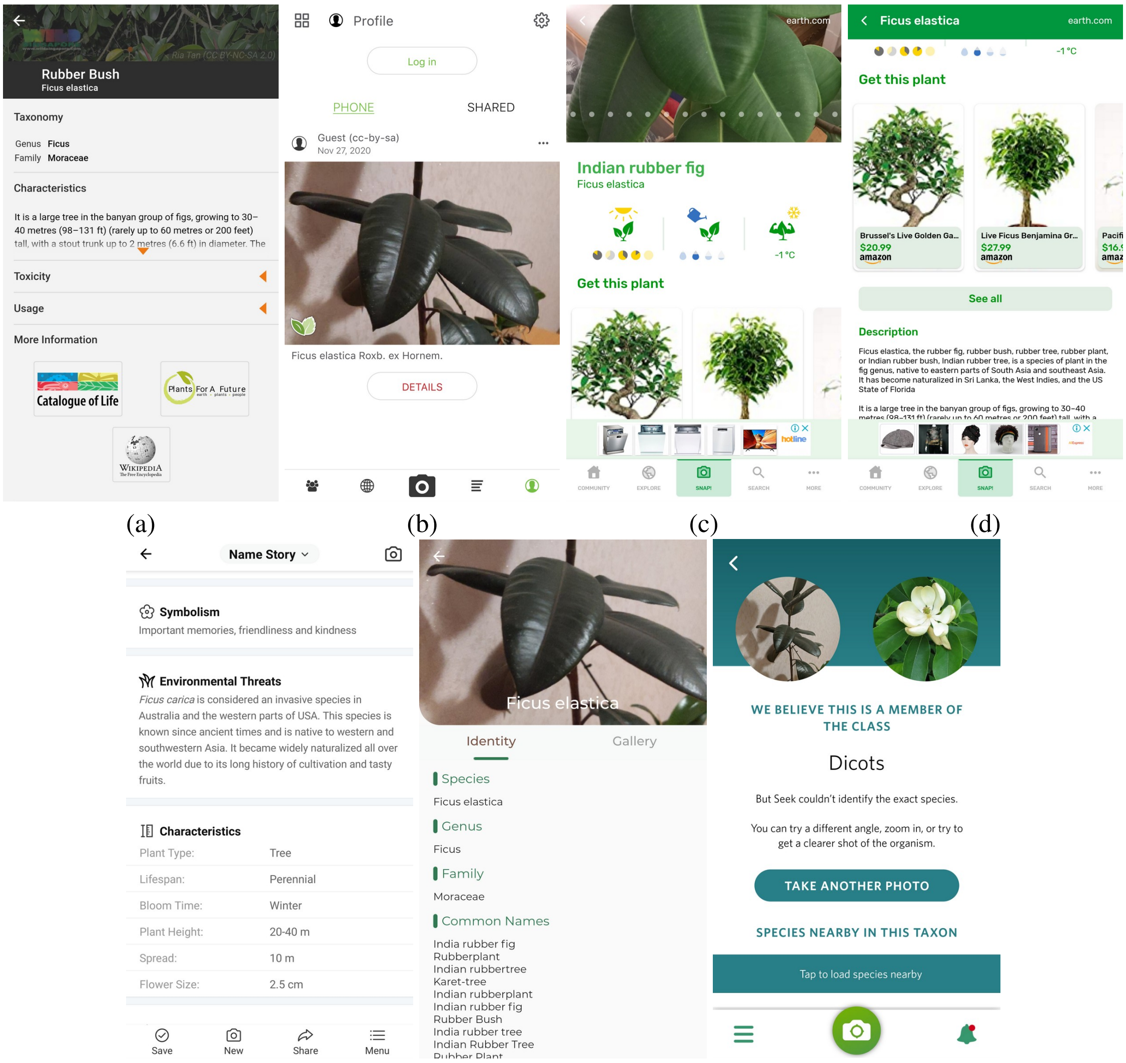


Figure 3: The interface of photo and data input of Flora Incognita (a), PlantNet (b) PlantSnap (c) PictureThis (d) LeafSnap Seek (e) apps.

the tab "My observations"; PictureThis has "My garden"; Leaf snap has "My plants". However, some apps do not provide an explicitly personal journal. For example, PlantNet only saves the history of observations.

Projects and social. Seek provides collaboration



(a) (b) (c) (d)

(e) (f) (g)

Figure 4: Data on identified plant Flora Incognita (a), PlantNet (b), PlantSnap (c, d), PictureThis (e), LeafSnap (f), and Seek (g).

through access to projects. Users can find and choose projects that they would like to join. It is worth noting that the app is ubiquitous and that there are even projects available in Ukraine. The project selection and specific project interfaces are presented in figure 6a.

Achievements. Seek-identification app provides a significantly different approach to increasing students' motivation. It provides achievements for each plant students may find, which motivates them to delve into new studies from time to time. The effect of achievement affects the brain as exaltation, and people desire it repeatedly. It is used in games to motivate students to play again and again (Abramovich et al., 2011; Hart and Albarracín, 2009; Weiner, 1985). In the case of Seek, some factors will motivate students to research nature.

The iNaturalist offers to observe plant and animal species, which a student can find nearby. This feature is activated by the "Exploring All" function and choosing "My location". Moreover, based on location, students can use Missions which gibes quests for students to do, for example, to find a "Rock Pigeon". Hence, students can observe nature nearby to study it in general terms while the program keeps encouraging students by illustrating progress through completion of various missions. The Exploring All and Missions functions are presented in figure 6b, c.

Table 4: Comparison results of mobile applications that can analyze plant photos.

Application	Number of plants in the database	Accuracy of the analyzing process	Links to other information services
Flora Incognita	4800 (only German)	The analysis algorithm is correct	Links to Catalogue of Life, Plants for a Future and Wikipedia. Flora Incognita, with a Russian interface, provides links to the Russian site
PlantNet	21920	The analysis algorithm is entirely correct	Gives only the name of the plant. Includes elements of social networks (by sharing plants student found and subscriptions). In addition, it contains links to Wikipedia.
PlantSnap	585000	The analysis algorithm is simple.	Has its own description. Searches via Amazon to give purchase options of the plant in question.
Picture This	10000	The analysis algorithm is simple.	Provides very structured information (including type, lifespan, height, flower diameter), care aspects, usage of the plant
LeafSnap	No data	The analysis algorithm is correct. Evaluation of health state (healthy and unhealthy) is included into determination process.	Contains links to Wikipedia, Pl@ntUse, Global Biodiversity Information Facility
Seek	No data	The analysis algorithm is the simplest. Achievements are given to users after some successful identifications	Has no detailed description but proposes "species nearby in this taxon"

3.3 Analysis of Application Identification Accuracy

PlantNet is the most straightforward app to install. Google Lens, LeafSnap and Flora Incognita have also simple installation procedure. Google Lens, LeafSnap, Flora Incognita, Seek have the most straightforward interface. Google Lens, PlantSnap, PictureThis, and PlantNet are characterized by the most uncomfortable identification process, which can be complicated for teachers. Results of detailed analyses on plant identification applications are presented in figure 7.

In general, Google Lens, LeafSnap, Flora Incognita, PlanNet, and Seek have proven to be the most usable after detailed research. However, the total number of points each application received is presented in figure 8.

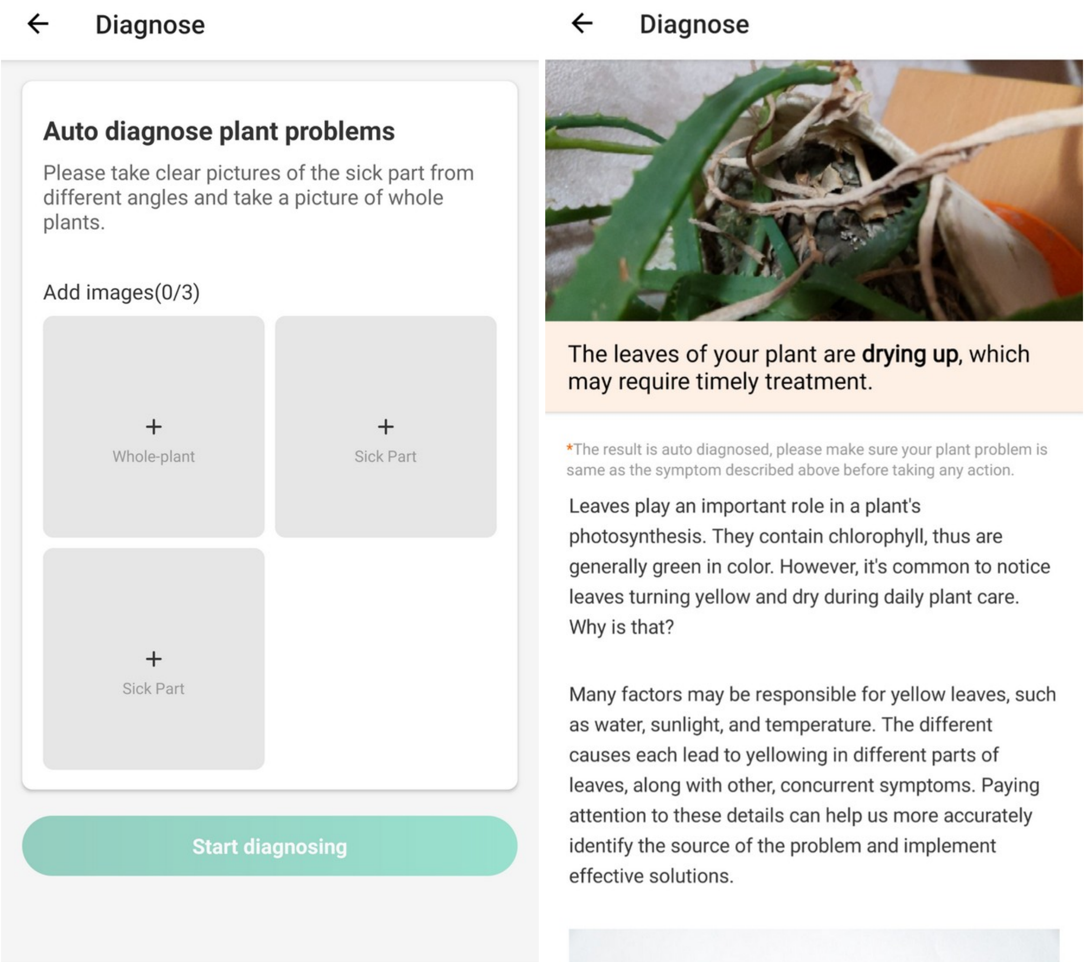
The most accurate apps are Google Lens, with 92.6% identification accuracy. Flora Incognita correctly identifies 71% of cases; PlantNet – 74%; Seek – in 76%, LeafSnap – in 76%. The PictureThis percentage of correct definitions was not determined, because this mobile application allows to identify only three plants per day for free. For a comparison of the identification plants accuracy by research applications, see figure 9.

Our previous work demonstrated that Google Lens does not differentiate native species from Ukraine. It seems that Seek, PlantNet and Google Lens mostly use data of American and European kinds of plants to train the neural network, and they have missed during identification of specific Ukrainian kinds of plants. Flora Incognita provides significantly different specific analyses; it may be due to Flora Incognita using a Russian database (similar to the Ukrainian region).

In our previous studies, it was shown that the accuracy of plant detection by the mobile application PlantNet is 55%. However, in the current test, the percentage of correct identification of plants by this mobile application has increased to 74%. This tendency indicates the ability of this neural network to learn.

The algorithm for determining plants using Seek also differs significantly. All other applications studied, except Seek, require a clear real-time photograph of the plant. Seek works with the user by interactively managing his activities in terms of image quality.

From the point of view of botanical science, the possibility to add different parts to the plants and choose the plant's type and geolocation access must



(a) (b)

Figure 5: PictureThis' app features autodiagnosis on pests and diseases function: photo input interface (a) and the result of the analysis (b).

affect the identification process accuracy. However, considering the results of the experiment, applications with a simple algorithm definition (analysis of a single image) more accurately identify plants. Therefore, it seems that internal algorithms of identification (due to higher statical characteristics of neural network) and the fullness of the database are more important than accuracy of data input or taking user geolocation into account.

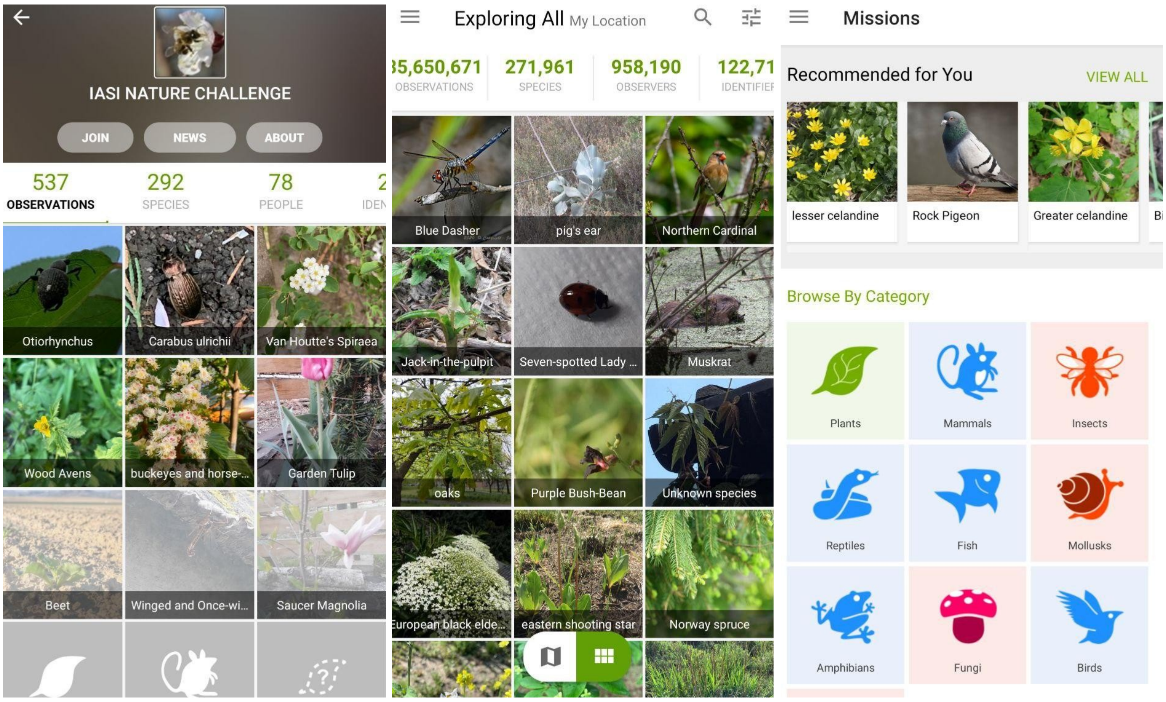
It should be noted that Seek identifies plants according to the algorithm used by professional botanists. Firstly, Seek defines the department, then the class, family, genus, and, finally, the species. Therefore, Google Lens is the most recommended app for use during classes (Bilyk et al., 2020). It is thus characterized by the highest general evaluation with 4.6 points of interface analysis, which is significantly higher than marks for other apps.

However, taking into account results of usability analysis and quality of analysis, it is possible to use Seek or Flora Incognita for students and teachers who do not like the Google Lens app for whichever reason. However, PlantNet cannot be recommended to use due to low accuracy which may result in half of incorrect analysis results.

3.4 Advantages of Using Mobile Phone Applications in the Educational Process

In our opinion, the use of mobile applications that identify plants during the education process has the following functions:

1. Function of creating a learning environment. Even in the works of Montessori (Montessori,



(a) (b) (c)

Figure 6: The Exploring All (a), Missions functions (b) and concrete project (c) functions.

1961) (a true classic of pedagogical thought), it was proven that the environment should develop the child. To a greater or lesser extent, mobile applications create such an environment. For example, Seek stimulates the child to search for new plant objects, manages the process of photographing plants, provides links to additional information about the plant, creates its own synopsis for the child, and motivates the child with "achievements".

2. Cognitive function. Only 70 hours are allotted to study all plants in Ukrainian schools. Such amount of time is insufficient for such task Mobile applications allow students to learn about the diversity of the plant world.

3. Training function. Due to the limited number of teaching hours, a teacher cannot focus enough on the development of practical skills, such as determining the life form of plants (bush, grass, tree, vine). Such skills are developed as a result of repeated training. Some applications, for instance Flora Incognita, request a definition of life form. All these functions contribute to the formation of this skill.

The use of mobile applications promotes the development of students with the following competencies:

1. *STEM competence*. When using mobile applications, students gain experience in the study of nature.

2. *Environmental competence*. Some applications, such as Seek, explain the rules of behavior in nature.

3. *ICT competence*. Mobile applications allow students to demonstrate the safe use of technology for learning.

4. *Lifelong learning competence*. The use of mobile applications teaches students to find opportunities for learning and self-development throughout life.

4 DISCUSSION

4.1 The Effect of UI/UX of the Apps on the Student's Motivation

The likelihood of students using mobile applications to identify plants depends on their interest. According to modern theories, there is individual and situational interest. Individual interest depends on the psychological characteristics of the individual. In contrast, situational interest arises in response to the peculiarities of the environment. Situational interest

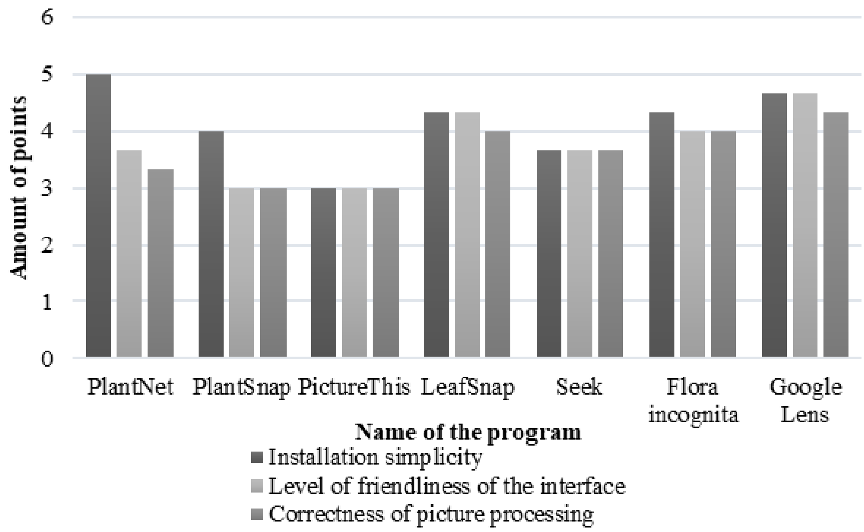


Figure 7: Results of detailed results on plants identification applications usability analysis.

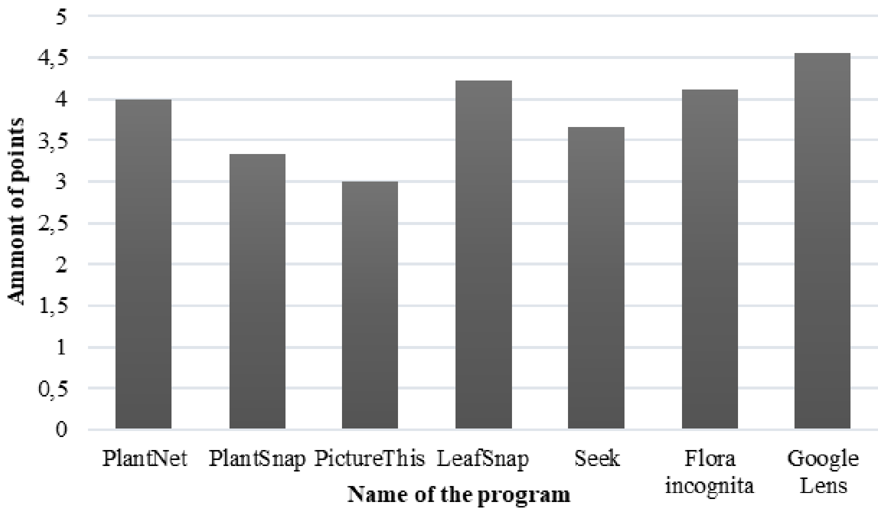


Figure 8: Integrated results on the usability of plants identification applications.

(SI) is divided into triggered situational interest and maintained situational interest (Linnenbrink-Garcia et al., 2010). Triggered-SI occurs quickly, directly, and on the "catch". Maintained-SI is a more stable form of interest in which the student begins to delve into the details. If maintained-SI deepens, this interest may become individual. According to Schiefele (Schiefele, 1991), Maintained-SI can be divided into maintained-SI, feeling component and maintained-SI, value component. These researchers believe that personality's value and sensory component support interest.

Situational interest may depend on the content of the study material. Quite a small number of students are interested in plants. However, many students may be interested in mobile applications. One way to capture users's attention is to provide mobile applications on the social network principle. PlantNet works accordingly. Users can share unique photos of plants and discuss the species. In modern pedagogics, social networks have significant didactic potential (Greenhow and Askari, 2017).

Enhancing students' motivation is an essential element, when modern informational tools usage is concerned. Motivation enhancement is significantly dependent on many factors. Situational interest plays a vital role in this context. In the case of mobile phones, students' motivation state is affected by both of them. Other factors affect motivation, such as engagement (Fredricks et al., 2004), well-being (Renshaw and Arslan, 2016; Bates and Boren, 2019; Renshaw, 2015), satisfaction (Ritzhaupt, 2019), positive

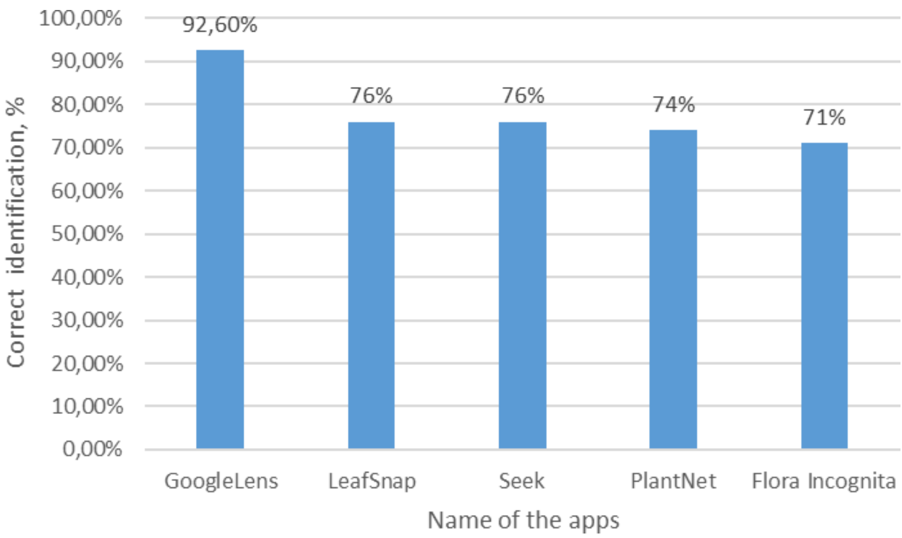


Figure 9: Comparison of the definition plants mobile apps accuracy.

and negative factors affect schedule (PANAS) (Ebesutani et al., 2012; Laurent et al., 1999). However, it seems that situational interest is caused by other factors; therefore, for analysis' sake, we will focus on situational interest. Indeed, some students will be looking for a tool that will help them satisfy their need for investigation of nature, and that causes a high level of maintained-SI when using identification mobile applications. However, triggered-SI will affect students that are not interested in nature investigation. For this purpose, the program's interface and UI/UX are very important because these are the components forming the first impression.

For example, the use of situational interest, which was triggered yet not maintained – markedly decreased from pre-test to post-test during a digital mathematics game (Rodríguez-Aflecht et al., 2018). This result may be explained by the program interface, which was neither easy to understand nor enjoyable to use. Consequently, enhancement of motivation when using such tools during biology classes becomes impossible with the interface, which contributes neither to the ease of understanding nor enjoyment of app use.

Due to the above understanding, detailed results on usability analysis (UI/UX) of plant identification applications are utterly significant (figure 7). The examples of comparison between different parts of the programs' interface are shown in figures 1-4. As shown in figure 7, the programs with the best UI/UX are Leaf Snap, Flora incognita, and Google lens.

The login process is an important part of UX, especially in the case of school usage. The experts took into account the login procedure during the evaluation of the simplicity and friendliness of the interface (figure 7). The most straightforward procedures were in Google Lens and Plant Net because it is possible to use them without additional login steps. Plant Snap and Seek also have relatively simple login procedure. Instructions are helpful, but their effect seems to have a much lesser influence on student motivation (figure 2). However, their absence may have a significant negative effect on students' motivation.

However, no programs were characterized by the absence of instructions. The simplicity and friendliness of the interface during the process of plant identification seem to deliver reverse accuracy within such a process. Even with the inaccuracy of inputting photos, some programs, such as Google Lens, nonetheless provide impressive results. Therefore, we will take into account the simplicity of such process. Google lens, PlantNet and Seek were also the easiest due to their one-click-based process. All the above steps are essential to use the factors to transfer situational triggered to maintaining interest. In most cases, obtaining additional data UX/UI will depend on maintaining situational interest. Consequently, obtaining additional data on UX/UI contribution to students' motivation will exhibit a lesser effect.

Furthermore, it is essential to consider that triggered motivation is affected not only by UI/UX, but also, by involving students in the investigation process, for instance, by providing the social network effect and communication with other young researchers – a function available in Seek.

The Seek mobile application system is interesting from the point of view of didactics. The principle of operation of this application uses gamification principles. Numerous studies have proven the high educational potential of games. In many cases, the application of games and simulations for learning provides an opportunity for learners to apply acquired knowledge and experiment. Some things cannot be applied in real-world contexts. Games can motivate to learn, increasing the likelihood that the desired learning outcomes will be achieved. Learning is defined as the acquisition of knowledge or skills through experience or practice, and what better way to learn is there other than through a game? (Pivec and Kearney, 2007).

The student can register in Seek and get a nickname. For each plant identified, he receives an achievement and becomes a higher-level user. During computer games, the participant learns to use their knowledge in a specific situation without even realizing it. These steps allows to use knowledge, skills, and abilities automatically (Facer et al., 2001). The impact of games on motivation to learn is not unambiguous; it all depends on the game itself. Students whose situational interest trajectories were stable (either high or low) presented no changes in individual interest, yet the individual interest of students whose situational interest was triggered but not maintained markedly decreased from pre-test to post-test. Results suggest that it is vital to use game-based learning not because games are believed to be "motivating"; rather, games with proven learning outcomes should be carefully selected (Rodríguez-Aflecht et al., 2018).

When a student uses Seek for a while, he sees that first, the mobile application defines the class, then the family, then the species. This knowledge is deeply remembered.

Therefore, Seek increases the motivation to learn because, in addition to virtual awards, it offers participation in real environmental projects.

4.1.1 Alignment With Relevant K-12 STEM Education Standards in the United States and Ukraine

The main document declaring the introduction of STEM education in Ukraine is the concept of the implementation of natural and mathematical (STEM) education (Cabinet of Ministers of Ukraine, 2020). According to this document, the task of STEM in education is the formation of skills for solving complex (complex) practical problems, comprehensive development of personality by identifying its inclinations and abilities; mastering the means of cognitive and practical activities; education of a person who strives for lifelong learning, the formation of skills of practical and creative application of acquired knowledge.

In our opinion, the use of mobile applications:

1. allows to solve a practical problem (determining the type of plant, for example, if it is a parasitic plant and one needs to get rid of it);
2. comprehensive development of personality is realized through the acquisition of biological knowledge, the practice of using mobile applications, and communication with people who have similar interests;
3. the concept of lifelong learning is perfectly implemented when using mobile applications because anyone can use them at any time.

In the United States and many European countries, the ISTE 2016 standard is one of the most well-known educational standards. According to this standard, the modern student must be able to solve specific problems, making optimal use of modern technology. Such technologies include mobile applications for identifying plants which solve a specific problem. ISTE states that students use collaborative technologies to interact with others, including peers and experts, to study problematic issues from different points of view. This item is significantly supported by mobile applications for identifying plants, which are created on the principle of social networks. Using these applications, a student can discuss s photos of the most interesting plants with others. According to ISTE 2016, students jointly explore the problems at both local and global levels and use technology to develop standard ways to solve these problems. Seek promotes real projects from researching a few faunas and flora representatives to solve global problems.

5 CONCLUSION

1. Apps related to plant identification can be referred to as those which can analyze photos, devoted to manual identification, and apps devoted to plant care monitoring.
2. It has been proven that LeafSnap, Flora Incognita, PlanNet, and Seek are the most usable plant identifier apps.
3. Seek and LeafSnap correctly identified plant species in 76% of cases, PlantNet correctly did this in 74% of cases, Flora Incognita correctly identified plant species in 71% of cases, which is significantly lesser than the same parameter for Google Lens (92.6%). Google Lens was characterized by the highest usability mark compared to PlantNet, Flora Incognita, LeafSnap, and Seek.
4. Based on the above, Google Lens is the most recommended app for use during biology classes. However, it is possible to use Seek or Flora Incognita for students and teachers who do not like the Google Lens app for whichever reason.

5. The Seek mobile application can be used as a learning environment.
6. PlantNet app is characterized by an accuracy of 55% and cannot be recommended for use during biology classes.

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How Concept Learning Changes Strategic Choice in Guessing Games?

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Keywords: Behavioral Game Theory, Guessing Game, K-Beauty Contest, Active Learning, R, Agent-Based Modeling.

Abstract: This paper deals with the k-beauty contest game. The research question formulated in this work is how players (mainly children and undergraduates) learn in complex strategic situations that they have never faced before and how we can model this learning process. We examine data from different games played during popular lectures about game theory and present findings of players' progress in strategic learning while competing with other players. The raw data gathered is available in an open repository for replication and analysis and an R file with data manipulations, metrics calculations, and plots. Based on the conclusions from experimental data, we create the agent-based model and launch ten thousand simulations for different setups. Then we apply analysis from experimental data and discuss findings and similarities between agents and humans.

1 INTRODUCTION

Game theory is a field of science investigating rational players' decision-making under uncertainty. The source of the uncertainty can be strategic structure, e.g., probability of certain events, lack of information about future possibilities, or decisions of other agents that can generate it. In the last case, we can talk about the interdependence of strategic actions, when some players' decisions affect others' payoffs. Such situations arise around us daily, and we, consciously or unconsciously, participate in them. The success heavily relies on our perception of the actions of other players.

The problem is how we can know the future actions of other players. We cannot, but we can start with some assumptions that will help create a framework, model, or theory of "mind", which will predict future (reasonable) actions. Game theory proposed approach, which is now under questioning (especially from the side of the experimental or behavioral economy). Nevertheless, we will start from standard notions and proceed to experimental data.

One can expect that other players will play "reasonably", and this game theory means they will try to achieve a better result in some agent's sense. This idea is grasped by the term **rationality**. Every rational player must calculate the best possible result, taking into account the rules of the game and the interests of other participants. In other words, think strategically. It is well known from theory that rational players will play Nash equilibrium (NE) if there is any, which is very useful in games where only one unique NE exists. The notion of rationality was indeed fundamental for the development of game theory. However, the problems with this notion are also quite famous.

First, it is very demanding because it presupposes that the agent has complete, transitive preferences and is capable of computing equilibrium in a given strategic situation. However, this is not feasible in many natural situations (for example, we know about NE in chess, but still no computer can compute it). Secondly, probably more important, there are many games where NE is the poor prediction of actual human behavior. This paper investigates some of the data from such a game and discusses the difference.

All this makes decision making exciting problem to investigate. This is a rich area of research, where theoretical constructions of the game theory seem to fail to work, and experimental data shows unusual patterns. These patterns are persistent and usually do not depend on age, education, country, and other things. During the last 25 years, behavioral game theory in numerous studies has examined bounded rationality (best close concept to the rationality of game theory), cognitive distortions, and heuristics people use to reason in strategic situations. For example we can note surveys of Crawford et al. (Crawford

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et al., 2013) and Mauersberger and Nagel (Mauersberger and Nagel, 2018). Also, there is a comprehensive description of the field of behavioral game theory by Camerer (Camerer, 2003).

We will concentrate on the guessing games, which are a significant part of research because of their simplicity for players and easy analysis of rules from a game-theoretic perspective. In this paper, we present the results of games played during the 2018-2021 years as part of popular lectures about game theory (Ignatenko, 2020). The audience of these lectures was quite heterogeneous, but we can distinguish the following main groups:

- children at schools (strong mathematical schools, ordinary schools, alternative education schools);
- students (bachelor and master levels);
- mixed adults with almost any background.
- adults with a business background
- participants of Data Science School
- participants of summer STEM camps for children

We propose a framework of four types of games, each presenting one idea or concept of game theory. These games were introduced to players with no prior knowledge (at least in the vast majority) about the theory. On the other hand, games have simple formulation and clear winning rules, making them intuitively understandable even for kids. This makes these games the perfect choice to test the ability of strategic thinking and investigate the process of understanding complex concepts during the play, with immediate application to the practice. This dual learning, as we can name it, shows how players try and learn in natural conditions and react to interaction challenges with other strategic players.

In this paper, we will concentrate on the first game – the famous p-beauty contest game. For this game, we analyze data and try to formulate simple rules which are plausible for an explanation of players' behavior. In the next section, we created the agent-based model using the Netlogo environment and discussed the model's main features. To investigate the model and its properties, we performed simulations using the BehaviorSpace tool of Netlogo; as a result, about 10000 games were simulated. Such a volume of data is impossible to get using human-based experiments. We recreated plots and metrics developed for human data and analyzed its similarity and differences. In the end, we formulate conclusions and future work directions.

First, let us start with some definitions.

1.1 Game Theory Definitions and Assumptions

Consider games in strategic or normal form in a 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. The strict definition is as follows.

A non-cooperative game in strategic (or normal) form is a triplet $G = \{\mathcal{N}, \{S_i\}_{i=\in\mathcal{N}}, \{u_i\}_{i\in\mathcal{N}}\}$, where:

- $\mathcal{N}$ is a finite set of players, $\mathcal{N} = \{1, \ldots, N\}$;
- S_i is the set of admissible strategies for player i;
- $u_i : S \to \mathcal{R}$ is the utility (payoff) function for player i, with $S = \{S_1 \times \cdots \times S_N\}$ (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 is still static if no player has any information on the decisions of others. In contrast, a dynamic game is one where the players have some (full or imperfect) information about each others' choices and can act more than once. In this work, we deal with repeated static games, which means that the same game is played twice (sometimes three times) with the same players.

Agents' rationality is a significant issue; sometimes, it is called full rationality (to differentiate it from bounded rationality – a less restricting notion). When a fully rational agent tries to find the best action, it usually depends on the action of other self-interest agents. So the first agent must form beliefs about the second agent's beliefs about the beliefs of the first agent, and so on. Such constructions seem too complicated, but they are based on the predictions of classical game theory, which assumes all agents to be fully rational.

One quite famous result by Aumann (Aumann, 1995) is that for an arbitrary perfect-information extensive-form game, the only behavior that is compatible with (1) common knowledge of rationality, and in particular by (2) each agent best responding to their knowledge is for each agent to play according to the strategy, obtained by the backward induction. Aumann and Brandenburger (Aumann and Brandenburger, 1995) showed that common knowledge of rationality, the game payoffs, and the other agent's beliefs are sufficient conditions for Nash equilibrium in an arbitrary game.

In this regard, the most accepted solution concept for a non-cooperative game is that of a Nash equilibrium, introduced by John F. Nash (Kuhn et al., 1996). 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. Of course, players also use information and beliefs about other players, so we can say that (in Nash equilibrium) beliefs and incentives are important to understand why players choose strategies in real situations.

The NE is the core concept of game theory, but it differs from experiments and sometimes reality. In some games, humans demonstrate convergence to equilibrium, but in others do not. This gap between similarly-looking games is slim and not easy to catch. We will consider guessing games as a playground to work with players' behavior.

2 GUESSING GAMES HISTORY

In early 90xx, Rosemary Nagel started a series of experiments of guessing games, summarized in (Nagel, 1995). She was not the first to invent the games; they were used during the lectures by different game theory researchers (for example, Moulin (Moulin, 1986)). In recent work (Nagel et al., 2017) authors provide extensive research of the origins of the guessing game with unexpected links to the editor of one french newspaper Alain Ledoux, who, as far as it is known today, was the first who used the rules and then publish an article about unusual patterns observed (Ledoux, 1981). The work of Nagel (Nagel, 1995) was the first experimental try to investigate the hidden patterns in the guessing game, and in this working framework of k-level models was proposed.

Later, Ho et al. (Ho et al., 1998) gave the name "p-beauty contest" inspired by Keynes's comparison of stock market instruments and newspaper beauty contests.

The beauty contest game (BCG) has become an important tool to measure the "depth of reasoning" of a group of people using simple abstract rules. To begin with, we should note that behavioral game theory aims to develop models, which explain human behavior in a game-theoretic setup more accurately, based both on experiments and theory (Camerer, 2003). There are two main approaches how to dealing with the problem of replacing full rationality with bounded rationality. The first view is to consider boundedness as an error. For example quantal response notion (Camerer et al., 2002) or ε-equilibrium (Leyton-Brown and Shoham, 2008) assume that agents make an error by choosing not optimal strategy profile. They play near-optimal response because they do not have the capacity to calculate the exact best action.

The second approach is to treat bounded rationality as a structural property of an agent's reasoning process. One of the most prominent classes of models of this type is the iterative model's scheme. They include the k-level reasoning (Nagel, 1995; Costa-Gomes et al., 2001), cognitive hierarchy (Camerer et al., 2004) and quantal cognitive hierarchy models (Wright and Leyton-Brown, 2017). All these models consider boundedness as an immanent part of the reasoning. Each agent has a non-negative integer level representing the degree of strategic reasoning (i.e., modeling of recursive beliefs) of which the agent is capable. Level-0 agents are nonstrategic – they do not model other agents' beliefs or actions at all; level-1 agents model level-0 agents' actions; level-2 agents model the beliefs and actions of level-1 agents; and so forth (Wright and Leyton-Brown, 2016). In this work, we support the latter idea, analyzing experimental data to estimate changes in numbers of different levels in the learning and teaching process.

2.1 Learning Models

Recently, game theorists began to research the process of reasoning toward equilibrium actively. Two prominent simple learning models are reinforcement and belief learning (e.g., fictitious play). In reinforcement, strategies have numerical attraction levels, which are reinforced (increased) when a strategy is chosen, and the result is good. Reinforcement is a good model of animal learning but does not gracefully accommodate the fact that people often choose strategies that have not been directly reinforced.

In the fictitious play, players form beliefs based on a weighted average of what others have done in the past, and best respond given their beliefs. Remarkably, weighted fictitious play is equivalent to a generalized reinforcement model in which unchosen strategies are reinforced by the forgone payoffs they would have yielded.

There are a lot of other approaches; we will mention the approach which enriches 0-level reasoning (Wright and Leyton-Brown, 2017). Specifically, they investigate general rules that can be used to induce a level-0 specification from the normal-form description of an arbitrary game.

Also, we can note work (Gill and Prowse, 2016), where participants were tested on cognitive abilities and character skills before the experiments. Then authors perform statistical analysis to understand the impact of such characteristics on the quality of making strategic decisions (using a p-beauty contest game with multiple rounds). In more recent work (Fe et al., 2019) even more elaborate experiments are presented. It is interesting that in the mentioned paper, experiments are very strict and rigorous (as close to laboratory purity as possible) in contrast to games played in our research. However, at the end of the day, the results do not differ very much.

As we know, there are not many works about game theory experiments for children. In our previous work (Ignatenko, 2020) we presented data from games with participants 15-18 years old. There is a master thesis (Povea and Citak, 2019), with the study of the behavior of children aged 8-11 in a beauty contest game with ten repetitions. The author found evidence that children are able to play a beauty contest game using not only cognitive skills but also empathy.

To deal with these problems, computer simulation, mainly agent-based modeling ABM can be used. Agent-based models are essentially a tool to discover patterns in behaviors that emerge from simple rules – micro behavior. Agent-based modeling for guessing games is not a very developed area of research. For example see paper (Nichols and Radzicki, 2007).

3 EXPERIMENTS SETUP

We claim that our setup is closer to reality than the laboratory, and this is the point of this research: how people learn under real-world situations. All games were played under the following conditions:

1. Game was played during the lecture about the game theory. Participants were asked not to comment or discuss their choice until they submitted it. However, this rule was not enforced, so usually, they have this possibility if they wanted;
2. Participants were not rewarded for a win. The winner was announced (so get some "good feelings"), but no more;
3. During some early games, we used pieces of paper, and we got some percentage of joking or trash submission, usually very small. Later we switched to google forms, which is a better tool to control submission (for example, only natural numbers are allowed).
4. Google forms give a possibility to make multiple submissions (with different names) since we did not have time for verification, but a total number of submissions allows us to control that to some extent.

The aim of this setup was to free participants to explore the rules and give them the flexibility to make a decision in an uncertain environment. We think it is closer to real-life learning without immediate rewards than laboratory experiments. Naturally, this setup has strong and weak sides. Let us 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 an integrated approach to active learning, when games are mixed with explanations about concepts of game theory (rationality, expected payoff, Nash equilibrium), and they allow participants to combine experience with theory;
3. Freedom and responsibility. The rules do not regulate manipulations with conditions. So this setup allows (indirectly) to measure the preferences of players: do they prefer to cheat with rules, choose random decisions without thinking or put effort into solving the task;
4. During the 2020-2021 years, lectures were mainly online. That fact brings new challenges for our experiments, but since we initially rely on google spreadsheets for gathering the answers, all routines remain mainly the same.

Weak sides are:

1. Some percentage of players made "garbage" decisions. For example, choose the obviously worse choice to spoil efforts for others;
2. Kids has (and often use) the possibility to talk out decision with the neighbors;
3. Sometimes participants (especially kids) lost concentration and did not think about the game but made a random choice or did not make decisions at all;
4. Even for the simplest rules, sometimes participants failed to understand the game the first time. We suppose it is due to conditions of lecture with (usually) 30-40 persons around;
5. Still, we should note that online lectures are less involving. It is demotivating for a lecturer not to see listeners and also demotivating for students to listen to lectures online.

3.1 Rules

In this paper, we concentrate on the p-beauty contest. The winning number is the closest to p of average. As usual, $p = 2/3$, but we have used other setups as well (for clarity, we omit data from that games in this analysis). Participants are asked to choose an integer number in the range 1 – 100, margins included. Note that some setups investigated in references use a range starting with 0. However, the difference is negligible. To provide quick choice calculation, we have used a QR code with a link to google form, where participants input their number. All answers were anonymous (players indicated nicknames to announce the winners, but then all records were anatomized).

4 RESULTS AND DATA ANALYSIS

In this section, we present a summary of data gathered during the games. A summary of the results of the game is given in table 1. Columns descriptions are:

- id is the id of the experiment;
- type is the type of group. Alternative H and M are for alternative schools (not in the governmental system) with humanitarian and mathematical directions, respectively. Math lyceum also goes for summer camps with participants from different lyceums;
- age is the approximate age of participants, only indicated for children, to distinguish possible borderline between stages of strategic reasoning;
- round is the round of the game;
- average is the average of choices;
- winning number is the average * 0.66;
- zlevel is the percent of players, choosing numbers bigger than 50. It is an estimation of 0-level players in this round. As one can expect, it is declining with round;
- median is the median of choices (sometimes it is more informative than average);
- count is the number of choices;
- irrationality is the percent of choices wider than 90.

First, we observe statistics of choices for different types of participants.

As we can see from the plot (figure 1) some setups have one round, some two and two cases have three rounds. It was limited by format (popular scientific lecture), so we can only safely compare two rounds.

Almost all winning numbers fall (roughly) in the experimental margins, obtained in (Nagel, 1995). With winning number no more significant than 36 and not smaller than 18 in the first round. Two exceptions in our experiments were Facebook online game (15.3) when players could read information about the game in, for example, Wikipedia. Moreover, Another is the alternative humanitarian school (40.1), where participants seem did not get the rules the first time.

4.1 Metrics and Analysis

The first metric to observe is the percent of "irrational choices" – choices that cannot win in (almost) any case. Let us 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 deviates to a smaller number – he/her will win, and others will lose. So playing numbers bigger than 66 is not rational unless one does not want to win. Furthermore, here we come to an important point, in all previous experiments, this metric drops in the second round and usually is very low (like less than 5%) (Ho et al., 1998). However, in our case, there are experiments where this metric becomes higher or changes very slightly. Moreover, initially, values are much higher than expected. So here, we should include the factor of unique behavior; we can call it "let us show this lecturer how we can cheat his test!" what is more interesting – is that this behavior is more apparent in the case of an adult than in kids.

It is also interesting to see a distribution of choices for different groups. We can summarize choices on the histograms (figure 2). Using models of strategic thinking, we will adopt the theory of k-levels. According to this idea, 0-level reasoning means that players make random choices (drawn from a uniform distribution), and k-level reasoning means that these players use the best response for the reasoning of the previous level. So 1-level reasoning is to play 33, which is the best response to the belief that the average will be 50, 2-level is the best response to the belief that players will play 33, and so on.

As we can see from the diagram (figure 2), some spikes in choices are predicted very well, but it depends on the background of the players. The best prediction is for the Data Science conference attendees, which presume a high level of cognitive skill and computer science background.

On figure 3, we can see boxplots defined by several players with different levels of perception for different types of players. We compare here ordinary schools and mathematical lyceums. Levels are defined in the following subsection, but we can see a pattern of behavior. The number of "irrational" (choices with big numbers) is decreasing, so as "next-to-win-but-bigger" numbers. Several 2-level reasoning, especially after explaining the equilibrium concept, is growing substantially, while some "too smart" choices from [1, 5] are more or less the same.

Table 1: Summary of first game for id of experiment and type of players. Explanation of columns is in the text

Id	Type	Age	Round	Average	Winning	Zlevel	Median	Count	Irrationality
1	Alternative H	12-14	1	66.7	44.5	69.23	78	13	46.15
1	Alternative H	12-14	2	3.91	2.61	0	3.5	12	0
2	Alternative M	12-14	2	42.82	28.54	23.52	45.0	17	0
2	Alternative M	12-14	2	24.37	16.24	0	26.5	16	0
3	Adults		1	40.57	27.05	31.57	40.0	19	5.26
4	Alternative H	12-14	1	52.54	35.03	63.63	55	11	9.09
4	Alternative H	12-14	2	15.41	10.27	8.33	6	12	8.33
5	Adults		1	22.98	15.32	11.76	17.0	102	0
6	TechSchool	16-18	1	43.41	28.94	35.29	45.0	51	3.92
6	TechSchool	16-18	2	46.5	30.99	35.48	29.0	62	32.25
7	Math lyceum	16-18	1	30.58	20.38	16	27.5	50	2.0
7	Math lyceum	16-18	2	14.26	9.5	5.26	7	57	5.26
8	Math lyceum	15-16	1	37.06	24.71	20.68	33.0	29	3.44
8	Math lyceum	15-16	2	26.20	17.47	10.34	17.0	29	6.89
9	Math lyceum	14-16	1	42.0	27.99	44.44	42.5	18	11.11
9	Math lyceum	14-16	2	23.1	15.39	5.0	19.0	20	0
10	Ordinary school	14-16	1	48.69	32.46	46.15	46.5	26	0
10	Ordinary school	14-16	2	19.78	13.18	0	22.0	23	0
11	DS conference		1	37.25	24.83	28.33	33.0	60	8.33
11	DS conference		2	21.44	14.29	15.78	9.0	57	12.28
12	Students		1	42.40	28.27	33.33	40.0	27	3.7
13	Students		1	27.37	18.24	12.5	25.5	8	0
13	Students		2	8.62	5.74	0	8.5	8	0
14	Math lyceum	14-16	1	41.05	27.37	22.22	35.0	18	11.11
14	Math lyceum	14-16	2	17.23	11.49	5.88	13.0	17	0
15	Adults		1	34.32	22.88	20.73	30.0	82	1.21
15	Adults		2	12.48	8.32	2.19	8.0	91	2.19
16	Adults		1	43.05	28.70	33.96	40.0	53	1.88
16	Adults		2	14.69	9.79	1.88	11.0	53	1.88
17	Adults		1	50.33	33.55	41.66	50.0	12	8.33
17	Adults		2	13.50	8.99	0	12.0	46	0
18	Math lyceum	14-16	1	41.72	27.81	36.36	37.0	11	9.09
18	Math lyceum	14-16	2	26.36	17.57	0	30.0	11	0
19	Math lyceum	14-16	1	29.43	19.62	13.63	25.0	44	0
19	Math lyceum	14-16	2	27.25	18.16	20.45	9.5	44	20.45
20	Students		1	30	19.9	5.2	27	19	0
20	Students		2	24.9	16.6	20	11.5	20	15
21	Ordinary school	14-16	1	43	28.7	33.9	40	53	1.88
21	Ordinary school	14-16	2	14.7	9.7	1.88	11	53	1.88

Interesting hypotheses that need to be tested in detail can be formulated: **Higher number of choices from [50, 100] in the first round leads to the higher number of choices from [1, 5] in the second round and vice verse.** We can support this hypothesis with the following plot (figure 5).

Another metric (Güth et al., 2002) is how much winning choice in the second round is smaller than in the first. Due to multi-level reasoning, every player in this game is trying their best to win but can't do all the steps to winning. So there are players who have 0-level reasoning. They choose random numbers. First-level players choose 33, which is the best response for players of 0-level and so on. Based on the result of the first round and, in fact, an explanation of the Nash equilibrium, players must know that it is better to choose much lower numbers. However, the graph shows that the decrease is quite moderate. Only students show good performance in this matter. Moreover, the tech school shows a (small) increase in winning number in the second round!

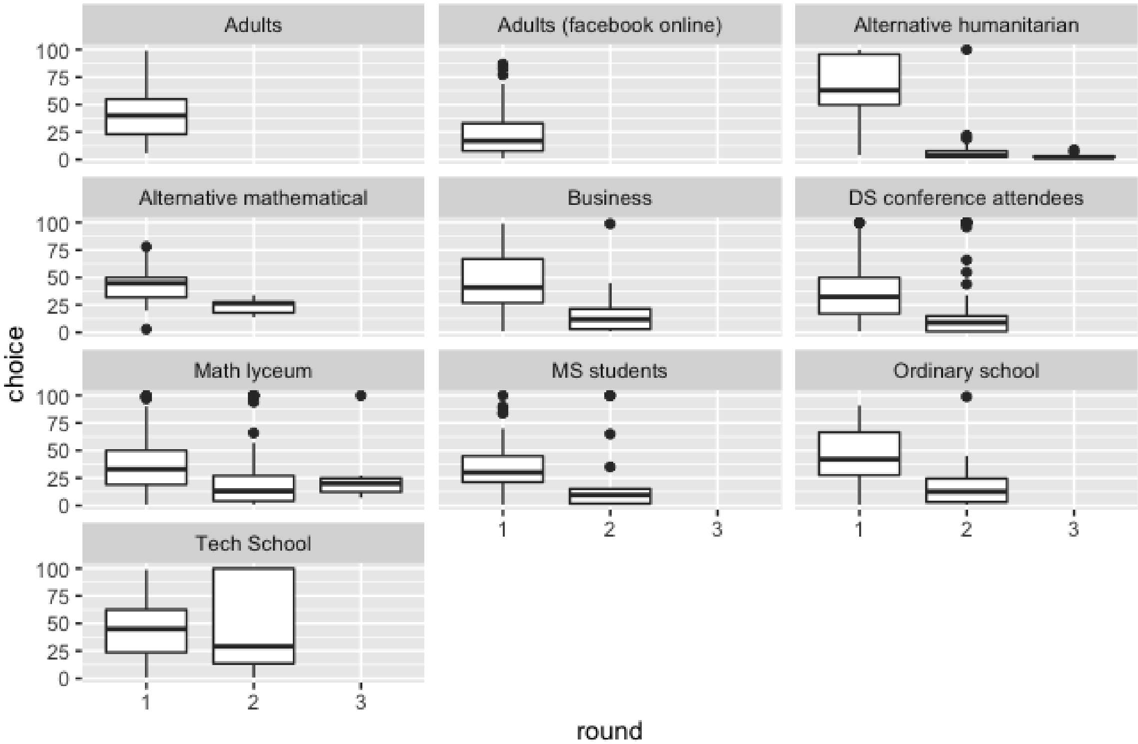

Figure 1: Histogram of choices for each round.

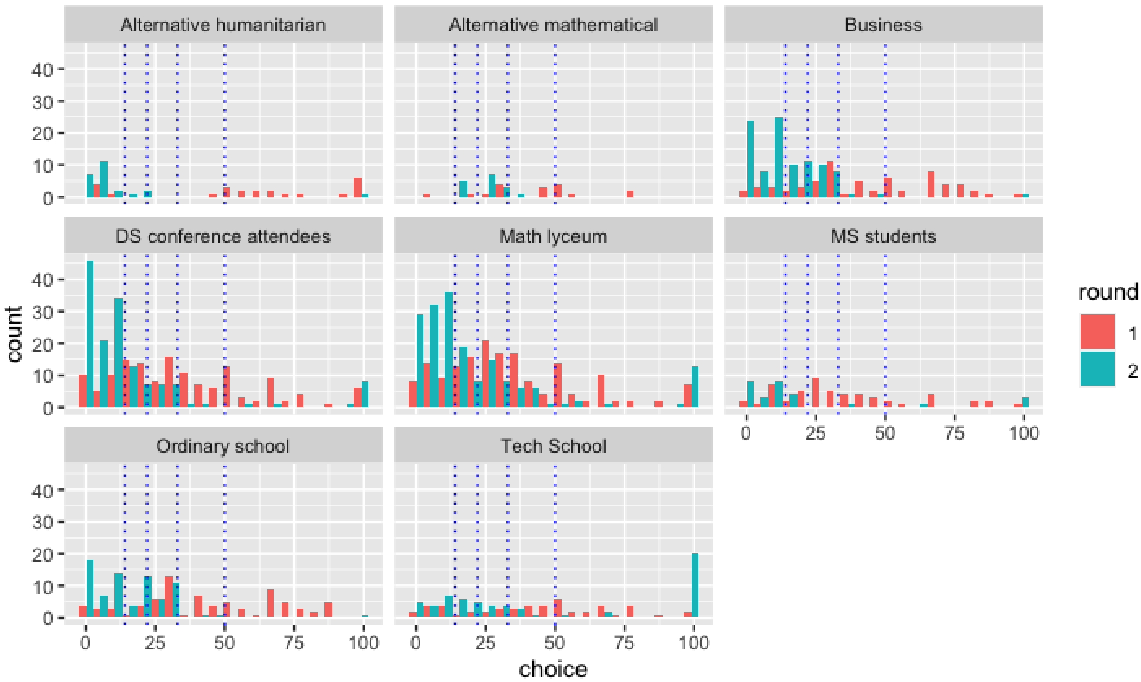

Figure 2: Histogram of choices for each round.

4.2 Levels of Reasoning Snalysis

Another point about the learning process in this game is how players' decisions are distributed over the space of strategies. We claim that there is a distinct difference in changes between the first and second rounds for different groups. To perform this analysis, we apply the idea of k-level thinking.

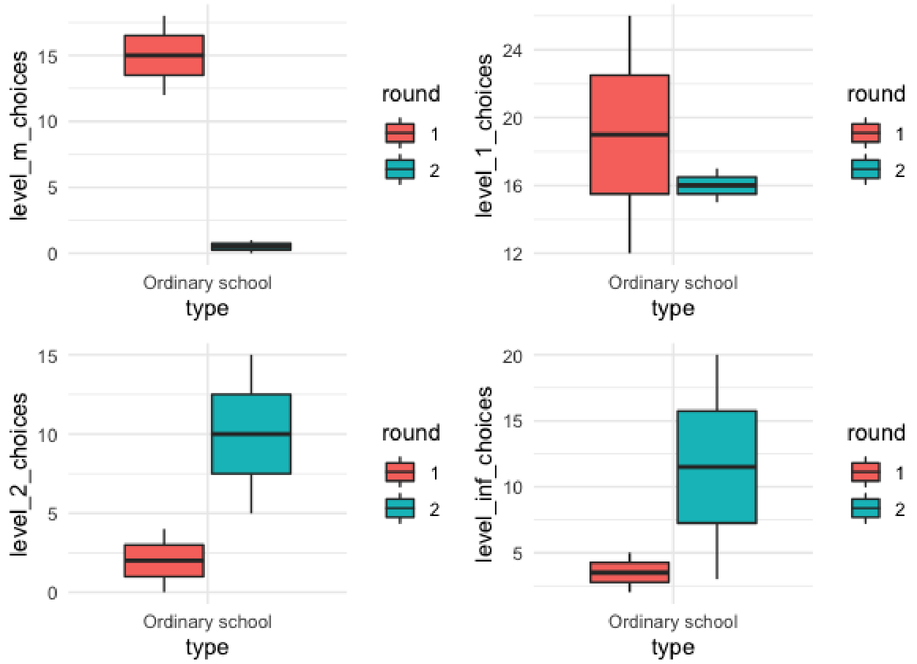

Figure 3: Change in winning number for number of ordinary schools participants.

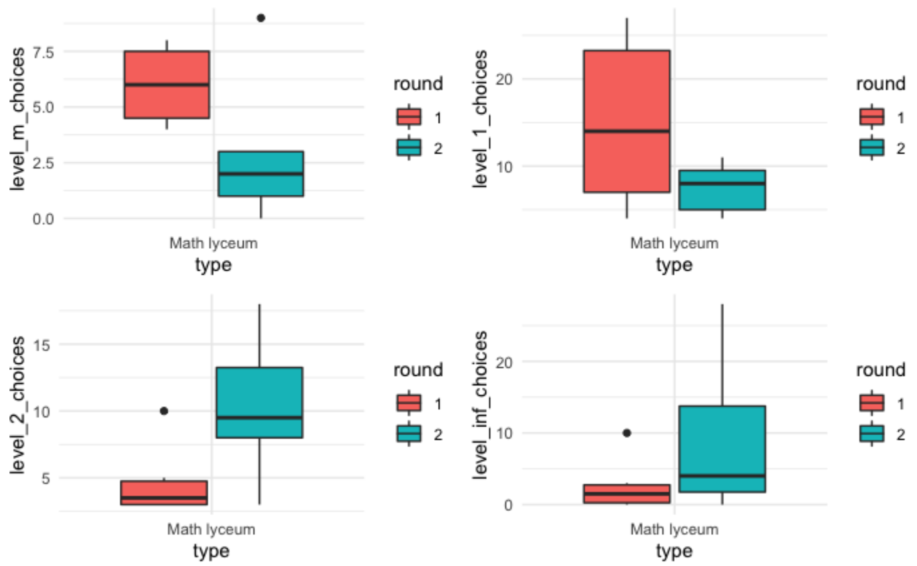

Figure 4: Change in winning number for number of mathematical lyceums schools participants.

To find differences, we need to simplify this approach. First, we define **b-level** players players who choose numbers from the range [50, 100]. Beginner players who do not understand rules (play randomly) or do not expect to win or want to lose intentionally (for reasons discussed above). The substantiation for such a range is that numbers above 50 did not win in any game. Second level we call **m-level**, it is for range [18, 50]. It is for players with middle levels of reasoning. The first-round winning number is usually in this range (and in part of the second rounds). Third level is **h-level**, it is for range [5, 18]. It is for high level reasoning and finally **inf-level** ([1, 5] range) is for “almost common knowledge” level of thinking.

By calculating the number of levels for each game, we can estimate change (in the percentage of the number of players) in adopting different strategy levels.

What conclusions can we draw from this data? There are no clear differences in changes, but at least we can summarise a few points:

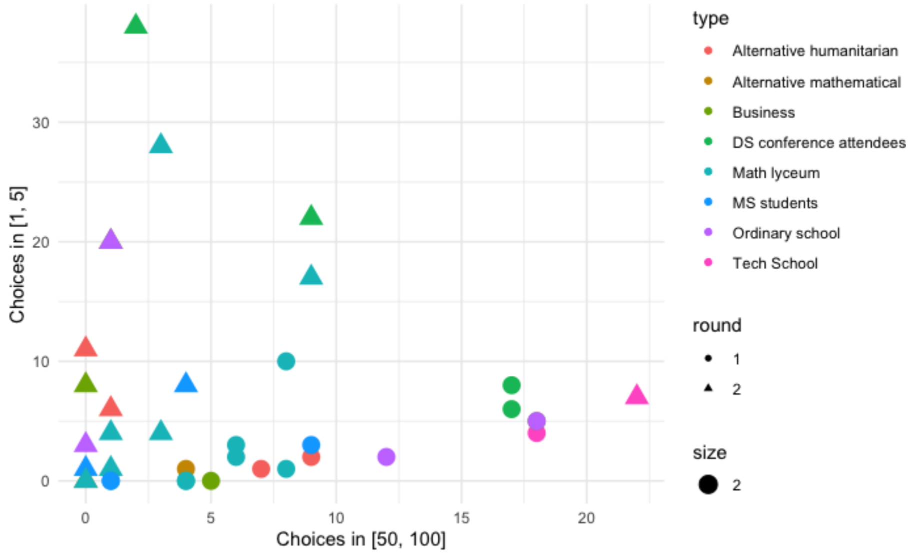

Figure 5: Choices number in [1, 5] range and in [50, 100] range by rounds and type.

Table 2: Summary of change in strategy levels

Type	b-difference	m-difference	h-difference	inf-difference
Alternative humanitarian	-72	-8	0	72
Alternative mathematical	-24	-6	30	-6
Alternative humanitarian	-52	0	17	43
Math lyceum	-9	-36	24	34
Math lyceum	-10	-24	28	7
Ordinary school	-49	12	20	4
DS conference attendees	-14	-32	14	27
MS students	-12	-50	50	12
Alternative mathematical	-17	-34	23	23
DS conference attendees	-17	-30	23	35
Business	-32	-17	21	28

- Usually after first round and equilibrium concept explanation there is decrease in **b-level** and **m-level**;
- Symmetrically, there is an increase in two other levels, but sometimes it is more distributed, sometimes it is (almost) all for **inf-level**;
- the Last situation is more likely to happen in schools, where kids are less critical of new knowledge;
- Usually second round winning choice in the realm of **h-level**, so groups with the biggest increase in this parameter are the ones with better understanding.

Another possible approach to the measurement of irrationality is to calculate the percent of choices wider than 50 (quite low chances for the win) and the percent of choices wider than 90 (no chances to win). We can see an interesting picture when we plot these metrics for different types.

As we can see here, there is a nice direct line of green dots of unknown nature. And all red dots are gathered below. This is interesting dependence that needs to be investigated in detail.

4.3 Size and Winning Choice

This game is indeed rich for investigation. Let us formulate the last (in this paper) finding of this game. Can we in some way establish the connection between the number of players and the winning number (actually with strategies players choose during the game)? To clarify our idea, see at figure 7. It is a scattered plot of a two-dimensional variable; the x-axis is for the number of participants in the game, and the y-axis is for the winning choice per round. Different colors are for different types of groups where games were played.

As we can observe, the first and second rounds form two separate clusters. This situation is expected

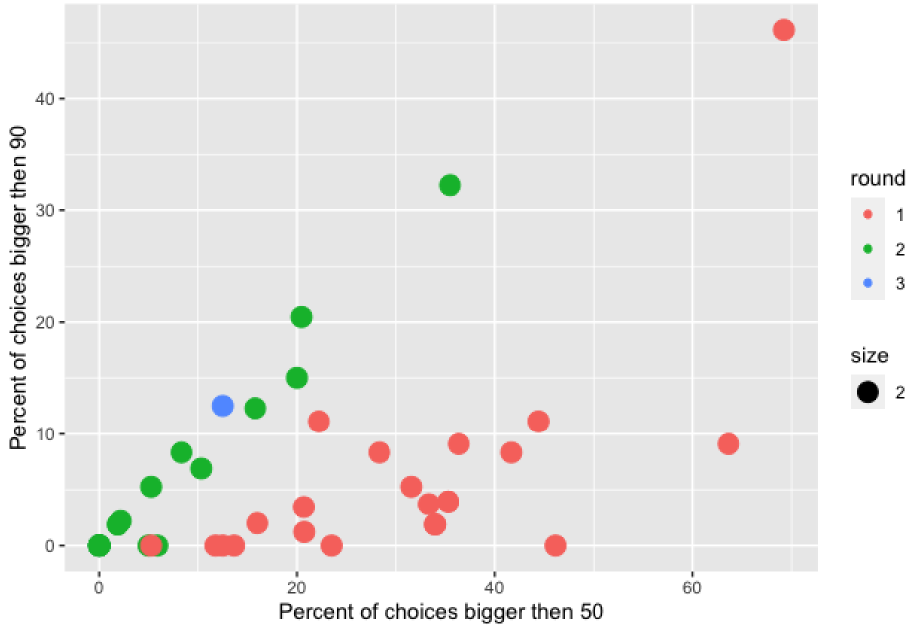

Figure 6: Irrationality of participants.

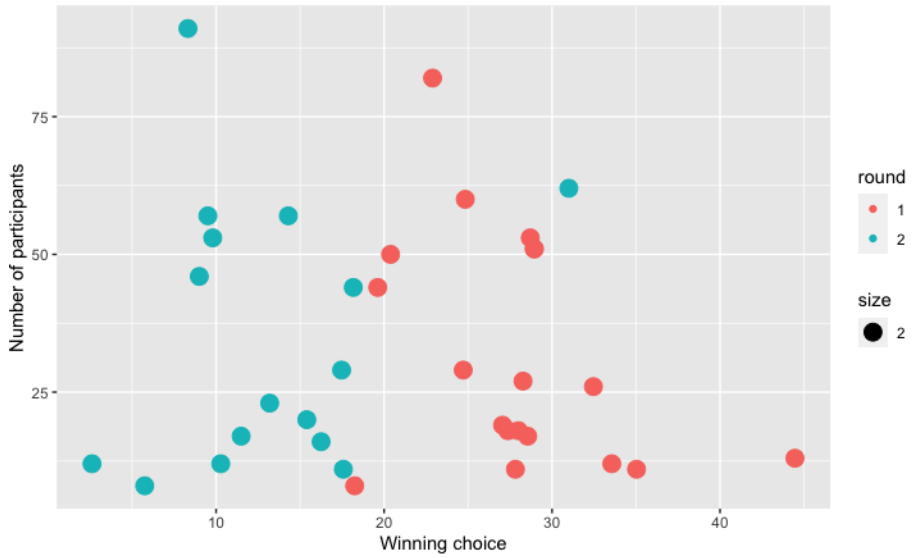

Figure 7: Change in winning number for number of participants.

and informs us that players learn about the equilibrium concept between rounds and apply it to practice. Also, there is a mild tendency for smaller groups to have bigger winning numbers. At least the variation is more significant.

This is yet too bold to formulate a connection between the size of the group and the winning number, but probably the reason is that when the size of the group is bigger, the number of "irrational" players increases. It can be due to some stable percentage of such persons in any group or other reasons, but it is an exciting connection to investigate.

4.4 Intentionally Irrational?

Another interesting finding is that after the first round finished, observing the result and listening explanation about the NE number of players who choose over 90 (it is an non-winning choice) increases. It is not accidental; data from (Povea and Citak, 2019) also show an increase in 2-5 rounds. We believe that this is quite an important part of the play. This phenomenon is evident in high school children with solid math backgrounds (usually, they have more freedom and self-confidence in choosing non-standard strategies).

All experimental data and R files for graphs can be accessed in the open repository (Ignatenko, 2021).

5 AGENT-BASED MODEL

The existence of irrational behavior challenges the basic game-theoretic assumption about self-interest and the capability to calculate the best option. In other words, real people do not think like machines or algorithms. They form hypotheses or expectations using simple rules. These rules are influenced by emotions and social norms and can be changed depending on feedback (reinforced). This use of inductive reasoning leads to two issues. First, what rules that people follow? Second, suppose we know these rules. How do we model the behavior of many interacting, heterogeneous agents in that situation? We start with the definition of agents and the formulation of rules of their behavior.

So we have agents of one type – players. Each agent has three variables: level of thinking (current level of reasoning), choice (a current number he chooses), and Boolean variable irrational, which is true or false.

Also, we define interface parameters, which define the setup of players. First of all, it is the number of players. We can also define the percentage of level 0 players, p of the game, and irrational setup, which will be explained later.

The setup of the game is following:

1) creates several players;
2) defines the level of reasoning for each player using the formula: level-0 percent from the interface, 100 – level-0 is divided into three parts. Two parts are level-1 reasoning, and one part is level-2 reasoning;

One round of the game proceeds in the following way:

1) each player chooses a number using their level of reasoning and some randomization. Basically, player with k level generates normal variable with mean $50 * p^k$ if $k > 0$ and $k \leq 4$. If $k = 0$, the choice is uniformly random from 1 to 100. When $k = 5$, the choice is 1 (this is an infinity level of reasoning);
2) if the player is irrational, he chooses 100. It is to model irrational behavior that can be observed from experiments;
3) the winner is calculated using the game formula;
4) players, with a choice wider than the winning number, increase their understanding level by 1. If the level is already equal to 5, it remains the same;
5) if the player is not winner, he becomes irrational with some small probability if boolean variable irrational is on.

The model is available in COMses library of Netlogo models. To measure experiments data we use BehaviorSpace tool with following parameters:

```
["percent-level-0" [50 5 100]]
["num-players" [10 10 100]]
["irrational1" false true]
["p" 0.66]
```

Here [10 10 100] means we launch simulation for 10, 20, and so on several players. On each step, we wrote to file the choices of players. 10 steps limited each particular games. In total, we had 11000 runs.

Epstein (Epstein, 1999) defines following characteristics of agent-based model:

1) heterogeneity; agents are different in some ways;
2) autonomy; each agent make own decisions;
3) explicit space; agents interact in a given environment;
4) local Interaction; agents generally interact with their neighbors and immediate environment.
5) bounded Rationality; agents have limited information and computing power. Agent behavior is generated by simple rules that may adapt over time;
6) non-equilibrium dynamics.

In this model, we consider only five levels, where level 5 means common knowledge when a player chooses 1. When no irrationality is in the model, we can observe typical convergence to equilibrium (figure 8) left, and this is a stable pattern.

But as we already know from the experiments, it is not what we can observe in real life. So irrational behavior was included to meet the pattern from the data. Irrationality in our model is implemented as 'anger' when a player who is currently a loser sometimes goes to irrational mode and chooses 100 in one next round. This leads to an exciting pattern (figure 8) right, when sometimes the winning number increases in the second round, but convergence to equilibrium is inevitable.

5.1 Data Analysis

In this section, we analyze data from simulations and compare them to previous results. In the following plot (figure 9) we can observe convergence towards

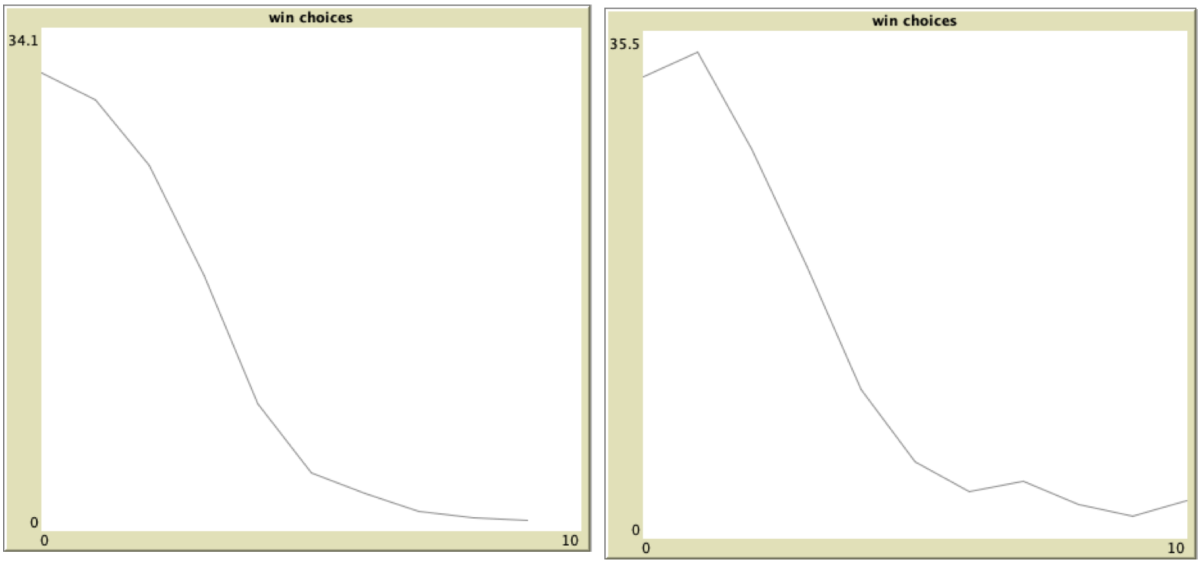

Figure 8: Plots of players win choice over round.

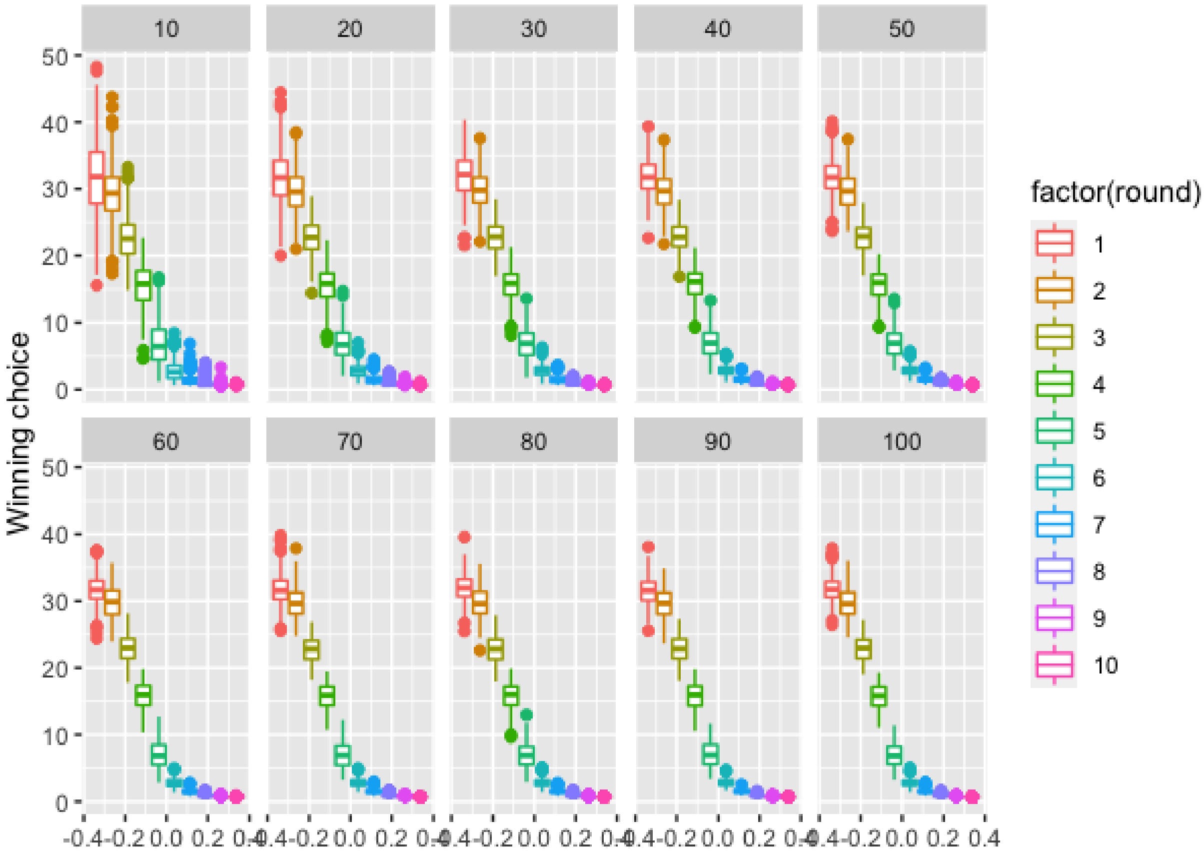

Figure 9: Plots of players win choice over round.

equilibrium. As expected volatility of choices is more significant in smaller groups.

Now let us plot (figure 10) winning choice in the first round compared to the winning choice in the second round. As we can see, there is a big cluster around (33,31). The color here is the initial percentage of low-level players. High level means that almost all players initially are randomizers, and then they learn

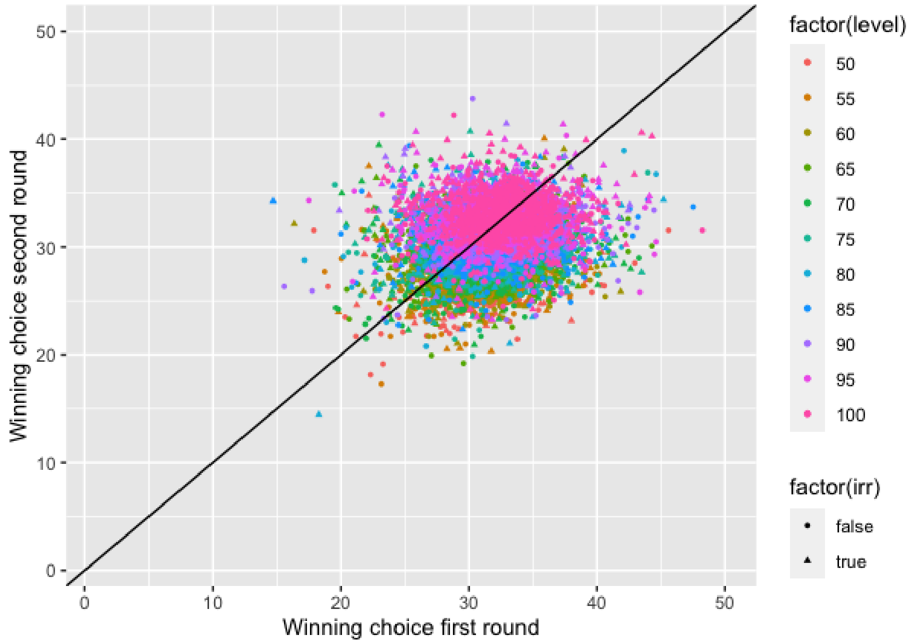

Figure 10: Plots of players win choice for first and second rounds.

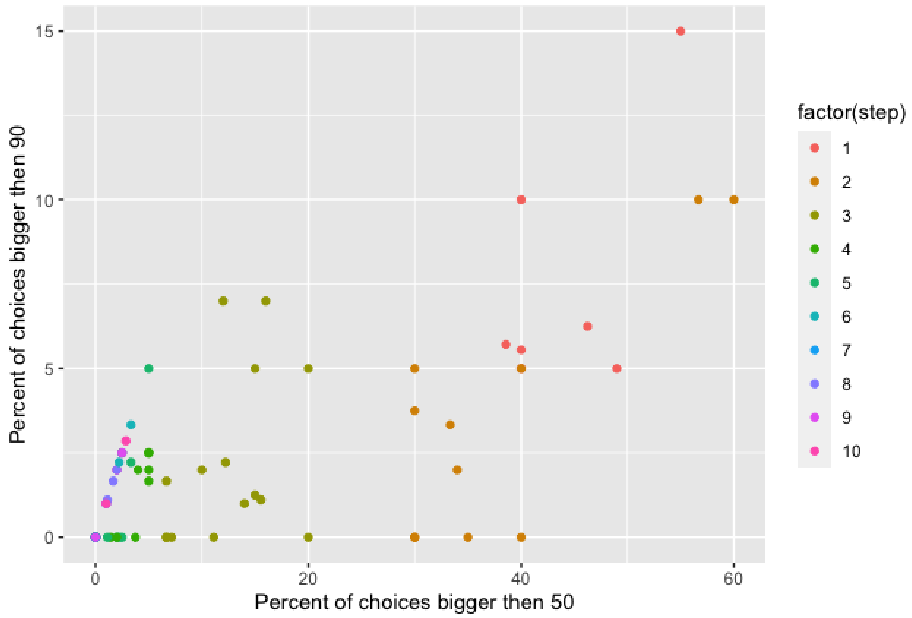

Figure 11: Irrationality of players.

from round to round. A trim level allows for more efficiency when points are like (30,20). This is quite similar to human experiments data.

The next plot is about the irrationality of players. It seems that there is a connection between the percent of players who chooses numbers bigger than 90 and the percent of players who chooses numbers bigger than 50. It is very similar to figure 8 from experimental data. The reason, as we can understand it, is in the nature of irrational behavior in games like the k-beauty contest. It was a common situation when players at some point (we have data for round 2) lost hopes of winning and just chose 100 for fun. At the same time, the majority of players are still thinking strategically and choose numbers around winning numbers (20 – 30 range). This gives a characteristic line of dots because, at some point, all players who chose numbers bigger than 50 are the players who chose 100.

6 CONCLUSIONS

In this paper, we have presented data from experiments on the k-beauty contest game. We provide access to raw data files and files with data manipulation, metrics calculation, and plot building. This will hopefully support reproducibility in this area of research. Then we discuss the results of the experiments and provide an analysis and explanation of patterns of behavior. It seems possible to confirm the existence of a pattern in decision-making – every group behaves almost the same way when dealing with an unknown strategic situation. We can formulate findings in a few short notes. First, participants have chosen not winning moves (> 66) partly because of a new situation and trouble understanding the rules. However, a high percentage of such choices was present in the second round, when players knew what was going on. This effect was especially notable in the cases of high school and adults and almost zero in the case of special math schools and kids below 9th grade. We can hypothesizeesis that high school is the age of experimentation when children discover new things ared do not afraid to do so. Second, the winning number as the decision of a group is decreasing in all cases, so we can see that group is learning fast and steady. Even if some outliers choose 100, the mean still declines with every round. There seems to be an unspoken competition between players that leads to improvement in the aggregated decision even if no prize is at stake. It is a plausible scenario when all participants choose higher numbers. However, this did not happen in any experiment. Third, a a stable percent of people choose about 100, and it is not about learning how to play the game. We think this is something like a -1 level of reasoning when the player intentionally plays a “bad move”, and this is an essential part of the model. If we neglect such persons and their motivation, our model will not be correct.

In the second part of the paper, we presented an agent-based model using conclusions about human behavior in the game. Simplification is the key to building good ABM, so in the model, agents have only a few parameters: level and irrationality. Based on these two parameters, agents choose a number on each step. Depending on other players’ choices model determine winners and losers: this state influences agents’ future level and irrationality. We perform about ten thousand games (each ten rounds long) and apply the same analysis as before. This approach shows that in some aspects, agents’ behavior is close to humans. Future investigation of this model will concentrate on the following possible modifications:

- deterministic choices of agents;
- different numbers of reasoning levels;
- rewards and punishments as elements of learning;
- implementation learning models from current research;
- build testing environment to automatically compare different learning strategies.

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The ICT Usage in Teaching Maths to Children with Hearing Impairment

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Keywords: ICT, Mathematics Performance, Teaching Maths, Mathematical Skills of Students with Hearing Impairment, GeoGebra.

Abstract: The purpose of our research was the modification of teaching strategies of maths for deaf and hard-of-hearing learners. More specifically, we aimed to study the possibilities of optimal use of interactive exercises such as LearningApps and GeoGebra Dynamic Mathematics system in order to provide methodical and didactic support for training sessions, but also to assure independent study and implementation of monitoring activities. The developed visual materials for teaching children with hearing impairments were partially introduced into the educational process in a pilot project for the retraining of 12 school teams working with children with hearing impairments in Kryvyi Rih in educational strategies, for learning mathematics in grades 8-9 of an inclusive type for instructors teaching in a mainstreamed classroom with a mix of hearing, deaf and hard-of-hearing students (students 12-14 years old: $N = 80$ children with hearing impairments; data collected in 2019-2021). In the context of research goals the academic success (algebra, geometry), and mathematical skills of students were analysed. According to the study results, there was a significant increase in the mean score of performance after the intervention than before the intervention. In other words, this increase represents the effectiveness of ICT educational methods. Furthermore, we highlighted some recommendations for using online service LearningApps, GeoGebra Dynamic Mathematics system, and project-based learning technologies in Mathematics, in particular.

1 BACKGROUND CONTEXT

On review of the literature, researchers have stated that deaf and hard-of-hearing learners may lack general vocabulary and the fundamental mathematical vocabulary needed to be able to understand maths concepts/processes such as seriation and classification (Ariapooran, 2017; Barrett, 2005; Nunes and Moreno, 1999; Ray, 2001). It is more difficult for children who are deaf or hard of hearing to acquire the connection between language and maths concepts from their environment incidentally (e.g., from conversations with parents and games with friends about the counting of subjects). Without this type of natural learning, a child with hearing impairment cannot boost beginning maths concepts such as “more/less” or “one/a lot” etc. without educational support (Barrett, 2005).

That is why most children with hearing impairment (HI) have a gap of approximately three years behind their hearing peers in mathematics (Nunes and Moreno, 1999).

Despite the importance of communication with other people as the basis of maths skills, communication with children with hearing impairments may be problematic and poor. That is why these children cannot take part in studying mathematical processes such as problem-solving, developing logic and reasoning, and effectively communicating mathematical ideas without communication skills and maths vocabulary (Le Brun, 2022). Perhaps we can boost maths Ukrainian vocabulary for deaf and hard-of-hearing learners if we use Information and Communication technologies (ICT) for visualisation maths. This is a relatively new area of enquiry, with little research existing in the literature. The current research, therefore, aims to investigate if using ICT for study of maths becomes a booster and helps to improve children’s performance on problem-solving tasks in maths, to predict and make observations based on the given information, which requires strong language skills and the ability to critically think.

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2 ANALYSIS OF PUBLICATIONS

The world standard of inclusive education strategy is based on the idea that students with special educational needs require support in getting key life competencies such as cognitive, non-cognitive skills, and "functional literacy" for independent life and socialisation (UNICEF, 2020). Particularly, the success of the students with hearing impairments in the targeted acquisition of these key maths competencies depends on class management, teaching approaches, and methods such as the universal design of learning or differential instruction with ICT (Global Education Monitoring Report Team, 2020). ICT is also a school subject in which students learn to use computers and other electronic equipment to store and send information (UNICEF, 2020).

According to a newsletter prepared by NORAD – Norwegian Agency for Development Cooperation and by AFD – Agence Française de Développement "Information and Communication A technology that supports the inclusion of children with disabilities in education" (National Deaf Center on Postsecondary Outcomes, 2020b). ICTs can support the inclusion of children with disabilities in education, allowing them to overcome some of the barriers that cause their exclusion. ICTs complement other face-to-face communication methods and tools such as teacher training and inclusive pedagogy (de Dinechin and Boutard, 2021). ICT is a tool for both an inclusive and gender-sensitive approach to education, which was introduced over the two years 2020-2022 during the transition to distance education due to COVID-19 pandemics (UNICEF, 2020).

In general, when teaching mathematics, ICT for deaf and hard-of-hearing learners can be divided into three main categories:

- educational content and digital media, the purpose of which is to convey lessons/skills to the student (for example, a learning video on stochastics with translation into sign language). An example would be the development of Best Practices at the Secondary Level of DeafTEC: Technological Education Centre for Deaf and Hard-of-Hearing Students (National Deaf Center on Postsecondary Outcomes, 2020b).
- Software that serves as an intermediary to make certain educational content/activities available (e.g., GeoGebra for geometry or LearningApps) (Rochester Institute of Technology, 2022a).
- Accessibility features that make the hardware accessible to everyone (e.g., software to convert maths problem text into sign language) (National Deaf Center on Postsecondary Outcomes, 2020a).

The main goal of the strategies of using ICT in inclusive education is designed to promote access to mathematics content based on the Standards of instructional strategies and should be based upon current and accurate information about the child's sensory functioning. Most researchers agree that access to appropriate ICTs can reduce differences in inclusive education, and deaf and hard-of-hearing learners must have access to ICT-based programs being a part of the schedule of school (Rochester Institute of Technology, 2022b). That is why digital inclusion in maths education as a process is a system of a student's empowerment through participation in education processes with ICT-programs (de Dinechin and Boutard, 2021); individual curricula of studying maths (Ray, 2001); providing reasonable accommodation of materials (Ray, 2001). However, despite the huge potential benefits of ICT usage in inclusive education, it only rarely worked in Ukrainian schools.

2.1 The Principles and Methods of Mathematics with the Instruction of Deaf and Hearing Students in Mainstream Classes

We need to highlight that for teaching deaf and hard-of-hearing learners, the same methods as for other children are used. However, the peculiarities of the psychophysical development of the students lead to other ways of applying these methods. In particular, the methods of teaching are remedial and developmental, and they stimulate deaf and hard-of-hearing learners to work independently and to take initiatives (Fritz et al., 2019).

The principles and methods of maths education in an inclusive class of the middle school are based on the determination of needs of deaf and hard-of-hearing learners:

Step one – to determine the current level of maths knowledge, communicative skills, and maths vocabulary of the children who are deaf or hard of hearing.

Step two – to determine the effective teaching style (visual, kinesthetic, poly-sensory and another one, especially if one of the styles dominates). For mainstream classes it is important to use multimedia approaches for a visual representation of maths course content (e.g., GeoGebra for geometry or LearningApps for particular stochastics is to achieve strong mastering of knowledge, the formation of practical skills to solve problems on the basics of combinatorics, probability theory, and mathematical statistics) (Kidd, 2018). Using LearningApps is especially important for students who are relying on speechreading for receptive communication as it reduces eyestrain. Also, there is an appropriate language model that can effectively provide not only the vocabulary to label objects but also a language model for expressing concepts and ideas, using the child's mode of communication in maths.

Step three – to identify specific aspects of the child's learning activities; where he or she needs outside help during the educational process. For example, use more than one mode of presentation for maths concepts. These may include manipulatives, verbal, gestural, pictorial, and symbolic modes. Encourage students to translate between modalities, particularly the language of mathematics, to make connections (Kollosche et al., 2019). For example, instructional strategies of using GeoGebra visualisation to provide an enriched learning environment that promotes a wide range of real world, meaningful mathematical experiences with opportunities for exploration and problem-solving in geometry. Initially introduce word problems as informal stories with maths facts through dramatization, using pictures, drawings, and manipulatives, and then translating the action into a maths sentence. Students can use images, objects, and visualise or pantomime the action in a problem to move from the concrete to more abstract representations of the problem.

2.2 Methods of Maths Teaching to Children with Hearing Impairments

There are specific methods of class management and teaching where children with hearing impairment (Kidd, 2018; National Deaf Center on Postsecondary Outcomes, 2020b; Nunes and Moreno, 1999; Ray, 2001; Singh, 2019). Firstly, teachers need to use alternative forms of communication and the strategy of studying maths based on non-verbal intelligence and competences (seriation, analogy, systematisation) (Fritz et al., 2019). The adaptation of the education maths content to the cognitive abilities of the students for children with HI, this is the removal of complex verbal material.

Secondly, it is visual learning. Taking into account the specificity of the HI, the types of showing objects are additionally selected. For example, for children with hearing impairment, the visual manuals should be specific, with details that concentrate on the perception of main things. The teacher needs some tips for classroom management: slowing down the educational process. Communication of the information for deaf and hard-of-hearing learners is carried out with consideration of the slower perception of the verbal information. For deaf and hard-of-hearing learners, more time is given to think about the answer (Kidd, 2018).

Thirdly, repeatability in teaching. The repetition variability should be used to fill the gaps in the perception of children with hearing impairment especially if we use ICT (Kidd, 2018). The optimization of the work pace and fatigue dynamics of deaf and hard-of-hearing learners. This tool is aimed at activation of the students' cognitive activities, support of their ability to work and includes, in particular: switching the students to different types of activities to prevent fatigue (gamification, visualisation, modelling, extrapolation examples in classroom space); using interesting facts, examples, and details in the process of presentation of the material; emotional presentation; organising the minutes of rest at the lessons; creating success situations for the deaf and hard-of-hearing learners (Shestopalova et al., 2019). Conceptually, difficulties of deaf and hard-of-hearing learners in middle school in maths class depend on the expression of disorders and manifest themselves in the following areas: fundamentally, it's understanding of spoken language and formation of active speech (Barrett, 2005).

Generally, the main purpose of studying maths is the formation of verbal-logical thinking children with HI and well as the formation of the auditory-visual-tactile perception of mathematical concepts (child with HI asks questions to clarify details; makes decisions on the use of approaches and materials learned earlier; can explain decisions and establish logical connections; knows how to systemize features; plans activities) (Rochester Institute of Technology, 2022a; Kidd, 2018).

3 CURRENT RESEARCH AND HYPOTHESIS

We have a goal of comprehensive estimation of if using ICT for the study of maths became a booster and helps to improve HI children's performance on problem-solving tasks in maths and their ability to predict and make observations based on the given information, which requires strong language skills and the ability to critically think.

Learning difficulties in this category of children are related to speech delay and specific problems in conceptual and figurative thinking (Barrett, 2005). In particular, the peculiarity of the formation of visual-action thinking is that it occurs almost without speech, which makes it imperfect and does not contribute to the transition to the visual image level. In turn, the formation of formal-logical thinking is also difficult

(Le Brun, 2022).

That is why the purpose of our research is the modification of teaching strategies for deaf and hard-of-hearing learners. More specifically, we aim to study the possibilities of optimal use of interactive exercises such as LearningApps and GeoGebra Dynamic Mathematics system in order to provide methodical and didactic support for training sessions, but also to assure independent study and implementation of monitoring activities. Consequently, some aspects of the problem of teaching maths to students with hearing impairment can be eliminated through the use of ICT as a provider of training materials through adapted, assistive devices, information and communication technologies, and support. However, there are some problems with ICT for children with hearing impairment. ICT as a provider of training materials adapted for maths teaching to deaf and hard-of-hearing learners is not firmly established and needs further research and testing.

The research question that guided the present study was: does ICT boost the maths skills of hearing impaired teenagers? The current research hopes to extend on the work of previous research by investigating that all three methods LearningApps, Geogebra, and STEM boost maths skills.

4 METHOD

4.1 Design

The design of the study includes a model of ICT application and the impact of effective inclusive education strategies and methods on the process of learning mathematics for children with hearing impairment. The study utilised a within subject design with one IV (intervention: pre vs post) and the DV being the maths performance (as outlined in the Materials section).

4.2 Procedure

The study consists of three stages:

The first stage was to collect data for diagnosing the level of mathematical abilities by analysing the level of spatial thinking of the Raven's Progressive Matrices (Raven, 2020), Rey-Osterriet Composite Figures Test (ROCF), Gottschaldt's Hidden Figure Test (GHFT) and the educational achievements in algebra and geometry of potential ICT users (students with hearing impairments). Purpose: at this stage, information was collected on the level of performance of a sample of students with hearing impairments, and their spatial skills were analysed using diagnostics.

The second stage consisted of an analysis of existing ICTs for teaching mathematics (algebra and geometry) classes, their usefulness, limitations, requirements, etc., which served as the basis for reflection in the analysis stage. Purpose: to study the possibilities of optimal use of interactive exercises LearningApps and the GeoGebra dynamic mathematics system for methodological and didactic support of training sessions, independent study, and control activities.

The third stage is the processing and analysis of data in order to make recommendations on the appropriateness of using ICT technologies in schools in Kryvyi Rih (taking into account the usefulness of ICTs, their cost, ease of use, impact on school inclusiveness, etc.). In addition, the main problems in the implementation of ICT and inclusive education programs were identified and recommendations were given.

4.3 Participants

Implementation of ICT programs in educational strategies signed in USL and voiced for learning mathematics in grades 8-9 of an inclusive type for instructors teaching in a mainstreamed classroom with a mix of hearing, deaf and hard-of-hearing students.

Table 1: Demographics of the sample ($N = 80$, mean age = 12.5; SD = 1.06).

Total of the Year	deaf students	hard-of-hearing students
2019 ($N = 30$)	8	22
2020 ($N = 21$)	6	15
2021 ($N = 29$)	10	19
Total	24	56

Overall, 80 participants took part in the study (40 females, 40 males; mean age = 12.5; SD = 1.06). Thirty participants were deaf from birth and 70 with hearing loss in early childhood (on average diagnosed at the age of 3; SD = 1.5). Tables 1, 2 present the detailed demographics of the sample.

Table 2: Demographics of the sample ($N = 80$, mean age = 12.5; SD = 1.06).

Mainstream class (N)	Special class (N)
24	56

There was no significant difference in intelligence score between different educational levels, $F(5.49) = 2.46$; $p = .05$. Participants were recruited through the Department of Education and Science of the Executive Committee of the Kryvyi Rih City and advertising in Non-Governmental organisations.

The work of the research team was aimed at developing a concept for supporting inclusive mathematics education in Kryvyi Rih in cooperation with the Department of Education and Science of the Executive Committee of the Kryvyi Rih City Council and Kryvyi Rih State Pedagogical University. The developed visual materials for teaching children with hearing impairments were partially introduced into the educational process in a pilot project for the retraining of 12 school teams working with children with hearing impairments in Kryvyi Rih using STEM methods and in the course of the Suziriya Mathematical Multidisciplinary Educational and Rehabilitation Centre for children with hearing impairments in 2019-2021.

4.4 Materials

4.4.1 Academic Success

In the system of Ukrainian education, educational success is assessed by summing up current grades in the classroom, and test works on the topic on the basis of a 12-point scale (max 12). The rating of grades is available to all students in the class. In the context of conducting mathematics lessons (algebra, geometry), the mathematical skills of students were analysed.

4.4.2 Stereotype Threat

For our study, situational factors that increase stereotype threat may include expectations of difficulty in maths, and the expectation of discrimination due to one's identification with a negatively stereotyped group of children with special educational needs. To reduce the repetitive experience of stereotype threat in teaching mathematics using ICT, we used a preliminary diagnosis of the Rey-Osterriet Composite Figures Test, the Raven's Progressive Matrices and the Gottschaldt's Hidden Figure Test, followed by the identification of the level of mathematical spatial abilities, the level of intelligence. To anticipate a decline in maths learning confidence, poor performance, and loss of interest in the relevant area of achievement, we pre-reported individual scores to students, emphasising that they did well on tests and that their spatial ability was sufficient for maths learning.

4.4.3 Raven's Progressive Matrices

Standard Progressive Matrices (RSPM) a classic study using this test contains numerous motors used for various purposes. RPM is a non-verbal test typically used to measure general human intelligence and abstract reasoning and is regarded as a non-verbal estimate (Raven, 2020). The Raven Progressive Matrices test is one of the non-verbal intelligence tests and is based on two theories developed by Gestalt psychology: the theory of form perception and the so-called "neogenesis theory" by Charles Spearman (Lovie, 1983). Raven's matrices can be applied to subjects with any linguistic composition and sociocultural background, with any level of speech development. We used several algorithms for the psychological interpretation of the results obtained: the definition of intelligence according to the percentage scale; the translation of the obtained results into an IQ-indicator (Raven, 2020).

4.4.4 Gottschaldt's Hidden Figure Test (GHFT)

This test measures figure-ground discrimination abilities. A participant is asked to look at 30 masked figures to find one of the 5 reference figures. Masked figures are presented in turn, it is necessary to record the total time of the task by the subjects. An example was given before starting the technique performing the exercise with the correct answer for children with hearing impairments to be sure that they understand the text of instruction. Calculation of results obtained by respondents according to the method "Figures of Gottschaldt" was carried out according to the formula:

$$I = \frac{N}{T},$$

where I – index of field dependence or field independence; N – the total number of points (correctly completed tasks); T – time to complete all tasks in minutes.

4.4.5 Rey-Osterriet Composite Figures Test (ROCF)

Rey-Osterriet Composite Figures Test (ROCF) is a neuropsychological technique, in which a participant is asked to paint an image (subtest 1), and then paint it from memory (subtest 2). The test figure itself (shown in the figure) is made up of 18 elements, which can be divided into three groups: the head form, the outer elements, and the internal elements in the head form. The technique allows for the development of memory, deep-space functions, and deep-constructive habits. It is significant that this test is included in the international list of tools for assessing cognitive dysfunctions in neurology.

All tests have traditionally been used as psychometric methods to assess factors of intelligence and/or disturbances in spatial perception. Through their combined use, researchers were able to obtain an integrative assessment of using ICT for the study of maths that became a booster and helps for problem-solving tasks in maths for a child to predict and make observations based on the given information, which requires strong language skills and the ability to critically think. Thus, it becomes possible to effectively identify the problems and opportunities for using ICT.

4.4.6 Criteria for Assessing the Academic Performance

The results of the e-learning course were examined to make judgments on students' academic performance. In such a manner, in case of the absence of mistakes in Gottschaldt's Hidden Figure test, the child's performance was rated as high. If one or two mistakes were made, the performance was deemed moderate. More than two mistakes corresponded to low academic attainment. The analysis of Raven's test results used several algorithms for the psychological interpretation of the results obtained: the definition of intelligence according to the percentage scale; translation of the obtained results into an IQ. When conducting Rey-Osterriet Composite Figures Test (ROCF), the level of student's visual and spatial thinking was determined high if the head form, the outer elements, and the internal elements in the head form without errors; average if the child was unable to copy form and details without mistakes; and low if no tasks were completed successfully.

4.5 Intervention Methods

The intervention lasted for each grade selected by the researchers (8th and 9th grade of high school) for two academic years (October to May) of online learning under quarantine restrictions during the COVID-19 pandemic. The intervention was carried out by integrating the ICT programs described in the article into the methodology of teaching mathematics by teachers and modifying the curriculum by the general school support team (teacher's assistants, psychologists, and parents).

An example of adapted and modified planimetry curricula for students with hearing impairments (Geometry, grade 8-9):

- Topic 1 (28 hours). Quadrilaterals. Quadrilateral, its elements. The sum of the angles of a quadrilateral. Parallelogram, its properties and signs. Rectangle, rhombus, square and their properties. Trapeze. Inscribed and circumscribed quadrilaterals. Inscribed and central corners. Thales' theorem. The middle line of a triangle, its properties The middle line of a trapezoid, its properties.
- Topic 2 (14 hours). Similarity of triangles. Generalized theorem of Thales. Similar triangles. Signs of similarity of triangles.
- Topic 3 (22 hours). Polygons. Areas of polygons. Polygon and its elements. Convex and non-convex polygons. The sum of the angles of a convex polygon. Inscribed and circumscribed polygons. The concept of the area of a polygon. Main properties of areas. Area of a rectangle, parallelogram, triangle. The area of the trapezium.
- Topic 4 (20 hours). Solving right triangles. Sine, cosine, tangent of an acute angle of a right triangle. Theorem of Pythagoras. Perpendicular and inclined, their properties. The ratio between the sides and angles of a right triangle. The value of sine, cosine, tangent of some angles. Solving right triangles.
- Topic 5 (4 hours). Solving triangles. Sine, cosine, tangent of angles from 0° to 180°. Basic trigonometric identity, reduction formulas.
- Topic 6 (16 hours). Cartesian coordinates on the plane. Coordinates of the middle of the segment. Distance between two points with given coordinates. The equation of a circle and a straight line.
- Topic 7 (20 hours). Vectors on the plane. Vector. Modulus and direction of the vector. Equality of vectors. Coordinates of the vector. Adding and subtracting vectors. Multiplication of a vector by a number. Collinear vectors. Scalar product of vectors.

4.5.1 Online Service LearningApps Usage for Teaching the Students with HI

Based on the conducted research the authors developed the teaching aid (Kramarenko, 2019). The first part covers general guidelines for teaching pupils with special educational needs using ICT and means of remote technologies. The second section focuses on the usage of LearningApps online training. The teaching aid provides both references on worked out exercises and QR codes which are generated through the service. The use of a variety of online resources, including online services and learning environments, is becoming increasingly popular. One of the prime examples of such environments is the LearningApps multimedia didactic exercising service (https://learningapps.org/). It is intended for the development, storage, and usage of interactive exercises in the educational process. Such exercises can be applied not only on a lesson with an interactive whiteboard but also as individual tasks for students with special needs (figure 1). A significant advantage of this service is the ability of task integration into Moodle LMS.

The educational aim of using interactive exercises of the LearningApps service in the study of Mathematics and in particular stochastics is to achieve strong mastering of knowledge, the formation of practical skills to solve problems on the basics of combinatorics, probability theory, and mathematical statistics, to show the connection between stochastics and real life and to teach students to carry out non-typical tasks.

4.5.2 Using GeoGebra in Mathematics Teaching

For the use of GeoGebra Maths Apps (Kramarenko, 2019) mathematics teachers are offered several visuals for visualisation of geometric constructions, the hypothesis concerning the properties of geometric figures, and the proof of theorems. GeoGebra Dynamic Mathematics (https://www.geogebra.org/) visuals include the usage of mobile phone applications such as Geometry, 3D-Calculator, Graphing Calculator, and the visuals demonstrating stochastic experiments in the teaching of probability theory and mathematical statistics.

It is extremely positive that using both of the above-mentioned services allows students to collaborate in the offered virtual classes (Google Classroom). These features have recently appeared. And they can play a significant role in socialisation, especially for deaf and hard-of-hearing learners. As our research has shown, Mathematics teachers practically do not use them in their work. Partly because of a lack of competence in this matter.

GeoGebra has become the leading provider of dynamic mathematics software, supporting science, technology, engineering, and mathematics (STEM) education and innovations in teaching and learning worldwide. We consider it reasonable to use the GeoGebra Maths Apps in teaching deaf and hard-of-hearing learners. The authors offered a mathematics teacher a teaching guide and tasks for students to use GeoGebra in teaching Planimetry and Stochastics. In particular, the use of built-in functions for calculating the values of combinatorial compounds, testing using GeoGebra and examining electronic visuals that simulate accidental events by Sada (Sada, 2021).

To present an experiment demonstration, a teacher can use the GeoGebra dynamic Maths program. In an exercise developed by a teacher in advance, a student will be able to simulate a large number of bone tosses and monitor their results. In developing visuals that model accidental events, we used the ideas of Sada (Sada, 2021).

5 RESULTS

Data obtained before and after the intervention from groups were analysed using descriptive and inferential statistics (t test, and repeated measures ANOVA), by SPSS software version 17 at $p < 0.05$ significance level. Kolmogorov-Smirnov test determined whether the data were normally distributed ($p = 0.9$) and also homogeneity of variances with $p = 0.21$ was determined. Nonparametric statistics were used to describe qualitative sociodemographic characteristics of participants. T-tests were used to compute the mean scores and compare the maths performance before and after the intervention. This quasi-experimental intervention study aimed to evaluate the effect of using ICT in maths courses.

The results of this study are based on the data of 80 students with hearing impairments participating in the research. The mean and standard deviation of their age was 12.5 ± 1.06. In this study, deaf students' performance in relation to the subjects (geometry, algebra) was examined before and after the training using ICT in the maths course.

To reduce the repetitive experience of stereotype threat in teaching mathematics using ICT, we used a preliminary diagnosis of the Rey-Osterriet Composite Figures Test, the Raven's Progressive Matrices and the Gottschaldt's Hidden Figure Test, followed by the identification of the level of mathematical spatial abilities, the level of intelligence (table 3). In addition, children with hearing impairments are more (63) related to the field-dependent style (1.9 ± 0.13) according to the results of the Gottschild Figures and trust visual impressions more and hardly overcome the visible field when it is necessary to detail and structure the situation (table 3).

A pretest of students' maths performance indicated that all children had a poor performance in advanced geometry such that the mean total performance score of students in the intervention group before the training was 6.3 ± 1.08; algebra (6.23 ± 1.04) (table 4). Therefore, based on the independent t-test results, there was no significant difference between the mean pretest scores in groups 2019-2021. The assumption of equality of variances was also met (Levene's test $p = .920$). Descriptive statistics are presented in table 4. The highest and the lowest mean scores, obtained in various dimensions of the performance checklist after the intervention, were on the topics how the position of the center of a circle (9.2 ± 1.01) and learning about the concept of an event, an impossible, accidental, and probable event (8.6 ± 1.04), respectively.

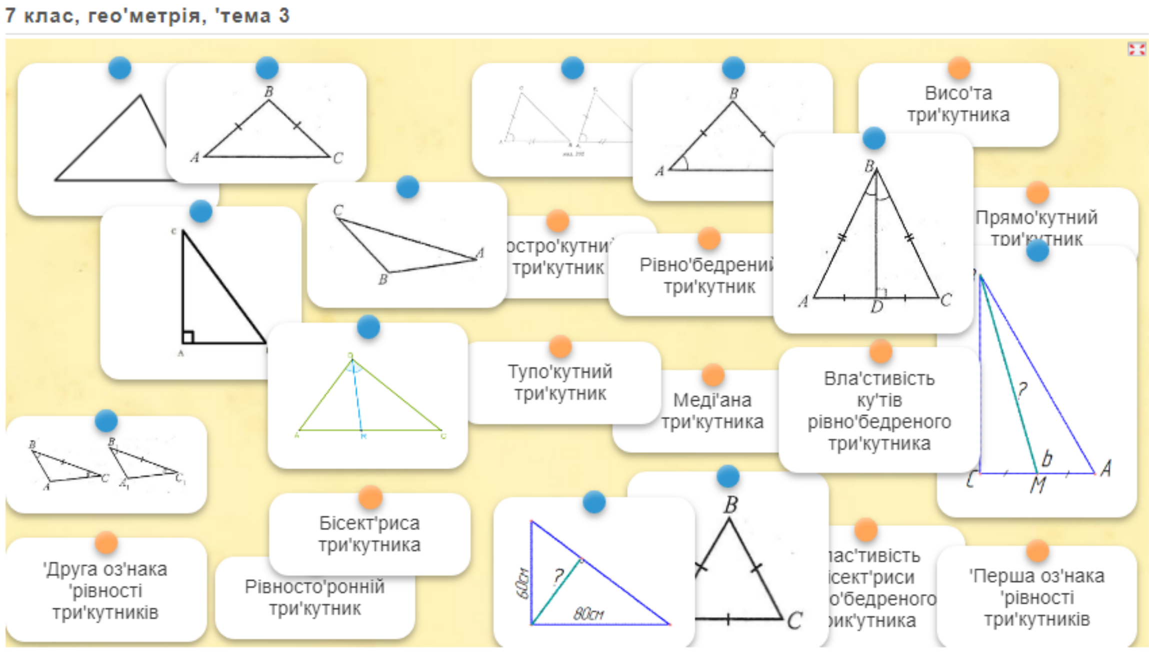

Figure 1: Geometry exercise for the topic "Triangles" (LearningApps software).

Table 3: Descriptive stats table of mean performance scores of students ($N = 80$).

Raven's Progr. Matr.^{ab}	Rey-Osterriet Comp. Figures Test^{ac}	Figures of Gottschaldt^{ad}
101.8 ± 6.43	8.1 ± 2.36	1.9 ± 0.13

*N*ote. ^{a} Data are presented as mean ± SD ^{b} IQ-index ^{c} Summary score of Copy Presence and Accuracy, Organization (According to BQSS (Le Brun, 2022)). ^{d} I index.

6 DISCUSSION

The research question investigated in this study was: does ICT boost the maths skills of hearing-impaired teenagers? The current research extended the work of previous research by investigating whether ICTs such as LearningApps, Geogebra can boost maths skills.

Previous research showed that most children with hearing impairment have a gap of approximately three years behind their hearing peers in mathematics (Rochester Institute of Technology, 2022b). Our participants before were known for their individual scores on Rey-Osterriet Composite Figures Test, the Raven's Progressive Matrices, and the Gottschaldt's Hidden Figure Test, emphasising that they did well on tests and that their spatial ability was sufficient for maths learning. This diagnostic was for the prediction of reducing the repetitive experience of stereotype threat in teaching mathematics using ICT.

According to the study results, there was a significant increase in the mean score of performance after the intervention than before the intervention. In other words, this increase represents the effectiveness of ICT educational methods. Furthermore, we highlighted some recommendations for using online service LearningApps, GeoGebra Dynamic Mathematics system.

6.1 Case Study – Example 1: Using Online Service LearningApps for Teaching the Children with HI

Let us demonstrate how LearningApps service interactive exercises can be applied at different stages of learning maths. For example, at the stage of learning about the concept of an event, an impossible, accidental, and probable event, it is reasonable to offer students an exercise to determine the type of event. The following events appear alternately in the exercise window. A student should determine which events are probable, which are impossible, and which are accidental.

Task 1. Determine "which" type is the event.

In this task, each word is stressed. It is reason-

Table 4: Comparison of mean performance score of students before and after intervention ($N = 80$).

Performance	Geometry	Algebra
Before intervention	6.3 ± 1.08	6.23 ± 1.04
After intervention	8.1 ± 1.9	8.2 ± 1.6
Paired t-test results (P, t)	0.001, 0.61	0.002, 0.21

able to introduce exercises to children with hearing impairment in such a way. In the following lessons, this exercise can be also used at the stage of refreshing students' basic knowledge on the topic.

Students with SEN may find it difficult to understand and memorise theoretical material, so it is best first to demonstrate examples of learned concepts and then return to the theory when necessary. For this purpose, it is reasonable to offer the students with special educational needs the opportunity to find a pair in the LearningApps online service during the initial consolidation stage. In the process of studying events operations, one should use as many examples as possible, reflecting not only the essence of these operations but also the differences between them.

Children with hearing impairment can easily find both the sum and value of events using definitions. So solving applied problems is important in this process. After students have mastered the theorems of adding incompatible events and multiplying independent events, they use them to calculate the probability of events, solving the corresponding problems.

Here are some other examples of tasks that can be conveniently created in LearningApps templates and used in Stochastics teaching.

Task 2. "Classification" exercise. The essence of this exercise is that the screen on the student's computer or mobile phone is divided into two fields: a right triangle and an isosceles triangle. Next, students are given definitions, properties, constituents, or examples of triangles to be referred to as a right triangle or an isosceles one. After completing the exercise, the student can "push" the button to the right from the bottom to check if the tasks are done correctly.

Task 3. "Classification" exercise. In figure 1 a screenshot of the 7th grade geometry exercise on the topic "Triangles" is presented (https://learningapps.org/display?v=p1gk6f39a22). The exercise is intended for students to repeat the types of triangles and consolidate knowledge on the signs of equality of triangles. A small number of words are used in the exercise. Stress is placed before the corresponding stressed syllables. Students must match concepts, names of theorems with corresponding pictures.

Task 4. "Match" Exercise. The essence of this exercise is that a student should connect the notion with its definition or example. For instance, the term "bisector" refers to the definition of a bisector of a triangle, to a certain notion corresponding to a picture that illustrates it, to calculate the perimeter of a triangle, if the lengths of its sides are given, etc.

The use of similar tests allows a teacher to determine the level of success of a child with hearing impairment and to identify gaps in his/her knowledge. It will help to correct his learning and to plan further work. For example, the possibility of repeated repetition of the exercises created with LearningApps will give students confidence. It will also contribute to better learning.

6.2 Case Study – Example 2: GeoGebra Dynamic Mathematics System

We have upgraded the set of visuals offered by Sada (Sada, 2021) to adapt it to students' learning in Ukrainian. For example, one of the exercises allows us to see changes and patterns in the process of any number of the tests carried out. The student can observe whether there is any tendency as the number of falls in a single number increases, and compare it with the number of falls in another number. Such activity in the lesson should be structured for a student with special needs in the form of clearly formulated actions, and algorithms for completing the task. Instructions should be brief and clear, repeated several times. It may be difficult for a student with disabilities to concentrate, so he or she has to be repeatedly urged to carry out, to control this process until its completion. The task should be adapted so the student has time to work at the pace of the whole class.

The task is complicated when the student is offered the following exercise: modelling and counting the results when throwing two, three or more dice and calculating the sum of the falling numbers, etc. By practising research on the tossing of two and three coins, it may be easier for the student to imagine the situation of tossing 4 coins and others. It gives a good result and use of the lessons of planimetry, the library of electronic visibility (Sada, 2021).

Task 5: How the position of the centre of a circle described around a triangle is related to the view of a triangle (figure 2).

It should be taken into consideration that the GeoGebra Dynamic Mathematics system can be installed on smartphones. So the children with hearing

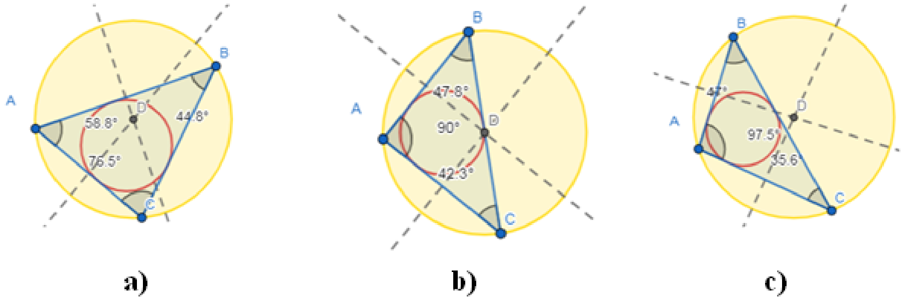

Figure 2: Investigation of the position of the centre described around a triangle of a circle (GeoGebra Geometry): a) an acute-angled triangle, b) rectangular, c) obtuse.

impairment will be able to check the correctness of their tasks during the lesson, especially when working independently or in groups. One can also start the exercise by using the link or QR code for the exercise. It is enough for the student to install a code scanner on his/her smartphone. One of these is the free Qrafter application, which allows you instantly to read QR codes using only your smartphone's camera and Internet access.

The use of GeoGebra in preparation for admission to higher education institutions provides ample opportunities for students with special educational needs. Using GeoGebra 3D Calculator, they will be able to develop spatial imagination, master the techniques of constructing spatial figures. A number of illustrations for solving problems of open type of external independent evaluation (EIE) are given by us in the manual (Kramarenko, 2019). Here are some of them in this article. These are two open-ended tasks with a detailed answer, which are evaluated by examiners according to special rules (EIE-2018).

Task 6. In a regular quadrangular pyramid SABCD, the side of the base ABCD is equal to c, and the side edge SA forms an angle a with the plane of the base. A plane c is drawn through the base of the height of the pyramid parallel to the plane ASD. Construct a section of the pyramid SABCD plane in, justify the type of section and determine its perimeter (figure 3).

By studying the function line, students will be able to use the GeoGebra Graphing Calculator to determine all possible solutions to an equation or inequality. This will provide visualization, help students better understand the process of solving such complex problems.

Task 7 (GeoGebra Geometry, grade 8-9). Construct an arbitrary convex quadrilateral. Investigate: a) the quadrilateral formed by the successive connection of the midpoints of this quadrilateral is a parallelogram; b) the area of the resulting parallelogram is half the area of the original quadrilateral (figure 4). Using the same visualization, it would be possible to investigate that the quadrilateral formed as a result of mapping an arbitrary point relative to the midpoints of the sides of the original quadrilateral is also a parallelogram. And therefore its area does not depend on the choice of a point inside. However, the substantiation of such a hypothesis goes beyond the mathematics curriculum for deaf children.

7 CONCLUSION

1. The conducted research proved the relevance of the problem of modifying the strategy of teaching mathematics to deaf and hard-of-hearing students based on the implementation of distance learning technologies. Studying the problems of teaching mathematics to deaf and hard-of-hearing students made it possible to draw the following conclusions: the most important task of a teacher and teacher's assistant is to encourage deaf and hard-of-hearing students to study; one of the effective ways of teaching mathematics to students of the specified categories is the use of remote technologies; in the text messages of visual aids offered to students with hearing impairments, it is advisable to emphasize each word so that they know how to read the words correctly.
2. We found that the LearningApps educational environment can be used at different stages of the lesson: during the organization of independent, individual activities, in joint research activities. Thanks to interactive exercises, deaf and hard of hearing students should become active participants in the educational process. The toolkit of the service allows you to create training classes, inviting them to your students by hyperlink. Since deaf and hard-of-hearing students put much more effort into the task, the system for evaluating the educational achievements of such students can be stimulating. After each student has completed

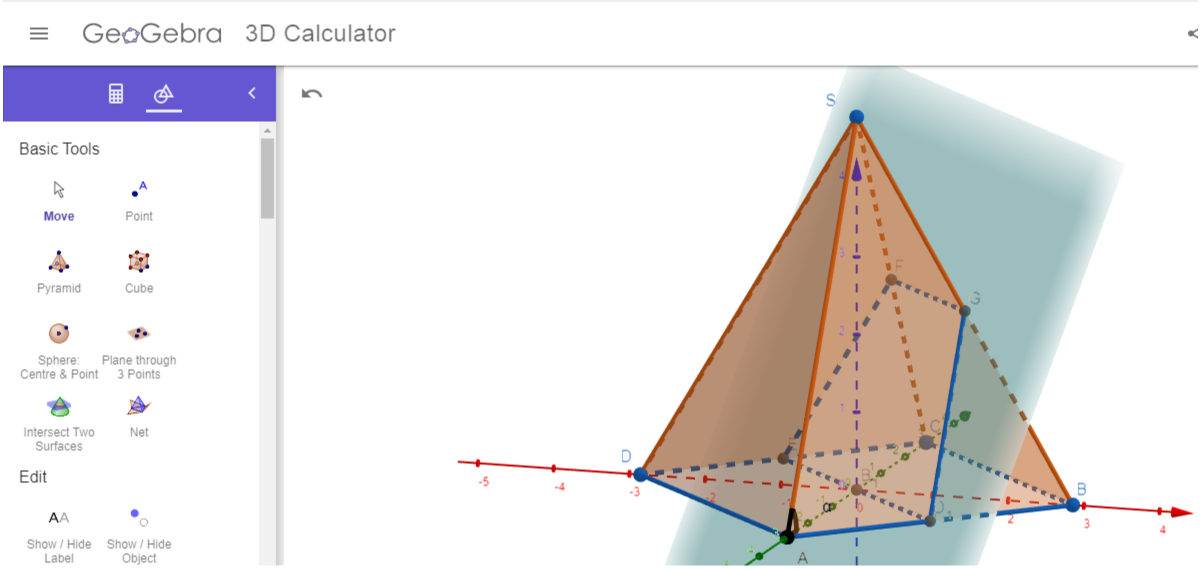

Figure 3: Examples of open-ended tasks (task 32 from EIE-2018 (https://zno.osvita.ua/mathematics/298/), GeoGebra 3D Calculator).

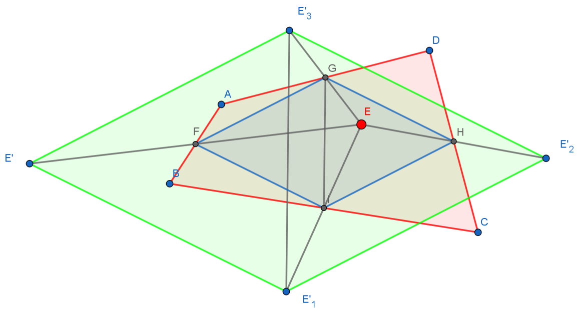

Figure 4: Studying the shape of a quadrilateral using GeoGebra.

each exercise, the teacher should analyze and compare the expected results with the actual performance of the students. A mandatory condition for teaching students with special educational needs in mathematics is feedback: to find out whether students are satisfied with their work and the knowledge they have acquired, whether they understand the importance of this knowledge for further study of the subject.

3. Using the proposed clarifications will help a student with hearing impairments to better understand mathematical material. Therefore, the student receives complete information if it is supported by visual perception of the text, tables, diagrams.
4. In order to investigate progressive shifts in the learning of mathematics by deaf and hard of hearing students using ICT, it is appropriate to compare the shifts in the scores of the diagnostic test and the test. Statistical groups can be analyzed by two G-tests and Wilcoxon tests. These algorithms involve the use of small sample sizes. So we used it and tested it for individual academic groups. We observed a trend of increasing values of the characteristic (scored points) from the initial training exercises to the control of the achieved level of knowledge and skills.

The prospects of the research are related to the expediency of using the GeoGebra dynamic mathematics system for the development of spatial imagination and spatial thinking, etc., in children with hearing impairments.

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Novel Methods for Integrating Personal Physiological Devices in STEM Education

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Abstract: STEM education employs a variety of computer-based methods to improve motivation, personalization, and the quality of learning and instruction in the STEM disciplines. However, STEM educators and researchers often lack the knowledge and skills to integrate Internet of Things (IoT) and emerging personal physiological devices (PPDs) to enhance STEM education research and practice. The number of smartwatches, bands, and other PPDs has been expanding but research has so far failed to keep pace with the application of these technologies in education. The concept of STEM (the academic and professional disciplines of science, technology, engineering, and mathematics), adopted by Ukraine for 2020-2027, highlights the necessity to develop such efforts in Ukraine. The use of PPDs in STEM education research and practice may contribute to the introduction of STEM practices to students in Ukraine. To advance our understanding of integrating PPDs in STEM education, we have developed 13 new methods that facilitate the use of PPDs in STEM courses and educational research. We used a variety of inexpensive and widely used devices to test our proposed methods. Our team was probably the first one to apply the process mapping approach of "As Is – To Be" in educational research using the Business Process Model and Notation (BPMN) method to evaluate changes in educational processes before and after using PPDs in Biology classes from both pedagogical and technological points of view.

1 INTRODUCTION

The US National Science Foundation developed and disseminated the acronym "STEM" in 2001 to replace "SMET". As a separate area of didactics, STEM stood out in the USA in 2009 with its "Educate to Innovate" program. However, in Ukraine, STEM use is still in its infancy. However, its use is much less compared to the traditional educational approach (Shapovalov et al., 2020) even contrary to its advantages. A key focus in STEM education has been on increasing the engagement and motivation of students to take up STEM (Azevedo, 2015; Belland et al., 2013). Furthermore, STEM courses are designed to facilitate the development of 21st century learning and digital citizenship skills such as communication, data processing, and project management, all of which largely depend on informed use of information technology (International Society for Technology in Education (ISTE), 2023; Battelle for Kids, 2019). Significant attention in STEM is dedicated to increasing the students' motivation.

The main factor in forming the STEM is the growing demand for well-prepared and qualified STEM professionals thus contributing to the increasing em-

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phasis on STEM in education. STEM professions require non-routine problem-solving skills and design and implementation of solutions to the current science, engineering, and design challenges for our society. Other factors have also contributed to the increased interest of educators, researchers and policy makers in the STEM approach within education. For example, there is a need to transform instructional methods in the educational space from more teacher-centered approaches (the sage on stage) to more content and student-focused active learning approaches (Freeman et al., 2014).

STEM education tools may be classified into instrumental measurers, software, and modern perspective, but not widely used tools. In turn, the instrumental measurers can be divided into digital laboratories, digital equipment, mobile phones, mobile phones with additional sensors, and intelligent devices. Software like graphical calculators, modelling environments, games and simulations, VR video, VR and AR (Azevedo, 2015; Belland et al., 2013; International Society for Technology in Education (ISTE), 2023; Battelle for Kids, 2019), 3D printing, 3D modelling tools (Almusawi et al., 2021), and so on. One of the promising modern tools without widespread use is the usage the Internet of Things (IoT) that has high untapped potential in education due to several advantages, such as using cloud computing as well as computation and visualization of data measured or captured by measurers. In addition, those devices connected to the personal ecosystem provide personalized data.

Internet of Things (IoT) can use cloud servers for data processing and storage. Internet of Things includes the M2M (machine-to-machine) connection method for measurement and interaction requiring no human involvement.

PPDs can be considered as part of the IoT that have automatic algorithms for processing information and notify about a specific user parameter change. PPDs such as IoT are electronic devices connected through the Internet or Bluetooth and NFC. They send measured (fixed) data into the cloud, where such data is saved. Users can get information using the cloud from any place using an Android/iOS application or web interface. The main advantages of its use is personalization (the personal connection of the device to the personal page of the application/web interface). Distinctive features of PPDs as smart tools are:

- Measurement of actual real-time data
- Processing of measured data and obtaining calculated indicators
- Analysis of the data to state changes or to display an important to the user parameters.

PPDs include fitness bands (tracks), smartwatches, smart scales, and smartphones. Smartwatches/bands, scales, temperature sensors, humidity sensors, and specific plant sensors possess most promising potential for use in the education process (Gubbi et al., 2013). Personal physiological devices (PPDs; or personal smart tools) possess most promising potential for enhancing the student learning experiences in STEM education courses.

The relevance of the research is substantiated by the increase in the number of personal wearable devices due to their much higher affordability and simplicity (Pal et al., 2020). There was an expected jump from 100 million in 2016 to over 373 million in 2020 (Laricchia, 2022) and even up to 1.1 billion in 2022 due to the transformation of mobile internet connection from 4G to 5G (Visual Paradigm, 2016).

2 METHODS

The study was conducted using the methods of theoretical and empirical research. Firstly, analysis and synthesis were used to determine the main trends in the use of PPDs in education. Next, a comparative qualitative analysis was conducted to examine and compare the best pedagogical practices using PPDs. The cultural-system analysis and synthesis also have been used to build a theoretical model of as is-to be process. The following devices were used for proving our experiments: Colmi band 1, Xiaomi mi band 4, Samsung Smart Fitness Band, and Xiaomi Mi Smart Scale 2.

To analyze the proposed teaching process modification, the use of “As is-to be” method (Next Generation Science, 2023; Common Core, 2011) was the first necessary step. This method uses the Business Process Model and Notation (BPMN) (Guest, 2007) to note the current process and the proposed approach for both technological and pedagogical process business analyses. BPMN provides a decomposition of the complex processes into simple elements and connects them by arrows to interpret the total process. Additionally, BPMN uses “lines” to decompose elements of the process by the executor, for example, teacher and student.

In general, BPMN is used in business analysis. Still, considering its specifics, it will be suitable for use in scientific work to justify the practicality of using proposed educational approaches. Besides, very few researchers have used BPMN to describe processes in education (Nechypurenko and Soloviev, 2018; Cabinet of Ministries of Ukraine, 2020).

Hotline (https://hotline.ua/) web-market and its filters were used to evaluate the characteristics and existence of devices that can measure the exact parameters.

3 RESULTS AND DISCUSSION

3.1 Existing IoT and PPDs ecosystems

The most popular devices are part of a smart home and are connected using Wi-Fi or Bluetooth protocols. The most common devices are scales, watches, and fitness trackers. The leading manufacturers of these products are Samsung, Xiaomi with Amazfit/Huami sub-brands, Apple, Google Nest and others.

Samsung smartphones can become a central link within the entire ecosystem. From a phone, one can control watches, devices, and headphones, write some notes, and then continue working on them on the other device. At the same time, all synchronization is seamless. Internet availability is the necessary prerequisite for the entire system to work smoothly and as intended. Even without the Internet, one can exchange data between a tablet and a smartphone using Samsung Flow. The heart and brain of their developments are Bixby 2.0, an intelligent assistant that easily connects to Samsung devices. Bixby 2.0 is the central hub of the IoT ecosystem, learning from the daily interaction with users' devices to better understand and anticipate all needs of its user.

Today more than two hundred companies and start-ups are located under Xiaomi, each responsible for its product type. The Amazfit brand is developing fitness trackers and intelligent clock, and SmartMi produces intelligent home appliances. Wearing electronics has long since ceased to be a curiosity, and today it helps monitor physical activity, sleep quality, and overall health for millions of users worldwide. Xiaomi could not remain indifferent and, together with Amazfit, has found its niche in the ranks of intelligent wearable gadget manufacturers. It is no secret that Xiaomi Mi Band is one of the best and most popular fitness trackers. The fitness bracelet is improving its capabilities with each new generation and becoming more functional. Moreover, it maintains a reasonably loyal price tag thus ensuring the gadget's enduring popularity.

Nonetheless, the company is not in charge of wearable gadgets. Household medical devices, such as electronic thermometers, inhalers, and tonometers, have also found their place within the model ranges of the aforementioned Chinese technology giants. Recently, Xiaomi has begun mastering another area – home simulators. At the moment, among Xiaomi's simulators, one can find the WalkingPad A1 folding treadmill. There is no doubt that the company will also cover other sports equipment for home sports in the nearest future.

Apple HomeKit and Health app are the platforms, the central purpose of which is to unite all the smart technologies within one home. The HomeKit platform was released by Apple back in 2014 as part of the WWDC conference, and already a year later, full-fledged devices based on it became available for sale. Starting with the iOS 8 operation system, Apple mobile devices would be able to manage compatible home appliances and home life support systems. One of the advantages of HomeKit is close integration with the Siri virtual assistant. Home Kit can be controlled by voice commands, which opens up enormous opportunities for home appliance developers and software developers. A native application appeared in iOS 10 to replace third party software. The program was able to take over the management of all Smart Home appliances equipped with the appropriate software. Apple's Health app allows to monitor health and daily activity whilst providing important information to one's family or friends when needed. It is especially critical in the event of an accident or sudden illness and while tracking fitness stress. The app excellently works with Apple Watch. For example, Apple Watch can measure the level of O2 in blood and take electrocardiograms.

Google began taking its first steps towards a smart home back in 2016 when it introduced the first Google Home speaker. It is supposed to be an analogue of Amazon Echo, i.e. it can control home appliances and be used as a multimedia device. The Google Cast application, which is used to configure and manage Chromecast devices, has since been renamed Google Home. One of the latest innovations from Google in this field was the Google Home Hub, shown last year. Google Home Hub is a tablet with a display that can combine information about your smart devices in the Google Home ecosystem and display it on a built-in display. In 2019, Google presented its product Nest Hub Max at a presentation. Google's Home Hub had a camera and added multiplayer functions. Several operating tools of Google Nest are supporting Google Assistant. In addition to the devices produced and presented by Google itself, many companies manufacture devices compatible with this ecosystem. Their number has already surpassed 500. Each day, there are more and more manufacturers producing products marked "works with Google Assistant".

However, it seems relevant to analyze the ecosystems of those companies based on the parameters that can be measured by particular equipment. The main parameters used during educational research are heart rate, blood pressure, ECG, oxygen content, weight, muscle, fat, bone, and water content in the human body. Exa plus devices of different companies that can measure exact parameters are presented in table 1.

3.2 Analysis of Proposed Teaching Process Modification

PPDs are capable of providing a transcendent educational experience, meaning students can interact with objects directly. They investigate whether it is necessary by themselves. By using PPDs, students can perform different activities such as assessing the level of O2 in blood, heart rate, and more. To create an intelligent lesson, it is necessary to achieve connectivity between innovative tools and smartphones via specific applications, for example, Xiaomi Mi Fit.

During the "As is" for research, STEM-lesson process anticipates that the teacher explains the theory, sometimes challenging for students' understanding, with further explanation of parameters that will affect the object or function. In all cases, the teacher will explain an experiment using the class board without any research, less often by providing demonstrations, and, very rarely, by conducting a group experiment. In these cases, a student does not understand the material clearly. Moreover, skills and competencies delivered using this process will be limited only by a specific topic, laid down in the lesson, which may be insufficient according to the latest international and Ukrainian documents.

The technical part for all demonstrations and group experiments will be mostly provided manually by students or teachers. The results will be calculated, processed, and interpreted manually. This time can be used more beneficially for students' teaching process. Thus, measurement starts with choosing the measurer and providing measurement. Obtained data must be noted and written using a class board or worksheets. The calculation is provided manually, which may be more useful than automatic computation. The best effect may be obtained by combining both manual and automated analysis. Obtained data is interpreted in graphs, board, or worksheets. Finally, the graphics and data are analyzed.

Typically for the "As is" process, the teacher starts classes from the theory and further transfers to the more practically oriented part, explaining the factors affecting some object or function. Pupils will have demonstrations, group experiments, or personal experiments based on the available innovative tools. Understanding of the materials will be better due to the higher speed of the research. Calculation and graph creation will be provided automatically. Students will work with personal data and graphs. Then they will understand how to work with graphics and data and how to use unique wearable intelligent tools to provide research that will motivate students to research and present better usage for health care. Due to personal experiments, students will have more questions than in the as-is process due to higher motivation. Proceeding towards the final part of "As is" process classes will finish with investigation and discussion of the results.

The main features of the "To be" approach are time-saving and motivation increase. From a technical point of view, "To be" process is significantly more automatic. In this case, all methods of measuring and analyzing are provided by teachers and students. The entire analysis process – which includes sending measured data to a smartphone, saving data, processing data and creating a graph – must be conducted by the teacher or student. The data using additional software can be imported to Excel for further processing.

The "To be" process is more interactive, engaging, and beneficial for students. Furthermore, it motivates them to provide personal research and learn how to use individual smart gadgets in healthcare. "To be" process may save much more time when used effectively. Surely, it is worth noting that students are familiar with how to process the data during the "As is" process. Thus, it seems useful to combine these methods.

3.3 Methods for Integrating Personal Physiological Devices in STEM Education

3.3.1 Methods That Can Be Used in Biology

Topic: Measuring heart rate before and after physical activity with smartwatches/bands.

Learning objective: Develop knowledge and skills to use a smartwatch/band to measure heart rate and study the effects of physical activity on heart rate.

Target age group: middle and high schoolers.

Equipment: PPDs or smartwatch/bands or fitness tracks with heart rate monitoring functions; blood pressure, oxygen concentration (optional)

Experimental procedure: This method involves selecting 10 participants of each biological sex for the study. Firstly, each participant takes their heart rate, blood pressure (optional), and oxygen concentration (optional) measurements at rest. Afterwards, each student must do 20 squats. Following this exercise, he/she needs to take measurements one more

Table 1: Examples of devices of different companies, that can measure concrete parameters.

	Samsung	Xiaomi	Apple	Google	Other brands
Smart watches/bands					
Heart rate	100% of devises: Samsung Galaxy Watch 1, Samsung Galaxy Watch 2, Samsung Galaxy Watch 3	100% of devises: Amazfit T-Rex, Amazfit Bip S, Amazfit Stratos	100% of devises: Apple Watch Series 1, Apple Watch Series 2, Apple Watch Series 3	N/A	100% Aspolo SmartWatch U8, UWatch U8, SmartYou DZ09
Blood pressure	-(3,9%)Samsung Galaxy Watch 3	- (0%)	- (0%)	N/A	5.5% Havit HV-H1100, UWatch DT88 Pro, Aspolo DT88 Pro
ECG	(0 %)	+ (4.4 %) Xiaomi Mi Watch Color, Xiaomi Haylou Smart Watch	+ (52.5 %) Apple Watch Series 5, Apple Watch Series 6, Apple Watch SE	N/A	7 % No.1 DT28, Lige Smart, Gelius GP-L3
Oxygen content	- (3,9 %) Samsung Galaxy Watch 3	- (0 %)	10,2 % of devises: Apple Watch Series 6	N/A	11.7% Aspolo M1Plus, Aspolo DT35, UWatch E66
Sleep quality (stages of the sleep)	100% of devises: Samsung Smart Charm, Samsung Galaxy Fit E, Samsung Galaxy Watch Active	100% of devises: Xiaomi mi band 4, Xiaomi mi band 5, Amazfit GTS,	100% of devises: Apple Watch Series 5, Apple Watch Series 6, Apple Watch SE	N/A	100% Aspolo SmartWatch U8, UWatch U8, SmartYou DZ09
Smart scales					
Weight measuring	N/A	+ (100%) Xiaomi Mi Smart Scale 1, Xiaomi Mi Smart Scale 2	N/A	N/A	100% Laretti LR BS0015, HUAWEI Body Fat Scale, AEG PW 5653 BT Black
Muscle, fat, bone, and water content in the human body	N/A	+ (100%) Xiaomi Mi Smart Scale 1, Xiaomi Mi Smart Scale 2	N/A	N/A	100 % Yunmai Mini Smart Scale, Garmin Index Smart Scale, Acme Smart Scale

time. The analyzed data can be personalized as a graph on their smartphone and in a table drawn on a blackboard. The teacher finds regularities related to all students (including sex, weight, age, etc.) and explains them to the audience (figure 3) and fill the table 2.

Data analysis: We need to find regularities before and after physical activity to analyze the data. For example, compare actual and relative changes in indicators after physical activity in boys and girls, and we need to find dependencies from other indicators, such as height and weight.

Topic: The effect of sleep duration on heart rate.

Aim: Demonstrate to students that sleep duration affects the functioning of the circulatory system. Use the personal example to prove to students the importance of sleep and adherence to the daily habit

Equipment: Smartwatches/bands with heart rate, blood pressure (optional), oxygen concentration (optional), ECG (optional).

Experimental procedure: The research is personalized, so each student must carry it out separately. The method foresees changing the time regime in two steps. Firstly, students during the experiment must get sleep daily for seven days, falling asleep at 22:00 and getting up at 7:00. As soon as they wake up, students measure their heart rate, blood pressure (optional), oxygen concentration (optional), ECG (optional), as well as the quality of their sleep. After the first seven days of the test, students must fall asleep at 23:00 and wake up at 6:00 with students measuring the same parameters and recording the findings. To determine the cardiac cycle, use figure 4.

Data analysis: Analysis of the data is performed through comparison of the heart rate and oxygen concentration in the blood during the first stage (falling

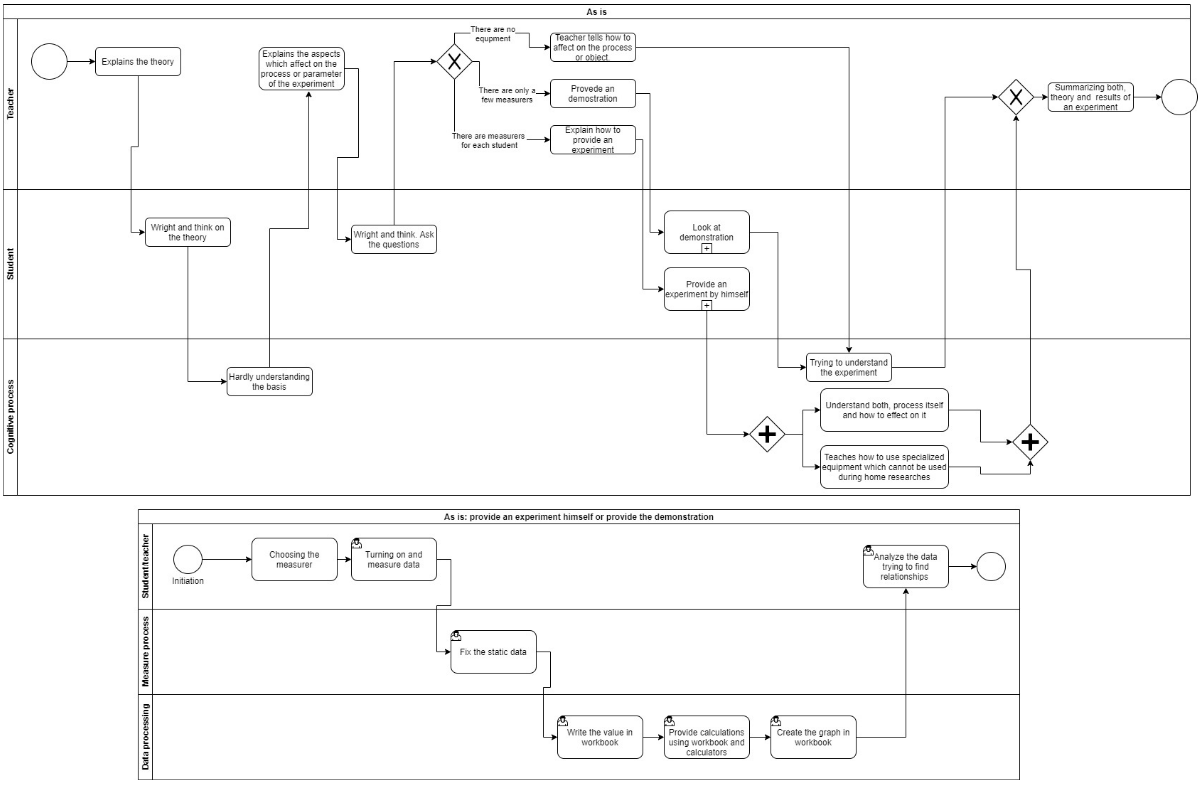


Figure 1: "As is" process (including technical interaction).

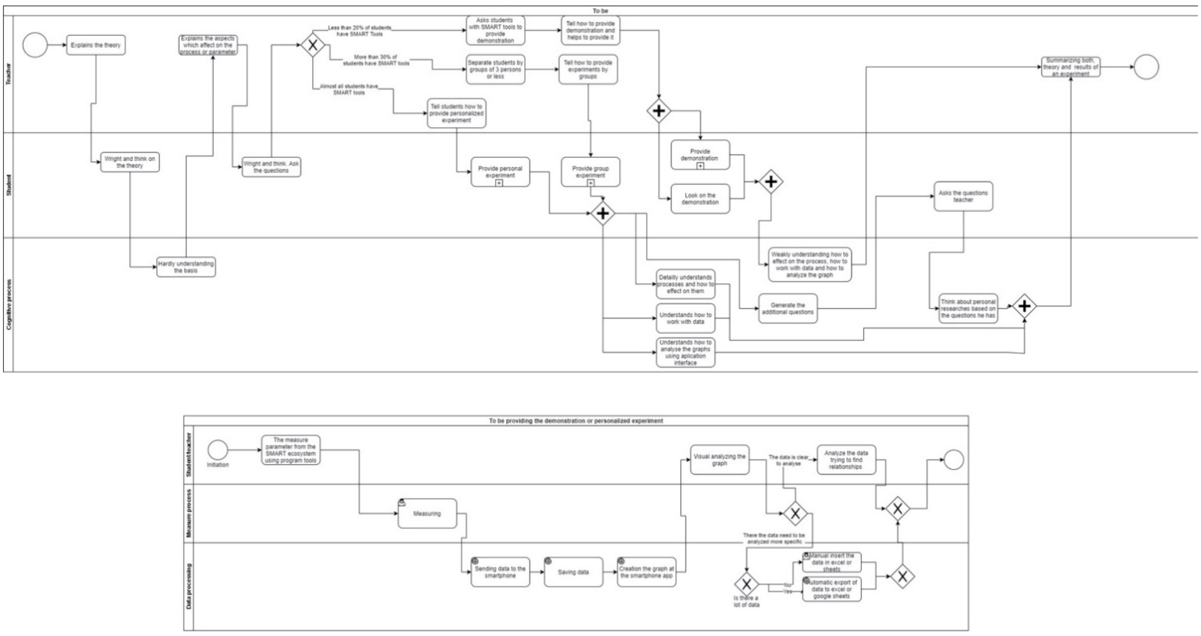


Figure 2: "To be" process (including technical interaction).

asleep at 22:00 and waking up at 7:00) and during the second stage (falling asleep at 23:00 and waking up at 6:00) with the normal condition. Using theoretical knowledge, changes in data must be attached to stress or adaptation state and fill the table 3.

The experiment is safe and can be conducted regardless of any health conditions. However, we recommend that the teacher or adults supervise the re-

Table 2: Table to experimental project "Measuring heart rate before and after physical activity with smartwatches/bands".

Age	Sex	Heart rate (before)	Heart rate (after)	Blood pressure (optional) before	Blood pressure (optional) after	Oxygen concentration (optional) before	Oxygen concentration (optional) after

(a)

(b) (c)

Figure 3: Experimental part of the work (a), heart rate before (b) and after exercise (c).

search. Based on the results, it is possible to study adaptation, human comfort areas, and stress conditions. Figures to illustrate analysis process is shown in figure 5.

To determine the cardiac cycle, use figure 4.

Topic: Determination of differences in muscle, fat and bone composition in males and females.

Aim: Demonstrate to students some differences

Table 3: Table to project "The effect of sleep duration on heart rate".

	Sleep duration	
	9 hours	7 hours
Heart rate		
Blood pressure (optional)		
Oxygen concentration (optional)		
The duration of the cardiac cycle on the ECG (*)		

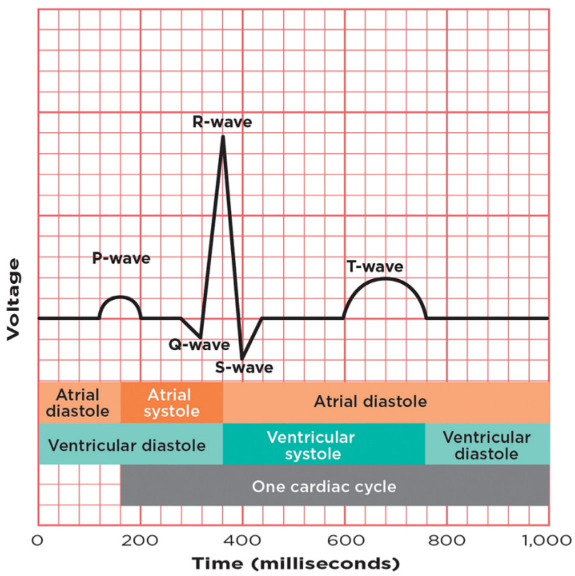
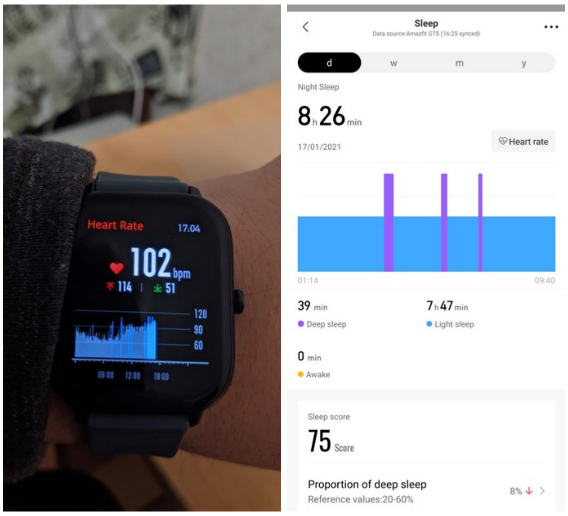


Figure 4: Relationship between ECG and cardiac cycle stages.

in male's and female's muscle, fat, and bone composition. Explain the reasons for such differences.

Experimental procedure: The technique involves selecting 10 participants of each sex for the study. Each of the students must measure muscle, fat and bone tissue. The analyzed data can be personalized as a graph on their smartphone and in a table drawn on a blackboard, where the teacher finds regularities and explains them to the audience and fill table 4.

Data analysis: To analyze the data, it is necessary to find regularities in the amount of muscle, fat, and bone tissue and compare the actual and relative speed



(a) (b)

Figure 5: Interface of smart watch's application sleep tab (Amazfit Zepp) (a) and the result of the analysis (b).

Table 4: Table to project "Demonstration to students some differences in male's and female's muscle, fat, and bone composition. Explain the reasons for such differences".

N	Age	Sex	The amount of muscle	The amount of fat	The amount of bone tissue

of change in male and female bodies. It is necessary to mention that the method is simple and easy to use in any school, especially, since it does not require sophisticated, expensive smart equipment. At the same time, it is useful because students measure the real indicator, compared to the traditional process, and they also learn to analyze data and graphs on their smartphones. Students are also more motivated to continue research after class. To analyze the data, we need to find regularities in the amount of muscle, fat, and bone tissue and compare the actual and relative speed of change in the amount of muscular, fat, and bone tissue in male and female bodies bodies (figure 6).

Topic: Determination of the oxygen saturation level in blood as indicator of SARS-CoV-2 (related to COVID-19).

Aim: Teach students to measure the level of blood saturation in the blood, which became especially relevant during the COVID-19 pandemic.

Equipment: PPDs or smartwatch or fitness trackers with the ability to monitor oxygen concentration – saturation.

(a) (b)

(c) (d) (e)

Figure 6: The procedure of weight measuring (a), example of weight displaying (b), interface of integral automatic weight state assessment (c), details of body state (d, e).

Experimental procedure: Measure your oxygen concentration in blood with smartwatch/band. If the value is less than 95%, consult a doctor immediately and fill the table 5 (figure 7).

Table 5: Table to project "Determination of the oxygen saturation level in blood as indicator of SARS-CoV-2 (related to COVID-19)".

Condition	Blood saturation (oxygen concentration)
Before dinner	
After dinner	
Before exercises	
After exercises	

Data analysis: This experiment can be performed once and can be ported to Excel for a long time every day. For a healthy person, the level is the same and does not depend on any factor.

Figure 7: The result of oxygen content in blood determination.

3.3.2 Methods performed for a Long Time

Topic: Diet effect on body parameters, especially on the amount of muscle, fat and bone tissue.

Aim: Demonstrate to students the relationship between diet and the amount of body fat, to form an understanding of healthy nutrition.

Equipment: smart scales.

Experimental procedure: Firstly, students measure the amount of muscle tissue, fat tissue, and bone tissue using smart scales. Based on the results of measuring the amount of fat, muscle, and bone tissue in your body, students define a goal for themselves (for example, to get rid of fat tissue), consult with a teacher and, based on it, choose the diet. Students provide daily measurements of the amount of fat, muscle and bone tissue for six months, preferably in the morning before meals. The data can be analyzed using a smartphone or using an Excel table and to do it, fill table 6.

Table 6: Table to project "Diet effect on body parameters, especially on the amount of muscle, fat and bone tissue".

N	Condition	The amount of muscle	The amount of fat	The amount of bone tissue
1	Before diet			
2	After diet			

Data analysis: Students must define the efficiency of the diet and make conclusions about the personal fit of the diet. Students must analyze the tendencies by determining the specific periods (stressed state of the organism and adaptation). The method can be used in any school, but it is a lengthy experiment. It is highly advised that such research is conducted under supervision of either a teacher or adults. It can be used as a source of data for research works aimed at participation in research contests among students.

Topic: The physical activity affects sleep duration and heart rate.

Aim: Demonstrate to students the physical activity effect on heart rate and sleep duration.

Equipment: Smartwatch or fitness trackers with heart rate monitoring functions; blood pressure, oxygen concentration (optional).

Experimental procedure: Measure the duration of sleep and heart rate, blood pressure, and oxygen concentration (optional) without physical effort before going to bed for a week. Afterwards, 3 hours before sleep, students must do one of the two possible things: A) Perform three sets, thirty squats each, and three sets with ten push-ups each; repeat the exercise cycle four times a week; spend three days resting. B) Perform a 2-4 km run each day for six days per week (1 day left to rest). Each day, students must measure the duration of sleep and heart rate, pressure, and blood oxygen level. Enter blood pressure, heart rate, and long and short sleeping phases into the table 7, and analyze the results.

Table 7: Table to project "The physical activity affects sleep duration and heart rate".

N	Condition	Heart rate	Blood pressure	Blood oxygen level
1	Before activity			
2	After activity			

Data analysis: Compare the measured parameters before the activities and during the "active" week. Define whether the quality of the long phase of sleep is increased, define the changes in heart rate before sleep. Finally, compare the obtained data with well-being. The method is simple and can be used in almost every school, especially considering that only smartwatch/band is required. In addition, it can be used as a source for data fused in research works aimed at participation in research contests among students.

Topic: Physical activity effect on human muscle and fat tissue amount.

Aim: Demonstrate to students that regular exercise increases the amount of muscle tissue.

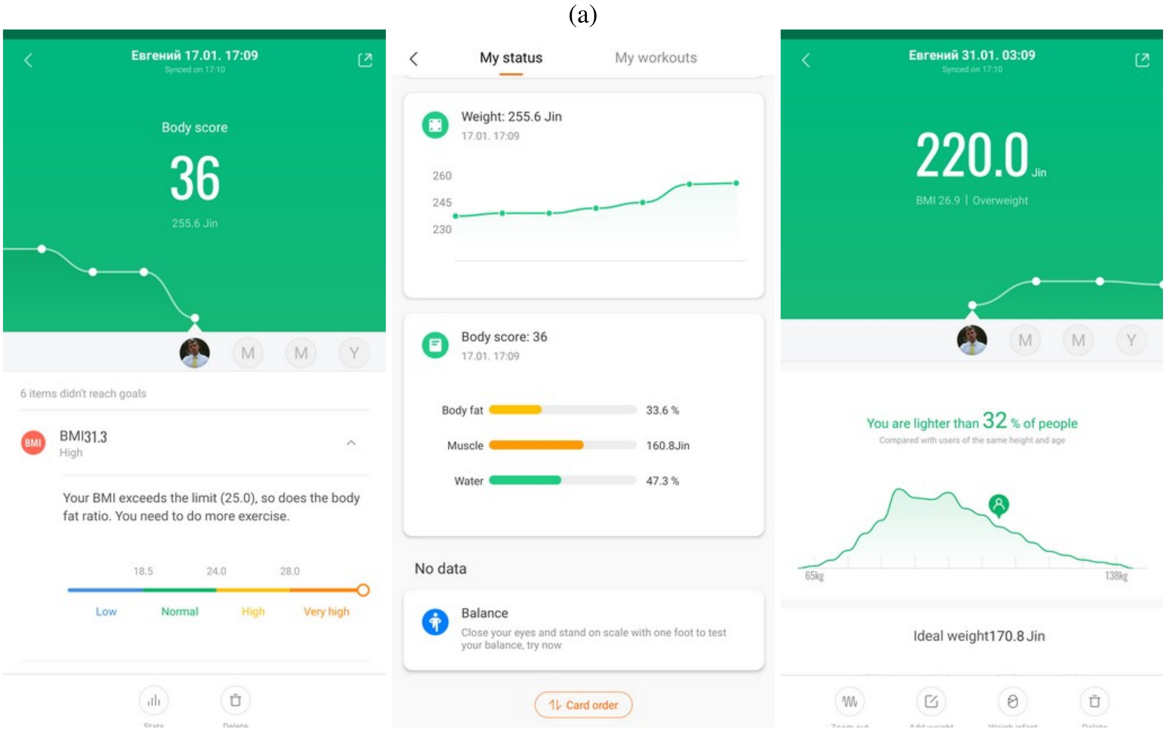
Equipment: smart scale.

Experimental procedure: Measure the amount of your muscle tissue using smart scales. Starting the next day, perform one of the two options:

A) Perform three sets, 30 squats each and three sets of push-ups, ten reps each. Repeat the exercise cycle four times a week. Leave three days for rest.

B) Make a 2-4 km run every day. Measure your muscle tissue using smart scales over six months. Measure the amount of your muscular tissue using

(a)



(b) (c) (d)

Figure 8: Screenshot of the method of mathematical modelling of student's nutrition ration (a), dynamic of the automatically body state estimation (b), current state of the body (fats, muscles, water content) (c) and weight dynamic and comparing with other users (d).

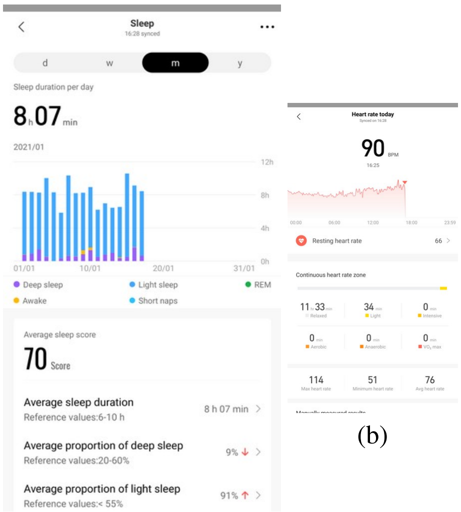
smart scales every day for six months. Capture data with the smartwatch/band interface as data or import it into Excel and, at the end of the year, analyze the data on your muscle tissue development and fill table 8.

Data analysis: Analyze the dynamic of the weight changes and their content. Define the tendencies in changes of fat and muscles tissue amount. Define changes in time stages (stress and adaptation). Calculate the weight of fat and muscles lost during the

Table 8: Table to project "Demonstrate to students that regular exercise increases the amount of muscle tissue".

N	Condition	The amount of muscle	The amount of fat	The amount of bone tissue
1	Before exercises			
2	After exercises			

research. Try to define whether the process of fat decrease is linear, or features steps. Describe the steps, if applicable. The method involves performing exercises, which can be qualified as doing sports, so a preliminary medical examination and teacher's supervision are required.



(a) (b)

Figure 9: Dynamic of the long and short stages of sleep (a) and dynamic of the heart rate (b).

Topic: Influence of fitness zone training on resting heart rate.

Aim: To teach students to individually calculate the maximum heart rate and the number of contractions that correspond to the fitness zone of physical activity, to select a set of exercises, the implementation of which will determine the required heart rate.

Equipment: PPDs or smartwatch/band or fitness trackers with heart rate monitoring functions.

Experimental procedure: Students measure heart rate with a smartwatch/band. For the next step, they calculate maximum heart rate according to the formula:

- For females $209 - (0.9 \cdot \text{age})$
- For males $214 - (0.8 \cdot \text{age})$

Then count 70-80% of maximum heart rate. This will be the optimal amount of heart rate during exercise. Students need to choose their own exercises, which will require the number of heartbeats controlled by a smartwatch/band. After three months of regular exercise, students measure their resting heart rate again.

Data analysis: Define the optimal physical activity that provides a student's heart rate in the fitness zone. Define the mean physical activity in the group and compare the individual results. Define dependencies of optimal physical activity on sex, weight and age.

Students learn to use smartwatches/bands and process their data when doing work.

Topic: Effect of holding breath on heart contraction.

Aim: investigate whether holding one's breath affects heart rate and ECG.

Equipment: Smartwatches/bands with heart rate, blood pressure (optional), oxygen concentration (optional), ECG (optional), stopwatch.

Experimental procedure: It is first necessary to measure the time of maximum possible period of holding breath in the standing and sitting position after inhalation/exhalation with a stopwatch. Between measurements, it is necessary to have a rest for no less than 5 minutes. Next, a student needs to hold his/her breath and measure one of the following parameters: heart rate, blood pressure (optional), oxygen concentration (optional), and ECG (optional) while standing. Rest for 5 minutes is due next. A similar experiment has to be repeated in a standing position.

Data analysis: Analyze the time of holding breath among different students. Does this value depend on inhalation/exhalation, body position, sex, and level of physical fitness? Fill in table 9 (A). Compare heart rate, blood pressure (optional), oxygen concentration (optional), duration of the cardiac cycle on the ECG without holding breath and with respiratory arrest during exhalation/inhalation in sitting and standing positions. Fill in table 10 (B).

Table 9: Table A to project "Effect of holding breath on heart contraction".

N	Condition (sex)	Respiratory arrest time after inhalation (c)	Respiratory arrest time after exhalation (c)
	Sitting position (female)		
	Sitting position (male)		
	Standing position (female)		
	Standing position (male)		

Table 10: Table B to project “Effect of holding breath on heart contraction”.

N	Condition	Heart rate	Blood pressure (optional)	Oxygen concentration (optional)	Duration of the cardiac cycle (optional)
	With respiration, in a sitting position				
	With respiration, in a standing position				
	Breath held after inhalation, sitting position				
	Breath held after inhalation, standing position				
	Breath held after exhalation, sitting position				
	Breath held after exhalation, sitting position standing position				

Topic: Influence of controlled hyperventilation on the duration of holding breath.

Aim: Demonstrate to students that the removal of CO2 from the body affects the breath-holding time.

Equipment: Smartwatches/bands with a stopwatch.

Experimental procedure: A student has to hold one’s breath for as long as possible, record the duration of this state. The next step presupposes assuming horizontal body position. A student has to take 30 intense breaths (breathe a little faster than usual) then exhale calmly and relax their lungs. Afterwards, oneneeds to move a little quicker than usual and then hold breath on exhaling as long as possible. It is necessary to record the duration of the breathless state. A student is to takeone deep breath next and hold you’re their breath for 15 seconds and repeat the actions described above two more times. This technique should not be used while swimming, driving, in the shower, or anywhere else while standing and fill table 11.

Table 11: Table to project “Influence of controlled hyperventilation on the duration of holding breath”.

N	Condition	Duration, seconds
1	Simple approach to holding breath	
2	Holding breath with hyperventilation, first time	
3	Holding breath with hyperventilation, second time	
4	Holding breath with hyperventilation, third time	

Data analysis: Compare the duration of holding breath without and with controlled hyperventilation. How does preliminary controlled hyperventilation affect the breath-holding time? What is the impact of each iteration?

Topic: Effect of hypoxia on blood oxygen levels.

Aim: Demonstrate to students that the concentration of oxygen in the blood can be temporarily affected.

Equipment: Smartwatches/bands with oxygen concentration.

Experimental procedure: Hold your breath for as long as possible. At the end of the period without breath, use the gadget’s oximeter function to measure the value of oxygen concentration in the blood. Assume a horizontal body position. Take 30 deep breaths (breathe a little faster than usual). Exhale calmly, just to relax your lungs. It would be best if you breathe a bit faster than normal. Hold your breath on exhalation as long as possible. At the end of the period without breath, use the gadget’s oximeter function to measure the value of oxygen concentration in the blood. Take one deep breath and hold it for 15 seconds. Repeat these steps two more times. This technique should not be used while swimming, driving, in the shower, or anywhere else while standing and fill table 12.

Table 12: Table to project “Effect of hypoxia on blood oxygen levels”.

N	Condition	Oxygen concentration, %
1	Before holding breath	
2	Simple approach to holding breath	
3	Holding breath with hyperventilation, first time	
4	Holding breath with hyperventilation, second time	
5	Holding breath with hyperventilation, third time	

Data analysis: Is it possible to reduce the oxygen concentration in the blood by simply holding your breath? Compare the value of blood oxygen concentration due to respiratory arrest with and without controlled hyperventilation. How does preliminary hyperventilation affect blood oxygen levels? What is the impact of iteration?

Topic: Effect of vagus nerve stimulation on heart rate.

Aim: Demonstrate to students that vagus nerve stimulation can affect heart rate.

Equipment: Smartwatches/bands with heart rate.

Experimental procedure: Measure your heart rate. Wash your face with cold water or immerse it in a bowl of cold water for a few seconds. Measure the heart rate again.

Data analysis: Compare heart rate before and after face contact with cold water. What is the influence of vagus nerve stimulation on heart rate? Can this effect be applied in practice?

Table 13: Table to project "Effect of vagus nerve stimulation on heart rate".

N	Condition	Heart rate, bpm %
1	Before nerve stimulation	
2	After nerve stimulation	

Topic: Does the heart rate change depending on the position of the human body?

Aim: Demonstrate whether the heart rate changes with the different position of the human body?

Equipment: Smartwatches/bands with heart rate.

Experimental procedure: Lie down horizontally. Wait a few minutes. Measure your heart rate. Sit up. Wait a few minutes. Measure your heart rate. Stand up. Wait a few minutes. Measure your heart rate.

Data analysis: Compare the heart rate at different body positions. Is there a difference? How can this be explained?

Table 14: Table to project "Does the heart rate change depending on the position of the human body?".

N	Condition	Heart rate, bpm %
1	Lying	
2	Sitting	
3	Standing	

4 DISCUSSION

4.1 Advantages of Using PPDs in the Educational Process

The main functions of PPDs devices in the educational process are defined as:

- *The training functions.* The training involves direct use of PPDs to study individual subjects, primarily STEM subjects. Most often, certain types of devices are used as a tool to perform a learning task. They can also be used in the design of research activities and the performance of research tasks.
- *The health-preserving function* involves using PPDs devices as a tool for monitoring the prime indicators of the body in order to form a healthy lifestyle with the subsequent formation of skills to control physical shape. It can also monitor vital signs for people in need of such service.
- *The control function* involves using devices as a tool for self-control and external control (parents, managers). We control certain activities and the children's GPS, especially among primary school and preschool children, by parents or other people performing parenting duties. If necessary, such control may be carried out by a teacher. It helps to increase self-control, which is supported by habits.
- *The ergonomic function* involves using devices to improve productivity, namely planning, coordinating the use of their time, and the effectiveness of the actual use of tools that help increase the productivity of each child and the educational process as a whole.

Rational use of PPDs devices and time allows the control the child's admissible physical, nervous and mental loads while also having the potential to increase said child's working capacity.

The use of smartwatches/bands in the learning process contributes to the development of principal competencies:

- *Mathematical competence* expressed in the formulation of navigation, calculation of the necessary parameters using indicators created at a reasonable age.
- *Competencies in the field of natural sciences, engineering and technology* are formed based on acquiring skills in working with physical parameters, vital signs, geolocation data, ability to work with different models of specific devices and their analogues, etc.; innovation is defined in the formation of skills in the use of leading technologies for personal and public health. During the connection process of smartwatches/bands with a smartphone, the students get acquainted with the concepts of "cloud technology", "synchronization", and "remote access". The mastery of this knowledge will facilitate information and digital competence formation.
- *Social competencies* manifest in the configuration of the ability to be aware of personal feelings and pay attention to internal needs, which

is displayed in the perceived need to maintain a healthy lifestyle. Smartwatches/bands encourage students to take accurate measurements of their heart rate, blood oxygen concentration and stress levels. This knowledge allows them to produce health-preserving competencies. For example, a student can see that negative emotions (anger, aggression) accelerate their heart rate on their smart clock. In addition, these devices can contribute to the motivation increase to maintain a healthy lifestyle. For instance, one can offer students a cup of coffee, an 'energy drink' and then measure their heart rate. Such experiments will demonstrate the effect of certain substances on the functioning of individual organs and systems.

Smartwatches/bands also have considerable potential to develop valuable skills and habits. For example, most of these devices have a reminder mode. At first, one can set up a notifier that one needs to do some exercises after 40 minutes in a sitting position (while doing homework). After 40 repetitions of this sequence, a helpful skill becomes a habit that can be reproduced without a smart device.

Notwithstanding, smartwatches/bands have the most pedagogical potential in shaping research competencies.

The document "The European Qualifications Framework for Lifelong Learning" (Guest, 2007) determines that a high-level specialist should have research competence in their field of knowledge. Research competence is the ability of the acquired education to perform educational research tasks and carry out research activities to obtain new knowledge and find ways to apply them, following the profile of the study (Nechypurenko and Soloviev, 2018; Cabinet of Ministries of Ukraine, 2020).

With the help of smart watches/bands, a student can obtain a large amount of data – this is the stage of acquiring new knowledge. A student can also analyze this data with mathematical tables – thus fulfilling the step of creating a knowledge system.

It is also possible to use smartwatches/bands to create motivation for learning activities within the STEM approach. For example, students observe the phenomenon of heartbeat acceleration after physical activity, and they will ask problematic questions: Why does it happen? How is the heart activity regulated? Therefore, the whole lesson is laid out around these questions of doubt.

There is also potential in using smartwatches/bands for students with special needs. For example, it is challenging to teach a child with hearing disabilities how to measure their pulse. Smartwatches/bands can help solve this issue.

This article presents several methods of using smartwatches/bands during the learning process. These methods can be divided according to the time they consume:

1) methods that can be directly used in the learning process at school;
2) methods that ensure long-term experiments, for example, within 24 hours, the latter's application is relevant to the performance of research work or projects by students;
3) methods that can be used out of school and after school.

Thus, the use of the smartwatch/band allows:

1) to create motivation for learning activities;
2) to create an impulse for a healthy lifestyle;
3) to develop information-digital, health care and research competencies.

4.2 Alignment of PPD Use with Curriculum Standards

IoT technologies and Cloud Services are becoming more and more popular in education (Fossland and Krogstie, 2016). IoT will significantly improve the quality of education. Implementation of IoT in education will create new ways to learn by supporting more personalized and dynamic learning experiences. IoT will give teachers new methods to explain the material during lessons (Fossland and Krogstie, 2016; Mendling and Weidlich, 2013). Moreover, IoT will offer an excellent opportunity to provide individual lessons to people with some disabilities (Morais et al., 2020). However it is lack of the studies related to using them in education. Furthermore, it was shown that the use of IoT technologies in the educational process will improve the quality of learning (Wiechetek et al., 2017). Besides, their scientific research showed that the use of IoT technologies significantly increases overall opportunities to fulfill creative abilities for both teachers and students.

Using the Internet of Things in Education is excellent for involving and educating students. Different researchers in their articles have tried implementing PPDs to provide various services in smart campuses accessible on handheld devices by ensuring ideal connectivity among multiple things. Some authors create educational systems based on wearable devices and IoT technologies (McRae et al., 2018; Abd-Ali et al., 2020). This education system integrates with the IoT tools and special apps to create more interactions between teachers and students in class while providing more innovative learning possibilities. Also, IoT can inspire school students and increase their concentration in the classroom during the lessons (Liang et al., 2019).

Previously, it was proposed to use such technologies as mobile Internet devices to form the general scientific component of a bachelor in electromechanics competency in the modelling of technical objects (Modlo et al., 2019a,b). However, using mobile Internet devices is a perspective way to improve the quality of education in general. The authors have proposed different tools to work with. For example, mobile augmented reality tools, mobile computer mathematical systems, cloud-oriented tabular processors as modelling tools, mobile communication tools for organizing joint modelling activities and more (Mavroudi et al., 2018; Pervez et al., 2018).

At the same time, despite showing promise PPDs are not widely used in education. There is currently no complete, systematic list of approaches and guidelines for integrating PPDs in the classrooms. Today, the most popular PPDs is a smartphone, but there is a lack of methods that have been proposed methods implying the use of smart scales and bands/watches. PPDs are becoming increasingly popular in most of the healthcare system. For example, some human diseases require constant monitoring of the heart. Devices used for this purpose transmit data to the cloud and, if necessary, signal their users regarding any issues, requiring immediate attention (Modlo et al., 2019b). PPDs have been used widely in everyday life, sport, medicine and healthcare (Wu et al., 2008). For example, wearable devices are used to monitor the state of the patients in clinics and to alert the doctors whenever necessary (Wu et al., 2008). However, there is a lack of studies that substantiated using of PPDs.

One of the proposed systems were collected data from the classroom, not only presenting information to students but also collecting data based on their interactions. This data can be uploaded and accessed by using a smart e-learning application. In smart classrooms, tools are aimed at either real-time monitoring of teaching space or PPDs that support students, when multiple functions are brought together (Modlo et al., 2019a; Stradolini et al., 2017; Veeramanickam and Mohanapriya, 2016).

Some schools, colleges and universities, such as Oral Roberts University in Oklahoma, have introduced the mandatory wearing of fitness bracelets to monitor students' physical activity during the day or physical training. However, there are also potential concerns about the consistent use of PPDs. For example, psychologists warn that wearing these devices can harm people with digestive disorders (Valks et al., 2019). Buchanan (Buchanan, 2015) also proves the positive role of fitness bracelets for students' health, as they create motivation to take the required number of steps per day. A study by Ertzberger and Martin (Ertzberger and Martin, 2016) showed that teachers wear fitness bracelets to increase motivation for physical activity).

4.3 Role of Personalized PPDs in Educational Standards of Ukraine

The introduction of STEM in Ukraine is regulated at the legislative level in the Concept of Development of Natural and Mathematical Education (STEM). According to this document, science and mathematics education (STEM) is a holistic system of science and mathematics education. The term 'interdisciplinary' in STEM according to Ukrainian interpretation means the integration of natural sciences (biology, chemistry, etc.), but not such disciplines as science, technology, engineering and math (Polikhun et al., 2018). Usually, in English-language sources, integration is understood as the relationship of one of the disciplines of sciences (biology, chemistry, or physics) with engineering and mathematics to solve a particular problem. According to the concept, the goal of STEM education is the development of personality through the formation of competencies, natural science picture of the world, worldviews, and life values using a transdisciplinary approach to learning. In our opinion, it is difficult to apply a transdisciplinary approach during the real process of learning at school. Transdisciplinary implies deep integration of disciplines in content and methods and foresees providing a new quality of research or problem-solving. Transdisciplinary provides close integration of knowledge fields, and – as a result – disciplines such as nanotechnology emerge. Due to the conditions of the modern Ukrainian school education system, such courses are practically not conducted. So, the term transdisciplinary will not be used in this paper.

In the Ukrainian Concept, STEM, natural sciences and mathematics are relegated to a single document. We believe that the concept quite successfully describes the aims of STEM education, including the formation of skills to solve complex, practical problems, comprehensive development of personality by identifying its inclinations and abilities; mastering the means of cognitive and practical activities; education of a person who strives for lifelong learning, the formation of practical skills, and creative application knowledge.

Thus, considering the Concept of natural-mathematical education (STEM) in Ukraine, the use of personal PPDs during the educational process is not only modern but may also be effective and promising.

Providing educational research with students using PPDs corresponds to STEM. Since biology is one of the scientific disciplines, it is corresponding to sciences (S). Furthermore, the teacher may ask questions and request students to find and analyze some scientific publications to formulate hypotheses. In addition, students provide the research using proposed methods. As a result of each work, students may make conclusions that are related to their optimum to reach some aim. For example, they may find their optimum that keeps their health and well-being during physical activities, which in turn leads to the formation of personalized methodology (technology; T) in personal health. Taking part in classes, students will think or ask about how a PPDs works: how it measures, how it provides calculation, and how it sends data on the devices. Thereby, it will develop their engineering thinking (E). Proposed methods contain all automated calculations by PPDs manual calculations by students, and analysis of obtained results (M).

Nevertheless, despite some deviations from the classical (American) interpretations of definitions related to STEM education in Ukraine, in our opinion, the Concept positively impacts the development of education and pedagogy in Ukraine and ensures using enchasing motivation and measuring tools such as PPDs.

4.4 Alignment with Relevant K-12 STEM Education Standards in the United States

The activities and methods for implementing PPDs in STEM education align well with a number of STEM education standards in the United States. For example, Next Generation Science Standards a relevant standard for students in elementary grades 4-PS4-3 Waves and Their Applications in technologies for Information Transfer (Next Generation Science, 2023). This standard supports teachers and students in generating and comparing multiple solutions that use patterns to transfer information (e.g., ECG information sent from a smartwatch to a mobile phone smartphone interface).

Similarly, the Common Core State Standards for teaching literacy and mathematics include a set of standards for measurement and data analysis. For instance, standard CSS.Math.Content.5.MD.B.2 requires that students learn to represent and interpret data such as plotting the trends in a person's ECG based on smartwatch recordings (Common Core, 2011).

Finally, a highly relevant set of US standards to support the use of PPDs in STEM education was developed in 2016 by the International Society for Technology in Education (International Society for Technology in Education (ISTE), 2023). For example, students are expected to "critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others" (1.3 Knowledge Constructor). Students are also supposed to engage in computational thinking to "develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions" (1.5 Computational Thinker). All these standards are highly relevant to the implementation of PPDs in STEM education and support teachers' use of smart technologies in the classroom.

Thus, the use of PPDs meets Ukrainian and American educational standards. The development of methods for using PPDs during the educational process is an urgent issue.

5 CONCLUSIONS

The number of PPDs increases due to their usability and usage potential. In 2022, up to 1.1 billion individual smart instruments may be represented due to the shift from 4G to 5G communication protocols, meaning that every seventh person on the Earth will use PPDs. The article showcases exact methods used during educational research of STEM-based processes.

The "As is – To be" BPMN method was proposed to evaluate the effect of the proposed method. Using these methods proved that using smart personal tools during STSTEM education characterized by enhanced automatization provides development of student's thought process, use of graphs, calculation and encourages students to conduct their own individual researches.

Training, health-preservation, mathematical competencies, competencies in the natural sciences, engineering and technology, and social competence can be achieved using personal physiological tools to provide educational research.

The following methods have been developed and are ready to use – "Measure of the heart rate before and after physical activity with smartwatches/bands", "Effect of sleep duration on heart rate", "Determination of differences in muscle, fat and bone composition in males and females", "Determination of the level of saturation in suspected COVID-19", "Diet effect on body parameters, especially on the amount of muscle, fat and bone tissue", "The physical activity effect on sleep duration and heart rate", "Physical activity effect of human muscle and fat tissue amount", "Influence of fitness zone training on resting heart rate".

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The Role of Digital Competency in Educational Process of Participants When Designing a Digital Educational Environment

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Keywords: Digital Educational Environment, Educational Strategies, Digitization of Education, SELFIE Tool, Digital Skills, K-12 Educational Policy.

Abstract: Graduates' digital competency isn't a new demand. On the contrary, it is a necessity, which is a response to the world's tendencies. Not taking into account the fact that those concepts today are among the hottest topics, and the most asked questions, there is still a lack of practical research and use, the results received from practice. Measuring digital competency is a key task for educational institutions to keep following their current state and to respond to the issues in time. Having this information, educational institutions could create studying programs, which would provide personal and professional development for education applicants. That's why the research covers a theoretical overview of the tools needed for estimating digital competency, and the importance of creating an educational policy on digital technology usage is described. The importance of conducting surveys about digital competency levels is justified in this work as well.

1 INTRODUCTION

Today digitalization has become one of the most significant tendencies of civilization development. Digitalization of objects and attributes shapes inclusive society and contributes to the renewal of management mechanisms, giving continuous access to health protection, education, and the economic sector. It raises the quality and number of governmental services being included and broadens opportunities for cooperation for people. The pandemic of COVID-19 and the war in Ukraine have proved the importance and necessity of spreading and popularizing digital technologies for ensuring safety, equal access to informational sources, national well-being, and stability of economical processes.

A modern graduate of a secondary educational institution must be competitive, mobile, and ready for constant learning. Such demands must lead to the renovation of the structure and content of educational services given by institutions of secondary education. Using and mastering the newest forms of educational activity, the modernisation of educational approaches will contribute to forming competent specialists, who will meet the needs and demands of Industry 4.0. In its turn, Industry 4.0 provides an implementation of new digital solutions for the optimization of production systems. New development opportunities appear thanks to the connection between Industry 4.0 opportunities and educational transformations. Education of workers for connecting complex productive environments plays a key role. The main educational role is in the development of competencies, necessary for a competitive and changeable market. Digital competency is the main condition for transformation in the 4th Industrial Revolution.

Such challenges and demands of the time caused the need for approval and implementation of The Digital Competence Framework for Citizens in Ukraine (Ministry of Digital Transformation of Ukraine, 2021b). The Framework was adapted after a complex expert analysis counting on the results of projects and scientific works concerning the development of digital competency in Ukraine and outside its borders. The Framework is based on the European model DigComp 2.1, which is adapted for the national, cultural, educational, and economic features of the country.

Yet we can see that until now the essence of education has stayed still, and conditions of learning and teaching are being changed very slowly and too carefully. On the governmental level documents which are supposed to regulate the implementation and spreading of digital technologies are being used, although

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the system of their usage is still incomplete.

The *purpose* of the article is to define the role of digital competency of participants in the educational process in projecting a digital educational environment.

2 LITERATURE REVIEW

Nowadays the question of learning theoretical, methodological and methodical aspects of digital transformation of secondary education and the creation as well as effective usage of the digital policy in an educational institution is fairly actual and not fully explored and summarised in the realisation of the Concept of a New Ukrainian school (Elkin et al., 2017), renewed Law of Ukraine "On the full secondary education" (Verkhovna Rada of Ukraine, 2020) and Framework of digital competency for citizens (Ministry of Digital Transformation of Ukraine, 2021b).

Problems of digital education are at the center of the pedagogical community attention, as evidenced by numerous conceptual and thorough studies of foreign and domestic scientists.

Berawi et al. (Berawi et al., 2020) claim that the spread of innovations changes stable economic systems and causes structural changes in various areas. Innovations become the basis of the need for digitalization of society. According to authors, digital technologies are used to manage integrated product life cycles and improve efficient, reliable and sustainable business operations. Artificial intelligence, internet of things, machine learning, blockchain, big data and other digital technologies are creating new conditions for the development of economies.

Zawacki-Richter and Anderson (Zawacki-Richter and Anderson, 2014) gives advice on how to organize distance education describing the positive aspects of distance education practices such as: cost issues, social justice issues, cultural biases, etc.

Gillpatrick (Gillpatrick, 2020) believes that the key drivers for changing education are the rapid introduction of new digital technologies, the development of new educational delivery systems, economic models as well as changing educational expectations from a new generation of learners, digital natives.

Gavrilova and Voronova (Gavrilova and Voronova, 2018) describes the theoretical aspects of modern digital environment development. The scientists describes the importance of digital culture skills as an indicator of successful pedagogical activity in the structure of the digital environment.

Barna and Kuzminska (Barna and Kuzminska, 2020) notes that today's challenges accelerate the processes of transformation of educational institutions. They describe the importance of designing, applying and developing a digital educational environment, the degree of possession of digital competences by all participants of the educational process. Analyzes of indicators of the educational institution's readiness for digital transformation and tools for their assessment are conducted. Digitization of educational environments (unlike to informatization) involves a change in the implementation of educational business processes, the creation of new services and forms of interaction for maximum realization of the potential of the educational process subjects and ensuring the accelerated development and evolution of institutions, economy and the state.

Morze and Strutynska (Morze and Strutynska, 2021) analyses the digital transformation processes currently taking place in the economy, production, education and society as a whole. Scientists assume that the driver of digital transformation is the influence of digital technologies. One of the key issues for the implementation of digital transformation is changes in the way of thinking and requirements for the competences of employees in the industry. First of all, it is related to people's understanding of digital transformation processes and their ability to use digital technologies effectively.

Researchers of the problems of education transformation pay considerable attention to the management of the formation of the state educational policy and directions of its development, part of which is the educational policy in the field of the use of digital technologies. Methodological principles and various aspects of the implementation of the state educational policy in the field of education management were studied by Karim (Karim, 2021). The author described the stages of design and implementation of the development of educational policy and practice in a globalized world

Hardy et al. (Hardy et al., 2021) describes Finland's experience from reforms to real implementation.

Separate issues of the digital transformation of educational policy highlighted in (Kuzminska and Nanaieva, 2016; Sych et al., 2021).

3 RESEARCH RESULTS

In 2021 the Concept of the development of digital competences was accepted (Cabinet of Ministers of Ukraine, 2021). This move was more than just necessary, as the absence of conceptual basics of how to form educational policy in the digitalization sphere doesn't allow to provide the development of other spheres according to modern demands, tendencies, and processes of global economic digitalization. The concept is made for solving specific tasks:

- defining law regulation of aspects of digital competencies;
- forming demands and descriptions for necessary digital competencies;
- renewing professional standards;
- shaping demands for digital competencies in educational institutions;
- creating an indication system for monitoring the development of digital skills and digital competencies;
- coordination of actions for the realization of governmental policy in the sphere of digital development and digital competencies.

The main obstacle on the way to creating digital transformation of the educational process is the lack of understanding of where to start, the absence of a systematic view and understanding of necessary and sufficient measures for a successful digital transformation as such. As the perspective of radical changes can be deceitful, it is important to understand which strategy to choose and how to develop an effective educational policy in the digital sphere and create a quality educational environment. Conduction of studies on the digital literacy of education applicants, graduates, pedagogical workers, and managers will contribute to the search for the right way for creating educational policies.

The approval of the Framework of digital competencies for citizens (Ministry of Digital Transformation of Ukraine, 2021b) makes demands for all the participants in the educational process as the basics of computer literacy, information literacy, the ability to work with data, creating digital content, communication and interaction in a digital society, digital safety, problem-solving in a digital society and lifelong learning are the competencies everybody working in educational sphere needs. Measures, described in the Framework, are wholesome and in one way or another, they define the necessary set of skills for teachers, students and managers. Those skills are necessary for both domestic and professional aspects. Usage of the Framework forwards adding and changing professional standards and demands for positions, also the creation of the programs for studies, training, and educational resources. Creating detailed professional Frameworks will contribute to increasing competitiveness and the level of giving services.

The Ministry of digital transformation of Ukraine together with the Ministry of Education and Science of Ukraine has created a project called "Conceptual referent Framework of digital competency of pedagogical and scientifically pedagogical workers" (Ministry of Digital Transformation of Ukraine, 2021a). The European model of Framework for educators called "The Digital Competence Framework for Educators" (DigCompEdu) is the base of the Ukrainian one (European Commission et al., 2017). The Framework for educators includes 5 measures, 5 spheres, 22 competencies and 5 levels of owning. It characterises digital technology in education as a transformed environment, which gives extended possibilities for learning without borders in time and location. Thanks to using the Framework comes up the opportunity of projecting individual education trajectories for educational applicants. New approaches for using technologies will contribute to a faster change from simple consumption of electronic resources to their creation. According to the approach described in the Framework, the teacher becomes a guide in the digital world instead of being a library full of knowledge as it used to be. Therefore, it becomes a push for increasing the level of personal competencies for teachers and managers of educational institutions.

Poor level of digital competency among teachers makes the process of forming high competency among students much slower. The results of the digital competency level made by the Ministry of digital transformation in 2021 (Ministry of Digital Transformation of Ukraine, 2021c) showed that almost 30 % of studying youngsters in the secondary educational institution system, 14 % in the secondary special education system and 3 % in unfinished higher education don't have basic digital skills and 39.4 %, 47.2 %, 26.7 % accordingly have skills on the level lower than medium.

In 2019 (Ministry of Digital Transformation of Ukraine, 2019) for the first time in the history of Ukraine, there was a sociological survey of the digital skills of citizens. After getting the results, the design of a National online platform for developing digital literacy started. Thus for today, we have already formed a certain bank of National testing for digital literacy (Ministry of Digital Transformation of Ukraine, 2023):

- Digigram 1.0 for citizens;
- Digigram 2.0 for citizen;
- For government workers;
- For medical workers;
- For teachers;
- ICDL Ukrainian digital citizen.

Digigram is a national test for estimating digital competencies. It consists of 90 questions. The tasks of the test are gathered according to the spheres of knowledge from the European The Digital Competence Framework for Citizens of DigComp 2.1. (Carretero et al., 2017), adapted by Ukrainian experts.

In 2021 (Ministry of Digital Transformation of Ukraine, 2021c) there was a repeated survey of digital literacy done among Ukrainians, and the following results were received. The questionnaire was held among 1800 respondents from 18 to 70 y.o. as a face-to-face interview, 410 respondents from 17 y.o. in an online format, 401 respondents from occupied territories of Donetsk and Luhansk region from 18 to 60 as a face-to-face interview, 349 respondents with hearing problems as an online questionnaire, and also 8 groups of respondents of other categories, specifically workers of medical sphere (doctors), educational sphere (teachers), local authorities and communal services sphere, elderly people (people of 60 and more years). For comparison, in 2019, the sample consisted of the following respondents: 1800 respondents from 18 to 70 y.o. as a face-to-face interview, 859 people from 10 to 17 as a face-to-face interview, 400 respondents from occupied territories of Donetsk and Luhansk region from 18 to 70 as a face-to-face interview, 219 respondents from 18 to 59 respondents with hearing problems as a questionnaire.

In the new research, we can see the dynamics of changes, the majority of which move to improvement. This way for the period of the 2019-2021 years the part of people who have Internet access rose by 4 %. The situation in 2021 was that 92 % of respondents had access to the web. For the majority of participants who didn't have access, the access wasn't considered a necessity.

Compared to 2019 (Ministry of Digital Transformation of Ukraine, 2019) the part of those who don't set Internet at home because of not being able to use it has shrunk by 17 %. We can see a decrease among respondents who have the "No skills" category and, as an outcome, the number of people with levels identified as "Basic" and higher, increases.

Dynamics of increase of digital skills is visible according to the next parameters:

- 36.8 % skills of creating digital content (+6.7 %);
- 79.2 % communicative skills (+3.5 %);
- 78.9 % informational skills (+2.8 %);
- 55,8 % skills of solving life problems (+2.6 %).

It is worth mentioning that from 2019 (Ministry of Digital Transformation of Ukraine, 2019) the most developed skills have been informational and communicative. Demand for digital skills is partially caused by increasing the number of people who within the last year faced problems connected to safety because of using the internet. Compared to the year 2019, the percentage of victims increased almost by 12 % and became 45.7 % of participants. From them, 37.3 % of Ukrainians faced fishing last year, and 18 % faced farming. A positive conclusion is the fact that almost half more people compared to 2019 (Ministry of Digital Transformation of Ukraine, 2019) became more careful and aware while using the Internet.

According to the research from 2019 (Ministry of Digital Transformation of Ukraine, 2019), 53 % of the population of Ukraine had digital skills lower than a basic level, in 2021 shrunk by 5.2 % or 1.42 million people and now is 47.8 %.

The percentage of people who used the Internet within the last 3 months at the moment of the survey was 88 % of the respondents, and 93 % of them did it almost every day. The most popular place for using the Internet was and stays home (89 % of Ukrainians), second place is work and place of study. The leader device for using the Internet is still a smartphone.

52 % of participants mention that they tried online tools, the most spread of which are applications for buying goods online, monitoring news on the Internet, and remote working for the first time during COVID-19. The third part of the respondents mentioned that since the pandemic started, they began spending more time online. 53 % of asked Ukrainians aged from 18 to 70 y.o. buy things online and this indicator is 13 % higher than in 2019 (Ministry of Digital Transformation of Ukraine, 2019). Most people buy clothes, and domestic goods and make regular payments.

An average Ukrainian spends approximately 3 hours 50 minutes online during the weekdays and 4 hours 05 minutes at the weekend.

8 from 10 of the participants think that using the Internet has more advantages than disadvantages, and 44.4 % are interested in improving their digital skills. The most interested in learning is the group of young people from 10 to 29 years old. Respondents are interested in learning the basics of online safety, quick and efficient searching for information on the net, being able to differentiate between reliable and non-reliable sources and using online banking services.

Therefore, there is a need in ensuring that society is ready for gaining the key competencies for the digital technologies sphere. Experience shows, that for the development of the digital competency of stakeholders in the educational process the sufficient condition is creating a digital educational environment, effective usage of which will lead to ensuring the quality of the results of educational activities of students.

The educational policy can fasten the progress of renewing approaches to using digital educational technologies. A clear plan for all the interaction levels will contribute to broadening the opportunities of educators for using digital technologies which help their professional activity.

For creating educational policy, it is essential to define the outer and inner components of the educational environment and tools to use, the efficient way for interaction between the participants of the educational process and the way of coordination, management, and estimation of the results. It is important to note that such activity isn't limited to working on an educational institution's territory, on the contrary, it continues to exist outside of those institutions, thanks to digital tools as well as other tools.

Based on scientific research analysis (Kulesz, 2017) we created a model showing the ways of projecting a digital educational environment (figure 1).

Relying on the model and The Digital Competence Framework for Citizens (Ministry of Digital Transformation of Ukraine, 2021b), we can create an algorithm for the implementation of digital educational policy in a secondary school institution (figure 2).

Innovations have great potential for ensuring the quality of educational programs, although participants of the educational process may not be ready for the integration of the technologies and not have corresponding knowledge and skills for using them. Successful usage of digital technologies in an educational program relies on teachers' and managers' readiness for accepting changes (Intel, 2019).

The world has already got different resources and tools for estimating the digital competency level. For instance, MyDigiSkills, Wheel of digital competency, Digital Skills and Jobs Platform, Digigram, and SELFIE.

MyDigiSkills is a tool allowing to define the level of digital competency based on each of five areas of the European system of The Digital Competence Framework for Citizens (DigComp) (Carretero et al., 2017):

- Informational literacy and data literacy;
- Communication and cooperation;
- Creating digital content;
- Safety;
- Problem solving.

The resource is available in Ukrainian, and the online questioning lasts for about 20 minutes and consists of 82 questions approximately.

The Wheel of digital competency is an online test for defining digital competency. It is available in English. The Wheel is designed by the Digital competency centre. The purpose of the survey is to create an understanding of the level of personal digital competency and to suggest resources for further development. The Wheel of digital competency is also theoretically based on an exploratory project of EU DigComp (Carretero et al., 2017).

Digital Skills and Jobs Platform is an online platform with an opportunity to estimate the digital competency level. According to the conclusions of the survey, there is an opportunity to create a road map for the development of your competencies based on interests and goals, and afterwards, there is the possibility of taking such a course on the platform.

From the point of view of the analysis of secondary educational institutions, therefore the main step before designing ICT policy should be the SELFIE tool (JRC et al., 2021), using which is, in our opinion, a necessary condition for creating an educational institution's outer policy in the sphere of digitalization of educational environment.

SELFIE is a free online tool, which helps schools estimate their usage of digital technologies for innovative and effective learning. This process of self-evaluation helps to start a dialogue about potential directions for development at schools. Thanks to SELFIE, schools can make a short description of where they stand in using digital technologies, taking into account boards of teachers, students and class tutors (JRC et al., 2021).

Usage of SELFIE by educational institutions is an important tool of the algorithm for implementing a digital policy of an educational institution. SELFIE lets schools find key problems in digitalization, form the ways of their solving, and set specific goals for key indicators of efficiency.

During 2020-2021 ninety-one educational institutions piloted SELFIE. The general quantity of respondents was 12714, 10447 were students, 1899 teachers and 368 institutions managers. 1193 primary educational institutions, 10592 secondary school institutions, and 929 professional education institutions took part in the experiment. The average level of digital preparation of participants, which went through the survey, was 7.97 (figure 3).

The highest indicator of preparations was seen among the managers of the institutions, average – of 8,81, although the teachers also showed a fairly high result of 8.25. The students showed an average result, which was 7.89 (figure 4).

Among educational institutions, the highest level is seen in professional educational institutions – 8.30. Almost equal data is seen among the primary educational institutions and secondary educational institu-

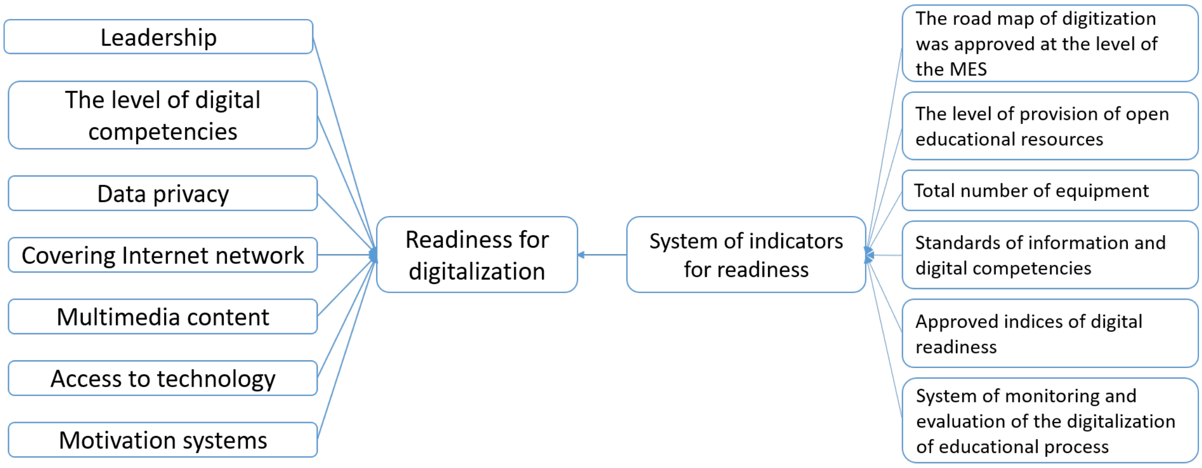

Figure 1: A model of projecting a digital educational environment.

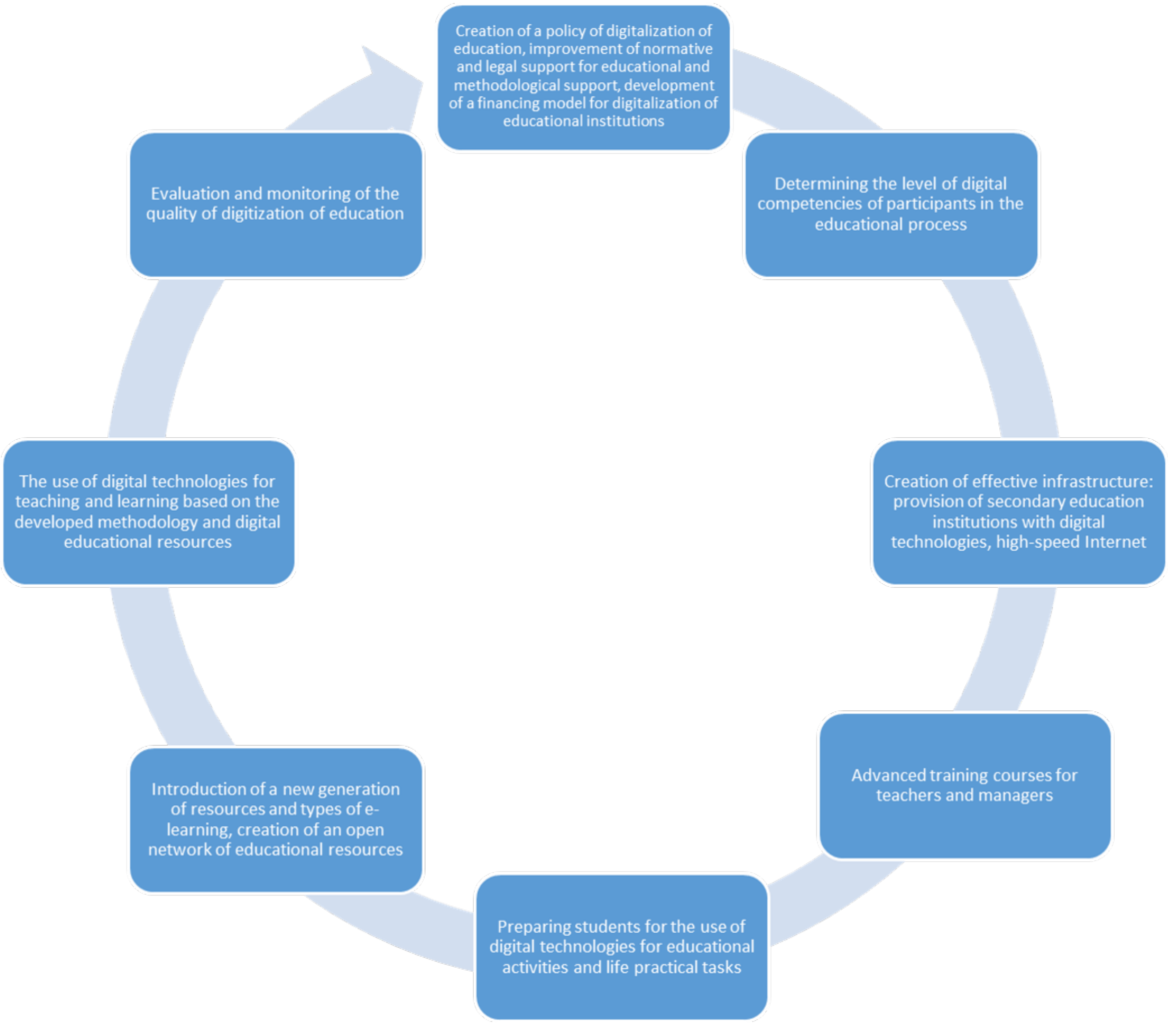

Figure 2: Steps for implementing digital educational policy into secondary educational institutions.

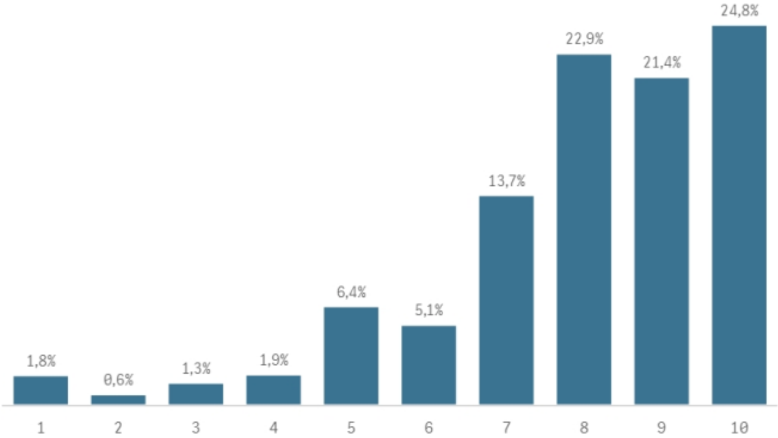

Figure 3: Percentage frequency distribution.

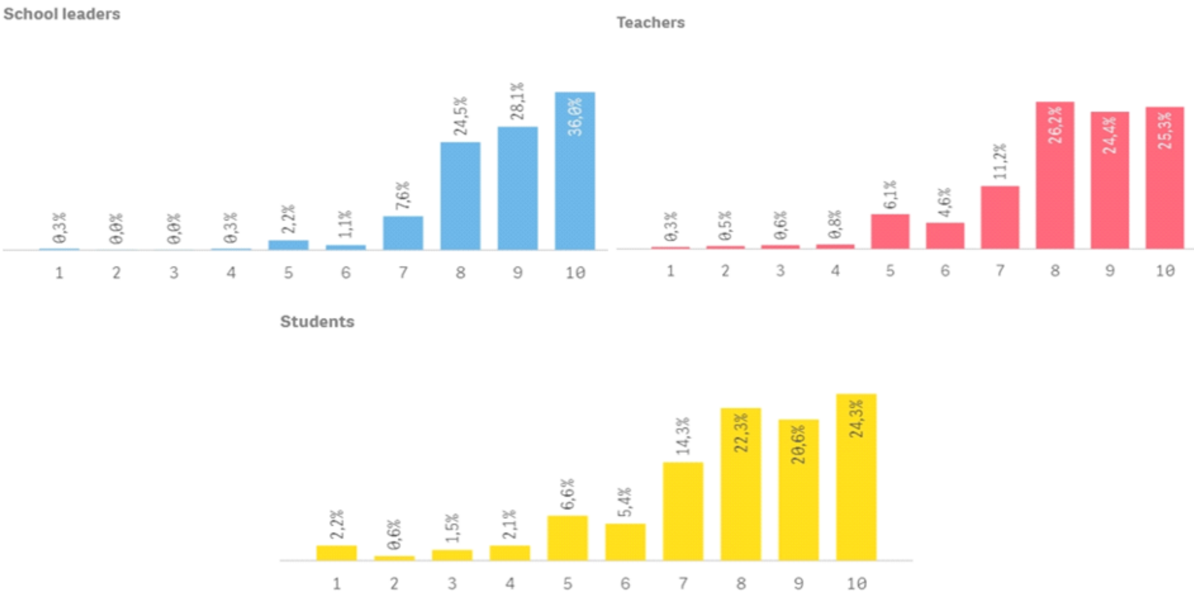

Figure 4: Percentage frequency distribution by user profile.

tions, which are 7.96 and 7.95 accordingly.

For now, educational institutions need to learn the results gotten, create a plan for fixing the existing flaws, and, as the next step, design a strategy of development for digital technologies.

The Ministry of Education and Science of Ukraine plans that from the beginning of a new academic year there will be preparation for a broad implementation of SELFIE (JRC et al., 2021) in all the systems of secondary and professional education.

4 CONCLUSIONS

Summarising foreign and domestic experiences analysis of scientific and methodical sources, methods, ways and tools of digital transformation of secondary education and organization of self-assessment of all the participants of educational process on the questions of implementation of digital technologies in Frameworks of designing educational policy, defining the ways of designing digital educational environment of a secondary educational institution, the results of the conducted survey let us make the following conclusions.

1. The modern educational system in Ukraine, and the educational process of every specific institution needs digital transformation, which can ensure the quality and efficiency of the educational process. For the sake of it, it is appropriate to foresee and project educational policy, which will include aspects of digitalization and development of

digital educational environment. Necessary and sufficient conditions for its effective usage is a high level of digital competency of all stakeholders of the educational process. Thanks to the fast development of digital technologies and modern techno trends systematic approach to digital transformation imply complex interaction of all participants in the educational process. For avoiding resistance to the usage of digital technologies it's important to delineate the advantages of digital transformation in education and popularise it on the governmental level as well as locally. Understanding and using educational digitalization are the key to success, that's why prioritizing this is important. Highlighting contribution to the development of digital community among teachers and students, having made its a base of the educational policy of an educational institution, it is possible to create quality and effective educational space for the new generation. In its turn, it will help an educational institution to stay actual, suggesting to educational applicants a modern level of learning. The level which is needed for further success in life. Projecting, designing, developing, and using a modern digital educational environment is the right way for the digital maturity of all its participants.

2. Realization of this model of digital educational environment requires creating a team of like-minded people, defining the main goals and tasks, technologies, methodologies, and innovations needed for their achievement. An important stage of the digital educational environment will be the stage of defining and further shaping of levels of digital competency of all the participants in the educational process: students, teachers, educational managers of different levels, parents as citizens of digital society, employers as citizens of digital society and business-communities.

3. Monitoring the level of digital skills and digital readiness of all the participants in the educational process is an integral part of the algorithm for designing and implementing digital policy in a secondary educational institution, and that is why every educational institution should be required to have demands for the digital competency level of all participants and ensure it with the help of arranging special seminars and training for advanced training and learning. Choice of the tool, which will allow an educational institution to arrange self-reflection and self-assessment correctly and will help estimate the level of readiness for the digitalising the educational environment, plays an important role. The SELFIE tool helps educational institutions to analyse and estimate the current state of digital competency, and to develop educational programs and processes in the future. Renewing the content of learning, improving the digital competency of all participants in the educational process, the newest pedagogical technologies, and modern logistical equipment are the factors which form the quality of given educational services.

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Advanced Technological Solutions to Support Distance Learning via Open-Source H5P Interactive Tools

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Abstract: The widespread introduction of distance learning in the conditions of quarantine restrictions caused by COVID-19 increases the need to modernize the resource-and-organizational as well as methodological support of the educational process. The materials of the present paper embrace the study of the possibilities of using open-source H5P tools to support distance learning in higher education institutions. The authors analyzed the state of research of the problem of development and introduction of interactive didactic H5P tools in higher education institutions and identified insufficient use of this tool in higher education institutions of Ukraine despite successful foreign practices in place. Based on the results of the comparative analysis of the functionality of various means to support distance learning, which have become most common in higher education institutions, they defined the benefits of using H5P to maximize the involvement of students in distance learning and demonstrated the wider possibilities of creation, use and distribution of interactive educational elements on the basis of H5P in comparison with other technologies. The paper presents the results of a questionnaire conducted among the academic staff of the National University of Life and Environmental Sciences of Ukraine and Wrocław University of Environmental and Life Sciences on determining the complexity of development and pedagogical feasibility of using various H5P tools to support distance learning. Based on the analysis of academic staff's needs, they determined the necessity for specialized training on pedagogical design of the content of H5P didactic materials, delivery technologies and methods of their use in teaching various disciplines of higher education.

1 INTRODUCTION

As new information technologies and digital tools are developed and disseminated, technologies for the development, delivery and use of educational content are being enriched to ensure the quality of e-learning, taking into account: students' learning styles and age characteristics (Umryk, 2013), the available resources and competence of the subjects of the educational process (Kuzminska et al., 2019). However, during the mass transition to distance learning (Stauffer, 2020) in the conditions of COVID-19 (Miller, 2022), the problem of providing quality education is relevant, which, in our opinion, requires the training of specialists who will be able not only to use ICT in educational activities, but also acquire competences in e-learning management (Morze et al., 2017). Analysis of the attitude of teachers and students to the opportunities and problems associated with the introduction of distance learning (El Refae et al., 2021) is the basis for the assumption of actualizing the need to develop interactive teaching materials and educational content as a means of ensuring quality student-centered education (Homanová and Havlásková, 2019). The creation of interactive didactic materials and methods of their use in the educational process will contribute to the involvement of students in active learning: students can create resources independently or "interact" with the teacher to increase motivation, better understanding of learn-

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ing material, practical skills, evaluation of their own learning activities, etc.

From a technical point of view, the use of tools to create interactive didactic materials was limited by the need for computer programming skills. However, with the development of H5P technology, an open-source Internet tool, the creation of such materials does not require special training.

Therefore, **the purpose of this study** is to identify the potential of H5P to support distance learning in higher education institutions and to analyze the teachers' needs as for its application in educational practice.

2 THEORETICAL BACKGROUND

H5P (https://h5p.org/) is a module with a library of learning resources developed in HTML5, which is integrated for direct use in publishing systems (namely: Wordpress, Drupal) and learning management systems (such as Canvas, Moodle or Blackboard). The latter allows you to create interactive learning elements (development can be done by both teachers and students, for example, when doing independent work), which can be used at different stages of e-learning to form both general and subject competences of students.

The conducted analysis of research and publications on the use of H5P service in education is the basis for expressing an assumption about the effectiveness of the use of this service in the process of training specialists regardless of the educational program and specialty.

Santos et al. (Santos et al., 2019) represent the method of using the H5P service as a tool for gamification of practical skills (students' laboratory work) on local network administration, which provides a fast, intuitive and attractive for students method of applying the Flip-Game Engineering and Technology methodology (Flip-GET), developed by researchers at the University of Cadiz.

Methodology and practical cases of H5P application in the process of learning English in higher education institutions in Japan and Indonesia are presented in (Wicaksono et al., 2021). The experience of using H5P didactic materials in the study of chemistry (Zeller et al., 2021) is an example of the transformation of video into an interactive educational resource. The results of a study of the use of H5P in the training of future specialists in biological sciences (Manacek et al., 2020) indicate that this platform is an effective and universal tool for forming students' critical thinking, independence and confidence in mastering educational material in problem-oriented learning. Methodical recommendations for creating an interactive H5P video for the implementation of personalized and active learning are given in (Singleton and Charlton, 2019; Thurner et al., 2022). The experience of using H5P tools for the implementation of blended learning (Sinnayah et al., 2021) and development flipped classroom framework (Wehling et al., 2021) based on learning management systems highlights the need for additional research on the application of these tools in the educational practice of Ukrainian higher education institutions.

Research tasks:

1. To investigate the functionality of H5P for the feasibility of using the H5P service to create and distribute interactive content.
2. To analyze the needs and readiness of the academic staff of the National University of Life and Environmental Sciences of Ukraine (NULES) and Wrocław University of Environmental and Life Sciences (WUELS) to create and use interactive didactic H5P materials in the educational process.

To achieve the goal and objectives of the study, the following methods were used: analysis of theoretical sources, study of successful H5P practices in the educational process of higher education institutions; generalization and systematization of experience in the use of e-learning support tools; empirical methods, in particular, questionnaires and monitoring of the educational process in higher education institutions during the implementation of distance learning during the COVID-19 quarantine restrictions.

3 MAIN FINDINGS

H5P is an open tool for creating, distributing and reusing educational interactive content, based on HTML5, CSS and JavaScript technologies, which does not require additional software for its work, therefore will work in all modern browsers, operating systems and devices.

Since H5P technology is integrated into a number of learning management engine drivers, such as Moodle, Canvas, Blackboard, Brightspace, and a variety of web content management systems, such as Wordpress and Drupal, integration into the higher education environment does not require additional costs at the technological level (environmental administration) and organizational – teachers can create educational content in a convenient for them environment with the ability to save and reuse. Figure 1 shows an example of creating and demonstrating the "interac-

Table 1: Comparative analysis of H5P, Moodle and Google Workspace functionality (not all the available H5P functionality is considered).

Purpose	Program	Module	Features
Folding text blocks (“accordion”)	H5P	Accordion	Ability to create a hidden (folded) text block with image formatting, etc.
	Moodle	Absent	Implementation using HTML, CSS or Bootstrap classes
	GWorkspace	Absent	
Interchangeable pictures swapping	H5P	Agamotto	Using simulation of dynamic change in time on the map, in space, zooming out/zooming in
	Moodle	Absent	
	GWorkspace	Absent	
Recording audio messages	H5P	Audio Recorder	Recording audio messages directly from the browser
	Moodle	Function in ATTO	The corresponding functionality is implemented in the built-in ATTO editor
	GWorkspace	Absent	
Creating flash cards	H5P	Dialog Cards, Flashcards	Several solutions are available
	Moodle	Absent	
	GWorkspace	Absent	
Creating test questions	H5P	12 types of questions	Drag and Drop, Drag the Words, Essay, Fill in the Blanks, Find Multiple Hotspots, Find the Hotspot, Image pairing, Image Sequencing, Mark the Words, Multiple Choice, Single Choice Set, True/False Question
	Moodle	15 types of questions + informal types of questions	Implementation of standard types of questions: Calculated, Simple Calculated, Drag and drop into text, Drag and drop markers, Drag and drop onto image, Calculated Multichoice, Essay, Matching, Embedded Answers (Cloze), Multiple Choice, Random Short Answer Matching, Select missing words, Short-Answer, Numerical, True/False
	GWorkspace	9 question types (in Google Forms)	Short answer, Paragraph (Essay), Multiple choice, Checkboxes, Dropdown, File upload, Linear scale, Multiple choice grid, Checkbox grid
Holding tests	H5P	Quiz	You can choose from only 6 types of questions; available mixing of questions, sample questions; not recommended for final testing
	Moodle	Quiz	Full-fledged testing with lots of settings, automatic checking and review of ratings; possible reuse of questions in different tests
	GWorkspace	Forms	Standard Google form with Google spreadsheets connected to display test results
Timeline creation	H5P	Timeline	Create a timeline with slides on timestamps
	Moodle	Absent	
	GWorkspace	Absent	
Interactive book creation	H5P	Interactive Book	Multi-page resource with an ability to embed almost any of the other elements of H5P on any page, including test questions
	Moodle	Book	Multi-page resource with text, graphic information, embedded video, audio; without the possibility of testing
	GWorkspace	Absent	

tive video" module directly in the Moodle environment (implemented in the training and information portal of NULES).

In the absence of a learning environment in an educational institution with which H5P technology is already integrated, interactive learning content can be created and stored in the commercial cloud (https://h5p.com) or in the community one (https://h5p.org) (H5P, 2023). To use the H5P cloud, you need to register, after which users have the opportunity to post their own projects, optimize downloaded videos, adjust the parameters of educational analytics for students using individual projects, share materials on other sites and use additional features. The https://h5p.org site is an open resource for creating interactive materials, testing them, and commenting on resources created by other users. In addition, the Lumi desktop application has been developed for teachers who prefer to create offline learning content. In any of the three described options, the program interface is identical, simple and clear. So far, templates have been developed to create 49 types of H5P content (https://h5p.org/content-types-and-applications). They can be approximately grouped into three main categories: game content (Games), multimedia content (Multimedia), and methods of testing students' knowledge (Questions).

Since a number of higher education institutions use learning management systems that have their own modules for creating interactive didactic materials to deliver educational content and organize e-learning (blended, distance learning), a comparative analysis of H5P, LMS Moodle and Google Workspace functionality was additionally conducted (table 1, 2).

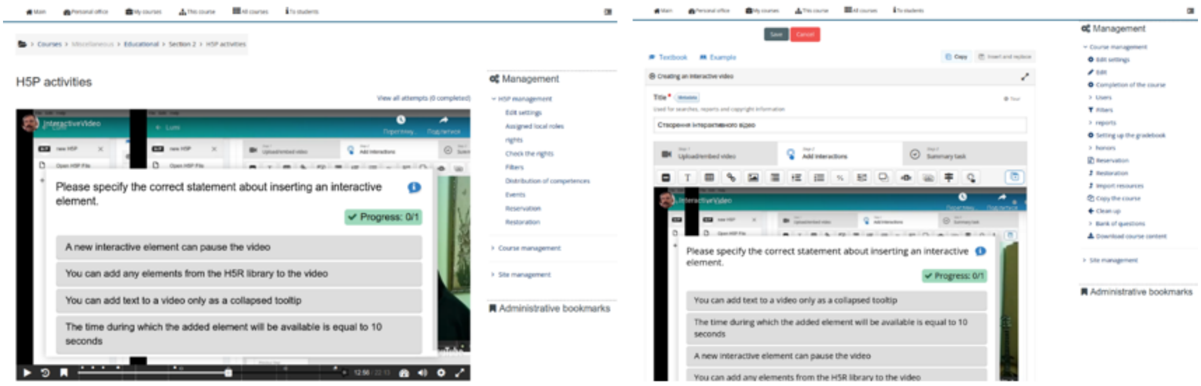
As you can see from table 1 and 2, H5P technology has many more unique interactive learning elements than those that Moodle and Google Workspace can offer. In addition, H5P can be integrated into other learning management systems to expand their functionality and increase the freedom of teachers to use pedagogical technologies and disseminate their own learning content. It should be noted that unlike Moodle, in which H5P is fully integrated, integration with Google Workspace involves embedding individual elements from the site https://h5p.com. You can also download the created H5P element to a local computer as a file and then distribute it not only in learning management systems, but also on the sites of publishing systems to which this technology is integrated.

To determine the feasibility of using H5P technology for the development of didactic teaching materials and the readiness of teachers to use them in the educational process (the second task of the study), specialized training of the academic staff of NULES and WUELS was conducted. Within the "Distance Learning Tools" course (https://elearn.nubip.edu.ua/course/view.php?id=3000) the representatives of the center of distance learning technologies NULES developed (https://elearn.nubip.edu.ua/course/view.php?id=216) a "Fundamentals of working with H5P" module, in which the teachers had the opportunity to get acquainted with the functionality and features of using H5P technology, as well as to develop separate didactic materials (figure 2).

To determine the attitude of the academic staff to the use of H5P technology in educational practice, a questionnaire was conducted (https://forms.gle/CgVpKWYkqgaUUhm16).

58 faculty members of NULES (46 members) and WUELS (12 members) were embraced by the questionnaire, who train future specialists in the field of technical sciences (41.7%), natural sciences (32.6%) and social sciences (25.7%). The vast majority of respondents are middle-aged people (5.7% – up to 25 years; 30.8% – 25-35 years; 41.3% – 35-45 years; 19.4% – 45-55 years; 2.8% – over 55 years old) with a sufficient level of digital competence (68.3% defined their own level of digital competence as sufficient; 25.6% – high; only 6.1% – basic). All respondents stated that they have experience in using e-learning resources, with 76.4% developing e-content independently. 100% of respondents supported the statement that the use of interactive educational content helps to increase students' learning motivation; 91.3% agree that the study material needs to be adapted to the learning styles and needs of the students. Therefore, it is possible to make assumptions about the high degree of readiness of the academic staff to use interactive content in the educational process. At the same time, H5P technology is new for the vast majority of respondents (awareness of specialized training was determined): to the question "Do you know about H5P technology?" 14.1% gave an affirmative answer, and only 1.2% stated that they have experience in developing their own didactic materials.

Upon completion of the training, 63.6% of respondents answered the question "Do you consider it appropriate to use didactic H5P materials in your own e-learning courses?" in the affirmative, especially if there is sufficient and quality methodological support (100% of respondents need methodological assistance). 27.1% refused because, in their opinion, the development of H5P materials for the discipline they teach (mainly in the natural sciences) requires additional equipment, for example, for video recording, and their use is restricted under the copyright law. Only 9.3% of the surveyed teachers gave the negative

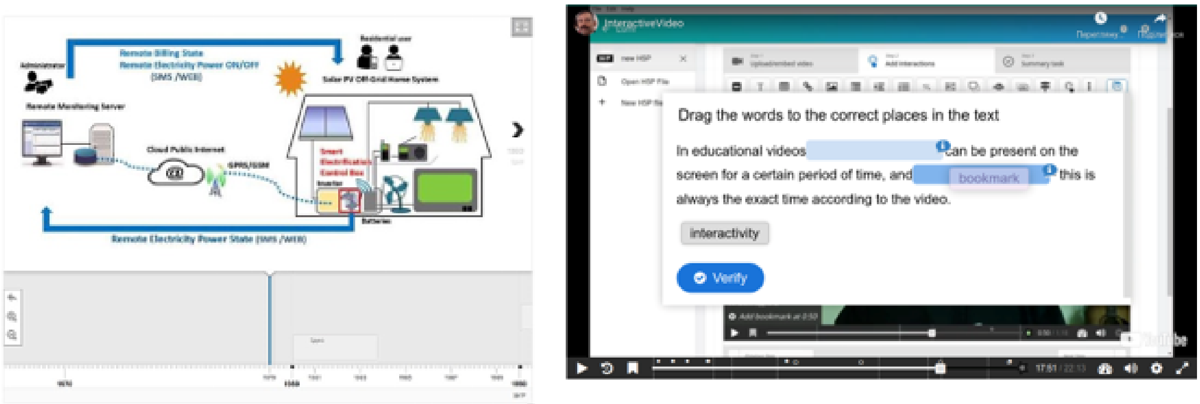


a) b)

Figure 1: Example of an educational interactive H5P element in the Moodle environment (a – educational video viewing mode, b – interactive video editing form).

Table 2: Comparative analysis of H5P, Moodle and Google Workspace functionality (not all the available H5P functionality is considered).

Purpose	Program	Module	Features
Interactive video creation	H5P	Interactive Video	Feed interactive material directly in the video clip; with a possibility to add test questions
	Moodle	Lesson	Video feed by separate clips with a possibility of adding test questions
	GWorkspace	Absent	
Construction of an individual trajectory of studying the topic	H5P	Branching Scenario	Ability to write a transition script depending on the pchoice of transition and answers to questions
	Moodle	Lesson	
	GWorkspace	Absent	
Panoramic image creation	H5P	Virtual Tour (360)	Panoramic image with the possibility of transition and explanations of the elements in the picture
	Moodle	Absent	
	GWorkspace	Absent	



a) b)

Figure 2: Examples of created interactive elements (a – timeline, b – interactive video with a question on top of the video).

answer.

Given the broad functionality of H5P, in the final questionnaire, researchers were asked to assess on a 5-point scale the pedagogical feasibility of using individual interactive H5P elements (table 1) in the learning process (group I questions) and the complexity of

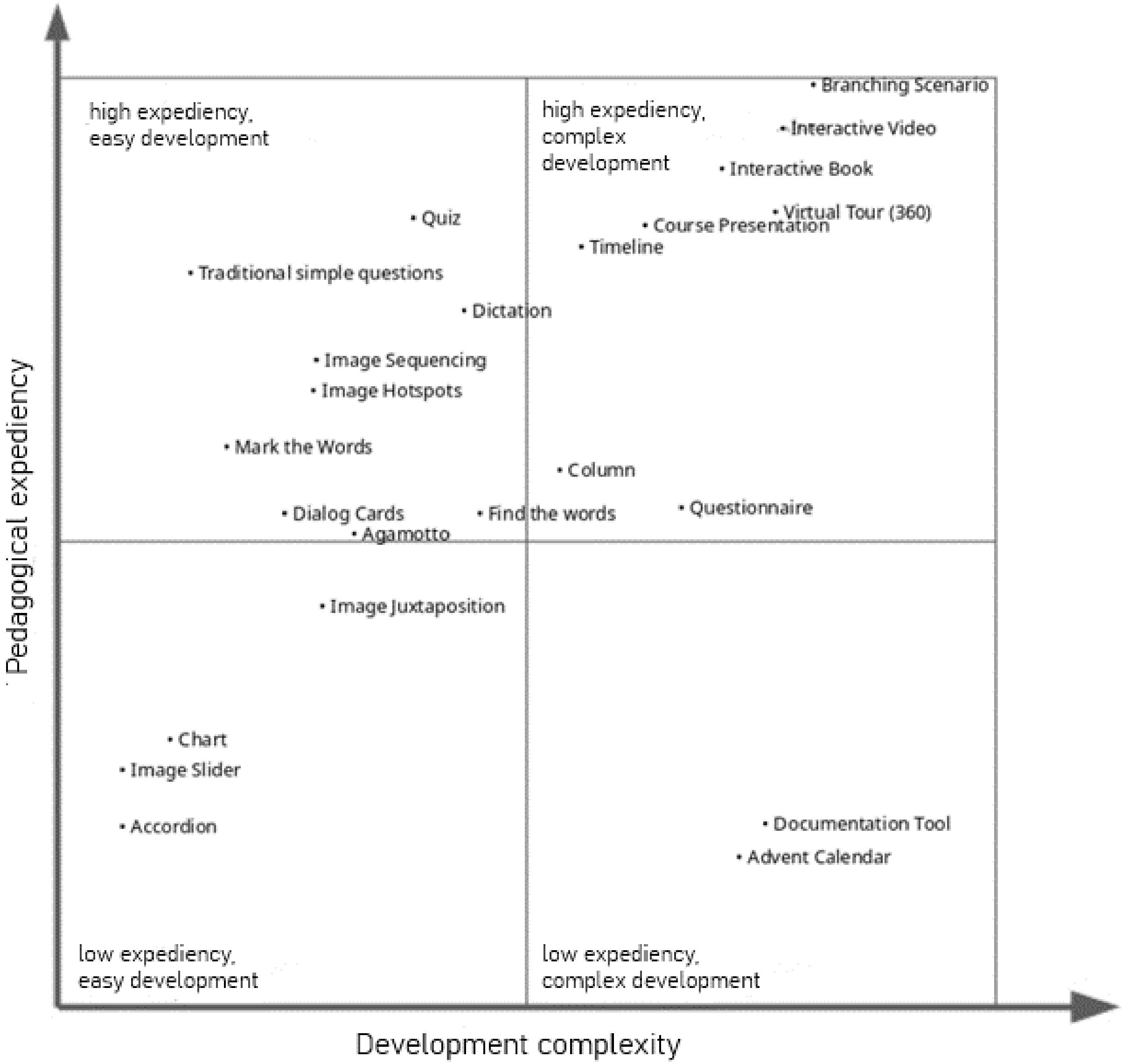


Figure 3: Matrix of correlation of development complexity and educational effect from application of separate elements of H5P technology.

their independent development (group II questions). Having created a matrix with four quadrants and reflecting the complexity of development (x-axis) and pedagogical expediency of application (y-axis), the authors visualized the attitude of the academic staff to the development and use of H5P didactic tools in the educational process (figure 3).

According to the academic staff surveyed (figure 3), the most optimal (high pedagogical expediency and ease development) is the use of different types of questions that can be added to the educational content. Not much more difficult to develop, but also appropriate, is the use of full-fledged tests. It should be noted that H5P developers do not recommend using such tests for final assessment, but only for the current test of knowledge and self-assessment of students. It should be noted that the pedagogical expediency of using educational elements with a script game ("Branching Scenario"), interactive video ("Interactive Video"), interactive book ("Interactive Book") is high, despite the relative complexity of their creation. Creating such interactive elements requires more prior training, digital competence, and implementation time from the teacher.

In general, the academic staff, according to the questionnaire, praised the educational effect of using H5P technology to support distance learning and noted their willingness to use it in the learning process. The need for additional training related to the pedagogical design of e-learning courses and methodological support in the use of interactive didactic H5P materials in teaching specific disciplines was also identified. The latter is defined as prospects for further research.

4 CONCLUSION

The massive transition to distance learning caused by the COVID-19 pandemic has highlighted the need for additional research to ensure the quality of education under quarantine restrictions. In this context, many factors favor the usage of the H5P service to create and disseminate interactive content as a means of strengthening the motivation and involvement of students in active learning. It is evidenced by:

- openness: H5P is an open-source software;
- integration with learning management systems such as: Moodle, Canvas, Blackboard;
- wide range of templates: 49 templates have been developed so far, based on which you can create materials of different complexity and degree of interactivity;
- choice of operating mode: you can work with interactive learning material on your own learning site, in the https://h5p.com cloud environment or in the desktop application;
- personalized use: teachers and students can store the created materials in personal environments or portfolios.

The results of comparing the H5P service with the Moodle and Google Workspace learning management systems are grounds for claiming that the development of interactive didactic content using H5P meets the requirements for innovative educational resources, expands the functionality of learning management systems and increases teachers' freedom to use pedagogical technologies. The questionnaire, conducted upon the completion of specialized training of the academic staff of NULES and WUELS, shows a high degree of readiness of the academic staff to use interactive content in the educational process if they are provided with technical and methodological support.

Among the various options for didactic content that can be created using H5P, teachers prefer to use interactive elements using educational video. However, given the complexity of independent development of such elements, the need to create a bank of educational video with the involvement of specialists in its shooting and editing is relevant. Instead, teachers have shown willingness to actively create a variety of test questions, as the proposed H5P templates significantly expand the functionality of LMS Moodle and Google Workspace.

Consequently, noting the potential of H5P as a tool to support distance learning in a broad context, the results of this study can be used by administrators and teachers of institutions of higher education to make a decision on the application of this technology in a specific HEI. Methodology of creating and using of interactive didactic H5P materials to support distance learning and professional development of the academic staff of Ukrainian and Polish higher education institutions are included in the prospects for further research.

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Computer Mathematics Systems and Tasks with Parameters

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Abstract: Methodological aspects of using software GeoGebra and GRAN1 for solving tasks with parameters are considered in the paper. Criteria of software selection are developed and a comparative analysis of the specified software for solving tasks with parameters is given.

1 INTRODUCTION

Modeling of various processes and phenomena is one of the main general methods used in scientific research.

Learning to solve tasks with parameters considered in the process of teaching mathematics is one of the preparatory stages for mathematical modeling, where models are studied under different conditions, in particular, under different values of the parameters of mathematical models.

For decades, solving tasks with parameters was usually included in the program of entry exams to higher education institutions of Ukraine, currently this skill is required for a successful completion of an external independent evaluation in mathematics, which has been held in Ukraine for more than 10 years. As evidenced by the practice and results of pedagogical research, solving tasks with parameters causes many difficulties for students (Ilany and Hassidov, 2014), more than 85% entrants at the external independent evaluation in mathematics do not even attempt to solve such tasks (Botuzova, 2019).

A number of publications are devoted to the teaching method of solving tasks with parameters (Amelkin and Rabtsevich, 2004; Gornshteyn et al., 1992; Prus and Shvets, 2016; Gonda, 2018; Zakirova et al., 2019).

With the development of computer technology and corresponding software, the range of such problems, means and methods of learning how to solve them have expanded. Among the most famous free educational software, that provide rational solving of tasks with parameters, GeoGebra, Wolfram|Alpha, SageMath and GRAN can be distinguished (Bhagat and Chang, 2015; Krawczyk-Stańdo et al., 2013; Gunčaga, 2011; Kramarenko et al., 2019; Kashitsyina, 2020; Hrybiuk, 2017; Kramarenko, 2005; Pokryshen, 2007; Ivashchenko, 2015; Zhaldak, 2016).

The topic of research publications on the use of software for the analysis of mentioned tasks covers various aspects of teaching methods for solving tasks with parameters: studying the forms of graphs of functions for different values of the parameter (Ilhan, 2013; Božić et al., 2021); using a computer to illustrate analytical solutions (Pokryshen, 2007; Gunčaga, 2011); the method of organizing the research activity of pupils and students in the process of preliminary graphic analysis of tasks solutions with the further analytical solution (Kramarenko, 2005; Hrybiuk, 2017; Kramarenko et al., 2019; Krawczyk-Stańdo et al., 2013; Gornshteyn et al., 1992); obtaining solutions of the tasks based on detailed graphical analysis (Ivashchenko, 2015; Zhaldak, 2016). As a rule, the cited works consider examples of tasks, where solutions can be obtained analytically, but this is an exceptional case in practice.

Despite the fact that a large number of studies on mathematics teaching methods have been devoted to this topic, in particular with the use of modern

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computer-oriented technologies, its importance is undoubtful, since the number of mentioned tasks and their types is constantly increasing. It is clear that for practical use it is important to know not so much the exact solution value of the task, which describes the mathematical model of a real process or phenomenon, but whether the task is compatible and stable. Then, with the use of modern software, it is possible to find an approximate value of a certain solution of the task with a predetermined accuracy, and that is quite sufficient for practice.

In this work there have been developed criteria for the selection of software, advisable for the use in the process of solving tasks with parameters.

The work contains examples of solving such tasks by both analytical and graphical methods. Considerable attention is paid to the tasks that cannot be solved by analytical methods. At that, the plotting of quite complex graphs of functions for different values of parameters with the use of appropriate software helps to avoid errors in the plotting of such graphs, to focus attention on the analysis of their form and to find the answer to the task question. Examining tasks that can be solved only approximately with the use of the graphic method expands the students' understanding that in the process of describing mathematical models of various objects and phenomena, such solutions are used as well.

2 COMPUTER MATHEMATICS SYSTEMS FOR SOLVING TASKS WITH PARAMETERS

Let's consider the conditions of selection and use of computer mathematics systems (CMS) for solving tasks with parameters.

Today, web-oriented software, including CMS, is being used more and more. As already mentioned, the software tools GeoGebra, Wolfram|Alpha, SageMath, etc are among the most popular freely distributed computer mathematics systems.

Wolfram|Alpha is a knowledge base of various scientific fields, including mathematical ones. It is based on various algorithms and technologies of artificial intelligence. The web-based version can be accessed at https://www.wolframalpha.com/.

SageMath is a free and open source math system licensed under the GPL. The web-based version can be accessed via the link https://www.sagemath.org/.

One of the most widespread educational computer mathematics systems in Ukraine is the software complex GRAN, as evidenced by a significant number of scientific and pedagogical publications devoted to various aspects of the organization and implementation of the educational process in modern learning conditions.

The software complex GRAN was developed at the National Pedagogical Dragomanov University under the leadership of M. I. Zhaldak. This complex consists of three programs: GRAN1, GRAN2D, GRAN3D.

The GRAN1 program is intended for graphic analysis and solving tasks related to the plotting of graphs of functions on the Cartesian plane, defined explicitly and implicitly, parametrically, tabularly, in the polar coordinate system; for processing statistical data, plotting graphs of the probability distribution functions of random variables, calculating definite integrals, the length of curves, the area of curved trapezoids, the area of surfaces and volumes of bodies of rotation, etc.

The first version of the GRAN1 was developed for the Yamaha personal computer back in 1990 by A. V. Penkov (Zhaldak et al., 2016). Later, GRAN1 was improved and adapted for use under the operating system of the Windows family by Y. V. Horoshko. In 2019, this software tool was laid out on a remote desktop, which allows it to be used through a browser remotely (Zhaldak et al., 2021), and not only on local computers. The GRAN-2D program is intended for graphical analysis of systems of geometric objects on a plane, and the GRAN-3D program is intended for graphical analysis of systems of three-dimensional geometric objects. The first versions of the GRAN-2D and GRAN-3D programs were developed in 2002. The complex is freely distributed and can be downloaded from the website https://zhaldak.fi.npu.edu.ua/.

One of the most common educational computer mathematics systems is the GeoGebra system. The first version of GeoGebra was developed in 2001-2002 by M. Hohenwarter (Hohenwarter and Fuchs, 2004). In December 2021, GeoGebra was acquired by the conglomerate Byju's (Singh, 2021). This software tool can be used both remotely and on a local computer by downloading the appropriate program modules. A component of the GeoGebra system are programs for graphic analysis and solving tasks related to the plotting graphs of functions on the Cartesian plane, defined in explicit or implicit form, in the polar coordinate system, tasks in the theory of probability, planimetry and stereometry. Using CMS GeoGebra, one can also create didactic materials for different users, provide access to them for others; create an educational classroom environment for students to use.

The table 1 analyzes the presence of program functions, which, in our opinion, are needed for graphical analysis of solving tasks with parameters.

Thus, it is advisable to use, first of all, GRAN1 and GeoGebra from the listed software tools for solving tasks with parameters. We will give appropriate examples.

3 SOME EXAMPLES

1. Solve the equation

$$1-\frac{3}{x+a-1}=\frac{5a}{(x+a-1)(x+1)}. \qquad (1)$$

To analyze the task, we will use CMS GRAN1. Let's plot graphs of functions

$$f(x)=1-\frac{3}{x+a-1}$$

and

$$g(x)=\frac{5a}{(x+a-1)(x+1)}$$

for specific values of the parameter a. To do this, we specify the parameter a by $p1$ (the default parameter name). Changing the values of the $p1$ parameter, for example, from -5 to 5 with a step 0.1 (these values are set by default) leads to a corresponding shape change of the graphs of the specified functions. The equation (1) solutions are the abscissas of the points of intersection of the graphs of the functions $f(x)$ and $g(x)$. Since for values of the parameter $p1$ from -4.9 to -3.1, from -2.9 to -0.1 and from 0.1 to 5 the graphs of the functions $f(x)$ and $g(x)$ intersect at two points, the equation (1) for such $p1$ has two solutions (figure 1).

If $p1=-5$, then visually the graphs of the functions intersect at one point, that is an exceptional case for the equation (1), since it, generally speaking, reduces to a quadratic equation, and therefore, under certain conditions, has two solutions. Therefore, it is advisable to consider the $p1$ parameter, for example, from -6 to 5.

Considering the shape of the graphs of the functions $f(x)$ and $g(x)$ for $p1=-5.2$, $p1=-5.1$, $p1=-4.9$ and $p1=-4.8$ and taking into account, that even increasing the scale for $p1=-5$ it is not possible to get a clear answer about the number of roots of the equation (1) (figure 2), we come to the conclusion about the need of analytical equation study (1) when the value of the parameter a is changing in a neighborhood of the point -5.

In the case when $p1$ equals -3 or 0 the graphs of the functions $f(x)$ and $g(x)$ intersect at one point, that is, the equation (1) has a unique solution (figure 3, figure 4).

Taking into account the continuity of the functions $f(x)$ and $g(x)$ on the corresponding intervals, it is possible to hypothesize about the existence of two solutions of the equation (1) for $a\in(-\infty;-5)\cup(-5;-3)\cup(-3;0)\cup(0;\infty)$ and about the existence of one solution of the equation (1) for $a=-5$, $a=-3$ and $a=0$. To confirm or refute it, as a rule, it is necessary to make an analytical study of the problem.

We present the analytical solution of the given equation. It is clear that $x\neq-1$, $x\neq 1-a$. Then

$$(x+a-4)(x+1)-5a=0$$

or $x^2+x(a-3)-4a-4=0$.

According to Viet's theorem

$$x_1=4,\ x_2=-a-1.$$

From the restrictions imposed on the variable x, it follows that

$$x_1\neq-1,\ x_1\neq 1-a,\ x_2\neq-1,\ x_2\neq 1-a.$$

The first and fourth conditions are obvious. Therefore, let's consider the rest of the conditions in more detail. From the inequality $x_1\neq 1-a$ we get that $a\neq-3$. That is for $a=-3$ the value $x_1=4$ is not a root of the given equation (in this case, the root will be $x_2=2$) (figure 2). The third inequality $x_2\neq-1$ is equivalent to $a\neq 0$. Therefore, for $a=0$ the root of the equation will be $x_1=4$ (figure 3).

Thus, if $a=-3$, then $x=2$ (figure 2), if $a=0$, then $x=4$ (figure 3), and if $a\neq-3$ and $a\neq 0$, then $x=4$ or $x=-a-1$ (figure 1).

Thus, the previously proposed hypothesis about the number of roots of the equation (1) was partially confirmed.

In figures 1-3 the parameter value respectively is 0.4, -5 and -3. Note that the parameter value can also be selected using a slider. At that, the same drawing can contain images of graphs of functions that correspond to different fixed values of the parameter.

As it is known, there exists a slightly different approach to constructing a geometric interpretation of the task (1). Namely, it is necessary to find the intersection points of the graph of the function

$$h(x)=1-\frac{3}{x+a-1}-\frac{5a}{(x+a-1)(x+1)}$$

for different values of the parameter a with the abscissa axis. It is clear that solving such a task using appropriate software is similar in complexity to the presented above. In figure 5 the graph of the function $h(x)$ is plotted under the condition that $a=0.4$. In this case the graph of the function $h(x)$ intersect the abscissa axis at two points, that is, the equation (1) has two solutions.

Table 1: Program comparison.

Program functions	GRAN1	GeoGebra	Wolfram|Alpha	SageMath
Plotting graph of a function given in explicit form	+	+	+	+
Plotting graph of a function given in implicit form	+	+	+	+
Using a parameter in the function definition and its change, automatic change of a graph depending on the parameter value, the possibility to change the parameter changing step	+	+	–	–
Plotting of a tangent to a curve at a point	+	+	+	+
Ability to change the scale	+	+	-	–
Determination of the coordinates of the intersection of graphs of functions	+	+	+	–

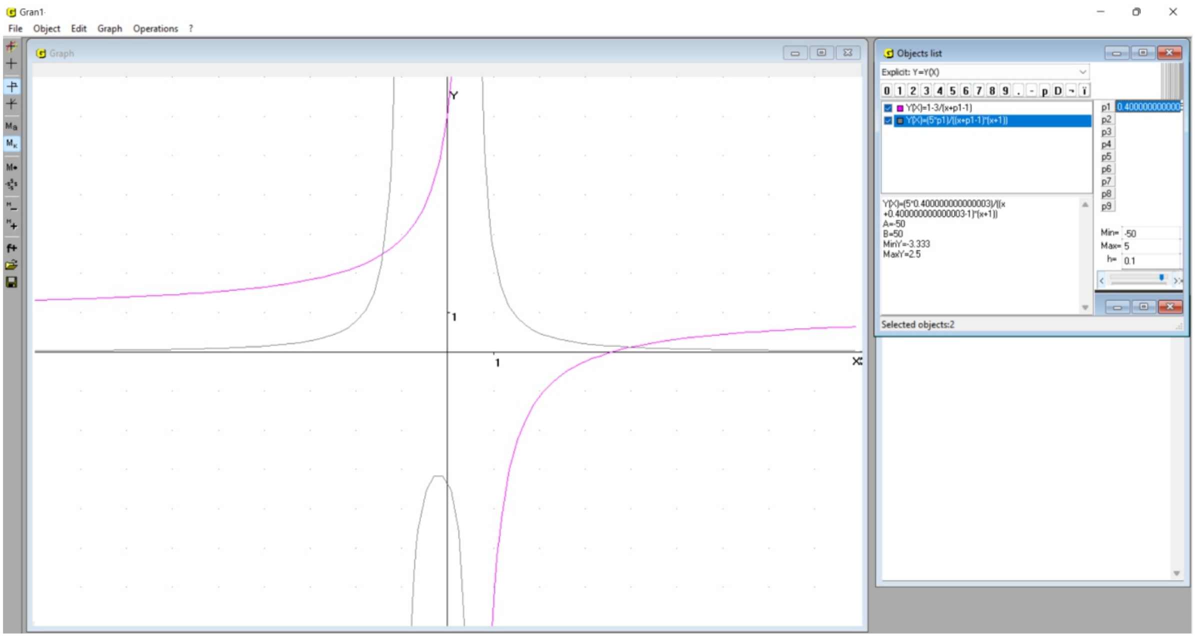

Figure 1.

Note that the use of this approach to solving tasks with parameters can lead to a more adequate geometric interpretation of the task. So, for $a = -5$ the graph of the function $h(x)$ at the point with abscissa $x = 4$ touches the abscissa axis (figure 6).

This means that

$$h(4) = 0,\ h'(4) = 0,$$

i.e. the equation

$$h(x) = 0,$$

and therefore the equation (1) has two identical roots $x = 4$. Indeed, by construction

$$h(x) = (x-4)^2\widetilde{h}(x),\ \widetilde{h}(4) \neq 0.$$

2. Find the number of roots of the equation

$$a^x = \log_a x. \tag{2}$$

In this case, we use GeoGebra software for graphic illustrations. Let's plot the graphs of the functions $f(x) = a^x$ and $g(x) = \log_a x$ for specific values of the a parameter. Increasing the value of the parameter a from 0 with a step of 0.1, we come to conclusion – if the parameter a takes values from 0.1 to 0.9, then the equation (2) has one root, from 1.1 to 1.4 – the equation (2) has two roots, and finally, if the parameter value is greater than 1.4, then the equation (2) has no roots.

It is clear that the use of only a graphical way of solving the equation (2) does not only not allow to make the correct conclusion about the number of roots of the equation for $a \in (0;1) \cup (1;\infty)$, but also does not allow us to express an adequate hypothesis about the length of the intervals of change of the parameter a, where the equation (2) has the same number of roots. And the situation is not improved by a significant decrease in the step of changing the parame-

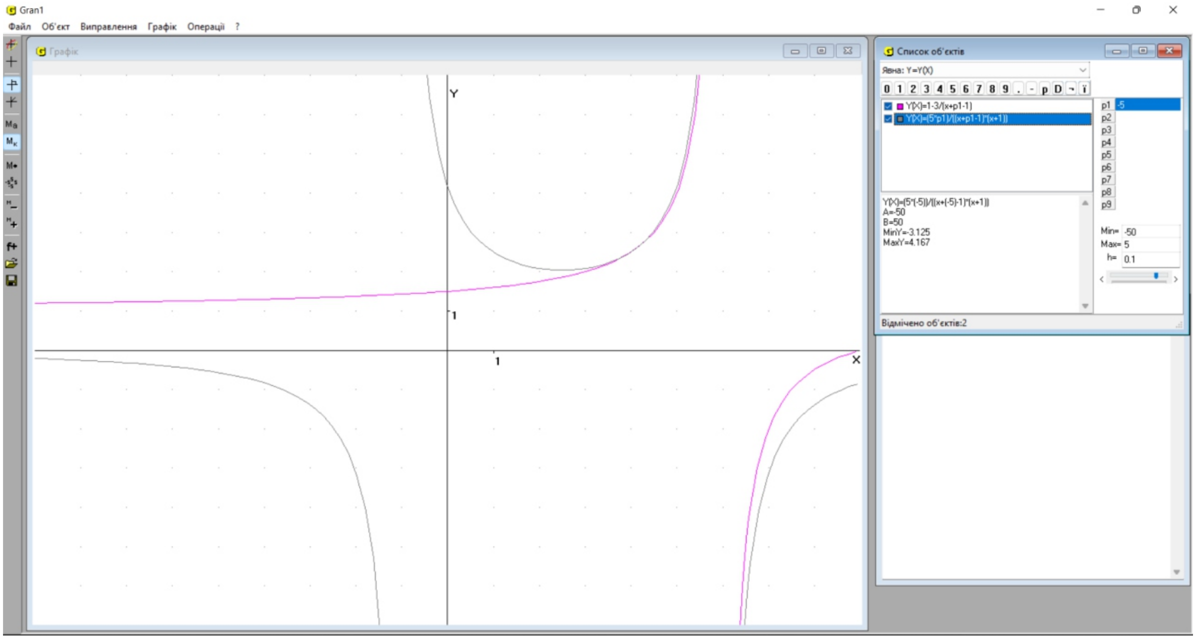

Figure 2.

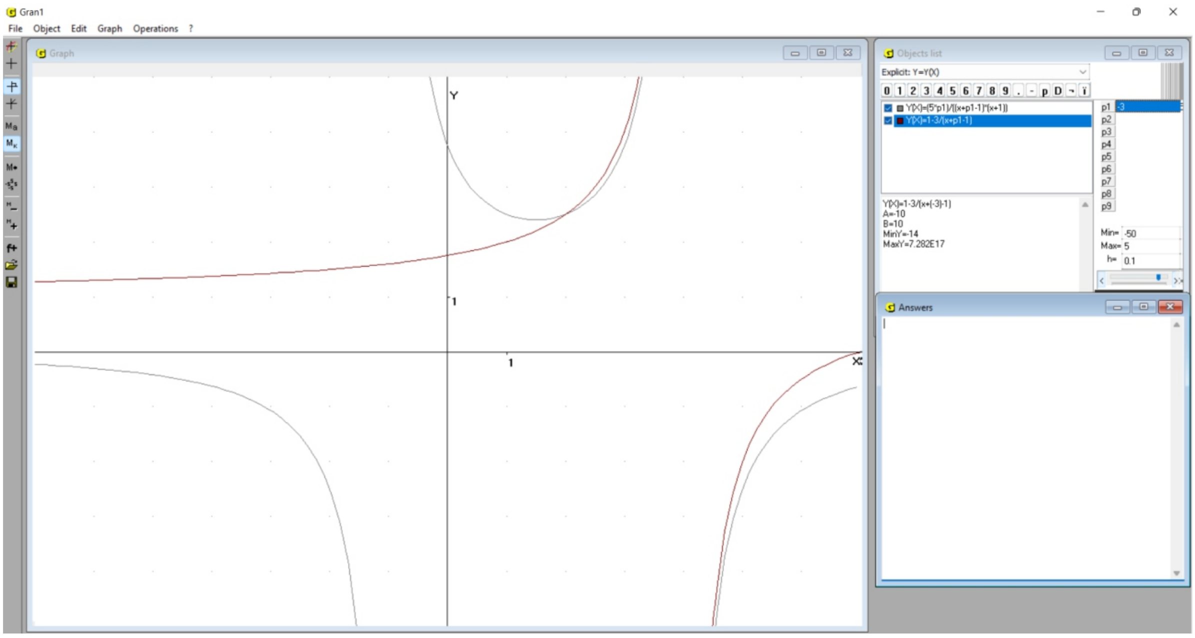

Figure 3.

ter a, since the values of the parameter, when passing through which the number of roots of the equation (2) changes, are transcendental numbers.

Therefore, an analytical study of the task is necessary.

On the condition of the task $x \in (0;\infty)$ and $a \in (0;1) \cup (1;\infty)$. Let it first $a \in (1;\infty)$. We find a tangent point M of graphs of the functions $y = a^x$ and $y = \log_a x$. It is clear that the abscissa of the tangent point will be the solution of the equation (2). Since these functions are mutually turned, their graphs are symmetrical relative to the line $y = x$. Taking into account the strict monotony of functions $y = a^x$ and $y = \log_a x$ and the immutability of the type of convexity of their graphs, we come to the conclusion that if the tangent point of the graphs of these functions

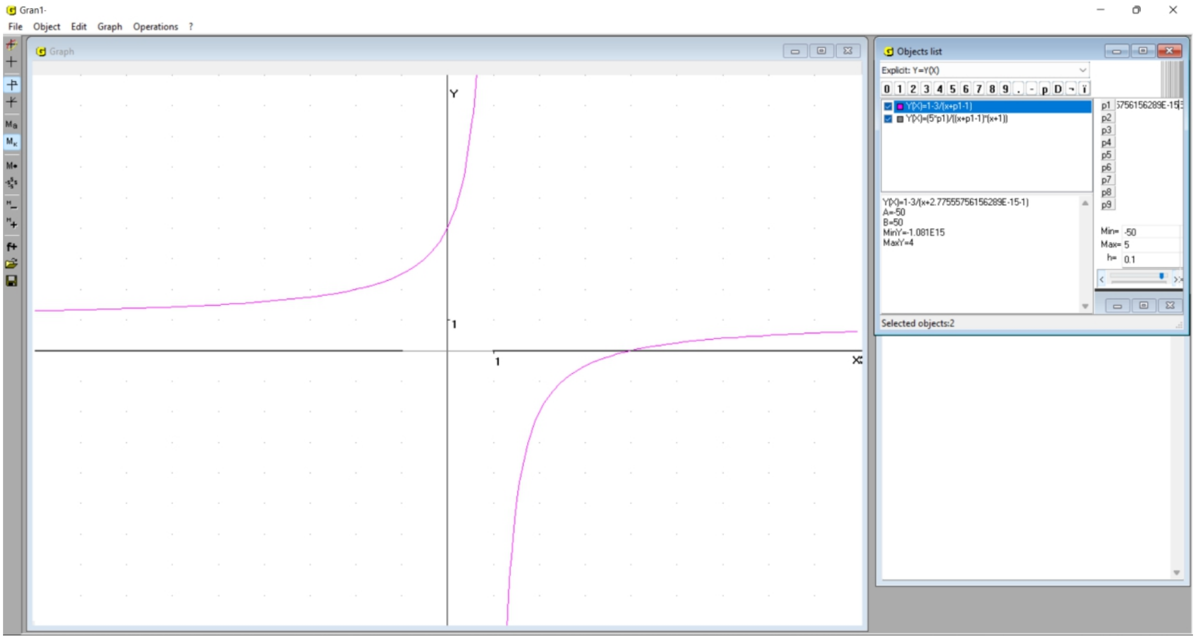

Figure 4.

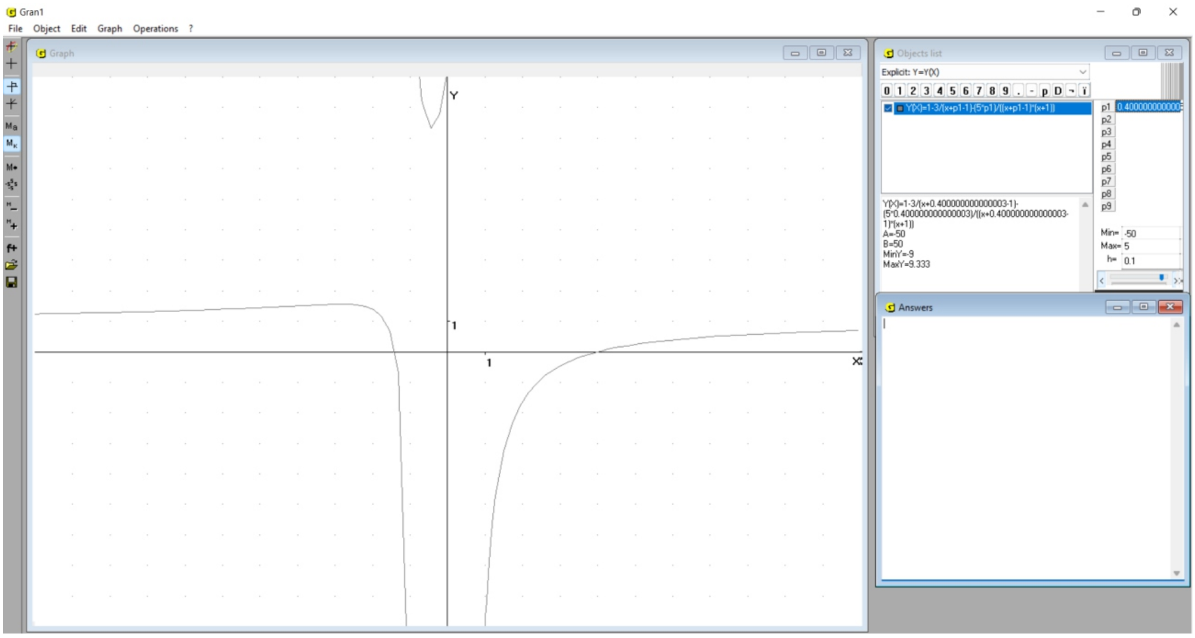

Figure 5.

exists, then it is unique and lies on the line $y = x$ (figure 6).

It is known that the coordinates of the tangent point of graphs of the functions $y = \varphi(x)$ and $y = \psi(x)$ meet the system of equations

$$\begin{cases} \varphi(x) = \psi(x), \\ \varphi'(x) = \psi'(x), \end{cases}$$

that in our case will look like

$$\begin{cases} a^x = x, \\ a^x \ln a = 1. \end{cases}$$

From here we get $a = \sqrt[e]{e}$, $M(e, e)$.

Suppose, that $a > \sqrt[e]{e}$. Then graphs of the functions $y = a^x$ and $y = x$ do not intersect, that is, the equation (2) has no solution (figure 8).

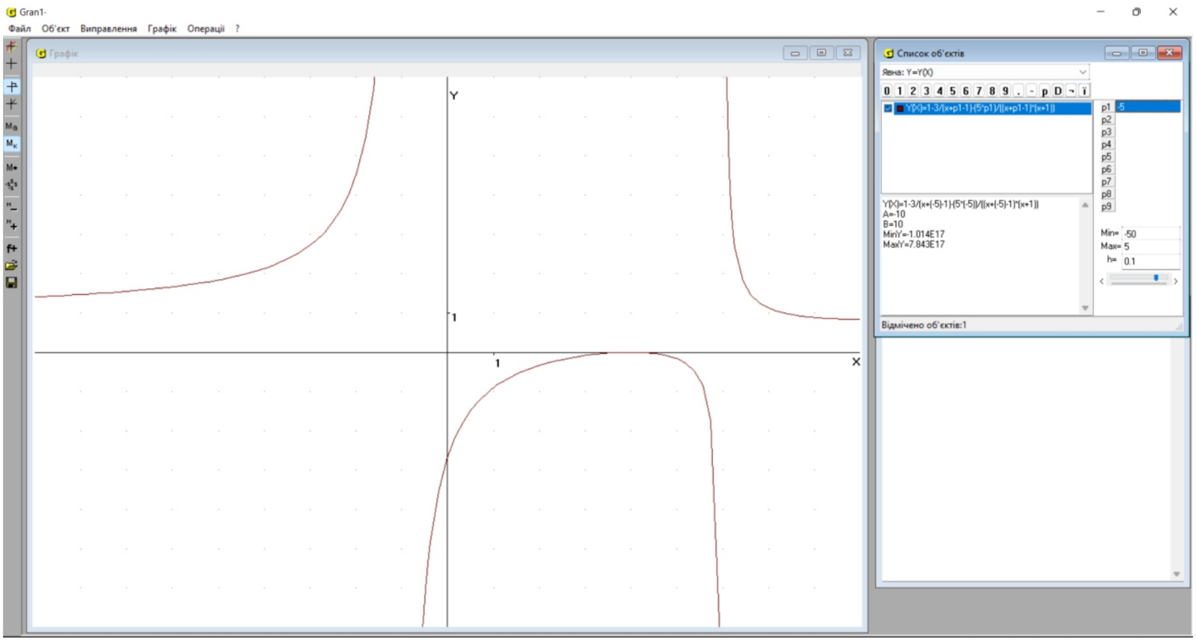

Figure 6.

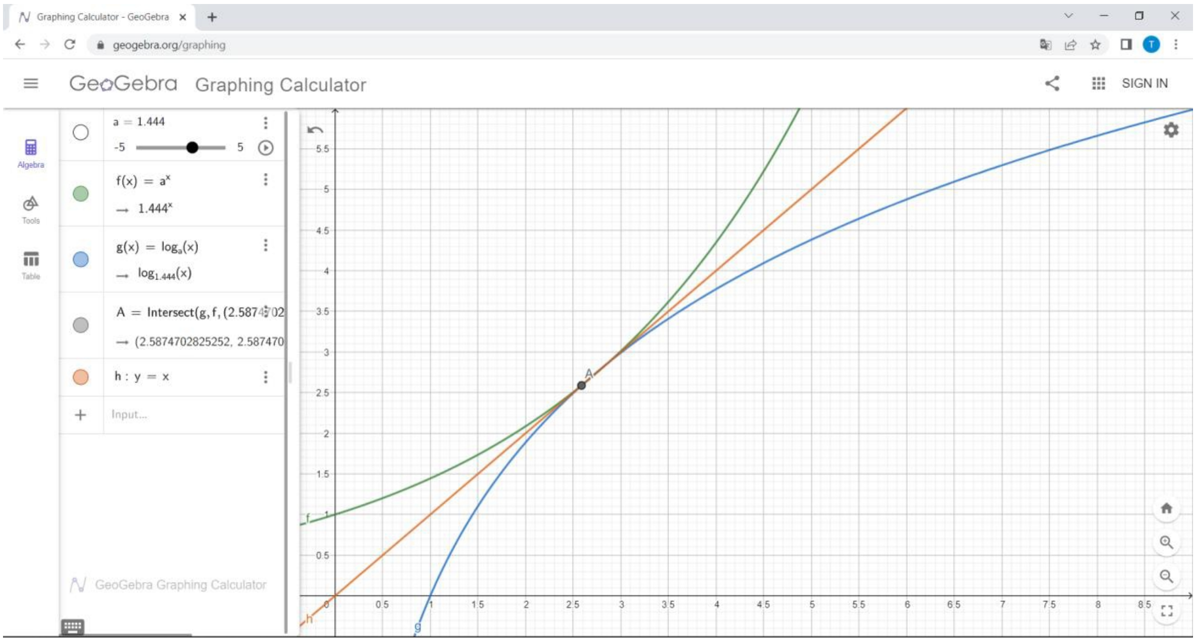

Figure 7.

Indeed, we denote as $h(x) = a^x - x$, $x \geq 0$. Then $h'(x) = a^x \ln a - 1$ and $x = -\frac{\ln\ln a}{\ln a}$ is a stationary point of function $h(x)$. Since $h''(x) = a^x \ln^2 a > 0$, $x \geq 0$, then $x = -\frac{\ln\ln a}{\ln a}$ is a minimum point of the function $h(x)$.

Taking into account that

$$h(0) = 1 > 0$$

and

$$h\left(-\frac{\ln\ln a}{\ln a}\right) = \frac{1+\ln\ln a}{\ln a} > 0, \; a > \sqrt[e]{e},$$

then $h(x) > 0$, $x \geq 0$, i.e. $a^x > x$, $x \geq 0$.

Let it now be $1 < a < \sqrt[e]{e}$. Then the equation (2) has two solutions.

Indeed, determining the function $h(x)$, like before,

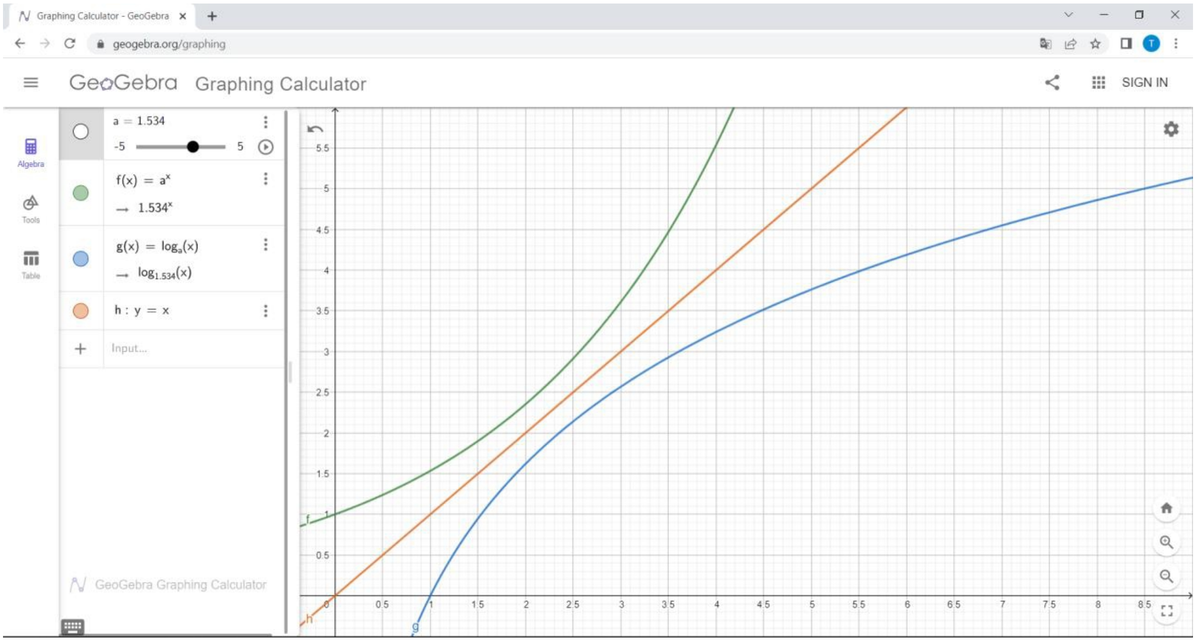

Figure 8.

we get

$$h(0) = 1 > 0,\ h\left(-\frac{\ln\ln a}{\ln a}\right) < 0,$$

$$\lim_{x\to+\infty} h(x) = +\infty.$$

Since graphs of the functions $y = a^x$ and $y = \log_a x$ have no points of inflection, then according to the Bolzano-Koshi theorem, they intersect at two points that are besides contained on the line $y = x$ (figure 9).

Let $0 < a < 1$. We denote as $l(x) = \log_a x - a^x$, $a \in [a_0;1)$, where a_0 will be determined below. Let's investigate the function $l(x)$ on monotony:

$$l'(x) = \frac{1 - xa^x \ln^2 a}{x\ln a}.$$

The value a_0 we select so that $l'(x) \le 0$, $x \in (0;\infty)$. Since $x\ln a < 0$, $x \in (0;\infty)$, $a \in (0;1)$, then $l'(x) \le 0$, $x \in (0;\infty)$, than and only when

$$1 - xa^x \ln^2 a \ge 0,\ x \in (0;\infty).$$

Select a_0 so that

$$1 - xa^x \ln^2 a \ge 0,\ x \in (0;\infty),\ a \in [a_0;1).$$

We denote as $m(x) = xa^x \ln^2 a$, $x \in (0;\infty)$ and investigate $m(x)$ per extremum. Calculating

$$m'(x) = a^x \ln^2 a(1 + x\ln a),$$

$$m''(x) = a^x \ln^3 a(2 + x\ln a),$$

we are convinced, that the stationary point $x = -\frac{1}{\ln a}$ of the function $m(x)$ is a maximum point.

Since

$$m(0) = 0$$

and

$$m\left(-\frac{1}{\ln a}\right) = -\frac{1}{e}\ln a \le -\frac{1}{e}\ln\frac{1}{e^e} = 1,\ a \in \left[\frac{1}{e^e};1\right),$$

then $a_0 = \frac{1}{e^e}$.

Thus, $l'(x) \le 0$, $x \in (0;\infty)$, and points where $l'(x) = 0$, do not form a segment. Therefore, the function $l(x)$, $x \in (0;\infty)$, $a \in \left[\frac{1}{e^e};1\right)$ is descending. Therefore, the equation (2) has one solution (figure 10).

Let it finally $a \in \left(0;\frac{1}{e^e}\right)$. In this case, the equation (2) has three solutions (figure 11).

Indeed, graphs of the functions $y = a^x$ and $y = \log_a x$ intersect at some point of the line $y = x$. Let us denote the abscissa of this point as x_0. It is clear that $x = x_0$ is a solution of the equation (2). Consider the interval $(0;x_0)$. Note that $\lim\limits_{x\to 0+} l(x) = +\infty$. Determine a sign of the number $l(x_0 - \varepsilon)$, where ε – is a quite small positive constant.

$$l(x_0-\varepsilon) = \log_a(x_0-\varepsilon) - a^{x_0-\varepsilon} = \log_a\left(1 - \frac{\varepsilon}{x_0}\right) +$$

$$+\log_a x_0 - a^{x_0}a^{-\varepsilon} = x_0 + \frac{1}{\ln a}\ln\left(1 - \frac{\varepsilon}{x_0}\right) - x_0 a^{-\varepsilon} =$$

$$= \frac{1}{\ln a}\ln\left(1 - \frac{\varepsilon}{x_0}\right) - x_0\left(a^{-\varepsilon} - 1\right) =$$

$$= \frac{1}{\ln a}\left(-\frac{\varepsilon}{x_0} - \frac{1}{2}\left(\frac{\varepsilon}{x_0}\right)^2 - \frac{1}{3}\left(\frac{\varepsilon}{x_0}\right)^3 - \ldots\right) -$$

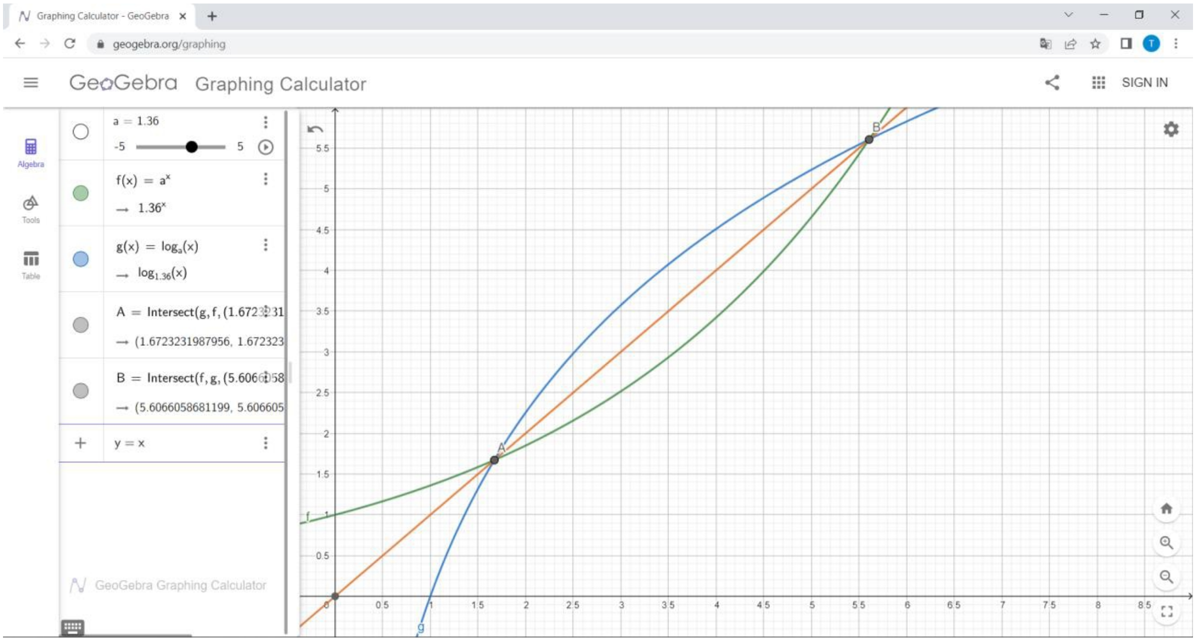

Figure 9.

Figure 10.

$$-x_0(-\varepsilon\ln a+O(\varepsilon^2))\leq$$

$$\leq-\frac{1}{\ln a}\left(\frac{\varepsilon}{x_0}+\left(\frac{\varepsilon}{x_0}\right)^2+\left(\frac{\varepsilon}{x_0}\right)^3+\ldots\right)-$$

$$-x_0(-\varepsilon\ln a+O(\varepsilon^2))=$$

$$=\varepsilon\left(-\frac{1}{(x_0-\varepsilon)\ln a}+x_0\ln a\right)+O(\varepsilon^2)<0,$$

since inequality

$$-\frac{1}{x_0\ln a}+x_0\ln a<0 \qquad (3)$$

is correct for all $a\in\left(0;\frac{1}{e^e}\right)$. Indeed, inequality (3) is equivalent to

$$x_0^2\ln^2 a>1$$

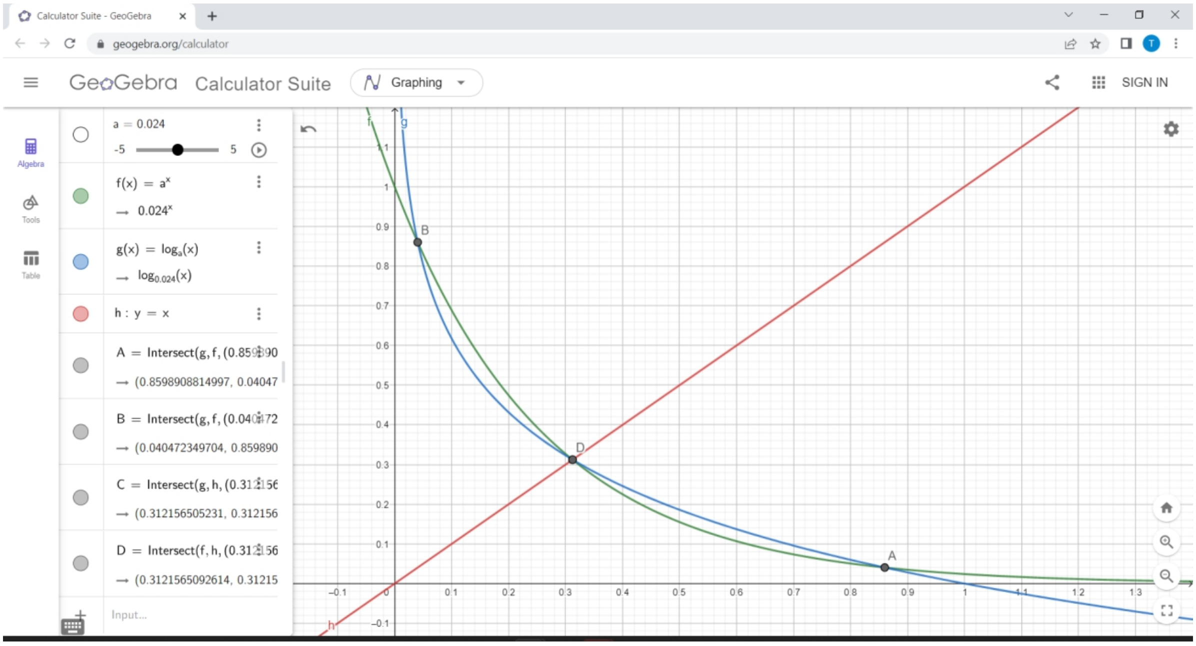

Figure 11.

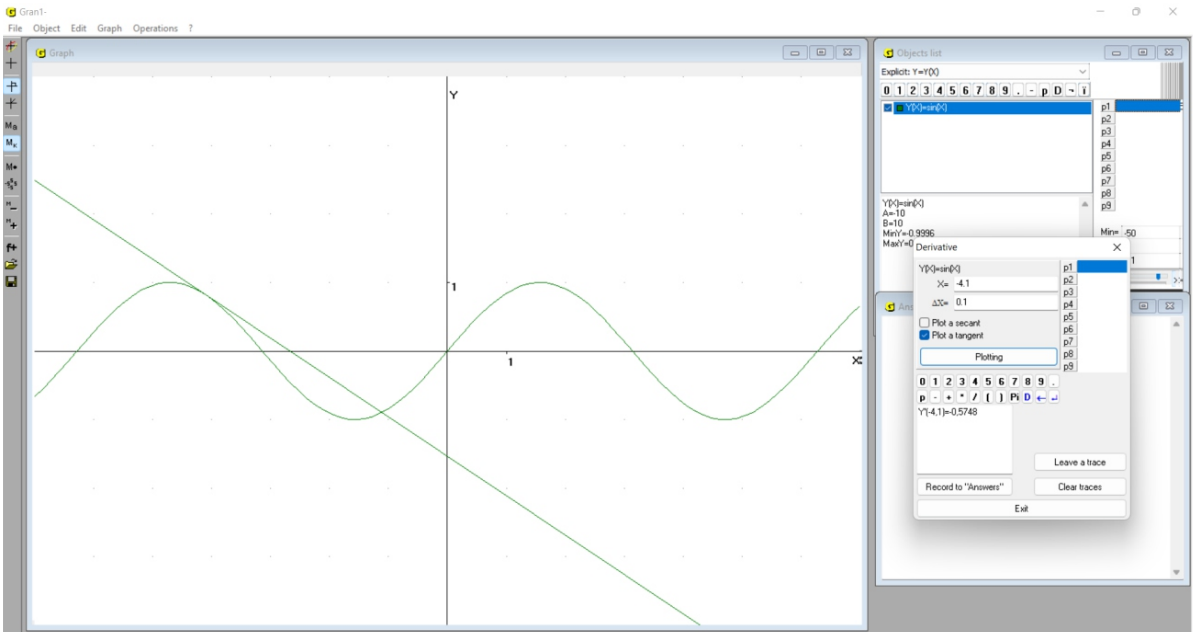

Figure 12.

or to

$$\ln^2 x_0 > 1,$$

i.e. $x_0 \in \left(0; \frac{1}{e}\right) \cup (e; \infty)$.

Since $x = \frac{1}{e}$ is a solution of the equation

$$\log_{\frac{1}{e^e}} x = x,$$

then the solution of the equation

$$\log_a x = x$$

is less than $\frac{1}{e}$, if $0 < a < \frac{1}{e^e}$. And therefore $x_0 \in \left(0; \frac{1}{e}\right)$, that is inequality (3) is correct.

Thus, according to the Bolzano-Cosh Theorem the equation (2) in the interval $(0; x_0)$ has a solution. For reasons of symmetry, taking into account the immutability of the type of convexity of graphs of the functions $y = a^x$ and $y = \log_a x$, it follows that for $a \in \left(0; \frac{1}{e^e}\right)$ equation (2) has three solutions.

Summarizing the analysis we come to the conclusion. Equation (2) has three solutions if $a \in \left(0; \frac{1}{e^e}\right)$, two solutions if $a \in (1; \sqrt[e]{e})$, one solution if $a \in \left[\frac{1}{e^e}; 1\right) \cup \{\sqrt[e]{e}\}$ and has no solution if $a \in \left(\frac{1}{e^e}; \infty\right)$.

3. Find the values of the parameters a and b, for which the equation

$$\sin x = ax + b \tag{4}$$

has two solutions.

The equation (4) will have two solutions if graphs of the functions $y = \sin x$ and $y = ax + b$ will intersect at two points. It is clear that one of these points is the tangent point of the graphs of these functions (figure 12).

In the GRAN1 program, it is possible to plot a tangent to a curve at a given point. In this case, the abscissa of the point of tangency can be considered a parameter. Further, by gradually changing the value of the parameter, one can observe the change in the position of the tangent and visually determine the number of roots of the considered equation. So, for which values of the parameters a and b does the equation (4) have 2 solutions?

Let the point with the abscissa x_1 is a tangent point of graphs of the functions $y = \sin x$ and $y = ax + b$. Also suppose that the solutions of the equation (4) belong to the segment $\left[-\frac{3\pi}{2}; 0\right]$.

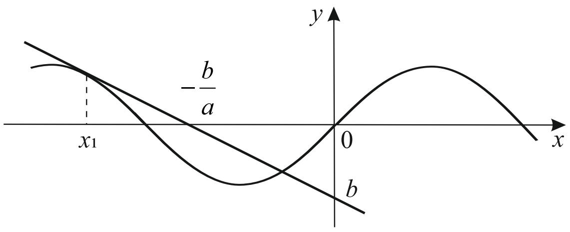

Figure 13.

Then the parameters a and b meet the inequalities

$$\begin{cases} -1 < a < 0, \\ -\pi < b < 0. \end{cases}$$

Since

$$\begin{cases} \sin x_1 = ax_1 + b, \\ \cos x_1 = a, \end{cases}$$

then, using the basic trigonometric identity, we get

$$\cos\left(\sqrt{\frac{1}{a^2} - 1} + \frac{b}{a}\right) = a. \tag{5}$$

Note that the inverse statement is correct as well. Namely, from the condition (5) it follows that at the point with the abscissa

$$x_1 = -\sqrt{\frac{1}{a^2} - 1} - \frac{b}{a}$$

graphs of the functions $y = \sin x$ and $y = ax + b$ touch.

The line $y = ax + b$ intersects the abscissa axis at the point $\left(-\frac{b}{a}; 0\right)$. Then when meeting the condition

$$-\pi < -\frac{b}{a} < 0,$$

the line $y = ax + b$ and the curve $y = \sin x$ will only have two common points.

Thus, if

$$\begin{cases} \cos\left(\sqrt{\frac{1}{a^2} - 1} + \frac{b}{a}\right) = a, \\ a\pi < b < 0, \end{cases}$$

then the equation (4) has two solutions.

Thinking similarly, one can find the conditions, under which there exist two solutions of the equation (4) at an arbitrary interval from the range $(-\infty; +\infty)$ so that at the whole range $(-\infty; +\infty)$ the equation (4) would have two solutions.

Note that the equation (4) can be solved approximately with the use of expansion of the function $y = \sin x$ in a Maclaurin series, namely,

$$x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots = ax + b. \tag{6}$$

Then, taking into account the convergence of the series in the left side of equality (5) in the range $(-\infty; +\infty)$, instead of of the equation (5) such equation can be considered

$$\sum_{k=1}^{p} \frac{x^{2k-1}}{(2k-1)!} = ax + b, \tag{7}$$

where the expression in the left part is a polynomial. The value of p is determined by the specified accuracy.

The equation (7) contains a polynomial of an odd degree with real coefficients. Therefore, it has an odd number of real roots. The latter fact in no way contradicts the proven statement of the even number of real roots of equation (4), since the equation (4) unlikely (7) is transcendental and the properties of the function $y = \sin x$ (limited, monotony, bulge) are significantly different from the corresponding properties of the polynomial $\sum\limits_{k=1}^{p} \frac{x^{2k-1}}{(2k-1)!}$.

Using the developed approach to solving the equation (4), it is possible to consider various problems related to finding a given number of their solutions.

4 CONCLUSIONS AND FURTHER RESEARCH PROSPECTS

The graphical method of finding solutions of equations, inequalities and their systems is based on the procedure of plotting graphs of the corresponding functions. In the case of implicit or parametric definition of functions, the process of plotting their graphs is quite complicated. The task becomes even more cumbersome if it contains a parameter. That is why they often try to solve these problems using various software tools.

This paper substantiates the expediency of using GRAN1 and GeoGebra computer mathematics systems for solving tasks with parameter. In the GRAN1 program, it is possible to write the formula of the function with the designation of parameters through the variables $p1$, $p2$, …, $p10$. At that, the parameter can be changed both by assigning it a certain value and by using a slider. In the process of changing the parameter values, the graph of the function is automatically constructed, taking into account the updates of the parameter values. Similar functions are inherent in the GeoGebra program. It is only needed to define the variables through which the parameters are denoted.

Using the automatic change of the shape of the graph for different values of the parameter, the change of the step of changing the value of the parameter, the change of scale for viewing the graph of the function or its fragment, the automatic determination of the coordinates of the point of intersection of the graphs of the functions, in the work there are established the conditions of compatibility of the geometric character of three illustrative tasks with the parameter and their analytical solutions are given. At that for geometrical support of the process of solving the specified tasks, GRAN1 and GeoGebra computer mathematics systems were used, as already mentioned above. The mentioned software tools are equally convenient for use in the process of solving tasks with parameters.

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Intercultural and Intracultural Diversity in Interdisciplinary Cloud-Oriented Foreign Language Teaching

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Keywords: Intercultural Communication, Intercultural Competence, Interdisciplinary Approach, Country Studies, Cloud-Oriented Environment, Learning Foreign Languages, Learning History, Media Resources.

Abstract: The article deals with the problem of the development of intercultural competence, which is one of the key competences in foreign language education. The focus lies on examining the opportunities available to use inter- and intracultural differences as a material for developing intercultural competence. The theoretical foundations on which the research was conducted are analyzed: the essence of intercultural communication, the conditions of its smooth flow; the essence of intercultural competence, its constituents and the relations between them; the role of country studies (both the country of the target language and its own history) in the acquisition of background knowledge, the ability to compare cultures, to tolerate differences between them, and furthermore. Considering that the development of intercultural competence at a level that would ensure the effective implementation of intercultural communication is primarily due to the presence, in addition to language acquisition, of intercultural knowledge, perceptions of the rules of communicative behavior and the positive disposition of learners, an important element is the approaching of the target culture, the removal of prejudices about the "alien". This can be achieved through the inclusion in the educational process of materials from the immediate environment of learners. For exemple, the theme "Foreigner in Ukraine" is used, in which work, on the one hand, reveals facts of the history some people in the European format, and on the other, the facts of the history of their own country, the history of their immediate surroundings, at the expense of which the story of "alien" is transferred to the personal sphere. The article also considers the possibilities of an interdisciplinary approach in foreign language teaching on a theoretical and practical level, proves the effectiveness of developing intercultural competence using the example of creating interdisciplinary connections between a foreign language and history. It is emphasized that in modern conditions, when the educational process has been transferred to a distance format, the creation of a cloud-oriented environment plays an important role, which on the one hand allows immersion in the language and on the other hand creates multiple opportunities, to include into the lesson relevant, authentic materials and a variety of actual information.

1 INTRODUCTION

A few centuries ago, most states in Europe were monocultural. Language was understood as the basis on which the state was built, so the principle of "one state – one language" was fundamental in most European countries. In the twentieth century, Europe has become multicultural for a variety of reasons, including historical, economic, social and educational influences. Two world wars, the founding of the European Union, the abolition of borders within its framework, integration processes, migration (refugees, guest workers), mobility in the educational sector, the open European labor market, tourism, globalization worldwide, Internet technologies that make the world a" global village" – all this has more or less changed the social structure in all European countries and allowed people from different ethnic, linguistic, cultural and religious contexts to get in touch and communicate.

In this regard, the question of readiness for intercultural communication becomes very topical. Under what conditions is one capable of intercultural interaction? The answer is clear: if you tolerate foreign cultures and have basic ideas about them and speaks the target language at least at level A1-A2. Linguistic (communicative) and intercultural compe-

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tence belong to the core of foreign language training in schools and universities, they are also regarded as goals at other educational institutions that offer foreign languages (language schools, language courses, online offers) when it comes to controlled teaching. However, the lack of time as a general problem in foreign language education, regardless of which educational institution is involved, often does not allow all components to be taken into account in the classroom; linguistic components are practiced more, while intercultural content as well as intercultural skills and positive attitudes towards the "foreign" are often neglected or not trained enough. Therefore, the question of how to teach intercultural content and effectively develop intercultural competence, which means are best suited for this, which forms and types of exercises can lead to success and in which areas of application is very topical today.

2 INTERCULTURAL ASPECTS OF FOREIGN LANGUAGE LEARNING

2.1 Intercultural Competence, Intercultural Communication and Intercultural Dialogue

In the research on the problems of foreign language teaching and the development of competence within its framework, the concept of "intercultural competence" is one of the central ones and is considered from different sides. One can find numerous definitions of this term, schematic and detailed description of its structure both in the contributions of scientists and in national and pan-European normative documents in the field of foreign language education. The development of "intercultural competence" is formulated as a learning goal in all foreign language curricula, but the purely pragmatic goal of learning a foreign language is to be able to communicate successfully and conflict-free with representatives of other cultures in their language, i.e. to communicate. Two more terms are important in this regard – "intercultural communication" and "dialogue of cultures".

The term "intercultural communication" has many definitions because it has been analyzed from different points of view. Based on the existing considerations of the German and Ukrainian researchers, we try to define the term in such a way that it could most clearly depict the essence of intercultural communication in the context of foreign language teaching.

Broszinsky-Schwabe defines the term as follows: "Intercultural communication refers to *understanding* between two or more people who belong to *different cultures*, which results in a number of difficulties and problems" (Broszinsky-Schwabe, 2011, p. 21). The scientist proposes the following understanding of intercultural communication: "Intercultural communication" also emphasizes the *meaning* of the *culture* for communication. Understanding is significantly influenced by the respective *cultural background*. The extent to which and whether the partners are aware of the *cultural difference* and *adapt to it is decisive for the success of communication between individuals or groups*" (Broszinsky-Schwabe, 2011, p. 11). It is about at least two notable features of intercultural communication: The importance of knowledge / understanding of the foreign culture and the attitude of the interlocutor to cultural differences, i.e. the perception of the culture, the tolerance of the "foreign" and understanding as a goal and result the communication.

The Ukrainian researcher of intercultural communication Batsevych (Batsevych, 2007) considers this notion in a broad sense and in a narrow sense. In a narrow sense, he understands this term as the process of communication (verbal or non-verbal) among people (or groups of people) belonging to different national linguistic-cultural communities, using different languages, having different levels of communicative competence, the result of which is communicative failure or culture shock. Among the important features of intercultural communication, Batsevych (Batsevych, 2007): the use of interlocutors in the intercultural shaped situations of different strategies and verbal means from those in their own culture, and the recognition of mutual "foreignness" of the cultures of communicants.

In a broad sense, he defines intercultural communication as "the whole spectrum of possible types of communication" that are possible outside of homogeneous social groups. Communicants from different ethnic groups or cultures as well as from different social groups are understood within the framework of a culture or society (age, gender, profession, etc. can appear as criteria) (Batsevych, 2007).

Batsevych (Batsevych, 2007) thus expands the barriers and broadens the concept of "intercultural communication" to those groups that may belong to the same cultural or ethnic group, but have differences in occupation, age, everyday life, social status, or education (on verbal and non-verbal level). But it's all about the differences that you notice anyway, the perception and acceptance of which and the willingness to come to an understanding requires a positive attitude.

For his part, Krumm et al. (Krumm et al., 2011) emphasizes: "One speaks of intercultural communication when people of different cultural backgrounds communicate with one another and are aware of the fact *that* their own perception and the perception of others differ, so that, in order to avoid misunderstandings, it is an intercultural one competence is required in order to communicate despite linguistically and culturally different points of view" (Krumm et al., 2011, p. 139). An important word in his understanding is "aware" because any participant in intercultural communication cannot notice and accept the differences if he is not aware of them.

In contrast to intercultural communication, which is understood as a process, the term "dialogue of cultures" is not conceived as theoretical and does not belong to the field of linguistics, but is understood as a socio-political phenomenon. While the term "dialogue of cultures" is used more often in Ukrainian specialist literature, the term "intercultural dialogue" is more common in the German-speaking scientific and political landscape. The following definition can be found in the "White Paper on Intercultural Dialogue «Living Together Equally in Dignity»": "Intercultural dialogue describes a process of open and respectful exchange of opinions between individuals and groups of different ethnic, cultural, religious and linguistic backgrounds and traditions in a spirit of mutual understanding and respect. The freedom and the ability to express one's opinion, but also the will and the ability to listen to what others have to say, are indispensable here. Intercultural dialogue contributes to political, social, cultural and economic integration and to the cohesion of societies with different cultures" (www.coe.int/dialogue, 2008, p. 17).

Based on this, it is clear that intercultural dialogue as a phenomenon in the socio-political area focuses on the interaction of cultures and their representatives on the basis of tolerance and acceptance of peculiarities and equality of different cultures, which contributes to understanding and conflict-free coexistence of people from different cultural contexts.

2.2 Intercultural Competence in Normative Documents and Research

The term "intercultural competence" has been conceptualized in different ways over the course of two decades: different interpretations have emerged depending on the researcher, the national characteristics and the period in which it was analyzed. The components in the structure of intercultural competence that were determined at the beginning of the research were constantly being added, which either expanded the term (as a result of powerful societal, social, political and / or educational policy, methodological and didactic developments) or described it more precisely, made it more concrete, reinterpreted. Normative documents contain already recognized formulations of the term "intercultural competence" and its structure, but are based on the results of scientific considerations, therefore they are theoretically justified and emphasize the practical value of intercultural competence, which is important for educational decision-makers, teachers, curricula and textbook developers.

The dynamics of the term development in normative documents can be illustrated using the example of selected definitions if they are analyzed in chronological order. For example, The Common European Framework of Reference for Languages (CEFR) (Council of Europe, 2001) does not consider "intercultural competence" as a particular competence among other competences. Sociocultural knowledge and intercultural awareness, which according to this edition of the CEFR belong to declarative knowledge, are also components of general competence. Sociocultural knowledge includes general knowledge about the society and culture of the community(s) and the character of people and its society (everyday life, living conditions, interpersonal relationships, values, beliefs, attitudes, body language, social conventions, ritual behavior, etc.). The (Council of Europe, 2001) defines intercultural awareness as that which arises "from the knowledge, awareness and understanding of the relationships" between "one's own" and "foreign" worlds. In this document, then, the cognitive side of interculturality is emphasized: it helps one "to be aware of regional and social diversity"; both cultures "to be placed in a larger context" (Trim et al., 2013, pp. 104-105).

In the next edition of the (Council of Europe, 2001) entitled "Common European Framework of Reference for Languages: learning, teaching, assessment. Companion volume with new descriptors" (Council of Europe, 2018) was published, one finds not only the term "intercultural competence", but also descriptors that – in contrast to the previous edition – allow to measure and assess intercultural competence. The following Aspects, Component and Skills become emphasizes : "Many notions that appear in the literature and descriptors for intercultural competence are included, for example: the need to deal with ambiguity when faced with cultural diversity, adjusting reactions, modifying language, etc.; the need for understanding that different cultures may have different practices and norms, and that actions may be perceived differently by people belonging to other cultures; the need to take into consideration differences in behaviors (including gestures, tones and attitudes), discussing over-generalizations and stereotypes; the need to recognize similarities and use them as a basis to improve communication; the will to show sensitivity to differences; readiness to offer and ask for clarification: anticipating possible risks of misunderstanding. Key concepts operationalized in the scale at most levels include the following: recognizing, acting on cultural, socio-pragmatic, and socio-linguistic conventions/cues; recognizing and interpreting similari ties and differences in perspectives, practices, events; evaluating neutrally and critically" (Council of Europe, 2018, p. 158).

The first thing that strikes you in this excerpt is not just the cognitive side (need for understanding, to take into consideration, need to recognize), but also the practical application of acquired intercultural knowledge, the willingness to act (to take, to show, to action). Second, the CEFR 2018 edition (Council of Europe, 2018) considers "intercultural competence" as a specific competence alongside other new terms, among which "pluricultural repertoire" and "plurilingual competence" with their descriptors for each of the levels from A1 to C2. In addition, today the understanding of the term "intercultural competence" has become much broader and primarily includes the ability to act according to the situation, to choose and use appropriate verbal and non-verbal language tools, as well as to master relevant communicative strategies and to develop personal qualities, that can contribute to successful communication and intercultural interaction (tolerance, empathy, etc.).

"To interact with members of another culture as *sensitively, respectfully and without conflict as possible, requires a cognitively and emotionally open personality who is willing to reflect on one's own standards and prejudices*, one's own self-image and that of others to think things through, to *react* to the experience of cultural differences with *tolerance for ambiguity and empathy*, and *to recognize other cultures as equals*" (Trim et al., 2013, p. 140). Following the definition given, it can be said that intercultural competence consists of at least three components: emotions and attitudes (tolerance, respect, empathy, reflection), language skills, intercultural knowledge, ability to compare and analyze (cognitive side) and action (behavioural pattern).

The Pan-European Framework of Reference for Languages (CEFR) counts *socio-cultural knowledge* and *intercultural awareness* to declarative knowledge and considers them as components of general competence. Intercultural knowledge includes: The general knowledge of the society and culture of the community(s) and the characteristics that are characteristic of this society (everyday life, living conditions, interpersonal relationships, values, beliefs, attitudes, body language, social conventions, ritual *behavior*, etc.) (Höfinghoff, 2006, pp. 103-104).

German scientists have confronted themselves with the term. For example, the Barkowski and Krumm (Barkowski and Krumm, 2010) defines "intercultural competence" as: "the ability to interact with members of another culture as sensitively, respectfully and without conflict as possible, [they] requires a cognitively and emotionally open personality that is willing to reflect on one's own standards and prejudices, to think through one's own image of oneself and others, to react to the experience of cultural differences with tolerance for ambiguity and empathy, and to recognize other cultures as equals [...]. Intercultural competence represents an important learning objective in competence-oriented concepts of foreign language teaching" (Barkowski and Krumm, 2010, p. 140).

Barmeyer (Barmeyer, 2011) has presented the structure, characteristics of intercultural competence and relationships between its components in a model (figure 1) where the same structural elements occur. The difference, however, is that Barmeyer (Barmeyer, 2011) counts foreign language skills as part of behavior, while we believe that skills belong to the cognitive block.

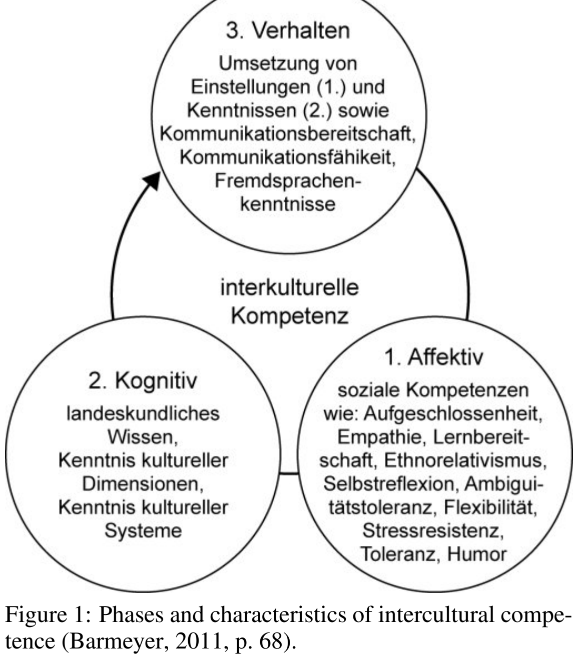

Figure 1: Phases and characteristics of intercultural competence (Barmeyer, 2011, p. 68).

According to this definition, corresponding psychologically determined personal characteristics are primarily important for the development of intercultural competence. It is assumed that the person has a certain amount of knowledge from the areas of culture, literature, everyday life and language skills, but they are not included in the definition; the attention is on the actions, reactions, activities, behavior of the speaker. It is also emphasized that intercultural competence is an important learning objective in foreign language teaching; not just what communicators need to have in order to have a successful conversation, but also seen as the meaning of the path that leads to it. It follows that taking into account these three components (knowledge and language skills), attitudes and behavior in the context of foreign language teaching is a prerequisite for the successful development of intercultural and, more broadly, communicative competence. The attitude, in our opinion, is at the center of the development process in the case of "intercultural competence" because a positive attitude towards other cultures arouses interest and motivates learning foreign languages and cultures. On the contrary, negative perception of the "foreign" acts as a disruptive factor when learning a foreign language and a foreign culture, leads to a lack of understanding and often triggers aggressiveness and not infrequently conflicts.

2.3 Intracultural Diversity as a Basis for the Development of Intercultural Competence

When learning a foreign language and in the case of "intercultural communication", the factor "intercultural knowledge" is fundamental. Without such knowledge, it would be difficult to understand, let alone embrace, a "foreign" culture. Regional studies form the basis of intercultural knowledge in foreign language teaching. The term "Landeskunde" has been interpreted similarly, but not identically, in theoretical sources of German-language scholarly discourse in different periods of time, so it would be useful to summarize views from different scholars.

Knowledge of a country includes systematized facts from various areas (history, culture, geography, politics, society, social affairs, everyday life, customs, etc.), which are not necessarily taught in foreign language lessons as part of the curriculum. In schools, learners usually learn about the culture of the target country in language classes, but many aspects are taught and learned in an interdisciplinary manner (geography, history, literature, art, society, politics, etc.). Foreign language teaching is a special area. It is claimed that "learning a foreign language is necessarily linked to content and knowledge: the foreign words carry meanings, the texts make statements about the target language country, optical media give pictures of foreign reality, even the sentences of form-related exercises convey content" (Storch, 1999, p. 285). In foreign language lessons, learners receive detailed information from listening or reading texts and other sources, which can later be processed and acquired in the target language, including vocabulary. In "German as a Foreign Language – A Didactics", Storch (Storch, 1999) quotes the statement by M. Deutschmann, who emphasizes the need to take regional knowledge into account when selecting the content for German lessons: "The question of regional studies in foreign language lessons is first of all the question according to content in foreign language lessons" (Storch, 1999, p. 285).

This content can be learned and acquired in many different ways. But in any case, if it is not about direct contact with the foreign culture, this process – regardless of whether it is controlled or not – is concentrated on the sum of facts, not on "experiencing the foreign culture". The "immersion" in a foreign culture is artificial, bound to lessons, so unfortunately it doesn't always turn out to be something that one perceives and experiences as something personal (Semerikov et al., 2022).

In multicultural societies today there is an opportunity to recognize and get to know foreign cultures on site. It takes intercultural learning to a higher level, because the learners not only get to know another culture as something familiar, something that is close by, but also learn and understand more about their own culture, into which the foreign one is integrated, about their own and European history. So the intracultural diversity becomes what can be considered as an aid in learning the cultural content in foreign language teaching. In addition, dealing with the topic "foreigners (German, English, French, etc.) in the home country (town, village)" creates favorable conditions for learning the "foreign" culture, makes the learners aware of the fact that the "foreign" is not so foreign, that they already have to do with the presence of languages, cultures and people in their environment. It contributes to the acceptance of the "foreign", teaches to tolerate them.

Another positive point of the presence of the "foreign" (people, companies, goods, cultural heritage) in the area and their use in foreign language teaching as a way of acquiring language skills and cultural knowledge about the target country is that this knowledge can be shared both online, as well as interactively. Learners have the opportunity both to search for information via the Internet and to communicate

Table 1: The term “regional studies” and its role in foreign language teaching.

Author	Expression	Area / target
Pauldrach	“Cultural knowledge is social knowledge. It can therefore be interpreted, depending on the interests of the information sources [...], its mediation is never complete per se” (Pauldrach, 1992, pp. 9-10).	foreign language teaching / private sphere
Solmecke	“a specific term related to foreign language teaching”; cultural information on the target language community as a curricular component of teaching a foreign language (Bausch et al., 2007, p. 13).	foreign language teaching
Dressler et al.	specific living conditions and behavior of the target culture (Dressler et al., 1980).	foreign language teaching; ability of learners to “behave appropriately in a foreign culture/society”
Zeuner	culture in the broadest sense or as the geographic, economic and political conditions of a country; Knowledge or previous knowledge about the country (often conveyed to learners through the media), experiences with the country and judgments or prejudices about the country (Zeuner, 2009, p. 5).	Context knowledge for learning foreign languages / private sphere
Puetz	”the minimal and didactically relevant goal of maximizing knowledge about an unknown country” (Bausch et al., 2007, pp. 127-128).	foreign language teaching / private sphere
Betterman	Country and culture-specific content, methods and strategies for their presentation, mediation, appropriation and application (Barkowski and Krumm, 2010, pp. 180-181).	foreign language teaching
Krumm et al.	Regional studies can no longer be presented as a clearly definable scientific sub-discipline of the subject DaF / DaZ , but rather as a theoretical-conceptual concept that is used in the context of foreign language didactic debates as an interpretation and argumentation pattern for describing (and contouring) the socio-cultural dimensions of language, language acquisition and language usage serves (Krumm et al., 2011, p. 1442).	foreign language teaching / private sphere / profession

directly with natives, to establish contacts with real people, which motivates them to take further steps in learning a foreign language.

2.4 “Foreign” Traces in Ukraine: Didactic Considerations

Migration processes have shaped the image of Europe for many centuries. As a result of these processes, there are many places on the map of Europe where the representatives of different ethnic groups live far from their national states. Different ethnic groups are represented in Ukraine, in almost all regions of the country where they have lived for a long time and where their descendants still live today (Hamaniuk, 2020). Their presence in eastern, western and central Ukraine has different reasons in terms of historical aspects, as well as the number of ethnic Germans, Bulgarians, Poles, Czechs or Russians in these areas. In Ukraine there are no regions like South Tyrol in Italy, where the population is bilingual (Italian and German); the representatives of other ethnic groups live together among Ukrainians and representatives of other ethnic groups. They maintain contacts with each other and stick to their traditions, but make a significant contribution to the development of the cultures of their neighbors. In this regard, the issue is not alien to Ukraine. It is no coincidence that native languages are also taught in schools alongside Ukrainian.

Foreign languages are taught in Ukraine in various teaching areas and at each level with specific goals: in kindergartens, in elementary school (English), in general schools English as L2 and as L3 (German, rarely French, Spanish or Russian), at the Schools with extended foreign language instruction (English, German, French), at universities as part-time German instruction (two foreign languages (English, German, French, Spanish, Chinese, Korean) in some subjects such as tourism, law, business, etc.), in philological faculties (English, German, French, Spanish, Chinese, Japanese), at language schools and language courses (a wider range on offer).

For each area and at each level, specific goals are set and age-appropriate textbooks are selected that can be maximally achieved. One of the strategic goals in foreign language teaching is the development of communicative language competence, but one should not forget intercultural competence, which is considered a part of communicative language competence. Since there is a lack of apprenticeship time in every teaching area, it is important to design the lessons in such a way that more skills are developed with each subject. The topic "Strange tracks in my environment" is considered a good reason for various activities. On the one hand, the topic "Strange and strangers" lets you experience and through its presence in the vicinity everything that does not belong to your own identity as something familiar, not perceive what is foreign, on the other hand it allows learners to understand more of the history and language of their homeland, of their own identity and the image of others.

"Strange tracks in my environment" is not a new topic. It can be called a "generative theme" because it is "interesting, thematically open, linguistically rich and culturally differentiable" and comes in different encodings, in the form of historical documents, films, photos, literary texts, songs" (Krumm et al., 2011, p. 1508). International contacts in the social, scientific, educational policy area, as well as linguistic and literary studies, the influences and connections of languages and cultures represented in the home country, have always been among the focal points in the research of philologists, culturologists and literary scholars. This research was mostly aimed at academics, while our practice-oriented approach is intended for a different target group, those who teach foreign languages. From a didactic point of view, this theme is very beneficial, as it allows to see the strange in the familiar. Ukraine, like many European countries, also has some language islands where German, Hungarian, Slovak ethnic groups live and where many traces of their cultures are clearly visible. The people who have lived in these areas for a long time are not largely bilingual in the sense that they can communicate Ukrainian and their native language on the same level, but historical, cultural, technical and economic traces of the former or present presence of foreigners the territory of Ukraine can be easily discovered. Using "foreign" languages and "foreign" cultures locally as a source of cultural knowledge is considered a good didactic way to motivate learners to learn a foreign language and its culture.

3 INTERDISCIPLINARY AND CLOUD-ORIENTED FOREIGN LANGUAGE TEACHING

3.1 Interdisciplinary Approach in Foreign Language Teaching

"Interdisciplinarity" is not a new term in the scientific and teaching environment; however, it is much discussed in the specialist literature. As Schatz (Schatz, 2009) notes in his study "Research-oriented, interdisciplinary teaching in a multidisciplinary environment": "Although interdisciplinarity is a scientifically well-studied topic, there is no coherent understanding of this term" (Schatz, 2009, p. 2). Labudde (Labudde, 2004) emphasizes "a shambles in defining" interdisciplinary teaching because so many components are tied together to designate the term: including intra-, trans-, multi-, pluri – or intra-disciplinary, interdisciplinary, -coordinating, -connecting or -linking. "The terms "cross-curricular" or "interdisciplinary" teaching apply as generic terms [...]. But that is where unity ends" (Labudde, 2004, p. 60).

A basic analysis of a number of classifications can be found in the scientific work by Dethlefs-Forsbach (Dethlefs-Forsbach, 2005) "Interdisciplinary teaching from the perspective of the subject music". The researcher characterizes attempts to systematize interdisciplinary teaching by Skiera (Skiera, 1994), Huber et al. (Huber et al., 1996), Hiller-Ketterer and Hiller (Hiller-Ketterer and Hiller, 1997), etc. For example, Skiera (Skiera, 1994) differentiates between three types of interdisciplinary teaching based on the didactic-methodological criterion (identification of subject-related cross-connections on a topic; multi-perspective treatment of a suitable topic over a longer period of time; formation of learning areas according to interdisciplinary thematic or methodological criteria). For his part, Huber et al. (Huber et al., 1996) determines five types of interdisciplinary teaching according to the organizational form (cross-subject, subject-linking, subject-coordinating, subject-complementary and subject-interrupting teaching) and three types according to orientation (orientation towards deepening and supplementing the subject; towards a change of perspective and reflection; towards a common problem). (Dethlefs-Forsbach, 2005, p. 179). Hiller-Ketterer and Hiller (Hiller-Ketterer and Hiller, 1997) also identify five types of interdisciplinary teaching according to didactic functions: to justify the need for specialist special courses, to demonstrate the usefulness of special courses for them, to relativize perspectives, for the purpose of demonstrating and testing common processes and formal interactions, for the reconstruction of everyday reality to build up the ability to act and to test it in limited actions (Dethlefs-Forsbach, 2005, p. 179).

Based on well-known classifications, including those mentioned above, Labudde (Labudde, 2004) developed his own summary classification, which describes certain types of teaching at the level of subjects and at the level of the timetable. This classification includes all of the types mentioned above (although they are called differently, but they contain similar content) and takes into account organizational as well as didactic-methodological and functional aspects of interdisciplinary teaching.

Labudde (Labudde, 2004) thus distinguishes three types of interdisciplinary teaching at the subject level, based on the relationships between the subject, the content taught and the way in which the content is incorporated into the teaching process. In the case of interdisciplinary teaching, relevant content from other subjects is introduced once into a single subject. Subject-linking teaching differs in the systematic and changeable nature of the linking of teaching content relevant to several subjects (basic concepts and methods). Labudde (Labudde, 2004) considers the so-called "subject-coordinating" or "theme-centered" lessons to be genuinely interdisciplinary, where the taught content is "an overarching theme or a key problem of humanity" that is processed "from the perspective of different subjects" (Labudde, 2004, p. 60). Subject-coordinated teaching provides for both systematic and one-off implementation and links subjects with one another that contain common problems or topics in their content.

At the level of the lesson table, Labudde (Labudde, 2003) distinguishes between supplementary and integrated lessons. The difference, explains Labudde (Labudde, 2003), is that in the first case it is about additional modules or disciplines, within the framework of which necessary content is taught, and in the second case "the individual subjects no longer appear in the timetable, but are in an integration subject such as NMM ("Natur – Mensch – Mitwelt") or 'People and Environment' embedded" (Labudde, 2003, p. 59).

It should be noted that all three types of interdisciplinary teaching at the subject level, as well as the two (subject-supplementing and integrated teaching) are relevant for use in foreign language teaching, depending on the goal and subject combination.

3.2 Interdisciplinary Approach in History and Foreign Language Teaching

One of the perspective directions in learning German is dealing with history. Successful communication requires not only a common language in which both / some interlocutors can communicate, foreign language skills at level A1 or higher, but also the desire to talk to each other. This desire or need arises when one has a common theme and *what* to say, when one wants to share or contradict, tell, discuss, clarify or express one's opinion about something (information, knowledge, experience). In this respect, history and historical content are on the one hand a good opportunity for communication in different contexts, on the other hand they are good material for understanding one's own identity and accepting the identity of the "other".

The following reasons can be given for the interdisciplinary use in foreign language teaching, at least from the perspective of Ukrainian teaching practice: diverse positive effects of interdisciplinary teaching (arouses interest in the subject and/or department), use of different methods and mutual linking, time economy and saving, development of analytical thinking (relationships are determined), inclusion of different knowledge and skills.

The subjects for interdisciplinary teaching depend on many teaching contexts. Different combinations are possible, but, in our opinion, among those most appropriate are literature, history, geography, politics, economics, and art – that is, the disciplines of the humanitarian field, because each of these disciplines is part of the geography in the sense of "knowledge of that destination country". The subject of history is particularly beneficial for the development of communicative skills on the one hand and for the development of intercultural competence on the other.

The term "history" has the following meanings: political, social, cultural development of a specific geographical, cultural area and the resulting sequence of events; scientific representation of a historical development; verbal or written description of an actual or imagined happening, event; story; [unpleasant] matter, matter (Müller et al., 1985, pp. 295-296).

"History" thus includes historical developments (city, country, world, humanity) and their descriptions in scientific or literary form; an event, something extraordinary or unpleasant, and its depiction; a school or study subject.

History as a subject and historical content within it are taught in different ways at educational institutions in Ukraine: two methods are most preferred: linear –

arranged chronologically from the past to the present or focused on events – certain events are considered two or three times, you change perspective, you delve into details. One analyzes not only consequences, but also reasons, motives and circumstances. The aim of the process, which focuses on events, is not only the knowledge that students acquire, but also the conscious examination of historical facts.

The positive thing about using historical content in foreign language teaching is that history, in each of the above-mentioned meanings and in different contexts, always appears as a good occasion for communication. Every story (as a scientific representation of historical events, a literary narration of an event, a family history or similar) contains specific data, describes the people involved and their deeds, evaluates processes, etc. In historical texts you will find concrete content (data and information) that is presented (illustrative, graphical, tabular) or verbal as a series of keywords naming events or processes. Based on this information, students can summarize content presented in schemes or diagrams. The visualization of the summarized information contains necessary data, vocabulary and, if illustrated in chronological chains, also the content rendering plan. This facilitates the way from the text (reception) via schematic, summarized or detailed representation to speech (production).

"Interdisciplinary forms of teaching are an opportunity to break new pedagogical and methodological paths and to open up new horizons for both the students and the teacher" (Aigner, 2015, p. 10). This thesis applies to the combination of foreign language teaching and history teaching. Knowledge of foreign languages allows students to access information sources that are not accessible in their mother tongue. It is not only about archive materials or scientific contributions, but also about diverse learning materials that are offered on different platforms today. On the other hand, the conscious examination of the history of the target country in foreign language lessons broadens the perspective of the learners, allows them to better understand today's everyday life and the views of the people who live in this country, which contributes to the development of intercultural competence (knowledge of the country, attitudes, intercultural actions and behavior).

History can be integrated into foreign language teaching in different ways. It depends on what is the focus: history on a social level (history of Europe and national history in the context of European history or world history, individual events or an epoch) or history on a personal level (well-known personalities, their lives, their work, family histories, etc.).

Each story text must be didactic for each level. The higher the language level of the learner, the lower the level of didactic knowledge. For level A2, authentic texts are offered with worksheets prepared by the teacher, which not only contain the necessary vocabulary, but also pre-filled schemes. Learners at language level B1 – C1 can collect information from the texts themselves, both authentic and in their mother tongue, so the following tasks would be useful:

1. Read the text and highlight the most important information.
2. Arrange the information (data) and events or processes according to the scheme: When? What? / Who? Where? How?
3. Gather words and phrases that you need for communication.
4. Compare your results.
5. Enter the collected data in the schema (diagram).
6. Summarize the most important information (orally or in writing).

Other ways in which the story can be used as a means of communication in the classroom are: talking to foreigners living or working in the area, asking for and summarizing information about their families, tabulating CVs and family histories and telling about their fates; choose a topic and search for information from different sources, graph it and talk about it; Collect, organize and process information in the mother tongue. Speak in a foreign language on the basis of the prepared schemes or tables on the topic.

Of course, there are also different exercises and tasks for other goals possible, e.g. for the expansion of vocabulary, for the development of grammatical competence, etc.

3.3 Cloud-Oriented Interdisciplinary Foreign Language Teaching: Ideas and Their Practical Implementation

First, general remarks on cloud-oriented foreign language teaching. 2019-2022 is already being called the time of virtual learning and teaching. COVID-19 and later the war in Ukraine caused many familiar processes and formats in the field of education to be designed differently (Kovalchuk et al., 2023). The teaching institutions in schools and universities, private language and art schools give lessons mainly online and use all possible Internet platforms, apps, technical possibilities that are available: computers, tablets, laptops, phones. The tendency to use different ICT in the classroom has been observed since

2000; therefore, enough practical experience has been gained with it and the results justified theoretically. But so many ICT in all their diversity have only been in use in schools and universities since 2019.

For foreign language teaching, the transition from traditional teaching and blended learning, which is well known in didactics, is advantageous because numerous technical possibilities create favorable conditions for immersion in a foreign language. With the help of ICT, an immersive cloud-oriented environment is created where receptive and productive language skills are developed. The positive is that thanks to modern technologies, virtual classrooms can be created with specific teaching content for different target groups (age, interests, language level, learning goals, etc.). Of course, different technologies (apps, programs, platforms, social networks) and content (internet and other sources) are chosen for the classes, where language skills and certain sub-skills are developed, and for theoretical courses.

The following resources are relevant for the design of the cloud-oriented environment for foreign languages: asynchronous (texts: official pages of newspapers/magazines, blogs; videos: YouTube offer topics such as history, society, environmental protection, family, etc., documentary, educational films, movies); synchronous/asynchronous (social networks, spreadsheets); synchronously (chats, learning platforms with interactive exercises, etc.). For theoretical disciplines, short and instructional films on specific terms (literature, history, lexicology, and stylistics), works, authors (literature), events (history), etc. can be used asynchronously on YouTube, as well as lectures on many disciplines, conference contributions, monographs, other publications/presentations. The platforms Google Classroom and Moodle, where the appropriate cloud-oriented environment is created, play a major role here, as well as Zoom and Google Meet, which ensure immediate, synchronous communication.

The following resources and tasks are conceivable for cloud-oriented interdisciplinary foreign language teaching with a focus on "history". There is a large selection of materials for asynchronous use. These are official pages of newspapers and magazines in the target language. These are visual and textual, auditory and audiovisual media, examples of which are provided by Huneke and Steinig (Huneke and Steinig, 2013, p. 44). For example, for level A2 – B1 you can download the edition "German History 1914 – 1990" where you can short texts with many pictures that illustrate the events, on 16 pages of German history of these years (free of charge), available at (https://www.bpb.de/system/files/dokument_pdf/Zeitleiste_deutsch_zum-Selbstdruck_16_Einzelseiten.pdf)

For level B1-C1 on the official website of https://www.bpb.de/shop/zeitschriften you will find free editions of three magazines (Fluter, Informationen für politische Bildung and APUZ (Aus Politik und Zeitgeschichte (From Politics and Contemporary History)), where historical contents are presented. It is about the history of different countries in different epochs (including Germany, France, the USA, Ukraine, China, etc.) and about the most important historical events, which are sometimes interpreted controversially. The editions are intended for young people, so all texts are written in clear and understandable language.

Another example are excerpts from the latest editions of German history, as well as excerpts from earlier publications, e.g. https://files.hanser.de/Files/Article/ARTK_LPR_9783446249387_0001.pdf. They are available free of charge and are relevant for learners from level B1.

Auditory media, which include podcasts, are also conceivable for creating the cloud-oriented environment, but much more favorable for interdisciplinary German history lessons is filmed history of Germany from ZDF "Die Deutschen", which includes a total of 20 films (45 minutes). In the center is a historical figure (Otto und der Reich, Luther und die Nation, etc.) who represents the entire epoch, and there you will not only find fragments that tell about the story like a movie, but also commentaries by scientists and brief information on the epoch. All films can be found to download for free at: https://www.zdf.de/dokumentation/terra-x/die-deutschen-140.html. There are already finished didactic versions: https://tinyurl.com/ysjrkfdw.

Not to be forgotten is the YouTube offer, where educational films, documentaries of various lengths, movies and literary adaptations in all possible languages and on historical events are available worldwide, sometimes with tasks. There is also an option to read comments and comment yourself. For example, on the history of Germany: in German "The 10 greatest turning points in German history" at https://www.youtube.com/watch?v=CDrpYGeXuy4, "Wir Deutschen" at https://www.youtube.com/watch?v=1miI2JlpFxg and in Ukrainian; on the history of France "The Animated History of France" at https://www.youtube.com/watch?v=ZNk2QOn9oGE in English; on the history of Scotland "The Animated History of Scotland"; on the history of Ukraine in Ukrainian at https://www.youtube.com/watch?v=LJFR_3myjUk, https://www.youtube.com/watch?v=ITw2Lk93qrY and in English at https://www.youtube.com/watch?v=zJvz3Ai9Ppw and many others.

Social media can be used both synchronously (chats) and asynchronously. Texts can be selected that also emphasize intracultural diversity and shared history. For example, the presence of Germans in Ukraine is discussed in comments on Facebook. In this case, one can not only develop tasks related to the texts with information, but also motivate the learners to take part in the discussion (figure 2).

You can use many Ukrainian Internet resources in the classroom, which are of theoretical/academic, as well as popular science nature, or are designed for learners. So, for example, the page "A day in history" (available at https://www.history.com/this-day-in-history) is bilingual (Ukrainian and English), contains interesting data about events on a specific day and can easily be used in the classroom. World History Encyclopedia (https://www.worldhistory.org/) provides not only verified fact texts on world events, but also educational materials. There you will also find many pictures, videos and an has many pictures, media materials and quizzes. These and many other pages of academic texts are conceivable for learners with a high level of proficiency, a genuine interest in history, and provided that the material is grammatically and lexically prepared.

When selecting the media for productive use in the classroom, it is important to remember that it is important that they primarily have a mediating function and that certain selection criteria must be observed. According to Huneke and Steinig (Huneke and Steinig, 2013) emphasize the following: authenticity (focus on target language, real reality of the target country rather than an "overly filtered art world"), level of sophistication (accessible but with the new material), prior knowledge (built on the prior knowledge but with new content), reflective handling (comparison of cultures, habits, events) and openness (different opinions and interpretations are possible) (Huneke and Steinig, 2013, p. 219).

4 CONCLUSION

According to European documents in the field of foreign language training and theoretical research results from recent years, the structure of intercultural competence includes language skills, knowledge of the destination and home country (cognitive level), attitudes, willingness to communicate and make contacts, acceptance of the foreigner, tolerance (emotive level), behavioral patterns (conative level) counted. Not to be underestimated are personal qualities and social skills (cognitive, emotive and conative) that can be considered as prerequisites for successful communication, and which include such qualities as the ability to: empathize, think analytically, compare, evaluate and receive information from different people and to link sources, areas of knowledge associatively, to draw conclusions. These skills and abilities are developed within different disciplines, which shows that the interdisciplinary approach should be used as one of the possible tools. Intercultural communication can be trained in different ways.

Foreign language teaching offers many opportunities for the development of intercultural competence, because the conditions of learning a foreign language are becoming more and more favorable for assimilation of foreign culture. You learn a language through its culture in word and spirit, which is why so much attention is paid to intercultural content and culture in foreign language classes. Another way to develop the intercultural competence is intracultural diversity, which is seldom used. Regional studies of a foreign culture through local history not only helps to learn about the target country and the people in this country and understand their development, but also about one's country, one's compatriots, one's own culture and history. It contributes to a positive and tolerant attitude towards others, because such acquaintance with the "foreign" world occurs through the "personal" (specific local people, familiar things).

From all classifications of types of interdisciplinary teaching, we consider the classification proposed by P. Labudde to be the best (it was based on the previously developed classifications (Hiller-Ketterer and Hiller, 1997)). All types (inter-subject, subject-linking, subject-coordinating) are relevant for the development of intercultural competence, most favorably in the case of foreign language teaching in combination with other disciplines there are two of them: interdisciplinary and subject-coordinating (theme-centered).

Many areas of knowledge and subjects in most curricula can be interdisciplinary linked to foreign language teaching: literature, geography, history, politics, economics, art, etc. All of these subjects contain components that are referred to as regional knowledge and that have a certain attitude towards the "foreigners" and to the "foreign" culture. Especially favorable for the development of intercultural competence is the combination "foreign language lessons + history lessons" because, firstly, history of the target country and the people allows learners to understand backgrounds that shaped the national character, spirit and way of thinking of the people; second, each story describes certain patterns of behavior, rituals, manners and customs that lead to the perception and later acceptance of the differences in both cultures.

Visit the page https://www.facebook.com/groups/deutsche.in.UA "Deutsche im Gouvernement Katerynoslav" and read reports and comments. Summarize new information.

In den Jahren 1762-1764 hat die Zarin Katharina II. viele deutsche Bauern nach Russland eingeladen. Sie kamen zuerst nach Sankt-Petersburg und wohnten in der schwedischen Festung Jamburg. Da war auch die erste bayerische Kolonie in Russland. Aber der Boden war da nicht sehr gut für die Landwirtschaft. 1773 haben 15 Familien aus Velburg, Burgenland, Oberpfalz, Bayern die Genehmigung bekommen, ins Gouvernement Katerynoslaw umzusiedeln. Sie haben zuerst im Dorf Kodak gewohnt und haben dann das neue Dorf Jamburg gegründet. 1789 wohnten in Jamburg 148 Männer, 1793 – schon 485. Im Russischen Reich wurden nur die Männer besteuert, darum hat man in erster Linie sie gezählt. Die Geschichte von Jamburg ist in einem Buch von Jakob Mohr beschrieben. Das Buch wurde 2004 in Deutschland gedruckt. Jakob Mohr hat nie in #Jamburg gewohnt, aber seine Mutter stammte aus Jamburg. *Jakob Mohr. Geschichten der bayerischen Kolonie Jamburg, derer Tochterkolonien und Verbannungsort Asbest. – Bad Laer, 2004. – 470 S.*	Catherine Glushak # Ganz abgesehen von der Frage, ob A. Poll als Deutscher betrachtet werden kann (er selbst hielt sich trotz seines deutschen Großvaters und des Namens für Ukrainer), haben Deutsche eine wichtige Rolle bei der Erkundung des Eisenerzvorkommens bei Krywyj Rih gespielt: in der Bergakademie Freiberg wurden die Erzproben untersucht, Fachleute aus Freiberg unter Leitung des bekannten Montaningeniers Leo Balthasar Leberecht Strippelmann (1826-1892) haben auf Bitte (und auf Kosten) von O.M. Poll das Vorkommen vor Ort studiert und ein Buch dazu geschrieben. Es hieß „Süd-Russlands Magneteisenstein- und Eisenglanzlagerstätten in den Gouvernements Jekatherinosslaw und Cherson" und wurde 1873 in Leipzig und Sankt-Petersburg (in russischer Übersetzung) herausgegeben. (Angaben aus Wikipedia) # Hier müsste man eigentlich auch davon absehen, dass die Gegend des heutigen Krywyj Rih damals gar nicht zu Gouvernement Katerynoslaw, sondern zu Gouv. Cherson gehörte. Aber das ist ja eine Kleinigkeit, die nur davon zeugt, wie weitreichend der Einfluss von Katerynoslaw schon immer war.

Figure 2: Excerpt from the worksheet on "German traces in the Ukraine".

Cloud-oriented environment creates additional opportunities for interdisciplinary use. It is created and expanded with the help of different resources (asynchronous, synchronous, asynchronous-synchronous); visual and textual, auditory and audiovisual media are used, depending on the language level of the learners, the language of the materials offered and the learning objective. The selection criteria must be observed because the learning success depends on them.

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Methodical System of Teaching Informatics to Pre-Service Mathematics Teachers

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Keywords: Pre-Service Mathematics Teachers, Informatics, Computer-Oriented Methodical System of Teaching, Informatics Competences, Model of Computer-Oriented Methodical System of Teaching Informatics to Pre-Service Mathematics Teachers.

Abstract: The article is devoted to the problem of development and implementation of computer-oriented methodical system of teaching informatics to pre-service mathematics teachers. Based on the analysis of scientific literature, the role and place of informatics in the competence-oriented training of pre-service mathematics teachers are revealed; the structure, content, indicators and levels of informatics competencies formation of pre-service mathematics teachers are clarified and characterized; the model of computer-oriented methodical system of teaching informatics to pre-service mathematics teachers has been developed. Theoretically grounded and developed the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers, consisting of the target (formation of informatics competencies of pre-service mathematics teachers), design (design the system of informatics competencies and methodical system of teaching), technological (creation of a computer-oriented learning environment for informatics courses) and result blocks; its experimental verification was carried out and confirmed on the basis of the developed criteria and indicators.

1 INTRODUCTION

The Law of Ukraine "About the Basic principles of development of information society in Ukraine for 2007-2015" defines the creation of an education system focused on the use of the latest digital technologies in the formation of a comprehensively developed personality as the main strategic goal of the development of the information society in Ukraine (Verkhovna Rada of Ukraine, 2007). To achieve this goal, the "Strategy for the Development of the Information Society in Ukraine" (Cabinet of Ministers of Ukraine, 2013) defines a number of priority areas of state policy, the implementation of which will ensure the improvement of the educational process, accessibility and effectiveness of education. Leading among them are: formation and development of the informational educational environment in the system of general secondary and higher education; implementation of an information system for supporting the educational process; development of the distance learning system and ensuring, based on it, the effective implementation and use of digital technologies at all educational levels of all forms of education (Cabinet of Ministers of Ukraine, 2013).

According to the "Concept of the Development of the Digital Economy and Society of Ukraine for 2018-2020", the main directions of digitalization of education are the development and implementation of innovative computer-oriented learning tools to create a digital learning environment and the development of a distance form of education using cognitive and multimedia technologies (Cabinet of Ministers of Ukraine, 2018). The main driver of the digitization of education is a competent teacher, whose training must meet social demands, take into account world trends and recommendations of influential international organizations. Among the factors of the imbalance between the public demand for highly qualified pedagogical workers, the prospects for the development of society, global technological changes and the existing system of pedagogical education, as well as the level of readiness / ability of modern teachers to implement educational reforms in Ukraine, the leading ones are the outdated content, structure, standards and methods of teaching in system of pedagogical education, as well as the inconsistency of key professional competencies of graduates of pedagogical education insti-

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tutions with the challenges of the digital society.

The action plan for improving the quality of physical and mathematical education involves: bringing the content of physical and mathematical education in line with the modern development of science and the needs of society; digitization of mathematics education by including laboratory workshops with a computer mathematics system, calculation visualization tools in mathematical disciplines; training of teachers to develop in students the ability to interpret quantitative data presented in tables, charts and graphs, teaching students to independently obtain the necessary information, analyze it, perform calculations and choose the optimal solution (Ministry of Education and Science of Ukraine, 2008). The decree of the President of Ukraine "On the declaration of the 2020/2021 academic year as the Year of Mathematics Education in Ukraine" provides for the creation of conditions for equal access to modern and high-quality mathematics education and ensuring the modern level of teaching mathematics disciplines, in particular with the use of effective technologies taking into account the best domestic and international practices (President of Ukraine, 2020).

Therefore, there is a socially determined and legally justified need to improve the quality of training of future teachers of mathematics, in particular informatics training. One of the leading directions for achieving this goal is the development and implementation of computer-oriented methodical systems and training tools for future teachers of mathematics.

2 THEORETICAL BACKGROUND

The problems of development, modification and implementation of computer-oriented methodological systems for teaching mathematics and informatics in institutions of general secondary and higher education were studied by Bieliavtseva and Kanevska (Bieliavtseva and Kanevska, 2007), Vlasenko et al. (Vlasenko et al., 2020), Horoshko and Pokryshen (Horoshko and Pokryshen, 2010), Gubanov (Gubanov, 2010), Zhaldak et al. (Zhaldak et al., 2021), Klochko (Klochko, 2017), Tryus (Tryus, 2010), Shokaliuk (Shokaliuk, 2012) and others.

The professional competences of the future mathematics teacher are considered in (Zhukova, 2009; Ramskyi, 2013; Marienko, 2022; Lovianova et al., 2019; Semenikhina et al., 2022; Rakuta, 2013; Matiash and Mykhailenko, 2020; Skvortsova and Romanyshyn, 2019; Hrabovskyi, 2016; Lebedyk, 2017; Razlivinskih, 2011; Sadulaeva, 2012). In particular, the use of digital technologies in the training of future mathematics teachers and the formation of their IT competences is highlighted in (Bilousova and Zhytienova, 2010; Gubanov, 2010; Zhaldak, 2003; Zhernovnykova et al., 2020; Kirilenko, 2009; Kolgatin et al., 2022; Krishtof, 2011; Robert et al., 2016; Kushnir, 2014; Sarkeeva, 2010; Senkevich, 2005).

Analysis of the current state of development of the information society in Ukraine and the world (Schwab, 2016; Schwab and Malleret, 2020), the potential of information technologies as a means of integrating mathematics, computer science and natural sciences (Gromov, 2001; Semenov, 1995; Karakozov and Ryzhova, 2019), as well as the problems of informatics training of future mathematics teachers (Ershov, 1987; Zhaldak et al., 2012; Tikhomirov, 2000) discovered that the prospects for the development of digitization tools should be reflected in the anticipatory content of teaching informatics disciplines at all levels of education. Therefore, modernization of IT training and IT competences of future teachers needs special attention (Zhukova, 2009; Ramskyi, 2013), since it is the teacher who must introduce digital technologies into the educational process, form students' IT competences, and prepare the new generation for full-fledged life in the information society.

Mathematics and informatics are related sciences that significantly influence each other in the process of their development and largely determine the development of natural sciences and technologies. The main source for changes in the education system is the public order, which reflects the development of technology, science and socio-economic relations. In the 20s of the 21st century, this complex, named Industry 4.0, is extremely computerized, which makes it necessary to clarify the IT competencies of future teachers by reflecting new content and new abilities. It is shown that the formation of key and subject information-communication (digital) and mathematical competences in the European educational space is considered as a component of the fundamental literacy of workers in demand on the labor market of the future. Therefore, in the process of forming general professional digital competences of the teacher, it is necessary to take into account such basic ICT innovations as open educational resources, social networks, mobile technologies, the Internet of Things, artificial intelligence, virtual and augmented reality, big data, programming, ethics and privacy protection.

As a result of the analysis of domestic, foreign (Commonwealth of Australia, 2022; Association of Mathematics Teacher Educators, 2017) and international (UNESCO, 2018) teacher training standards, the components and indicators of such general professional digital competences as the ability to: evaluate, implement and use ICT-oriented educational platforms have been determined; application of e-learning in social media; pedagogical design for e-learning; analysis, implementation and evaluation of the effectiveness of evaluation; application of ICT-related knowledge; implementation of improved educational practices; analysis of industrial implementations and e-learning systems. Special attention should be paid to the recommendations of the Association of Mathematics Teacher Educators and the National Council of Teachers of Mathematics of the USA aimed at pedagogically appropriate and balanced use of ICT in teaching mathematics in general secondary education institutions.

The generalization of the theoretical provisions gave reason to specify the structure, indicators and levels of formation of the IT competencies of the future mathematics teacher: at the first (initial) level, competencies related to performing tasks with the help of a personal computer, various software and digital devices are formed; at the second (minimum basic) competences in the use of ICT in any field are formed; the third (basic) develops competences in a wide range of ICT, including animation, the basics of cloud technologies, cyber security, digital media, computer networks, programming, computer systems and web development; the fourth (advanced) develops digital competencies related to solving a wide range of problems related to database management, computer game development, computer network configuration, programming, system administration, and web development; the fifth (in-depth) level provides for further development of general professional and formation of specialized competencies in computer networks, programming, web development, business analysis, cloud computing, cyber security, databases, design and development of computer games, system administration and system analysis; the sixth (research) level completes the process of forming informatics competencies of future mathematics teachers at the second level of higher education.

3 EMPIRICAL RESEARCH OF STUDENTS' VIEWPOINTS

Based on the analysis of various approaches to the design and development of methodical systems of education, the components of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers are determined. The choice of a methodical system as an object of modeling is related to the need to reflect in the model its structural components, technologized in terms of competencies, results and goals, external factors affecting the system, principles and approaches to its design. In the developed model of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers (figure 1), ICTs determine the goal, serve as design factors and leading means of teaching informatics disciplines.

The model consists of four blocks.

The target block reflects the goal: the formation of informatic competences of future teachers of mathematics, which is a component of the professional competences of a mathematics teacher, which are summarized in integral competence: the ability to solve complex specialized tasks and practical problems in the field of general secondary education in the process of teaching mathematics, which involves the application of psychological-pedagogical theories and teaching methods and is characterized by complexity and uncertainty of conditions. The formulation of the goal involved taking into account social, educational and information technology factors: crisis phenomena in science and mathematics education, the social need for competent mathematics teachers, the need to change professional IT competencies and new means of Industry 4.0.

The design block reflects the process of designing the system of informatics competences of the mathematics teacher and the core of the methodological system of learning, which consists of interconnected components (goals, content and technology of learning informatics) based on systemic, competence-based, activity-oriented and personally-oriented methodological approaches and the principles of a harmonious combination of traditional and innovative technologies, continuity, extensibility, invariance and variability, predictability, contextuality, integrability; general didactic and partially didactic principles of teaching informatics and principles of designing an open methodical system: feedback, dynamic balance, integrity and structural stability of the system.

The system of IT competencies of a mathematics teacher is designed in the form of a hierarchy, each level of which is a certain specialization or specification of the previous one: at the first level there are basic IT competencies, which at the second level are specified in competencies in system administration, web technologies, programming and system analysis; the third level reflects the development of: competencies in system administration – in competencies in computer networks and cyber security, competencies in web technologies – in competencies in cloud technologies, competencies in programming – in competencies in the development of computer games, com-

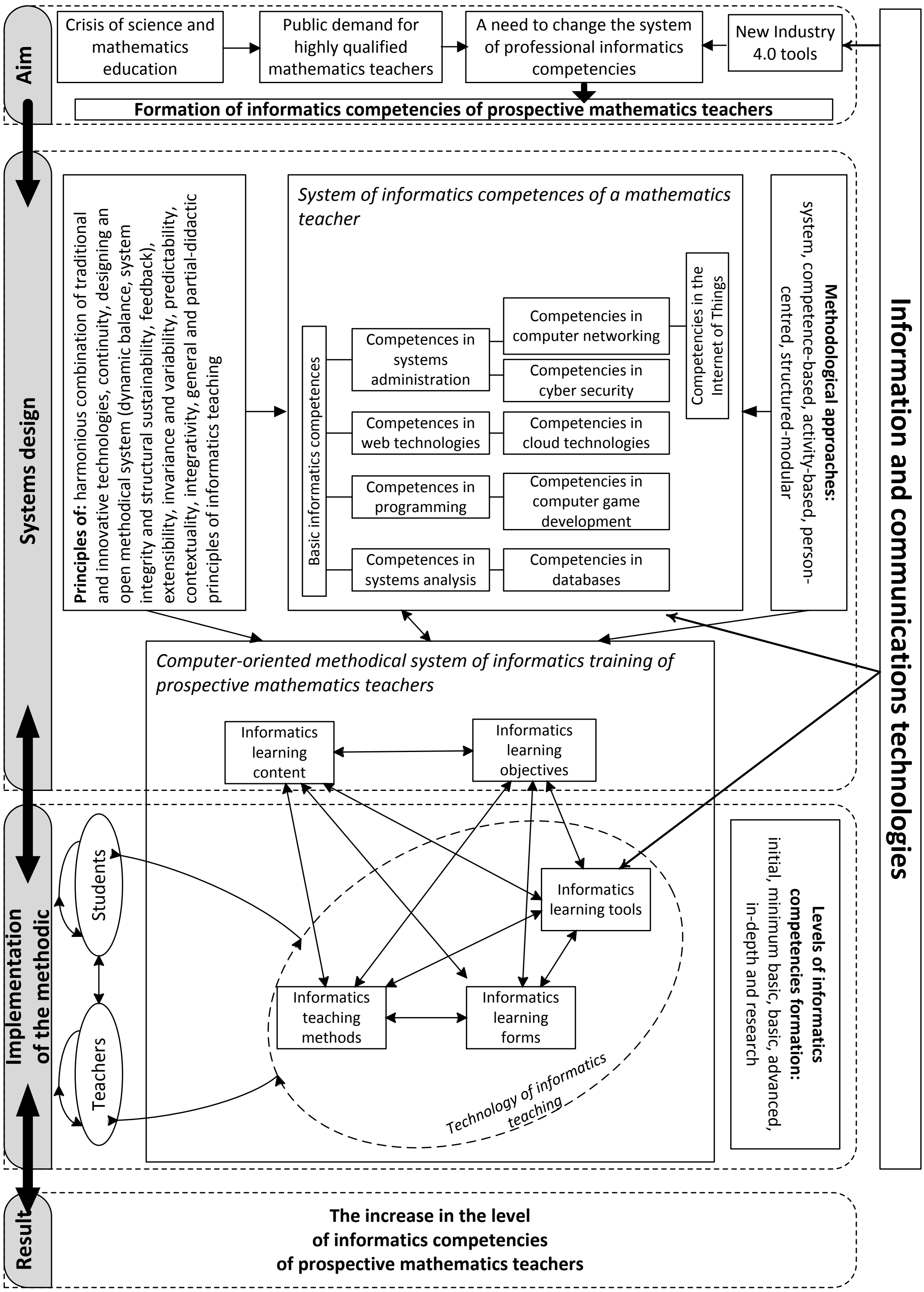

Figure 1: Model of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers (Semerikov et al., 2021).

petencies in system analysis – in competencies in databases; the fourth level reflects promising competencies in the Internet of Things, which is the development of competencies in computer networks.

The components of the system are interconnected not only through the learning goals and the technological result, formulated in terms of the informatics competencies of the mathematics teacher, but also through the content of education by mapping: the structure of informatics competencies – to the structure of informatics training in the relevant educational program; the content of informatics competences - on the content of training in informatics disciplines; mandatory and optional IT competences – for the structuring of IT disciplines.

The technological block reflects the process of creating a computer-oriented learning environment for informatics disciplines, in which there is direct and ICT-mediated educational communication between teachers and students, monitoring and diagnosis of the level of formation of informatics competencies at one of six levels: initial, minimum-basic, basic, advanced, in-depth and research.

The resulting block of the model reflects the projected goal of applying the developed methodical system: increasing the level of formation of informatics competencies of future mathematics teachers. The latter is considered both as a current result, which is diagnosed in the process of forming informational competences, and as a component of the overall result of professional training, which is diagnosed after the completion of the process of their formation.

Semerikov et al. (Semerikov et al., 2021) defines the principles of classification of teaching aids, selects teaching aids for general and special purpose IT disciplines, and provides elements of their application methodology. The interrelationships of the informatics competencies of future mathematics teachers with a wide range of tools have been revealed, which made it possible to characterize the following groups of leading tools for teaching informatics disciplines: communication tools; means of creating documents; means of access to databases; means of digital media technologies; hardware testing tools; software development and testing tools; project management tools; computer modeling tools.

In the training of informatics disciplines of future teachers of mathematics, it is appropriate to use learning strategies (Ploetzner, 2012) – sequences of effective teaching methods used purposefully and flexibly are increasingly automated, but remain consciously applied: yes, the method of problem presentation, heuristic and research the methods can be used both sequentially with increasing the level of formation of students' IT competences, and simultaneously in a group of students with different levels of their formation.

4 COURSEWARE STRUCTURE AND BACKGROUND OF EMPIRICAL STUDY

Experimental work on the research problem took place in 3 stages:

1) the *analytical-declarative stage* (2012 – 2013), the task of which was to study the state of computer science education of future mathematics teachers and to determine approaches to solving the research problem. In order to implement the set tasks, dissertations, domestic and foreign standards for the training of mathematics teachers, sources on computer science education and the formation of digital competencies of the future mathematics teacher were analyzed, which made it possible to formulate a research hypothesis. At the first stage, the main attention was paid to the issues of using ICT means of organization, monitoring and diagnosing the results of independent work of students in informatics disciplines. The conditions for the use of distance learning technologies in the training of future mathematics teachers were determined, and the content and forms of organization of training in informatics disciplines were selected. The identified problems of informatics training of future mathematics teachers provided an opportunity to identify competence and system approaches as leading to achieving the research goal;
2) the *design and research stage* (2014 – 2016) is dedicated to clarifying the structure and content of the mathematics teacher's informatics competencies and justifying the feasibility of using Web 2.0 tools for the development of research telecommunications projects, mathematical packages as universal programming and modeling environments, cloud-oriented the G Suite tool for comprehensive online support for teaching informatics disciplines for future mathematics teachers. At the second stage, the main components of the model of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers were determined and the ascertaining stage of the pedagogical experiment was conducted;
3) the formative and generalizing stage (2017 – 2020) is devoted to the development and implementation of a computer-oriented methodical sys-

tem for training informatics disciplines for future mathematics teachers. The formative stage of the pedagogical experiment was conducted; the obtained results of experimental work were analyzed, elaborated and summarized; general conclusions are formulated and prospects for further research are determined.

114 students of Kharkiv National Pedagogical University named after H. S. Skovoroda and Kryvyi Rih State Pedagogical University took part in the formative stage of the pedagogical experiment to test the effectiveness of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers (the control group 71, experimental – 43). Comparison of the distributions of participants of the control and experimental groups at the beginning of the experiment using the H-criterion of Kruskal-Wallis showed the absence of statistically significant differences between them at the 0.05 level ($H = 3.6435 < H_{crit}(0.05) = 5.991$).

The training of informatics subjects of the students of the experimental group was carried out according to the updated educational programs. In particular: in the educational discipline "Informatics", aimed at the formation of basic IT competencies of a mathematics teacher, the content module "Hardware and software of computing systems" has been updated to ensure the formation of basic competencies in the basics of system administration and application software for automating the document flow of an educational institution and competences for organizing safe joint work in a cloud-oriented educational environment; content modules have been introduced to the educational discipline "Methodology of Informatics Education" to ensure the formation of basic competencies in intellectual property, development and implementation of educational innovations, interaction with educational ICT clients and project activities; in the educational discipline "Computer Networks", content modules related to the design, installation, configuration and management of local networks of the scale of a computer class, support of network ICT systems, troubleshooting of computer networks have been updated, network security, Internet of Things, installation and configuration of virtual machines and desktop virtualization; the content modules of the educational discipline "Programming Languages" reflect competence in programming technologies, object-oriented programming, database programming, designing user interfaces, developing mobile applications and software extensions.

To ensure the formation of competences in web and cloud technologies and the development of computer games, new educational disciplines "Cloud technologies" and "Development of computer games" were introduced, which consider the issues of developing websites, social media, choosing and configuration of cloud services, 2D and 3D modeling, complex design and development of 3D interactive games (including mobile and online), their content and media components, characters with elements of artificial intelligence, as well as the creation of game environments for the organization of joint educational activities.

The effectiveness of the methodical system was determined by measuring the level of formation of IT competencies at 6 levels: initial (0-51 points), minimum-basic (52-60 points), basic (61-70 points), advanced (71-80 points), in-depth (81-90 points) and research (91-100 points). After the completion of the formative stage of the pedagogical experiment, the comparison of the distributions of students of the control and experimental groups according to the level of formation of IT competences using the χ^2 Pearson test showed that they have statistically significant differences at the 0.01 level $\chi^2 = 17.253 > \chi^2_{crit}(0.01) = 15.086$. Taking into account the presence of individual violations of the conditions for applying the Pearson's χ^2 test (in 25% of the categories, the number of observations was less than 5), an additional test of the hypothesis that the level of formation of IT competences in the experimental group increased was performed using Fisher's angular transformation: $\phi^* = 3.969 > \phi^*_{crit}(0.01) = 2.31$, which is the basis for the conclusion that in the experimental group the level of formation of IT competencies has increased, and therefore, the research hypothesis is proven.

5 RESULTS AND DISCUSSION

In order to test the effectiveness of the developed computer-oriented methodical system of teaching informatics to pre-service mathematics teachers, a formative stage of the pedagogical experiment was conducted, during which 71 students studied according to the traditional methodical system (control group), and 43 students – according to the author's method (experimental group). Using the Kruskal-Wallis test, it was established that at the beginning of the experiment, the distributions of participants in the control and experimental groups did not have statistically significant differences. After the experiment was completed, the level of formation of the informatics competencies of mathematics teachers was diagnosed, and statistically significant differences at the 0.01 level were established in the distributions of students of the control and experimental groups according to the Pearson criterion ($\chi^2 = 17.253 > \chi^2_{crit}(0.01) = 15.086$), and by applying the angular Fisher's transformation confirmed the statistical significance of the increase in the level of formation of IT competencies of the students of the experimental group ($\phi^* = 3.969 > \phi^*_{crit}(0.01) = 2.31$). Taking into account that the experimental group used the developed computer-oriented methodical system of teaching informatics to pre-service mathematics teachers, the indicator of the effectiveness of which is the diagnosed increase in the level of formation of informatics competences, it was concluded that the research hypothesis is proven.

6 CONCLUSIONS

The conducted analysis of the current state of informatization of society, the development of information technologies and the directions of reforming STEM education made it possible to conclude that its digitalization requires an end-to-end comprehensive appropriate use of models, methods and tools of informatics, systematic design of the anticipatory content of learning in informatics disciplines and modernization of informatics training of future teachers of mathematics.

It is shown that informatics as a complex discipline, the object of which is information processes of any nature, the subject is new information technologies, and the methodology is a computational experiment, is the basis for the integration of natural sciences, ICT, engineering and mathematics in STEM education.

The main areas of modernization of the professional training of mathematics teachers are identified and characterized: digitalization of research-oriented teaching of mathematics, informatization of the content of the teaching of mathematical disciplines, and strengthening of the IT training of mathematics teachers. It is substantiated that future teachers of mathematics should master new information technologies (mobile, ubiquitous, cloud-fog and quantum computing) and the ability to remotely manage social (in the process of distance learning) and cyber-physical systems, as well as the application of mathematical methods and models of artificial intelligence to them intelligence for the implementation of optimal management of training and robotic systems.

According to the results of the analysis of the standards of key competences, basic and full secondary education, training of teachers and specialists in information technology, the system of computer competences of the mathematics teacher was clarified in terms of structure, content and indicators of their formation. It is shown that the formation of IT competences of a mathematics teacher begins with basic IT competences: from the basics of system administration, in application software, from the organization of safe joint work, from digital media, from intellectual property, from the development and implementation of innovations, from interaction with educational ICT clients and project activities. Further development of basic IT competences takes place: in competences in system administration, which acquire further development in competences in computer networks (in computer network administration, in troubleshooting computer networks, in network security and in virtualization) and the Internet of Things, as well as competences in cyber security; in competences in web technologies, which acquire further development in competences in cloud technologies; in programming competences, which acquire further development in computer game development competences; competencies in system analysis and competencies in databases.

A model of a computer-oriented methodical system for training informatics disciplines for future mathematics teachers has been developed, which consists of four blocks: 1) target, which defines the goal of forming the informatics competencies of future mathematics teachers; 2) design, which reflects the process of designing the system of informatics competences of the mathematics teacher and the components of the methodical system of learning (goals, content and technology of learning informatics), interconnected on the basis of systemic, competence-based, activity-oriented and personally oriented methodological approaches and the principles of a harmonious combination of traditional and innovative technologies, continuity, extensibility, invariance and variability, predictability, contextuality, integrability, general didactic and partially didactic principles of teaching computer science and principles of designing an open methodical system; 3) technological, which reflects the process of creating a computer-oriented learning environment for informatics disciplines, in which direct and ICT-mediated educational communication, monitoring and diagnosis of the level of formation of informatics competencies takes place; 4) result, which reflects the achievement of the predicted result of the application of the model – increasing the level of formation of informatics competencies of future mathematics teachers.

The developed model is specified in the components of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers. Competencies related to innovative means of general education (electronic educational resources, social networks, mobile technologies, programming tools, virtual and augmented reality tools) and special purpose tools (means of compliance with confidentiality and ethics of data processing, Internet tools) are reflected in the content of training in informatics disciplines. things and means of artificial intelligence). It was determined that the leading means of teaching informatics disciplines for future teachers of mathematics are means of communication; creation of documents; access to databases; digital media technologies; hardware testing; development and testing software development; project management; computer modeling. It is shown that the educational activity of future teachers of mathematics acquires a research orientation under the condition of constructing educational strategies from methods of active learning, in particular, the method of projects, trainings, business games, cooperative learning. The selected learning strategies determined the choice of forms of organization of the educational process in general, educational classes in informatics, educational activities in class, independent work, practical training and forms of organization of control activities.

7 PROSPECT FOR FUTURE RESEARCH

The performed research does not cover all aspects of the analyzed problem. Further scientific searches for its solution are expedient in the following directions: integration of programming systems and computer mathematics in the professional training of future mathematics teachers; modernization of learning calculation methods based on the use of models and artificial intelligence tools; integrated teaching of mathematics and informatics in a specialized school; application of means of an immersive environment for the development of virtual manipulatives.

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The Use of Mobile Internet Devices in Teaching Bachelors of Electromechanics Modeling of Technical Objects

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Abstract: The article is devoted to the problem of using development and implementation of methodic of using mobile Internet devices in learning bachelors of electromechanics in modeling of technical objects. Based on the analysis of scientific literature, the content of the bachelor of electromechanics competency in modeling of technical objects, the criteria for its formation and the model of using mobile Internet devices in learning bachelors of electromechanics in modeling of technical objects are theoretically substantiated and developed. The methodic of using mobile Internet devices in learning bachelors of electromechanics in modeling of technical objects was developed and experimentally tested; the concept of a mobile Internet device is clarified; the system of mobile ICT for learning bachelors of electromechanics has been improved; the methodic of learning bachelors of electromechanics to computer modeling was further developed.

1 INTRODUCTION

The Law of Ukraine "About the National Informatization Program" (Verkhovna Rada of Ukraine, 2022) defines the creation of an education system focused on the use of the latest ICT in the formation of a comprehensively developed personality as the main direction of the use of information and communication technologies (ICT), which provides the opportunity for each person to independently acquire knowledge, skills and abilities during education and professional training.

The goal of the Strategy for the development of higher education in Ukraine for 2022-2032 is to update the content, forms, methods and means of education through the wide introduction of modern ICT and electronic content into the educational process (Cabinet of Ministers of Ukraine, 2022). The absolute priority of education development is the introduction of modern ICTs, which ensure the improvement of the educational process, accessibility and effectiveness of education, and the preparation of the younger generation for life in the information society. Among the key directions of the state education policy defined by the strategy, two directions are interrelated. This is the informatization of education and the creation of a modern material and technical base of the education system, which require updating the outdated fleet of computer equipment, due to an increase in the share of mobile Internet devices (MID), which are the leading modern means of ICT education (Chieng, 2007).

One of the components of the professional training system of a modern engineer is computer modeling of technical objects and processes, which are widely used in all types of engineering activities. Modeling plays a special role in the training of specialists in the field of knowledge 14 "Electrical engineering", providing from 60% in the cycle of mathematical, natural and scientific training to 72% in the cycle of professional and practical training of electrical engineering and electromechanics bachelors. This is connected to the fact that, on the one hand, computer modeling of electromechanical objects and the processes flow in electromechanical systems is one of the types of professional activity of an electromechanical engineer, and on the other hand, to the fact that mathematical modeling is the basis of fundamental (physical and mathematical) training of an elec-

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tromechanical engineer. Therefore, the ability of electromechanics bachelor to apply the modeling methods, theoretical and experimental research using ICT is the basis of the general professional competences of electromechanics bachelors in modeling technical objects.

Despite the fact that ICT tools are actively used by electromechanical engineers, the method of their use in the process of teaching professionally oriented disciplines for electromechanics bachelors has been considered in few studios of Ukrainian researches (Sobko, 2002; Kobysya, 2012). The analysis of theory and practice of the researched problem revealed a contradiction between:

- the high level of mobility of an electromechanical engineer in the professional activity process and ensuring its ICT support with the help of mobile devices, on the one hand, and the lack of focus on their use in the process of training bachelors of electromechanics at the HEI – on the other hand;
- the need to develop integral competence in electromechanics bachelors in solving specialized problems and solving practical problems characterized by the complexity and uncertainty of the conditions – modeling of technical objects, and the insufficient level of development of its components;
- the significant influence of mobile Internet devices on all components of the process of teaching bachelors of electromechanics modeling of technical objects and the lack of scientifically based methods of their use.

2 METHOD

The relevance of the investigated problem, its insufficient development in pedagogical theory and practice, as well as the need to resolve isolated contradictions led to the choice of the research object – the process of teaching bachelors of electromechanics modeling of technical objects – and the research subject: the method of using mobile Internet devices in the process of teaching bachelors of electromechanics modeling of technical objects.

The *purpose* of the study is to theoretically justify, develop and experimentally verify the methodology of using mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects.

The *hypothesis* of the study is the assumption that the methodically justified use of mobile Internet devices in the training of bachelors of electromechanics in the modeling of technical objects will contribute to increasing the level of formation of their competence in the modeling of technical objects.

In accordance with the purpose and hypothesis, the following main *tasks* of the research are defined:

1. To analyze the sources of the problems of teaching bachelors of electromechanics modeling of technical objects and the use of mobile Internet devices in education.
2. To theoretically substantiate the content, structure, criteria and levels of formation of the competence of the bachelor of electromechanics in the modeling of technical objects.
3. To develop a model of the process of using mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects.
4. To develop a method of using mobile Internet devices in training of bachelors in electromechanics modeling of technical objects
5. Experimentally verify the effectiveness of the developed methodology in the process of forming the competence of bachelors of electromechanics in modeling technical objects.

The following *research methods* were used to solve the tasks:

- *theoretical* – analysis, generalization, systematization of the legal framework, educational standards, Internet resources, modern mobile ICT learning tools to determine the theoretical basis of the research, substantiation of the model and methods of using mobile Internet devices in education bachelors of electromechanics modeling of technical objects;
- *empirical* – purposeful pedagogical observations, conversations with teachers and students, questionnaires, analysis of teachers' work experience, expert evaluation to determine the structure and content of the competence of a bachelor of electromechanics in modeling technical objects, selection of mobile Internet devices for training bachelors of electromechanics in modeling technical objects entities; ascertaining and formative stages of the pedagogical experiment – for the purpose of approbation of the proposed methodology and experimental implementation of the main provisions of the study into the practice of higher education institutions;
- *statistical* – for quantitative and qualitative analysis of learning results according to the developed methodology.

The theoretical and methodological foundations of the research are philosophical propositions about the unity of theory and practice, interdependence and interrelationship of objective and subjective factors of personality formation; conceptual ideas of the philosophy of education (Andrushchenko, 2020; Savchenko and Kurylo, 2018; Kremen and Ilyin, 2020); theoretical foundations of the organization of the educational process in institutions of higher education (Atanov and Dudyanova, 2003; Yildirim et al., 2019), in particular technical higher education institutions (Luzik et al., 2019); theoretical foundations of modeling of training and education systems (Bykov, 2010; Dokuchaieva, 2022); scientific provisions of the competence approach in education (Spirin, 2010; Ovcharuk and Ivaniuk, 2021; Volkova et al., 2021), in particular, the formation of competence in modeling (Teplytskyi, 2000; Teplytskyi et al., 2019); theoretical and methodological principles of professional training of specialists in electromechanics (Roney, 1966a,b; Sobko, 2002; Wang et al., 2009; Kobysya, 2012; Dixit, 2012); scientific provisions of the theory and methods of using ICT in education (Bykov, 2010; Robert et al., 2016; Leshchuk et al., 2022; Nychkalo et al., 2021; Semerikov et al., 2021; Volkova et al., 2021; Zhaldak et al., 2021; Kukharenko et al., 2022; Spirin et al., 2022); theory and practice of implementing innovative technologies in institutions of higher education (Bespalko, 2018; Savchenko and Kurylo, 2018; Symonenko et al., 2020; Drushlyak et al., 2021; Volkova, 2022), in particular the use of mobile ICT in education (Slovak, 2013; Tkachuk, 2013; Echkalo, 2014; Kyslova and Slovak, 2015; Kazhan et al., 2020; Stepanyuk et al., 2020; Amelina et al., 2022; Tkachuk et al., 2022).

3 THEORETICAL PRINCIPLES OF THE USE OF MOBILE INTERNET DEVICES IN TEACHING BACHELORS OF ELECTROMECHANICS MODELING OF TECHNICAL OBJECTS

Analysis of the theory and practice of professional training of bachelors of electromechanics in Ukraine and abroad (Roney, 1966a,b; Hanson, 1994; Motorina, 2002; Vishniakova, 2004; Vaughan et al., 2008; Wang et al., 2009; Kobysya, 2012) made it possible to determine that one of the leading trends in its modernization is the synergistic integration of various branches of engineering (mechanical, electrical, electronic engineering and automation) for the purpose of designing, manufacturing, operation and maintenance of electromechanical equipment (Dixit, 2012). This approach, called mechatronics, involves the meaningful integration of various disciplines of professional and practical training of electromechanics bachelors based on the concept of modeling and the complex use of various forms of organization and training methods based on the concept of mobility.

It is shown that with such an approach, mobile Internet devices – multimedia mobile devices that provide wireless access to information and communication Internet services for collection, systematization, storage, processing, transmission, presentation – become the leading means of forming the competence of a bachelor of electromechanics in the modeling of technical objects all kinds of messages and data (Chieng, 2007; Modlo et al., 2018). The possibilities of using mobile Internet devices in education in order to ensure equal access to education (Molina and Chirino, 2010), personalization of education (Kinshuk et al., 2010), instant feedback and assessment of learning results (Bas and Slovak, 2014), organization of mobile learning (Traxler, 2021) are characterized, effective use of study time (Idrus, 2015), formation of mobile learning communities (Kukharenko, 2013), support of situational learning (Restivo et al., 2014), development of continuous “seamless” learning (Fernando et al., 2013), provision of communication connection between formal and informal education (Baloch et al., 2012), minimization of the consequences of the destruction of the educational process in areas of military conflicts or natural disasters (Dahya, 2016), assistance in education for persons with special educational needs, improvement of the quality of communication and management of an educational institution, maximization of cost effectiveness.

The generalization of the theoretical provisions gave grounds to define the competence of a bachelor of electromechanics in the modeling of technical objects as a personal and professional education, which includes a system of knowledge, abilities, skills, activity experience in the modeling of mechatronic systems and a positive value attitude towards it, and is manifested in the readiness and ability to apply modeling methods and software and hardware tools for process analysis, system synthesis, assessment of their reliability and efficiency for solving practical problems in professional activity, and distinguishing its components: cognitive, praxeological, axiological and information-communicative (communicability, ability to adapt and integrate). The structure of competence is reflected in the corresponding system of competences (figure 1).

The content of each competency is specified in competency matrices, which contains assessment criteria for 4 components (cognitive, praxeological, axiological, information-communicative) at 4 levels (levels of formation, low, medium and high). The use of the defined assessment criteria made it possible to determine the integral level of formation of the competence of the bachelor of electromechanics in the modeling of technical objects. Taking into account that the highest level of systematicity in the process of its formation is achieved during preparation for state certification (exam, passing of the qualification work), it is appropriate to take into account its detection by students during state certification when assessing the level of formation.

4 METHODICAL PRINCIPLES OF USING MOBILE INTERNET DEVICES IN THE EDUCATION OF BACHELORS OF ELECTROMECHANICS OF MODELING TECHNICAL OBJECTS

The model of the process of using mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects (figure 2) contains: socially and technologically significant factors that determine the expediency and necessity of developing a methodology for using mobile Internet devices in teaching bachelors of electromechanics modeling technical objects; methodological approaches (competent, systemic, interdisciplinary, model and activity) use of mobile ICT and learning tools; a target block that specifies the goal – formation of the competence of a bachelor of electromechanics in the modeling of technical objects; content-technological block, which reflects the connection between the content of education and the formation of individual components of the competence of a bachelor of electromechanics in the modeling of technical objects and the technology of using mobile Internet devices in the education of bachelors of electromechanics in the modeling of technical objects (a system of forms of organization of the educational process with using mobile Internet devices, methods of their use and mobile ICT tools); a diagnostic result block containing evaluation criteria, indicators, levels of formation and tools for diagnosing the competence of a bachelor of electromechanics in the modeling of technical objects. The implementation of the process of using mobile Internet devices in the training of bachelors of electromechanics in modeling technical objects is an appropriate method of use, the components of which are partial methods of using mobile Internet devices in the formation of general scientific, general professional and specialized professional components of the competence of a bachelor of electromechanics in modeling technical object.

It was determined that the leading ones for the formation of general scientific competences are: in applied mathematics, the content of the academic disciplines “Higher mathematics” and “Computer technology and programming”; in ICT – “Computer technology and programming” and “Engineering and computer graphics”; in fundamental sciences – “Higher mathematics”, “Theoretical mechanics” and “Electric machines” (Modlo et al., 2019a,b). It was determined that in the process of forming the general scientific component of the competence of a bachelor of electromechanics in the modeling of technical objects, it is advisable to use: for visualization of the structure of objects and the results of modeling – mobile means of augmented reality (SIKE Software); at all stages of modeling – mobile computer mathematical systems with object and symbolic input type (Scilab on cloud, MATLAB Mobile, Octave, SMath Studio, SageCell); cloud-based spreadsheet processors as modeling tools (Google Sheets, Microsoft Excel) and text editors for software description of models (Google Documents, Microsoft Word); mobile automated design systems for creating and viewing physical properties of models of technical objects (Electrical, Autodesk Inventor, AutoCAD – DWG Viewer & Editor, A360 – View CAD files, Fusion 360); mobile communication tools for organizing joint modeling activities (Modlo and Semerikov, 2014; Syrovatskyi et al., 2018; Kiv et al., 2019; Shepiliev et al., 2020).

It has been established that the content of the educational disciplines “Computing technology and programming”, “Theory of automatic control” and “Modeling of electromechanical systems” are the leading ones for the formation of general professional competences: from solving professional problems by means of ICT; in electric machines – “Electric machines” (Modlo et al., 2020). It is substantiated that for competence in the application of various methods of presentation of models and competence in critical thinking, it is not possible to single out the leading educational disciplines – the formation of these components of the competence of a bachelor of electromechanics in the modeling of technical objects takes place throughout the professional training of a bachelor of electromechanics. It was determined that in the process of forming the general professional compo-

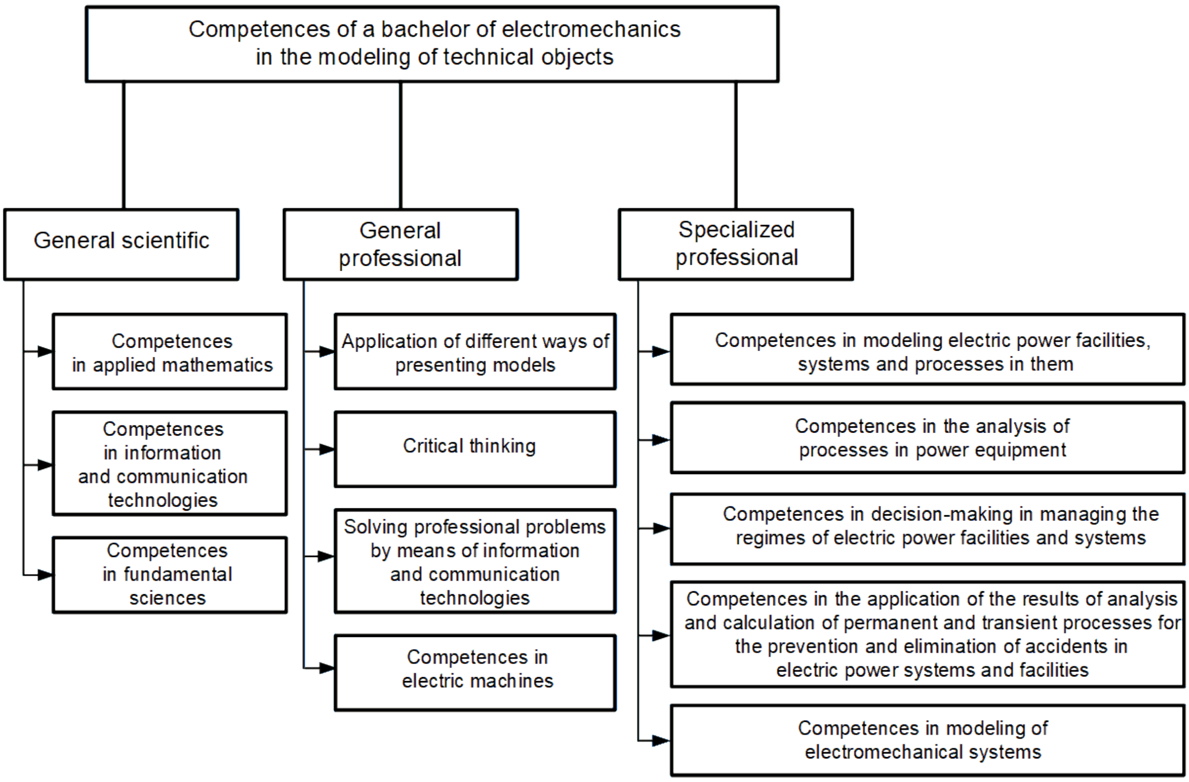

Figure 1: The system of competences of a bachelor of electromechanics in the modeling of technical objects.

nent of the competence of a bachelor of electromechanics in the modeling of technical objects, it is advisable to use: cloud-oriented spreadsheet processors, such as Google Sheets as modeling tools, including neural networks (Modlo, 2013); visual modeling systems, such as Xcos and Simulink, for structural modeling of technical objects (Modlo and Semerikov, 2018); mobile computing mathematical systems, such as SageCell, Scilab and MATLAB Online, used for all stages of modeling; mobile communication tools for organizing joint modeling activities. It was determined that the content of the educational discipline "Modeling of electromechanical systems" is leading to the formation of specialized professional competencies: in the modeling of electric power objects, systems and processes in them, and in the modeling of electromechanical systems; from the analysis of processes in power equipment – "Theoretical foundations of electrical engineering"; in making decisions on the management of modes of electric power facilities and systems and in the application of the results of analysis and calculation of permanent and transient processes for the prevention and elimination of accidents in power systems and facilities – "Automatic control theory" and "Electric drive theory". The expediency of using specialized systems for calculating electric circuits (ZRLC(Circuit solver)) in the process of formation of the specialized professional component of the competence of the bachelor of electromechanics in the modeling of technical objects is substantiated. visual modeling systems for simulation modeling of technical objects (Xcos); means of simulation of dispatch control and data collection for simulation modeling of processes in electric power systems (Simple-Scada); mobile computer mathematical systems (Scilab); mobile communication tools for organizing joint modeling activities. Leading forms of organizing the educational process using mobile Internet devices: demonstrations for the formation of new concepts and methods of action using mobile augmented reality devices; laboratory work, during which all classes of mobile ICT tools are comprehensively used; lectures: informative (when presenting new material), lecture-seminars (provided the problem-based method is used), demonstration lectures (for the comprehensive formation of modeling skills) and consultation lectures (for the preparation and support of a research project); a business game using SCADA systems to develop operator skills means of simulation modeling; work in pairs and small groups; project form of education; consultations (face-to-face and remote).

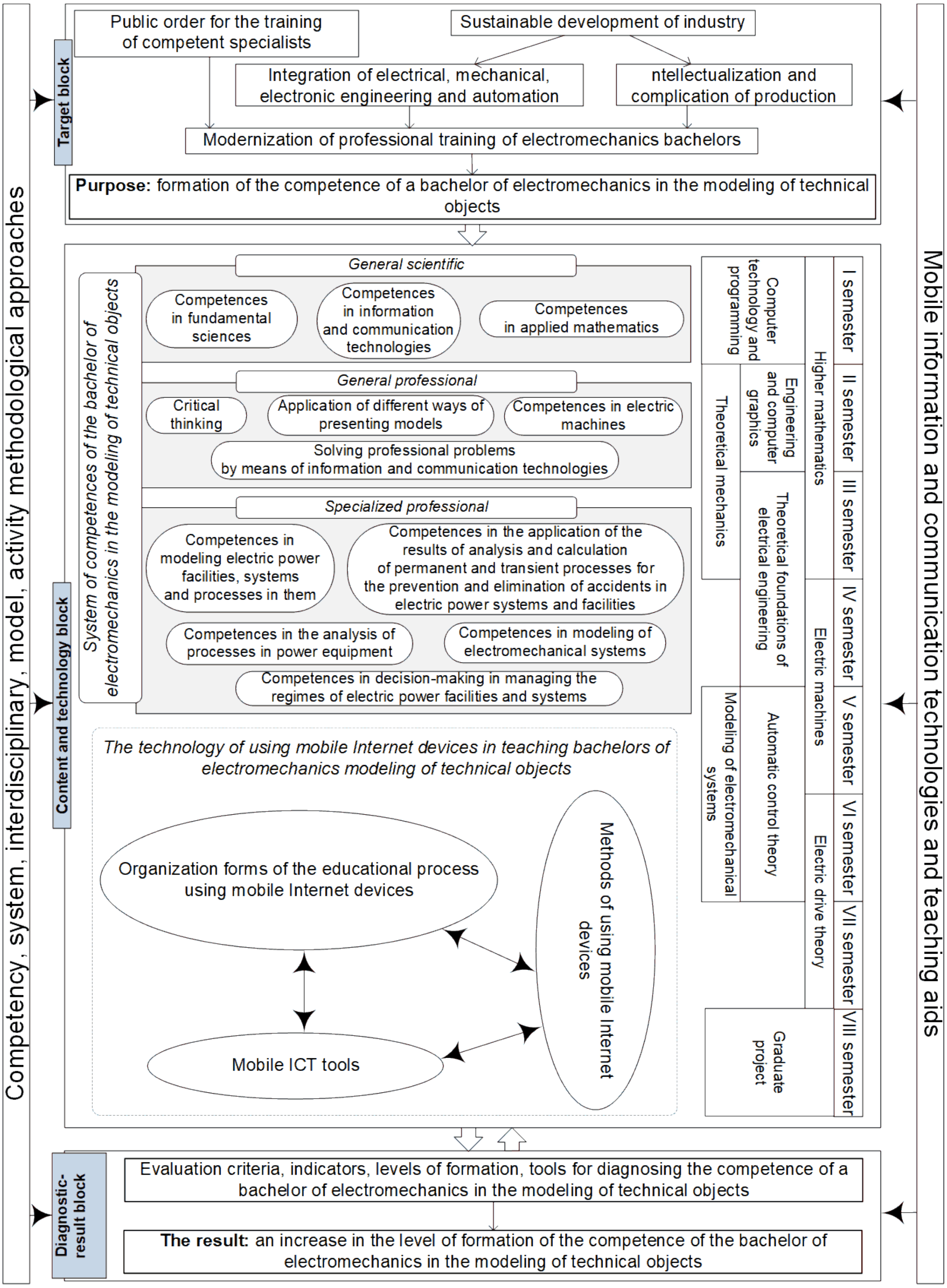

Figure 2: The model of the mobile Internet devices using process in teaching bachelors of electromechanics modeling of technical objects.

The leading methods of using mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects: the method of problem presentation, in which mobile Internet devices are used as a means of obtaining information from various sources related to the subject of the lesson; partial search method, in particular, the techniques of symbolic and figurative vision, which correspond to different ways of presenting the model of a technical object – mathematical and structural; the method of errors, which is advisable to apply when presenting the model both as a program in a mobile computer mathematical system and as a structural diagram in a visual modeling system; the research method is used as the main one in the process of forming the competence of a bachelor of electromechanics in the modeling of technical objects; the project method is used to organize joint educational and research activities of modeling students; the method of demonstration examples is used in lectures, demonstrations and in practical classes to study the adequacy of ready-made models and their further development; computational experiment (as one of the stages of modeling) and programming (as one of the methods of implementing the model); lecture method.

In table 1, the MID software tools, which are leading to the formation of each component of the competence of a bachelor of electromechanics in the modeling of technical objects, are highlighted with a "$\surd$" mark.

5 EXPERIMENTAL WORK

The development and testing of the theoretical provisions of the research took place in three stages.

The task of the *analytical-declarative stage* of the research (2007 – 2011) was to study the current state of training in the modeling of technical objects of bachelors of electromechanics, the use of mobile Internet devices as a means of learning, and the selection of the starting points of the research. To implement the tasks, the scientific and methodological literature on the use of mobile ICT in education, domestic and foreign experience of training specialists in electromechanics was analyzed, which made it possible to formulate the relevance of the research and its hypothesis. Developed, tested, and improved training programs, virtual laboratories for modeling technical objects and systems; studied modern domestic and foreign methods of using ICT in the training of bachelors of electromechanics; a theoretical analysis of domestic and foreign psychological-pedagogical literature was carried out to find out the degree of study and development of the problem, the ascertaining stage of the pedagogical experiment was carried out.

At the *design and research stage* of the research (2012 – 2015), the system of competences of the bachelor of electromechanics in the modeling of technical objects was determined, the educational course "Modeling of electromechanical systems" was designed and developed, mobile Internet devices and software tools for learning the modeling of electromechanical systems were selected, a model of the use of mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects was developed. As a result of an expert survey aimed at determining the contribution of each component of the competence of a bachelor of electromechanics in the modeling of technical objects to its formation, it was determined that the contribution of general professional and specialized professional competences is the same – 35.3% for each group, while the contribution of general scientific – 29.4%. Among general scientific competences, competence in applied mathematics was the leading one, among general professional competences – critical thinking, and among specialized professional competences – competence in modeling electromechanical systems. Processing the results of the survey made it possible to determine quantitative indicators of the formation of each of the components of the competence of the bachelor of electromechanics in the modeling of technical objects and an integral indicator reflecting the level of the formation of competence in general.

At the *formative and generalization stage* of the research (2016 – 2018), a method of using mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects was developed, the formative stage of the pedagogical experiment was conducted; the obtained results of experimental work were analyzed and summarized; general conclusions are formulated and prospects for further research are determined.

201 students majoring in "Electromechanics" took part in the formative stage of the pedagogical experiment: the control group (CG) – 150 students of the Kryvyi Rih National University, who studied according to the traditional method, which did not involve the systematic use of mobile Internet devices, and the experimental group (EG) – 51 a student of the National Metallurgical Academy of Ukraine, who studied according to the developed method of using mobile Internet devices in the process of teaching bachelors of electromechanics modeling of technical objects. Processing of the results of the experimental work was carried out using the Kolmogorov-Smirnov criterion. It was established that before the beginning

Table 1: The use of mobile Internet devices in the process of forming the competence components of the bachelor of electromechanics in the modeling of technical objects.

Software tools	General scientific component	General professional component	Special professional component
mobile computer math systems	√	√	√
mobile communication tools	√	√	√
cloud-oriented table processors	√	√	
visual modeling systems		√	√
mobile tools of augmented reality	√		
cloud-oriented text editors	√		
mobile CAD-systems	√		
specialized systems for calculating electric circuits, means of modeling dispatch control and data collection			√

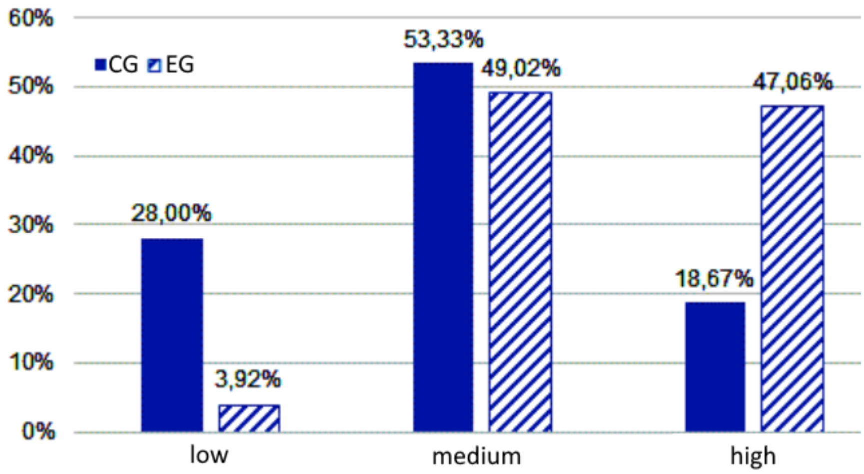

Figure 3: Distribution of CG and EG students according to the level of formation of the competence of the bachelor of electromechanics in the modeling of technical objects after the completion of the formative stage of the experiment.

of the formative stage of the pedagogical experiment, there were no statistically significant differences in the distributions of CG and EG students of one year of admission based on the results of the entrance exams.

After the completion of the formative stage of the pedagogical experiment, the integral level of competence formation of the bachelor of electromechanics in the modeling of technical objects was diagnosed, and the distribution of CG and EG students by level was compared (figure 3). Statistically significant differences at the level of 0.99 in the distributions of students of the control and experimental groups were established ($\lambda = 1.752 > \lambda_{crit}(0.01) = 1.63$).

Based on the fact that the experimental group used the developed method of using mobile Internet devices, we come to the conclusion that this was a factor in increasing the level of formation of their competence in modeling technical objects, and therefore, the research hypothesis is proven.

6 CONCLUSION

The obtained results of the research give grounds for making the following conclusions:

1. Analysis of the experience of professional training of electromechanics bachelors in Ukraine and abroad made it possible to determine that one of the leading trends in its modernization is the synergy of mechanical, electrical, electronic engineering and automation in mechatronics for the purpose of designing, manufacturing, operation and maintenance of electromechanical equipment. The study of mechatronics involves the content integration of various disciplines of professional and practical training of electromechanics bachelors based on the concept of modeling and the technological integration of various forms of organization and training methods based on the concept of mobility. According to this approach, mo-

bile Internet devices – multimedia mobile devices that provide wireless access to information and communication Internet services for the collection, systematization, storage, processing, transmission, presentation of all kinds of messages and data – become the leading means of education for bachelors of electromechanics. The work reveals the main possibilities of using mobile Internet devices in education to ensure equal access to education, personalization of education, instant feedback and assessment of learning results, organization of mobile learning, effective use of time in classrooms, formation of mobile learning communities, support of situational education, the development of continuous "seamless" education, ensuring the connection between formal and informal education, minimizing the consequences of the destruction of the educational process in areas of military conflicts or natural disasters, assisting in the education of persons with special educational needs, improving the quality of communication and management of an educational institution and maximizing efficiency of its costs.

2. The competence of a bachelor of electromechanics in the modeling of technical objects is a personal and professional education that includes a system of knowledge, abilities, skills, experience in modeling mechatronic systems and a positive value attitude towards it, and is manifested in the readiness and ability to apply methods and software-hardware modeling tools for process analysis, system synthesis, assessment of their reliability and efficiency for solving practical problems in professional activity. The competence structure of a bachelor of electromechanics in the modeling of technical objects is reflected in three groups of competences: general scientific (in applied mathematics; in ICT; in fundamental sciences), general professional (application of various ways of presenting models; critical thinking; solving professional problems by means of ICT; in electric machines) and specialized professional (in modeling of electric power objects, systems and processes in them; in the analysis of processes in power equipment; in decision-making on the management of modes of electric power objects and systems; in the application of the results of analysis and calculation of permanent and transient processes for the prevention and elimination of accidents in electric power systems and objects; in modeling of electromechanical systems). The content of each competency is defined in the competency matrices allowed to develop criteria for evaluating their formation according to cognitive, praxeological, informational and communicative components at the levels of unformedness, low, medium, and high.

3. The model of the process of using mobile Internet devices in the training of bachelors of electromechanics in modeling technical objects is built on the basis of competence, system, interdisciplinary, model and activity approaches and consists of three blocks: the target, which specifies the goal – the formation of the competence of bachelors of electromechanics in modeling technical objects; content-technological, which reflects the connection of the content of education with the formation of individual components of competence and the technology of using mobile Internet devices in teaching bachelors of electromechanics modeling of technical objects (a system of forms of organization of the educational process using mobile Internet devices, methods of their use and mobile ICT means); and diagnostic results, containing evaluation criteria, indicators, levels of formation, and tools for diagnosing the competence of a bachelor of electromechanics in the modeling of technical objects.

4. The implementation of the technology of using mobile Internet devices in the training of bachelors of electromechanics in the modeling of technical objects is an appropriate method of use, the components of which are partial methods of using mobile Internet devices in the formation of general scientific, general professional components of the competence of a bachelor of electromechanics in modeling technical objects, disclosed on the example of the academic disciplines "Higher mathematics", "Computing technology and programming", "Engineering and computer graphics", "Theoretical mechanics", "Electric machines", "Automatic control theory", "Modeling of electromechanical systems", "Theoretical foundations of electrical engineering", "Electric drive theory". The leading forms of organizing the educational process using mobile Internet devices are demonstrations, laboratory work, lectures, business games, work in pairs and small groups, project form and consultations; the leading methods of using mobile Internet devices in the teaching of bachelors of electromechanics modeling of technical objects are lecture, partial research, problem, research, error method, project method, method of demonstration examples, computing experiment and programming, and the leading means are mobile computer mathematical systems (universal tools used at all stages of modeling training), mobile communication tools (for

organizing joint modeling activities), cloud-based spreadsheet processors (as modeling tools, including neural networks), visual modeling systems (for structural modeling of technical objects), mobile tools of augmented reality (for visualizing the structure of objects and modeling results), cloud-based text editors (for software description of models), mobile automated design systems (for creating and viewing the physical properties of models of technical objects), specialized systems (for calculating electric circuits), means of modeling dispatch control and data collection (for simulation modeling of processes in electric power systems).

5. In order to verify the effectiveness of the method of using mobile Internet devices in the training of bachelors of electromechanics in the modeling of technical objects, a pedagogical experiment was conducted, at the formative stage of which 150 students of electromechanics studied according to the traditional method, which did not involve the systematic use of mobile Internet devices (control group), and 51 electromechanical students studied according to the developed methodology (experimental group). With the application of the Kolmogorov-Smirnov criterion, it was established that before the beginning of the formative stage of the pedagogical experiment, there were no statistically significant differences in the distributions of students of the control and experimental groups of one year of admission according to the results of the entrance tests. After the completion of the formative stage of the pedagogical integral level of in the modeling of technical objects, statistically formation significant of the experiment differences of the bachelor of were the electromechanics competence of established at the level of 0.99 in the distributions of students of the control and experimental groups. Considering that the experimental group used the developed method of using mobile Internet devices, it can be concluded that its implementation became a factor in increasing the level of formation of their competence in modeling technical objects, and therefore, the research hypothesis is proven.

7 FUTURE WORK

The performed research does not cover all aspects of the analyzed problem. Further scientific searches for its solution are expedient in the following directions: the use of augmented reality tools in the training of future mechatronics specialists; virtualization of the environment for professional and practical training of future mechatronics specialists; SCADA systems as a means of teaching bachelors of electrical engineering and electromechanics.

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Digital Tools for Designing Interactive Tasks for Teaching German and Analyzing Learners' Performance

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Abstract: The article focuses on the use of interactive tools to create the interactive exercises for German lessons and to assess learners' performance. The concept of didacticization of educational materials and authentic texts is considered. The steps of didacticization of authentic texts are indicated and examples of the use of digital tools for the didacticization of authentic materials are given in order to use them in the educational process to develop language competence, as well as to check the achieved learning outcomes. It is proved that the use of mobile applications and Web 2.0 interactive tools helps to organize students' work in and outside classrooms effectively for the formation and improvement of their language competence.

1 INTRODUCTION

The most important task of foreign language teaching at universities is the practical mastery of a foreign language, the ability to conduct a foreign language communication with native speakers, taking into account the cultural characteristics, because the language and the culture are inseparable (Piankovska, 2020). Modern foreign language teaching relies on the authenticity of teaching materials, because learning a foreign language involves getting to know the foreign culture and because linguistic content is always linked to cultural and social information.

One can motivate students to learn German by offering them well-prepared materials to which they bring experiences from their own world and which encourage them to see their own world anew from a changed perspective (Hufeisen and Neuner, 2004, p. 30).

Appropriate use of media can further increase motivation to engage with the materials because technologies are taken for granted by modern young people, and they enjoy using various mobile devices in their everyday lives to communicate and research, play and learn.

We should also not forget that students must be able to use modern information and communication technologies and digital tools to solve the job-related problems (Standard, 2019).

The use of the authentic materials, taking into account the methodological-didactic principles, certainly contributes not only to the development of linguistic and regional competences, but also to increasing the motivation to learn German (Vyrsta, 2020). And the preparation of the texts with the help of Web 2.0 tools also promotes the students' media competence, among other things (Kazhan et al., 2020).

2 DIDACTIZATION OF THE AUTHENTIC MATERIALS

In the methodological literature there is a lot of discussion about the use of authentic materials and one can also find different definitions of authenticity. Mostly it is about texts from newspapers or magazines, song texts, audio texts or similar, which are used parallel to a textbook in class and are linguistically authentic (Bärlund, 2012).

Since authentic texts are both linguistic and cultural products, they give learners the opportunity to observe and draw conclusions about the customs and rules of communication in the target culture, which can help learners form a cultural frame of reference

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for the language (Mishan, 2005, p. 45).

The relevant literature deals with either authentic or synthetic texts, and their use in the classroom depends on the particular goal. However, we should not forget that authentic texts are often quite difficult for learners and therefore require a certain adaptation to the learners' level of knowledge.

As for the adaptation of the authentic texts, there are different opinions about it. Nosonovich (Nosonovich, 2000) believes that:

1) adapted texts lose the characteristic features, the individuality of the author and the national peculiarity;
2) authentic texts differ in style and content and are therefore of interest to learners; they illustrate the functioning of language as adopted by its speakers;
3) use of artificial, simplified texts can lead to further difficulties in perceiving real-life texts (Nosonovich, 2000, p. 12).

Wicke (Wicke, 1997), based on the experience of his work with authentic texts, points out that learners have an extraordinary interest in everything "other" connected with everyday life, i.e. in authentic materials (Wicke, 1997, p. 22).

Heyd (Heyd, 1990) notes that the formation and development of skills with artificial, non-existent texts is hardly possible, because they are not typical for the real communication process.

A different point of view regarding the use of the authentic unprepared texts is represented by Weigmann (Weigmann, 1999). He believes that the authentic text used for teaching purposes, first of all, changes the addressee for whom it was written. Weigmann (Weigmann, 1999) believes that authentic texts, due to their language complexity, may even reduce the motivation to read, as they exceed the level of knowledge of learners. Therefore, they can and must be adapted for teaching (Weigmann, 1999, p. 73).

Below we give an example of an authentic text used in language history class (not adapted) with the task of underlining the lexical units whose spelling differs from modern German literary language and explaining the differences. Then the students were to find obsolete words and grammatical structures and try to replace those with modern German words and rewrite the text.

Ankauf zweier Glokken in der Kolonie Elisabethdorf und hiernach getroffene christliche Ordnung (Stach, 1942, p. 22-23)

Bevor noch der Stamm der, aus Badnern und Hessen-Darmstadtern bestehenden, Gemeinde der Kolonie Elisabethdorf ganz aussterben mögte, beschloß diese Gemeinde; damit die heranwachsende Jugend die christliche Ordnung kennen lerne und bewahre, in welcher ihre Aeltern im Auslande erzogen worden, einige Glokken anzukaufen und zur gewohnten Sitte anzuwenden. Im Herbste des 1836 sten Jahres ging der Beschluß, zur Freude Aller, in Erfüllung. Zwei ziemlich große Glokken wurden aus Charkow besorgt und unter einen Glokkenthurm gebracht. Von Stund an traf die Gemeinde auch die Anordnung, durch Läuten der Glokken folgende christliche Sitte, zu der der Prediger noch ermahnte, festzustellen, nämlich: bei Anbruch des Tages zur Erinnerung an das Morgengebet; und Mittag die Mittagsstunde und den Gott schuldigen Dank für Speise und Trank an's Herz zu legen, bei eintretender Abenddämmerung zum Dank gegen den Geber aller guten Gaben, nach vollbrachtem Tagewerke, durch ein zu betendes Vater Unser aufzufordem; um 9. Uhr Abends jedem Gemeindegliede einen Wink zu geben, daß auf Straßen und in Schenken Ruhe hergestellt werde; an Sonn- und Festtagen den Beginn des Gottesdienstes anzuzeigen; nach der Predigt, beim Beten des Vater Unsers, allen zu Hause Befindlichen ein Merkmal zur Verrichtung desselben Gebets darzubieten; und bei Leichenbegängnissen den Leichenzag anzukündigen und feierlicher zu machen. Außerdem hat gedachte Gemeinde noch die Einrichtung beim Gebrauch der Glokken hinzugefügt: den Abend vor einem Festtage um die gewöhnliche Zeit, statt, wie an gewöhnlichen Tagen, mit einer, alsdann mit beiden Glokken zu läuten, um den bevorstehenden Festtag anzuzeigen; ingleichen bei Beerdigungen mit beiden Glokken zu läuten, und so auch das dritte und letzte Mal an Sonn- und Festtagen, als eine Viertel-Stunde vor Beginn des Gottesdienstes.

However, such historical texts are very specific and are hardly suitable for regular German lessons, where modern authentic texts should be used. In this regard, the Internet portal of the Germans of Ukraine also offers many interesting materials, namely the traveling exhibition (Eisfeld, 2019), which presents interesting facts about the history of the Germans in Ukraine. The author of the concept of this exhibition and the texts for it is Dr. Alfred Eisfeld, a Russian-German historian, expert on the history and culture of Germans in the Russian Empire, the Soviet Union and the CIS and author of numerous scientific works. Part of the exhibition is devoted to the Azov region and is about the colonies founded in the 18th-19th centuries by German resettlers from West Prussia, Bavaria, Hesse, Alsace and Baden near Mariupol.

The texts and pictures from the exhibition were used in the regional studies classes in the 7th semester and in the language practice classes in the 3rd semester as part of the topic "Germany and Germans".

Die Ansiedlung deutscher Kolonisten in den Steppen des Asowschen Gebiets erfolgte in mehreren Etappen. Die ersten Kolonien wurden am Fluss Molotschnaja 1804–1810 gegründet. Außer den Mennoniten siedelten sich hier aus Württemberg, aus Baden und Preußisch-Polen Stammende an, welche den Molotschnaer Kolonistenbezirk bildeten. Das Zentrum wurde Prischib. Die in den Jahren 1818–1819 aus der Umgebung von Danzig, Elbing und Marienburg (Preußen) angekommenen 500 Familien von Katholiken und Lutheranern hielten sich 5 Jahre lang in den alten Kolonien auf, weil das ihnen zugeteilte Land sich als für die Bewirtschaftung nicht geeignete wasserlose Salzerde erwies. Sie lehnten es ab, dort zu siedeln. Schließlich wurde ihnen Land in der Nähe von Mariupol zugewiesen, auf dem die Mariupoler Kolonien, auch Planer Kolonien oder Preußenplan genannt, mit dem Zentrum in Grunau gegründet wurden (1823). Die 1822 in der Nähe von Berdjansk von schwäbischen Pietisten gegründeten 3 Kolonien wurden als Separatisten-Kolonien bezeichnet. Die Pietisten haben schon in ihrer Heimat die Verbindung mit der lutherischen Kirche abgelehnt. Sie wurden Chiliasten oder Separatisten genannt.

When preparing the regional studies texts, one should follow certain steps suggested by Rösler and Würffel (Rösler and Würffel, 2014, p. 119):

1) establish sublearning objectives;
2) analyze vocabulary and linguistic structures and adapt the text as needed;
3) develop tasks related to the text.

Since our idea was to didactize the texts with the help of the digital applications, the next section is about digital tools that are suitable for this purpose.

3 DIGITAL APPLICATIONS FOR THE DEVELOPMENT OF LINGUISTIC PERFORMANCE

Digitalization is reaching into all areas of life, and the learning process is of course no exception (Sych et al., 2021). Students need to master technologies that are available to them so that they can use them to learn German successfully and later, as future teachers of German, to carry out their own teaching activities.

The Internet offers a wide range of modern online tools and applications for learning a foreign language (Kuts and Lavrentieva, 2022). Of course, everything in this area changes very quickly, and one should inform oneself regularly in order not to miss important developments. In addition, care should be taken to ensure that language teaching encourages students in the competent use of media and develops media literacy.

In this article, we focus on the ability to use media and look at digital offers that can bring regional studies topics closer to students. We are interested in the Web 2.0 platforms that can be used to create interactive exercises, because the idea is to didactize the found materials in such a way. For our goals we have chosen two tools: Learningapps and Wordwall, which are similar in their functions, but differ in the external appearance and in some additional possibilities.

LearningApps.org supports learning and teaching processes with small interactive, multimedia building blocks that are created online and integrated into learning content (Kramarenko, 2017). A whole range of different exercise options are available for the building blocks: Match Pairs, Group Matching, Number Line, Simple Sequence, Free Text Response, Match to Picture, Multiple Choice Quiz, Cloze, App Matrix, Audio/Video with Overlays, Million Game, Group Puzzle, Crossword, Puzzle, Match with Map, Word Grid, Where's What, Hangman, Horse Race, Pairs Game, and Guess (LearningApps, 2023). The apps do not represent self-contained learning units, but must be embedded in a teaching scenario, which actually offers unlimited possibilities for creating your own exercises (LearningApps, 2012).

Wordwall, a Web 2.0 tool that can be used to design vocabulary and grammar exercises, as well as various learning games, puzzles and tests, has similar functions. The templates range from simple quiz formats such as true-or-false to crossword puzzles and fill-in-the-blank exercises. There are various design options, images can be inserted from an image archive of Wordwall or even your own photographs. This allows you to adapt the task to the topic and the learning group. For example, you could use pictures to visualize certain facts in a lesson on the topic "German Traces" (Hamaniuk, 2020; Karpiuk, 2020; Kazhan, 2020b). You can also use a differentiated approach by providing pictures as additional help.

Some exercise types, such as multiple-choice quizzes, are suitable for collaborative play, i.e. learners can participate in the quiz together via their own end devices, which is in line with the principle of learner activation. Some task types can be saved and printed as PDFs, and can therefore be used not only digitally but also analogously, if it fits the logic of the lesson.

It should be noted, however, that both applications can only be used to create closed task formats, i.e. those for which there is only one solution that the computer can evaluate as correct, automatically marking the other solutions as incorrect. To encourage creativity and critical thinking, more exercises should be developed that involve discussing and debating the content. And this means that digital and analog offerings should be closely linked in the learning process. The interactive exercises can serve as a basis for further engagement with the topic, as an introduction to the topic, as exercises that awaken interest in the topic and increase motivation to learn German.

4 DIGITAL APPLICATIONS FOR PERFORMANCE EVALUATION

Evaluation of learners' performance is an essential part of the educational process, and competence orientation is one of the most important principles of teaching German. That is why formative evaluation as such approach, which allows to reduce negative aspects in learning, to promote individualization of educational process, to increase motivation to learn and autonomy of learners (Zhorova et al., 2022), is absolutely contemporary and corresponds to the goals of teaching German.

Nowadays, there are many digital tools that can be successfully used for formative evaluation. Depending on the goal of the evaluation, you can use them in different phases of teaching.

AnswerGarden (https://answergarden.ch) can be integrated in the context of numerous teaching situations, for example as a simple brainstorming tool, as a survey or as anonymous feedback. The words entered are visualized directly in real time as a word cloud. The tool is free and no account is required to use it. The disadvantages include the fact that the interface is completely in English and that the app for iOS requires a fee.

With *ChatterPix* (https://www.duckduckmoose.com/educational-iphone-itouch-apps-for-kids/chatterpix/), you can make pictures talk and practice speaking and reading aloud in this way. The learners take or select a photo, write a text and speak or read it aloud. In this way, a short story is created. The products can be shared, for example, a common padlet where the learners introduce themselves or tell about their daily routine, and so on. This is very easy and fun for the learners. For formative assessment one can use the tool by evaluating the texts created by the learners according to certain predefined criteria. The texts can be assessed by both teachers and learners. The app is free and intuitive to use.

Wordwall (https://wordwall.net/) offers a lot of possibilities for formative evaluation, as it is possible to use created exercises on different templates, so it can serve not only for evaluation but also for practice. A big advantage is that the teacher has an overview of the learners' answers, so it is easy to see the learning progress of each individual. Such intermediate results can also be very helpful for further planning, which has a positive effect on the achievement of the global learning goal. Another plus point is that you can also print out many exercises as PDFs. Most templates are available in both interactive and printable versions. After creating an activity, you can transfer it from one template to another with a single click. This saves time and is great for internal differentiation. The tool can be used in class if learners have access to their own devices, or as homework.

Cacoo (https://cacoo.com/) is a tool that can be used in many ways, for example to create diagrams, mind maps, infographics or sketches. For schools and for the educational sector, the use is free, but a registration with a school address is necessary. The program works cloud-based and therefore simultaneous collaborative use is possible. A number of templates and templates can be used to create collaborative products.

For formative evaluation, this can be used by, for example, repeating vocabulary on a particular topic, creating a mind map. The mind map can be developed during the lesson and the teacher determines whether the learners have learned the vocabulary. The results are discussed immediately in class.

Tagxedo (http://www.tagxedo.com) is an alternative to the tool known to all as "Word Cloud". However, to use Tagxedo, the Silverlight browser plugin must be installed. With Tagxedo you can create word clouds in real time, customize font, theme, color, alignment and shape, save as images for printing and sharing with many options, display word clouds as thumbnails and select the one you want for further customization or saving, choose from many default fonts, limit the word cloud to selected shapes (heart, star, animals, etc.), use images as custom shapes (e.g., a portrait, an animal silhouette). In class you can use Tagxedo as an introduction to the topic and also for evaluating the results.

Formative evaluation is one of the most effective forms of performance assessment that allows learners to fill in the gaps in their knowledge and skills. And using digital tools for formative evaluation helps learners become more motivated and interested in the language.

5 POSSIBLE APPLICATIONS OF THE CREATED INTERACTIVE EXERCISES

The exercises described here were used in regional studies classes in the 7th semester and in language practice classes in the 3rd semester as part of the topic "Germany and Germans". The broad objective was to acquaint the students with the German traces in their own region, the sub-objectives were related to the development of sub-skills. After each exercise, which was fulfilled in individual work, the reflection phase was scheduled, where the students reflected on the content in plenary and had the opportunity to ask additional questions to the teacher.

Beispiel 1 (Kazhan, 2023a).

Aufgabe: Ergänzen Sie die Lücken im Text, indem Sie die Wörter von der Leiste oben in die Lücken im Text ziehen.

Ziel: Die Studierenden kennen die Geschichte der deutschen Kolonisten, sie können die Bedeutung der Wörter aus dem Kontext erschließen und beherrschen die Lesestrategien auf der Satzebene.

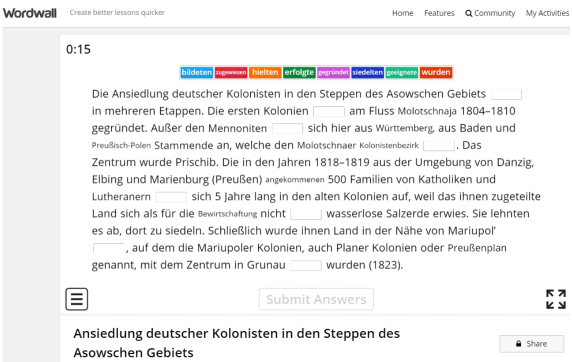

Figure 1: Interactive exercise "Settlement of German colonists in the steppes of the Azov region".

The interactive exercise works on the principle of "drag and drop" and can be controlled by the students themselves. The teacher can see the progress of the students if the appropriate settings have been made. This was not our goal, we did not develop the exercises for summative evaluation, but for practicing, that's why we tried them out together in class and discussed the content afterwards.

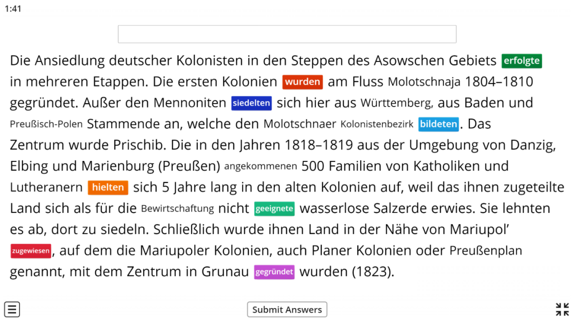

Figure 2: Interactive exercise "Settlement of German colonists in the steppes of the Azov region" (solution).

Beispiel 2 (Kazhan, 2023c).

Aufgabe: Bringen Sie die Wörter in die richtige Reihenfolge.

Ziel: die Studierenden kennen die Geschichte der deutschen Kolonisten im Asowschen Gebiet, sie kennen die Wortfolge in verschiedenen Satztypen und können die Sätze bilden.

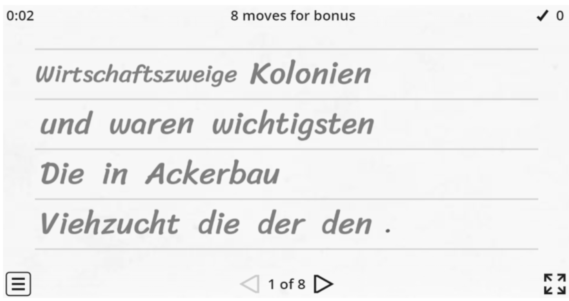

Figure 3: Exercise "Economic branches in the colonies".

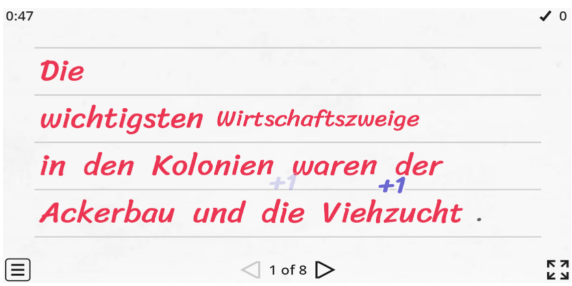

Figure 4: Exercise "Economic branches in the colonies" (solution).

The reflection phase is also an important component in this exercise because in its development we were guided by the theoretical foundations of constructivist theory established by Jonassen (Jonassen, 1995). He believed that learning tasks should model the real world by creating a problem-based learning environment and that learners should be involved in the mental processing of information. They should reflect on how they achieved a particular learning outcome and also be accountable for it. To solve a particular problem, they would, according to Jonassen, combine new knowledge with what they already have and try to achieve the cognitive goal in an active and purposeful way. Moreover, they have to work in groups to acquire new knowledge and skills, as they are part of a group working together to create a knowledge system in the classroom (Jonassen, 1995, p. 61).

Beispiel 3 (Kazhan, 2023b).

Aufgabe: Bringen Sie die Buchstaben in die richtige Reihenfolge, sodass Sie die Namen von Kolonien bekommen, deren Gründung im 18. Jahrhundert auf Initiative der Zarin Katharina II. stattfand.

Ziel: die Studierenden kennen die Geschichte der deutschen Kolonisten im Asowschen Gebiet, sie kennen die Namen der sogenannten Mariupoler Kolonien.

Figure 5: Exercise "Mariupol Colonies".

Figure 6: Exercise "Mariupol Colonies" (solution).

Exercise 3 is directly connected to exercise 4, which was created with learning apps. Here it is about the students listening to the names of the Mariupol colonies and finding them on the virtual map. The map is also available in printed form in the room, and after completing the interactive exercise, they go to the map to discover the former German colonies and understand where they were actually located.

Beispiel 4 (Kazhan, 2020a).

Aufgabe: Hören Sie die Namen von Mariupoler Kolonien, deren Gründung im 18. Jahrhundert auf Initiative der Zarin Katharina II. stattfand, und finden Sie die an der Karte.

Ziel: die Studierenden kennen die Geschichte der deutschen Kolonisten im Asowschen Gebiet, sie können die Namen der sogenannten Mariupoler Kolonien beim Hören verstehen.

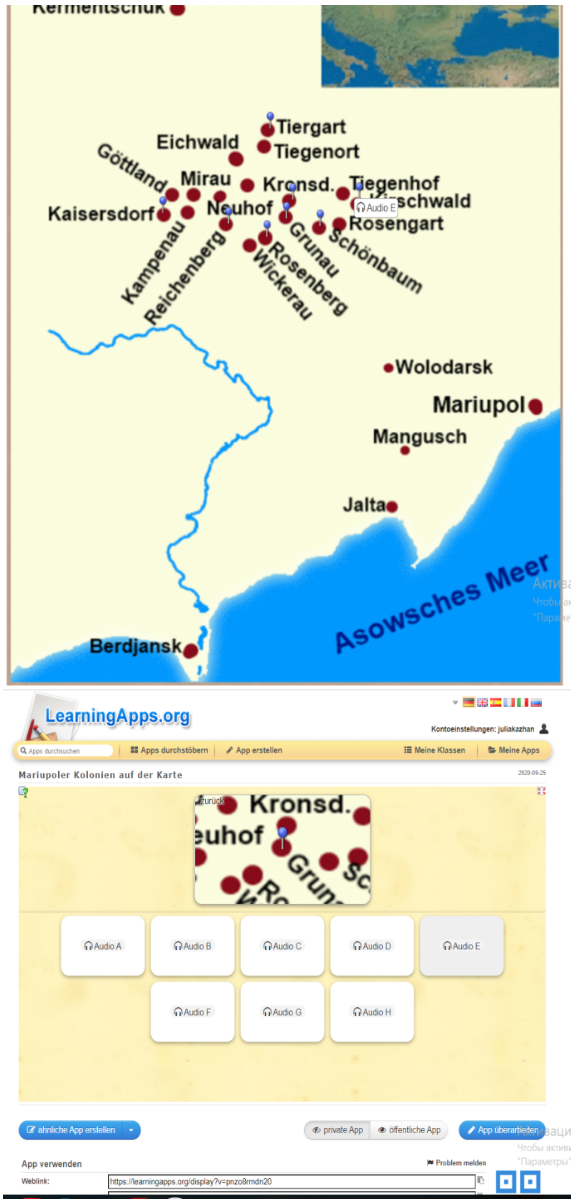

Figure 7: Exercise "Mariupol colonies on the map" (Amanda, 2019).

Beispiel 5 (Kazhan, 2019).

Aufgabe: Spielen Sie das Spiel „Wer wird Millionär?". Entscheiden Sie sich für die richtige Variante.

Ziel: die Studierenden kennen interessante Tatsachen über die Deutschen im Asowschen Gebiet.

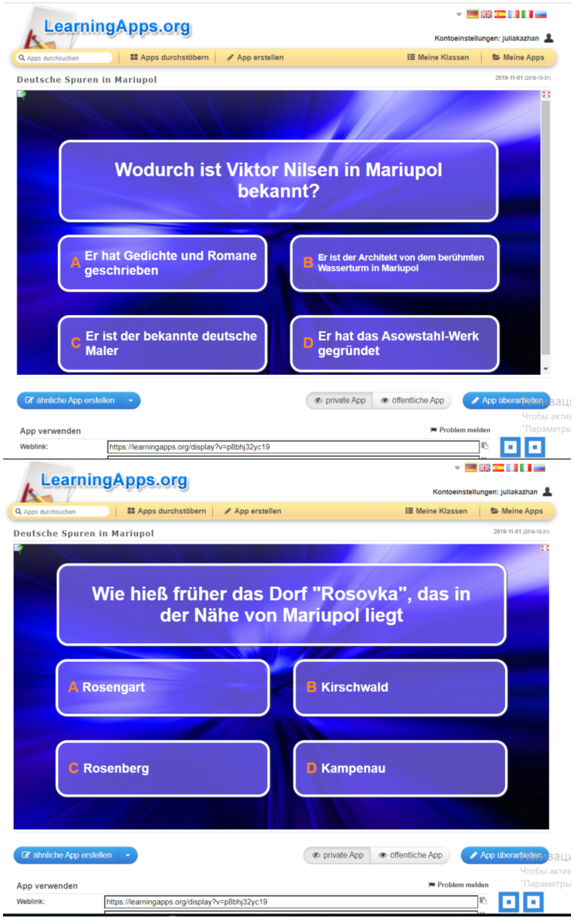

Figure 8: Exercise "Who wants to be a millionaire?".

In developing this interactive exercise, we used information about well-known Germans such as Peter Regier, who founded one of the largest shipping companies in the Russian Empire in Mariupol, and Viktor von Graff, who created the first artificially planted forest in the arid steppes of Azov, and architect Viktor Nilsen, according to whose design the famous water tower in Mariupol was built.

6 CONSLUSION

As can be seen from the above examples, the digital tools offer many possibilities to didactize the authentic materials and to evaluate the learners' performance. The students' feedback on the materials and on the exercises was very positive. The analysis of the questionnaires that the students filled in after completing the tasks testifies that the students enjoyed the topic and the exercises, that they were motivated and interested. Thanks to the interactive exercises developed on the basis of the authentic materials, they would have developed their country knowledge skills and media literacy. This was because they had to develop similar exercises based on the recommended materials for their fellow students as homework. The students also found the reflection periods after the interactive exercises very important because they had been stimulated to reflect and discuss.

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Mobile ICT for Teaching Informatics of Future Bachelors of Professional Education

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Keywords: Mobile ICT, Computer Sciences, Teaching of Future Bachelor's in Professional Education, Information and Communication Competences of Future Bachelors in Professional Education, Model of Mobile ICT Application as a Training Tool for Teaching Computer Sciences to Future Bachelors in Professional Education, Methods for Mobile ICT Application to Teaching Computer Sciences to Future Bachelors.

Abstract: The paper considers the problem of using mobile information and communication technologies as a tool of teaching Computer Sciences to future bachelors in Professional Education. Based on the analysis of the scientific literature, the problem of applying information and communication technologies to teaching Computer Sciences and training future bachelor's in Professional Education is theoretically analysed. The content, criteria and levels of information and communication competences of future bachelor's in Professional Education are defined. The model of applying mobile information and communication technologies to training future bachelors in Professional Education is theoretically substantiated and developed. Methods of using mobile ICT as a training tool for teaching Computer Sciences to future bachelors in Professional Education are developed and their effectiveness experimentally verified. The structure and content of information and communication competences of future bachelor's in Professional Education are improved. Methodical foundations of teaching Computer Sciences to future bachelor's in Professional Education are elaborated.

1 INTRODUCTION

The Concept for implementing the state policy in Professional Education and training "Modern Professional (Professional) Education and Training" for the period up to 2027 (Cabinet of Ministers of Ukraine, 2019) notes that nowadays qualifications of workers, including graduates of Professional Educational and training institutions, do not meet current and future socio-economic needs. The problem is supposed to be solved by creating a system of quality assurance of Professional Education, which includes informatization of Professional Education, development of pedagogical software tools, and access to global information resources as well as improvement of the system of training, retraining, and professional development of teachers.

In Ukraine, the decline in the state order for workforce training, coupled with significant variation in the volume across different sectors of the economy, necessitates the training of bachelor's in Professional Education – future teachers at colleges and Professional Education institutions who can quickly adapt to meet the labour market's demand for qualified workers, considering international practices. This requires the development of information and communication technologies (ICT) competences of future bachelor's in Professional Education, for in-service training.

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2 LITERATURE REVIEW

National and international researchers have been studying various aspects of this issue: the creation and use of ICT tools (Sultana and Brown, 2017; Tan et al., 2019; Bingimlas, 2009; Heo, 2016; Matteucci et al., 2013), the use of ICT in training bachelors in Professional Education (Singh and T. S., 2014; Lytvyn et al., 2020; Humeniuk, 2018; Tytova, 2018; Loftus and Kinsella, 2021; Sell and Rüütmann, 2015; Tsidylo et al., 2019), training of future bachelors in Professional Education (Bakum and Tkachuk, 2014; Köhler et al., 2013; Kersten, 2018; Diachok et al., 2020; Ravi, 2022), formation of components of ICT competences and teaching Computer Sciences (Hevko et al., 2021; Oleksiuk and Oleksiuk, 2022; Seidametova et al., 2022; Spirin et al., 2018; Shepiliev et al., 2020; Shyshkina, 2013; Vakaliuk, 2015; Yatsko, 2014).

Improving the structure of teachers' training and retraining is a priority task for development of continuous teacher-training education, aimed at implementation of acmeological and axiological principles in teachers' training, formation of motivation and creation of conditions for their training and self-development in the course of professional activity, comprehensive modernization of the content, forms, and methods of education and training technologies in accordance with the requirements of the information civil multicultural society.

Ensuring the principles of continuous teacher-training education development, including integration of national educational traditions and global best practices, flexibility in responding to social changes and prognostication, innovativeness, etc. requires modernization of Computer Sciences training for future bachelor's in Professional Education, based on the use of mobile ICT tools, which provide the opportunity to meet educational needs of the learning target anytime and anywhere.

3 THEORETICAL PRINCIPLES OF TEACHING COMPUTER SCIENCES TO FUTURE BACHELORS IN PROFESSIONAL EDUCATION

After analysing the current state of training bachelors in Professional Education, the problem of forming their information and communication competences, the structure and content of ICT training of bachelors in Professional Education in Computer Sciences are determined.

In Ukraine, bachelor's in Professional Education major in Specialty 015 Professional Education. The training content is harmonized with the international IGIP standard, specified by area of expertise and expressed in terms of competences (International Society for Engineering Pedagogy, 2023).

The conducted analysis of standards for training bachelor's in Professional Education reveals the need to modernize components of the national standard of higher education for bachelor training. The result analysis of the expert survey made it possible to single out 18 general professional competences of bachelors in Professional Education:

1) the ability to apply the system of knowledge about communication patterns and methods of managing an individual and a group in the training process;
2) the ability to control and correct the educational process;
3) the ability to perform work at the appropriate qualification level (by profession);
4) the ability to master new types of equipment and innovative technologies (by profession);
5) the ability to adapt, adjust and use modern training technologies, automated learning systems, and electronic learning tools in professional and educational activities;
6) the ability to use modern methods of theoretical education in general professional subjects, general technical subjects and specific subjects (disciplines), as well as industrial training in the selected field;
7) the ability to improve the training process by searching for optimal methods, forms, and tools of teaching, using modern training and information technologies;
8) the ability to organize one's own work in a reasonable manner, and to possess general labour skills and abilities;
9) the ability to analyse the results and process of one's own work, setting and implementing tasks in the field of professional self-improvement, establishing the compliance of one's professional activity with changing requirements;
10) the ability to predict the results of professional and training activities;
11) the ability to form professional knowledge, skills and abilities of those who study, to ensure their professional, social and personal development;

12) understanding the essence and social significance of one's profession, the main problems in a specific field of one's activity;
13) the ability to acquire new knowledge using modern technology;
14) the ability to maintain and control labour and production discipline;
15) the ability to conduct psychological and pedagogical diagnosis, analyse its results and apply them to managing individual training activities;
16) the ability to work with regulatory, technical and reference literature;
17) the ability to prepare documents (work schedules, instructions, plans, applications, business letters, etc.), and reports (by area of expertise) according to established formats;
18) the ability to create a training complex, develop its main components and adapt them to the actual situation of the institution.

The analysis of international (UNESCO, 2018) and foreign standards (Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland, 2019; Gérard, 2006) and the results of an expert survey enables determining 13 specific professional (information and communication) competences of bachelors in Professional Education (digital technologies). The compentences are formed when studying Computer Sciences according to the following content blocks: theoretical foundations of Computer Sciences, architecture of modern computer technology, basics of algorithmization and programming, computer system software, computer technologies in professional activities of bachelors in Professional Education.

4 MODELLING AND DESIGN OF MOBILE ICT APPLICATION TO TEACHING COMPUTER SCIENCES TO FUTURE BACHELORS IN PROFESSIONAL EDUCATION

The content of information and communication competences of future bachelors in Professional Education is determined when designing a tool for monitoring the formation of competences and diagnosing the level of their maturity, i.e. the competence matrices. In the matrices, the rows correspond to specific criteria (cognitive, operational-technological, and value-motivational), the columns correspond to the levels (low, medium, and high), and the cells to the maturity indicators of each competence. Assessment of the maturity level of information and communication competences of future bachelors in Professional Education is proposed at 6 levels – initial, minimum basic, basic, high, advanced, and research (according to Spirin et al. (Spirin et al., 2018)).

According to the hypothesis, mobile ICTs, applied to teaching Computer Sciences, which, following Rashevska and Tkachuk (Rashevska and Tkachuk, 2015) are defined as a set of mobile hardware and software tools and a system of methods and forms of using such tools in teaching Computer Sciences for receiving, storing, processing and reproducing audio, video, text, graphic and multimedia data in the context of operational communication with global and local electronic educational resources, will contribute to improving the maturity level of information and communication competences of future bachelors in Professional Education (Tkachuk et al., 2020b).

The developed structural and functional model of mobile ICT application as a tool of teaching Computer Sciences to future bachelors in Professional Education (figure 1) (Tkachuk et al., 2018) is based on competence-based, personality-centred and systematic methodological approaches, built on the principles of Professional Education, general didactic principles, Computer Sciences teaching principles and mobile learning principles, taking into account current conditions and trends in mobile ICT development.

The model consists of four blocks:

1) the purpose-oriented block, which identifies the factors of change in training bachelors in Professional Education that led to the design of the information and communication competence system of future bachelors' training in Professional Education and the corresponding goal – its formation in the process of studying Computer Sciences with mobile technologies;
2) the content-technological block, which defines the content blocks of Computer Sciences, mobile ICT tools, forms of organization and methods of teaching them;
3) the diagnostics block, which defines general and special tools of monitoring and diagnosing the process of competence development; and
4) the result block, which defines the predicted result of the model implementation – increasing the level of maturity of information and communication competences of future bachelors in Professional Education (digital technologies). All blocks of the model are interconnected both directly and through their components.

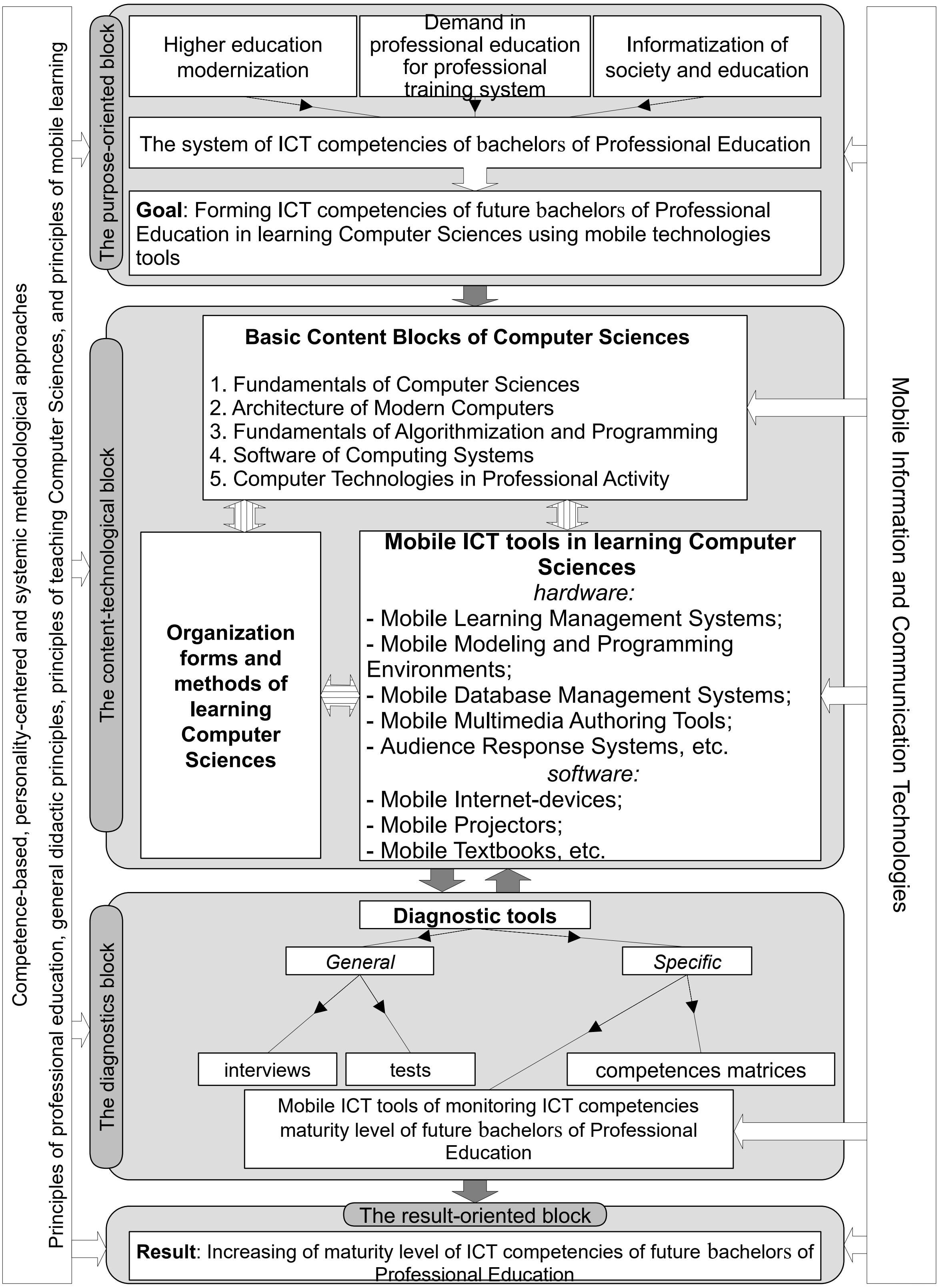

Figure 1: Model of mobile ICT application in teaching Computer Sciences to future bachelors in Professional Education (Tkachuk et al., 2018).

5 METHODOLOGICAL BASIS OF MOBILE ICT APPLICATION IN TEACHING COMPUTER SCIENCES TO FUTURE BACHELORS IN PROFESSIONAL EDUCATION

In the course of the research, we have developed a structure of methods for mobile ICT application in teaching Computer Sciences to future bachelors in Professional Education. There are determined goals and the content of teaching Computer Sciences to future bachelors in Professional Education and relevant mobile ICT tools for teaching Computer Sciences to future bachelors of Professional Education are selected. The main components of methods for mobile ICT application as a tool for teaching Computer Sciences to future bachelors in Professional Education are described.

Based on the results of the expert survey, the feasibility of teaching Computer Sciences by using the following mobile ICT tools is determined (table 1):

- Mobile Learning Management Systems – adaptive, accessible, and mobile e-learning resources that support educational and administrative tasks, assign participant roles in the training process, assess students' learning outcomes, contribute to collaboration between students and teachers, facilitate various types and methods of presenting educational materials, etc;
- Mobile Modeling and Programming Environments – software packages adapted to different operating systems and mobile devices that combine the basic tools needed to write and debug software;
- Mobile Database Management Systems – software for creating and managing databases which allows users and programmers to design, create, retrieve, update, and manage data through client access to the server side provided by a mobile software interface and/or mobile Internet devices;
- Mobile Multimedia Authoring Tools – mobile software that develops electronic training resources based on multimedia principles, spatial proximity, temporal contiguity, coherence, modality, redundancy, personalization, interactivity, signaling, and consideration of individual differences;
- Audience Response Systems – mobile software for measuring students' learning outcomes through automatizing current and final control processes based on the latest testing tools and comprehensively enhancing the learning process.

It is revealed that:

- Mobile Audience Response Systems and Mobile Learning Support Systems are universal tools for teaching Computer Sciences;
- Mobile Multimedia Authoring Tools are highly feasible for all Computer Sciences, except for low-level and system programming and system software, which also allows for their universal classification;
- Mobile Modeling And Programming Environments are the leading tools of teaching theoretical foundations of Computer Sciences and the basics of algorithmization and programming (with the exception of visual programming and low-level and system programming);
- Mobile Database Management Systems are the basic teaching tools only for database programming.

Methodology of using mobile ICT as a tool of teaching Computer Sciences to future bachelors in Professional Education is defined as a theoretically grounded set of methods, ways, techniques and forms of using mobile ICTs:

- methods of using mobile audience response systems (Plickers);
- methods of using mobile learning support systems (Moodle and Intune for Education);
- methods of using mobile multimedia authoring tools (augmented reality multimedia authoring tools);
- methods of using mobile modelling and programming environments in Machine Learning training (Pydroid and Jupyter Notebook environments);
- methods of using mobile database management systems in teaching relational DBMSs (the Google Cloud SQL server and mobile clients).

6 ORGANIZATION, CONDUCT AND RESULTS OF EXPERIMENTAL WORK

In the course of the research, experimental work was carried out to design a system of information and communication competences. At the confirmation stage of the pedagogical experiment, 57 students were included in the control and experimental groups. Pearson's χ^2 criterion was used to find

Table 1: Assessment of feasibility of mobile ICT application to teaching Computer Sciences to future bachelors in Professional Education (Tkachuk et al., 2020a).

Content block	Group of Informatics subjects	Mobile ICT tools					
		mobile learning management systems	mobile modelling and programming environments	mobile database management systems	mobile multimedia authoring tools	mobile audience response systems	Average efficiency estimate for subject **group**
Theoretical principles of Informatics	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**
Architecture of modern computing machines	Architecture of Computer Systems and Networks, Microprocessor Systems	4.09	3.55	3.00	4.09	4.27	**3.80**
Basics of algorithmization and programming	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**
	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**
Software of computing systems	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**
Computer technologies in professional activity of professionals in engineering pedagogy	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**	

out whether there are statistically significant differences between the obtained distribution of the levels of information and communication competences of students in the control and experimental groups. The calculated empirical value of the criterion $T_{emp} = 1.556 < T_{crit}(0.05) = 7.815$ provided the basis for concluding that there are no statistically significant differences in the control and experimental groups.

After the completion of the formative stage of the pedagogical experiment, which included the systematic teaching of Computer Sciences through mo-

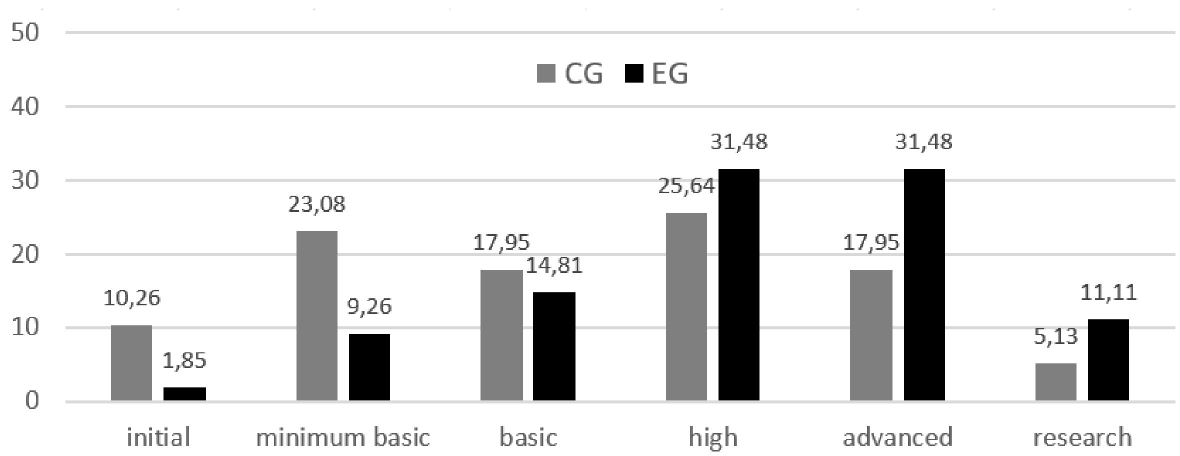

Figure 2: Distribution of students of the control (CG) and experimental (EG) groups by levels of information and communication competences after the formative stage of the pedagogical experiment.

bile ICT application according to the developed methods, the diagnostics of the maturity level of information and communication competences of future Professional Education bachelors was repeated (figure 2). The results processed with Pearson's χ^2 criterion reveal that $T_{emp} = 8.38$ is greater than the critical $T_{crit}(0.05) = 7.815$ at the 0.05 level of statistical significance and less than the critical $T_{crit}(0.01) = 11.345$ at the 0.01 level of statistical significance. This provides a basis for concluding that when the formative stage of the pedagogical experiment is completed, there is a statistically significant difference between the experimental and control groups at the 0.05 significance level.

The results show that after the formative stage of the educational experiment, the percentage of students with initial, minimum basic, and basic levels of competence decreased (8.40 %, 13.82 %, and 3.13 %, respectively), while the percentage of students with high, advanced, and research levels increased (5.84 %, 13.53 %, and 5.98 %, respectively). Thus, it can be assumed that an increase in the number of students with high information and communication competences is due to the transition from lower level groups, i.e., the effect of the increase in the level of information and communication competences of future bachelors in Professional Education in Computer Sciences. To verify this assumption, the ϕ^* criterion, i.e. Fisher's angle transformation, was applied. The calculated criterion value $\phi^* = 2.51$ is higher than the limits at the levels of statistical significance 0.05 ($\phi^*_{crit}(0.05) = 1.64$) and 0.01 ($\phi^*_{crit}(0.01) = 2.31$). This gives grounds to assert the existence of the effect of increasing the maturity level of information and communication competences of future bachelors in Professional Education (Digital Technologies) in the experimental group at the formative stage of the pedagogical experiment at the level of significance of 0.01.

Based on the fact that the experimental group applied the developed methods of using mobile ICTs as a tool of teaching Computer Sciences to future bachelors in Professional Education, we can conclude that this was a factor of increasing the maturity level of their information and communication competences, and, therefore, the research hypothesis is proven.

7 CONCLUSIONS

1. Bachelors in Professional Education are trained in accordance with the international IGIP standard, and in Ukraine, they major in Specialty 015 Professional Education. Its component is Computer Sciences training, which is carried out in the following content blocks of Computer Sciences: 1) theoretical foundations of Computer Sciences; 2) architecture of modern computer technology; 3) basics of algorithmization and programming; 4) computer system software; 5) computer technologies in professional activity of bachelors in Professional Education.
2. Students majoring in Speciality 015.39 Professional Education (Digital Technologies) and teachers of Computer Sciences have a high level of technological readiness, an average level of psychological readiness and a low level of methodological readiness to use mobile ICTs in training, which necessitates the development of appropriate research principles. Based on the results of the expert survey, basic and auxiliary mobile ICT training tools are identified for each of

the content blocks of Computer Sciences.

3. The result of teaching Computer Sciences to future bachelors in Professional Education majoring in Digital Technologies is the maturity level of their information and communication competences. The content of information and communication competences is determined when designing a tool for monitoring the formation of competences and diagnosing the level of their maturity through competence matrices. A comprehensive methodology for assessing the maturity level of information and communication competences of future bachelors in Professional Education (digital technologies) is developed.
4. The developed model of using mobile ICTs as a tool of teaching Computer Sciences to future bachelors in Professional Education is based on competence-based, personality-oriented and systematic methodological approaches, built on the principles of Professional Education, general didactic principles, principles of teaching Computer Sciences and mobile learning principles, taking into account current conditions and trends in mobile ICT development.
5. Methodology of using mobile ICTs as a tool of teaching Computer Sciences to future bachelors in Professional Education is defined as a theoretically grounded set of methods, ways, techniques and forms of mobile ICT application to teaching Computer Sciences to future bachelors in Professional Education. The components of the methodology are partial methods of using Mobile Audience Response Systems, Mobile Learning Support Systems, Mobile Multimedia Authoring Tools, Mobile Modelling And Programming Environments, and Mobile Database Management Systems.
6. The analysis of the results of the experimental work allows asserting that the experimental group at the formative stage of the pedagogical experiment has the effect of increasing the maturity level of ICT competences of future bachelors in Professional Education. Based on the fact that the experimental group used the developed methods, we can conclude that this was a factor in increasing the maturity level of ICT competences.

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Developing Research Competencies in High School Students Through Specialized Chemistry Education: A Computer-Based Approach

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Keywords: Students, Self-Development, Research Competencies, Educational Chemical Research, Structuring of Competencies, System of Research Competencies, Cognitive Activity, Experiment, Development, ICT, Computer-Based Chemistry Training.

Abstract: The article discusses the trends in the development of the education system with a focus on specialized education in chemistry. The goal of specialized education is to deepen theoretical knowledge, improve practical skills, and foster independent and continuous self-education in students. The school chemistry course prioritizes the unity of theory and practice, a research approach to teaching, and differentiation. Research competencies are described as new personality formations that develop gradually in the process of educational and research activities. Specialized chemistry education is the optimal form for the formation and development of students' research competencies. The key concept of the study is research competencies of high school students in specialized chemistry teaching, which are defined as a systemic professionally oriented property of the student's personality. A system of research competencies of high school students in specialized chemistry education is designed, consisting of three groups: general scientific research competencies, scientific research competencies, and special chemical research competencies. The article also discusses the stages of educational and research activities, lesson and extracurricular forms of organizing educational and research activities, and the importance of forming research competencies in students.

1 INTRODUCTION

The main tasks of the National strategy for the development of education in Ukraine for the period up to 2021 in general secondary education are to update the content, forms and methods of organizing the educational process; create conditions for strengthening the professional orientation of students, providing specialized training, individual educational trajectory of students in accordance with their personal needs, interests and abilities; increase the effectiveness of the educational process through the introduction of the achievements of psychological and pedagogical science, pedagogical (President of Ukraine, 2013).

The Concept for the development of science and mathematics education (STEM education), aimed at consistent and systematic solution of issues related to ensuring sustainable innovative development of science and mathematics education and improving its quality, identifies among the ways to solve this problem, in particular, the creation of information and methodological complexes for science and mathematics subjects (electronic manuals, virtual laboratories, electronic databases, educational portals, etc.), as well as ensuring conditions for their use (Cabinet of Ministers of Ukraine, 2020).

According to the Law of Ukraine "On Education" (Verkhovna Rada of Ukraine, 2017) specialized secondary education corresponds to the third level of the National Qualifications Framework, which requires students to develop the ability to work effectively in a team, critical thinking, independent educational and professional activities, responsibility for its progress and results, oral and written communication skills, etc. Studies of in the field of theory and methodology of ICT in education have proven the effectiveness of using ICT tools to develop these abilities. According to the (Verkhovna Rada of Ukraine, 2017), specialized education in science involves the acquisition

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of competencies by students in research and development, design, invention and rationalization activities that can be supported by ICT.

The main tasks of specialized education include assistance in the development of creative independence, the formation of a system of ideas, value orientations, research skills – components of research competencies that will provide a school graduate with the opportunity to successfully realize himself/herself. The issues of forming students' research competencies in the context of specialized education were considered by Alibekian (Alibekian, 2013), Verbytskyi (Verbytskyi, 2012), Zhuk (Zhuk, 2021), Kiv et al. (Kiv et al., 2019).

The main goal of competence-based learning of chemistry students is to develop the competencies necessary for the creative realization of the individual and the acquisition of skills of independent scientific and practical research and development activities, and the leading forms of organizing such activities are laboratory work and projects aimed at forming students' research competencies. The theoretical and methodological foundations of specialized teaching of chemistry were developed in (Jegstad et al., 2022; Sawatruksa and Rodpun, 2019; Segerblom, 1931; Velychko and Fitsailo, 2010). ICTs as a means of teaching chemistry were considered by Aksela (Aksela, 2005), da Silva et al. (da Silva et al., 2019), Derkach (Derkach, 2021), Hernández et al. (Hernández et al., 2014), Husaruk (Husaruk, 2010), Lewis (Lewis, 2004), Martínez-Argüello et al. (Martínez-Argüello et al., 2018), Sadykov and Čtrnáctová (Sadykov and Čtrnáctová, 2019), Silva and Ramos (Silva and Ramos, 2016).

The realization of the purpose and tasks of specialized chemistry education is impossible without taking into account the principle of flexibility, which consists in providing opportunities and conditions for changing the content, methods and forms of organization of specialized education, in particular the main form of meeting individual student requests according to individual plans and programs (for example, in rural areas in the absence of students to form a class) – distance learning, which occurs mainly through the indirect interaction of remote participants in the educational process in a specialized environment that operates on the basis of modern psychological, pedagogical, and information and communication technologies.

The analysis of the experience of organizing specialized chemistry education has revealed a *contradictions* between the potential of computer-oriented chemistry education in the formation of research competencies of high school students and the lack of development of methods for using ICT in the process of forming research competencies in students of specialized classes, which gives rise to a socially significant problem, which is the focus of this research.

2 RESEARCH METHODOLOGY

Research object is information and communication technologies for teaching chemistry in general secondary education.

Research subject is the process of using information and communication technologies as a means of forming research competencies of high school students in specialized chemistry education.

Research aim is to substantiate the theoretical and methodological foundations of the use of information and communication technologies as a means of forming research competencies of senior pupils in specialized chemistry teaching.

The research hypothesis: the process of using ICT as a means of forming research competencies of senior pupils in specialized teaching of chemistry will be effective if

- the system of research competencies is designed as interrelated groups of general scientific, natural scientific and chemical research competencies;
- the selection of general and special purpose ICT tools aimed at forming research competencies of senior pupils in specialized teaching of chemistry;
- the model of forming research competencies of senior pupils is substantiated.

In accordance with the research aim, subject, and hypothesis, the following main *research objectives* have been identified:

1. Based on the analysis of scientific literature, to identify and reveal the theoretical and methodological foundations of the process of forming students' research competencies in specialized chemistry education.
2. To determine the content, structure and features of the system of research competencies of high school students in accordance with the tasks of specialized teaching of chemistry.
3. To identify and characterize information and communication technologies as a means of forming research competencies of students in specialized classes in chemistry.
4. To theoretically substantiate the model of forming research competencies of senior pupils in specialized chemistry teaching by means of information and communication technologies.

5. To develop and experimentally test the effectiveness of the methodology of using information and communication technologies as a means of forming research competencies of senior pupils in specialized chemistry teaching.

To solve the tasks, the following *research methods* were used:

- theoretical – analysis, generalization, systematization of scientific, methodological and psychological-pedagogical literature on topical research issues, current state standards of general secondary education, school curricula and textbooks to determine the theoretical and methodological foundations of the research, development of methods of using information and communication technologies as a means of forming research competencies of high school students; modeling to develop a model for the formation of research competencies of high school students in specialized chemistry teaching by means of information and communication technologies;
- empirical – diagnostic (targeted pedagogical observation, interviews with teachers and students, questionnaires, analysis of teachers' work experience) to determine the state of formation of research competencies of high school students;
- experimental (stating and formative stages of the pedagogical experiment) – to test the developed methodology for the formation of research competencies of high school students.

The theoretical and methodological foundations of the study are the philosophical positions on the unity of theory and practice, interdependence and interconnection of objective and subjective factors of personality formation; fundamental ideas of systemic (Afanas'ev, 1981; Aver'janov, 1985; Blauberg and Judin, 1973; González, 2011), personal and activity (Brushlinskij, 1979; Gal'perin, 2012; Davydov, 2008; Rubinstein and Myasoed, 2009; Talyzina, 1974), competence (Bibik et al., 2019; Il'chenko, 2015; Lokshyna, 2022; Ovcharuk, 2020; Tarasenkova et al., 2019; Khutorskaya and Korol, 2008), cognitive (Bruner, 1984; Piaget, 1980; Vygotsky, 2004) approaches; provisions of the theory of pedagogical systems (Bespalko, 2018; Härkönen, 2009; Derkach and Kuz'mina, 1993), theoretical foundations of modeling of training and education systems (Bykov, 2008; Cifuentes and Olarte, 2023; Dokuchaieva, 2022); scientific provisions of education informatization (Bykov et al., 2017; Gergei and Mashbits, 1986; Glushkov, 1976; Gurevych et al., 2020; Hrynevych et al., 2021; Kademiya and Kobysia, 2017; Kuzmina et al., 2022; Meniailenko et al., 2017; Panchenko, 2021; Polat, 2009; Robert et al., 2016; Semerikov, 2021; Vlasenko et al., 2020; Vakaliuk et al., 2022; Volkova et al., 2021; Zhaldak, 2012), in particular the use of ICT in the educational process of general secondary education (Monakhov, 1986; Morze et al., 2022a; Zhaldak, 2013); theoretical foundations of research-based teaching and learning (Rakov et al., 2009; Mongkonthan, 2021; Park et al., 2023); provisions of the theory and methodology of teaching chemistry at school (Garnett and Tobin, 1989; van Rens et al., 2010; Roehrig and Luft, 2004; Yaroshenko, 2021); conceptual provisions of specialized education (Chebykin and Maksymenko, 2008; Tarasenkova et al., 2020; Volkovyskii et al., 1987), in particular chemistry (Halkyard, 1944; Pak, 2012; Velychko and Fitsailo, 2010); psychological and pedagogical features of computerization of the educational process in general secondary education institutions (Lehka and Shokaliuk, 2021; Monakhov et al., 1986; Smulson, 2012).

3 THEORETICAL FOUNDATIONS OF THE FORMATION OF RESEARCH COMPETENCIES OF HIGH SCHOOL STUDENTS IN SPECIALIZED TEACHING OF CHEMISTRY

Modern trends in the development of the education system, due to the intensification of the development of all spheres of science and the establishment of new social requirements for the individual, are aimed at forming the skills of independent and continuous self-education in students. Based on the views of Bibik et al. (Bibik et al., 2019), Chebykin and Maksymenko (Chebykin and Maksymenko, 2008), Velychko and Fitsailo (Velychko and Fitsailo, 2010) on the content, purpose and ways of implementing specialized education, we note that specialized education in chemistry provides students with opportunities to deepen their theoretical knowledge and improve their practical skills in chemistry; to conduct individual and group research aimed at acquiring skills of independent scientific and practical, research and search activities by high school students; to develop their own intellectual, mental, creative, moral, social qualities, as well as the desire for self-development and self-education.

One of the main features of the school chemistry course is the priority of the principle of unity of theory and practice (Pedersen, 1983; Podlasyi, 1982; Wiggins, 2011), the research approach to teaching (Lim, 2022; Morze et al., 2022b; Peltekova et al., 2014; Rakov et al., 2009) and the principle of differentiation (Gruber, 2008; Unt, 1981; Yaroshenko, 2021), which is reflected in the organization of various types of educational and *research activities* of students, which is understood as an activity aimed at mastering subjectively new knowledge and leading scientific methods of its acquisition, carried out in accordance with the methodology of scientific research in the chosen field, and in the widespread use of the research approach in teaching chemistry, in particular in the context of specialized education.

Based on the general theoretical provisions of the competence-based approach in school education (Bibik et al., 2019; Lokshyna, 2022; Lupión-Cobos et al., 2022; Ovcharuk, 2020) O. Savchenko, scientific views of Baizulaeva (Baizulaeva, 2010) and Golovan' (Golovan', 2012) on the structure and content of research competencies, *research competencies* are interpreted as qualitative new personality formations, the formation and development of which occurs in the process of students' educational and research activities with a gradual complication of its types.

Taking into account the fundamental ideas of the personality-activity approach (Davydov, 2008; Gal'perin, 2012; Talyzina, 1974), scientific principles of specialized education (Chebykin and Maksymenko, 2008; Tarasenkova et al., 2020; Volkovyskii et al., 1987) and features of the implementation of specialized teaching of chemistry (Pak, 2012; Velychko and Fitsailo, 2010; Yaroshenko, 2021), the key concept of the study – *research competencies of high school students in specialized chemistry teaching* – is defined as a systemic professionally oriented property of the student's personality, which combines knowledge, skills, experience of educational and research activities in chemistry and a positive value attitude towards it and is manifested in the willingness and ability to conduct educational chemical research using general scientific, natural scientific and special chemical methods.

The main driving force in the formation and development of students' research competencies in chemistry is educational and research activities, the stages of organization of which generally correspond to the stages of organization of research activities, and specialized chemistry education is the optimal form of education for the formation and development of students' research competencies. It has been proved that the priority lesson forms of organizing educational and research activities in specialized teaching of chemistry, the use of which contributes to the formation of students' research competencies at a high level, are the solution of educational and research tasks and laboratory work, and the leading extracurricular forms are chemical workshops, educational and research projects, individual educational and scientific research, practical and home chemical experiments, the implementation of which is advisable during elective classes and in extracurricular scientific and educational activities.

Based on the research of Khutorskoi (Khutorskoi, 2012) on the structuring of competencies, Pometun and Remekh (Pometun and Remekh, 2019) on the connection of general subject and subject competencies, Il'chenko (Il'chenko, 2015) on the ways of forming natural scientific competencies of schoolchildren, Timirgalieva (Timirgalieva, 2013) on the essence and features of the development of chemical competencies of high school students, a system of research competencies of high school students in specialized chemistry education, consisting of three groups, is designed:

- general scientific research competencies (GRC), which are related to the mastery of universal research methods necessary for research activities in the process of studying any discipline, and include the following abilities: the ability to formulate the research hypothesis (GRC-01), the ability to plan the hypothesis testing (GRC-02), the ability to realize and justify the relevance of the research (GRC-03), the ability to evaluate the moral and social aspects of scientific research (GRC-04), the ability to find and use the reference materials that are necessary for the research (GRC-05), the ability to think critically (GRC-06), the ability to analyze and formalize the research results (GRC-07), the ability to formulate conclusions (GRC-08), the ability to substantiate the submission of research results, to protect the own opinion, to discuss (GRC-09), the ability to work together in the research process (GRC-10);
- scientific research competencies (SRC) related to the study of real natural objects and the relationships between them, which are necessary for research activities in the field of natural sciences and are represented by: the formation of representations about the stages of the cognitive activity in natural sciences, the elements of metrology (SRC-01), the ability to plan an experiment (SRC-02), the ability to carry out the individual operations competently during the experiment (SRC-03), the ability to conduct experiments in order to know the properties of bodies and substances, to identify the features of the growth, the development

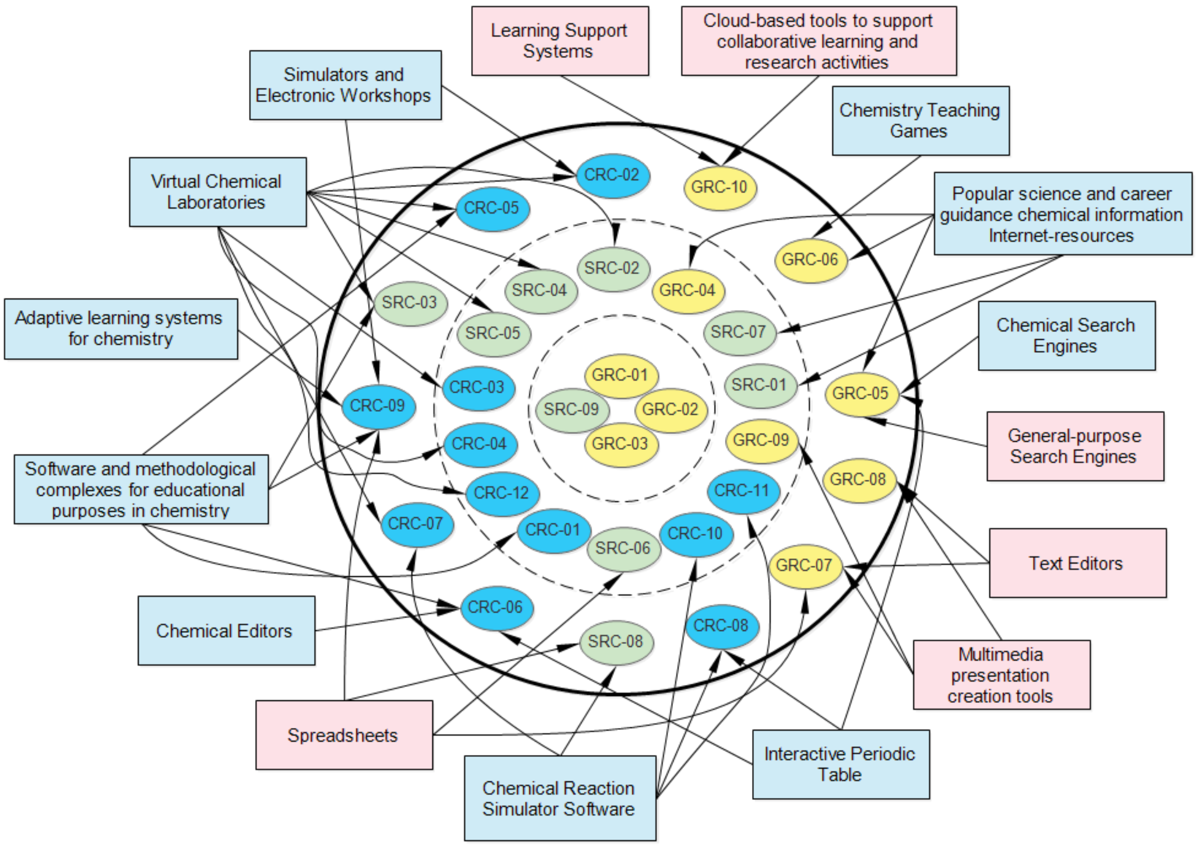

Figure 1: Interrelation of ICT tools with the formation of a system of research competencies of high school students in specialized chemistry education.

and the behavior of organisms (SRC-04), the ability to adhere to the safety rules during the experiment (SRC-05), the ability to perform the mathematical analysis of the experimental research results (SRC-06), the formation of representations of the general laws of nature and the natural sciences picture of the world, the general structure of the universe, the integrity of nature (SRC-07), the ability to use the experimental and statistical methods and the modeling in the study of objects of live and inanimate nature (SRC-08), the ability to distribute work in the process of experiment that the purpose of optimization (SRC-09);

- chemical research competencies (CRC), which are related to the mastery of special chemical research methods necessary for research activities in the fields of chemical sciences, include the ability to: the ability to distinguish the chemical phenomena of nature from the others (CRC-01), the ability to use the chemical dishes and equipment correctly (CRC-02), the ability to adapt the existing chemical dishes and equipment for the experiment needs (CRC-03), the ability to compose and use the devices for carrying out the experiments (CRC-04), the ability to perform the laboratory operations correctly: heating, cooling, filtering, mixing, weighing, etc. (CRC-05), the ability to use the chemical symbols, the formulas, the modern Ukrainian chemical nomenclature (CRC-06), the ability to predict the course of chemical reactions, based on the properties of the substances that are taking part in them, and the conditions of the reaction (CRC-07), the ability to justify the relationship between the structure of matter and its properties (CRC-08), the ability to perform the various types of chemical calculations (CRC-09), the ability to draw conclusions about the properties of matter, based on the structure of the molecule substances (CRC-10), the ability to draw conclusions about the structure of substances based on their properties (CRC-11), the ability to solve the experimental problems in chemistry (CRC-12).

The different groups of the system of research competencies of high school students in specialized chemistry education are shown in figure 1.

4 METHODOLOGICAL FOUNDATIONS OF USING INFORMATION AND COMMUNICATION TECHNOLOGIES AS A MEANS OF FORMING RESEARCH COMPETENCES OF SENIOR PUPILS IN SPECIALIZED TEACHING OF CHEMISTRY

Theoretical analysis of the conceptual provisions on informatization of education (Fedorenko et al., 2019; Li, 2021; Liu and Wang, 2021; Mynbayeva and Anarbek, 2016; Qi et al., 2009; Wang and Xing, 2011; Wen, 2022; Yan and Yang, 2021), the use of ICT in the educational process of general secondary education (Gil-Flores et al., 2017; Lai and Pratt, 2004; Mooij and Smeets, 2001; Webb, 2002; Wikan and Molster, 2011), taking into account the psychological and pedagogical features of computerization of the educational process of schoolchildren, the results of the analysis of the theory and practice of specialized teaching of chemistry gave grounds to distinguish two main groups of ICT learning tools in accordance with the tasks of specialized teaching of chemistry, in particular: general-purpose tools used to support the teaching of any discipline, and special-purpose tools that are specific means of supporting the teaching of chemistry.

Based on the results of the expert survey (Nechypurenko et al., 2021), 17 ICT tools were selected, the use of which contributes to the formation of research competencies of high school students in specialized chemistry teaching: seven general-purpose tools (spreadsheets; tools for monitoring and self-monitoring of learning achievements; tools for creating multimedia presentations; general-purpose search engines; learning support systems; text editors; cloud-based tools for supporting collaborative learning and research activities) and ten special-purpose tools (adaptive automated learning systems in chemistry; virtual chemical laboratories; electronic periodic systems; computer modeling of chemical processes; educational games in chemistry; popular science and career guidance chemical information resources on the Internet; software and methodological complexes for educational purposes in chemistry; simulators and electronic workshops; chemical search engines; chemical editors).

It has been proved that most research competencies correspond to one or more leading ICT tools to support their formation. It has also been found that 16 selected ICT tools are leading in the process of forming at least one research competence, with general-purpose ICT tools being necessary for the formation of primarily general scientific ones, and special-purpose tools – for the formation of chemical and natural scientific research competences of high school students in specialized chemistry education. Schematically, the types of these connections are shown in figure 1.

ICT tools for the formation of senior students' research competencies in specialized chemistry education have become one of the key elements of the developed model of the formation of senior students' research competencies in specialized chemistry education by means of ICT, which consists of four blocks (figure 2).

Thus,

- the goal unit contains components that define the goal – the formation of research competencies of high school students using ICT (rapid growth of chemical knowledge and the need of society for highly qualified specialists in chemistry, computerization of all types of chemical activities, pre-professional training in chemistry in high school and research-oriented teaching of chemistry);
- the conceptual unit reflects modern approaches to the implementation of a competence-based approach in specialized chemistry teaching and contains normative documents (international and state standards), the content of chemistry teaching, an expert survey as the main selection tool and a designed system of research competencies of high school students in specialized chemistry teaching;
- the technological unit contains a set of ICT tools for the formation of research competencies of high school students in specialized chemistry teaching, which is interconnected with the methods of specialized chemistry teaching and forms of organization of students' research activities in chemistry and determines the ways to achieve the goal;
- diagnostic and result unit includes the predicted result of applying the model – increasing the level of high school students' research competencies in specialized chemistry education and a set of assessment criteria, indicators, levels and means of diagnosing the formation of students' research competencies, designed to determine the effectiveness of achieving the result.

The components of the model that ensure the interconnection of all units are information and communication technologies, methodological approaches

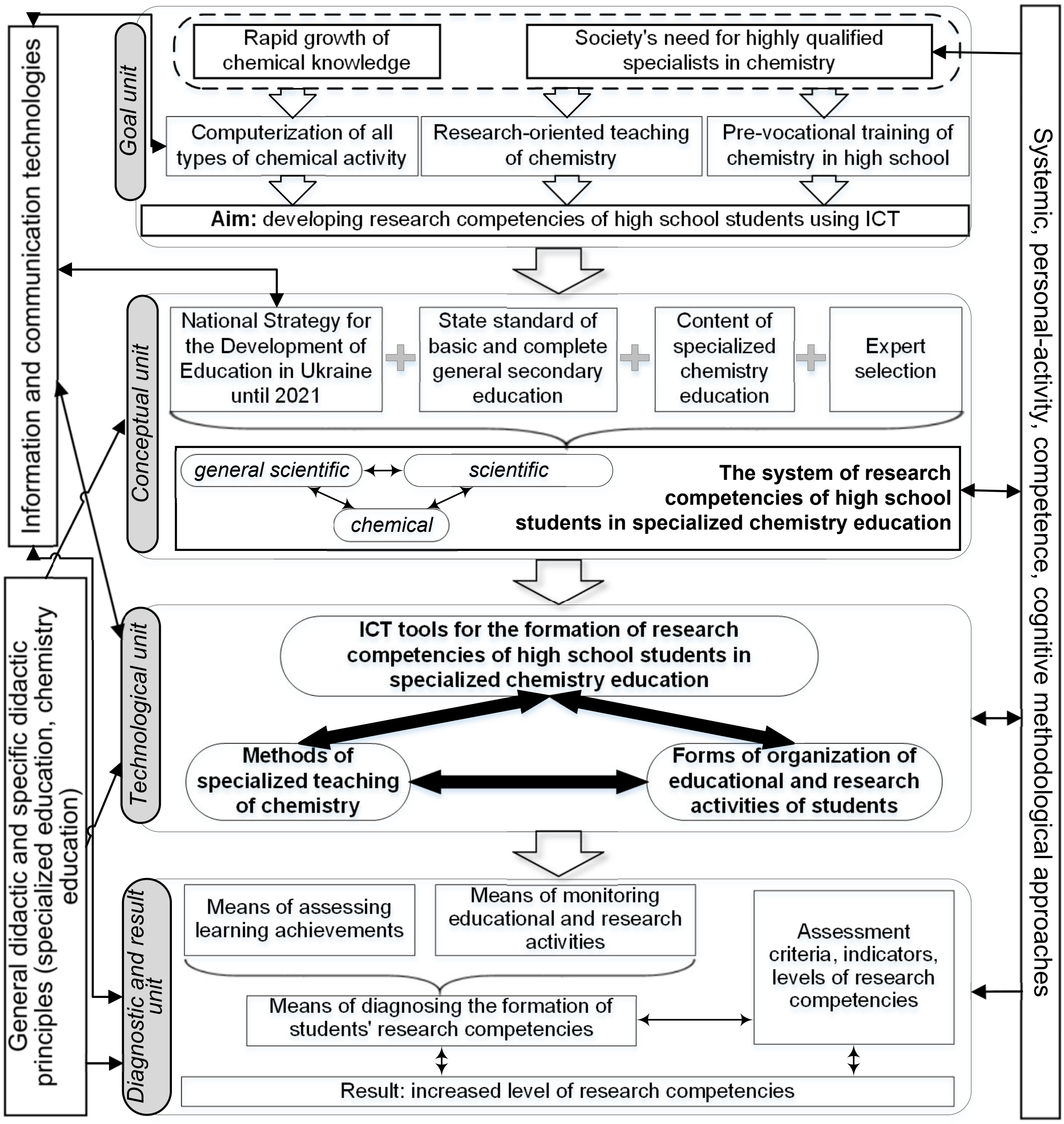

Figure 2: The model of research competence formation of high school students in specialized chemistry teaching using ICT.

(systemic, personal-activity, competence, cognitive) and principles (general didactic and specific didactic – specialized education, chemistry education).

In accordance with the model of forming research competencies of high school students in specialized chemistry teaching using ICT, a methodology for using ICT as a means of forming research competencies of high school students in specialized chemistry teaching has been developed, consisting of a target block (formation of students' research competencies), content block (teaching the basics of quantitative chemical analysis) and technological block (ICT tools, methods and forms of their use in specialized chemistry teaching). Proceeding from the fact that the formation of a system of research competencies of high school students is effective provided that the appropriate selection of ICT tools and conditions for their use for the formation of each of the research competencies, the developed methodology was tested in the process of teaching the optional course

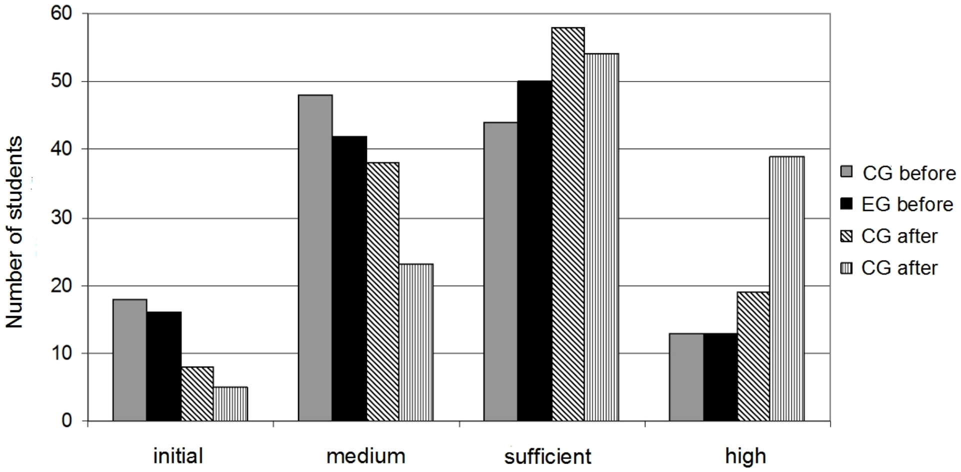

Figure 3: Levels of research competencies of high school students of high school students in the control (CG) and experimental (EG) groups at the beginning and end of the pedagogical experiment.

"Fundamentals of Quantitative Chemical Analysis", as well as individual topics of the high school chemistry course at the specialized level.

5 EXPERIMENTAL WORK

The research and experimental work consisted of three stages: analytical and stating (2007 – 2009), design and search (2010 – 2013) and formative and generalizing (2014 – 2017). At the first stage, the problem was identified and the research hypothesis was formulated.

At the second stage, the structure of research competencies and indicators for diagnosing the level of their formation were determined, which was carried out through observations, conversations, questionnaires, studying the products of students' activities, high school students' performance of psychological tests, sets of test tasks and written tests in the subject. This made it possible to determine the levels of research competencies on a four-level ordinal scale (initial, intermediate, sufficient and high) using research competency matrices that were filled out for each student. The level of formation of the system of research competencies of high school students in specialized chemistry education was determined based on the level of formation of each individual research competency and its contribution to the formation of the system of research competencies.

At the third stage, in order to test the effectiveness of the developed methodology of using ICT as a means of forming research competencies of high school students in specialized chemistry teaching, the curriculum of the optional course "Fundamentals of Quantitative Chemical Analysis" was developed (Nechypurenko and Soloviev, 2018); the selection of ICT tools was carried out, the use of which ensured the formation of research competencies of high school students in the process of their study in the optional course; control (CG) and experimental (EG) groups were formed, in which the process of formation of research competencies was monitored.

The results of the pedagogical experiment showed no significant difference in the distribution of CG and EG students by levels of research competencies at the beginning of the experiment and the presence of such a difference after its completion against the background of a general increase in the number of students with sufficient and high levels of research competencies in both groups (figure 3).

The statistical processing of the pedagogical experiment data was carried out using Pearson's χ^2 test. The results of the statistical processing confirmed the assumption that there were no significant differences between the distribution of CG and EG students at the beginning of the experiment by the levels of formation of research competence groups (χ^2_{emp} = 0.943; 1.751 and 1.243 for general scientific, natural scientific and chemical research competencies, respectively) and the system of research competencies in general (χ^2_{emp} = 0.884) and showed the presence of significant differences at the level of $p = 0.01$ in the distribution of CG and EG students by the levels of formation of the system of research competencies in general (χ^2_{emp} = 11.470) and significant at the level of $p = 0.05$ differences in the distribution of CG and EG students by the levels of formation of chemical research competencies (χ^2_{emp} = 8.649) after the pedagogical experiment, which confirmed the research hypothesis.

6 CONCLUSION

The article presents a theoretical generalization and solution to the scientific problem of using ICT as a means of forming research competencies of high school students in the process of specialized chemistry teaching. The research results give grounds to draw the following conclusions:

1. Based on the results of the analysis of scientific literature, regulatory and legislative documents, it was found that in general secondary education the priority task is to update the content, forms and methods of organizing the educational process; create conditions for strengthening the professional orientation of students by providing specialized training and individual educational trajectory of students in accordance with their personal needs, interests and abilities; improving the quality of the educational process through the introduction of ICT as an effective means of forming research competencies.

   The theoretical and methodological foundations of the process of forming students' research competencies in specialized chemistry education are revealed, which include a definitional analysis of the key concepts of the research, a theoretical substantiation of the model of forming research competencies of high school students in the process of specialized chemistry education, a designed system of research competencies of high school students in accordance with the tasks of specialized chemistry education, a description of ICT as a means of forming research competencies of students in specialized classes in chemistry.

2. Based on the fundamental ideas of competence, personality and activity approaches, scientific principles of specialized education and taking into account the peculiarities of its implementation in the process of teaching chemistry, the key concept of the study – research competencies of high school students in specialized teaching of chemistry – is defined as a systemic professionally oriented property of the student's personality, which combines knowledge, skills, experience of educational and research activities in chemistry and a positive value attitude towards it and is manifested in the readiness and ability to conduct educational chemical research using general scientific, natural science and special chemical methods.

   It has been proved that the main driving force for the formation and development of students' research competencies in chemistry is educational and research activity, which is considered as an activity aimed at mastering subjectively new knowledge and leading scientific methods of its acquisition, carried out in accordance with the methodology of scientific research in the chosen field, and the stages of its organization correspond to the stages of organization of research activity. On the basis of a methodologically sound combination of traditional and innovative technologies, it is established that the priority forms of its organization are the solution of educational and research tasks and laboratory work, and the leading extracurricular forms are chemical workshops, educational and research projects, individual educational and scientific research, practical and home chemical experiments, the implementation of which is advisable during optional classes and in extracurricular scientific clubs.

3. Taking into account theoretical provisions on the structuring of competencies, the relationship between general subject and subject competencies, ways of forming natural scientific competencies of schoolchildren, the essence and features of the development of chemical competencies of senior pupils, a system of research competencies of senior pupils in specialized teaching of chemistry is designed, consisting of three groups: general scientific research competencies related to the mastery of universal research methods; natural scientific competencies that provide for the development of scientific research. The article investigates the links between different groups of the research competencies system and establishes that the formation of some research competencies indirectly determines the development of others, which requires the selection of means for the formation of research competencies of high school students in specialized education, taking into account the interrelated development of all three groups of competencies with an emphasis on those that have the most connections with other competencies and can be considered key research competencies.

4. The research identifies 17 ICT tools that contribute to the formation of research competencies of high school students in specialized chemistry education, including seven general tools (spreadsheets; tools for monitoring and self-monitoring of learning achievements; tools for creating multimedia presentations; general-purpose search engines; learning support systems; text editors;

cloud-based tools for supporting collaborative learning and research activities) and ten special-purpose tools (adaptive automated learning and teaching tools).

It has been proved that the most significant ICT tool for the formation of research competencies is virtual chemical laboratories, which are appropriate for the formation of the largest number of research competencies of high school students in the process of specialized chemistry education (Nechypurenko and Semerikov, 2017; Nechypurenko et al., 2019, 2020).

5. The developed model for the formation of research competencies of senior pupils in specialized teaching of chemistry using ICT consists of the following interrelated units: goal, the components of which determine the purpose of forming research competencies of senior pupils using ICT; conceptual, reflecting modern approaches to the implementation of a competence-based approach to specialized teaching of chemistry; technological, which contains a set of ICT tools for the formation of research competencies of high school students in specialized chemistry teaching, interconnected with the methods of specialized chemistry teaching and forms of organizing students' research activities in chemistry; diagnostic and result, representing the predicted result of the model.

   The components of the model that ensure the interconnection of all blocks are information and communication technologies, methodological approaches (systemic, personal and activity, competence, cognitive) and principles (general didactic and specific didactic – of specialized education and chemistry education).

6. The methodology of using ICT as a means of forming research competencies of high school students in specialized chemistry teaching consists of a target block (formation of students' research competencies), a content block (teaching the basics of quantitative chemical analysis as a universal course for different chemical profiles) and a technological block (ICT tools, methods and forms of their use in specialized chemistry teaching).

   The experimental verification of the developed methodology in the form of a sequential pedagogical experiment and the results of statistical processing of the data confirmed the assumption that there were no significant differences in the distribution of students of the control and experimental groups at the beginning of the experiment in terms of the levels of formation of research competence groups (χ^2_{emp} = 0.943; 1.751 and 1.243 for general scientific, natural scientific and chemical research competencies, respectively) and the system of research competencies in general (χ^2_{emp} = 0.884) and showed the presence of significant differences at the level of $p = 0.01$ differences in the levels of formation of the system of research competencies in general (χ^2_{emp} = 11.470) and significant at the level of $p = 0.05$ differences in the levels of formation of chemical research competencies (χ^2_{emp} = 8.649) after the completion of the pedagogical experiment, which confirmed the hypothesis of the study.

The research results can be used in the process of organizing research teaching of chemistry using ICT in general secondary and higher education institutions of various profiles; in the process of professional training of future chemistry teachers; in the system of postgraduate pedagogical education and advanced training of science teachers; in the self-educational activities of high school students.

7 FUTURE WORK

The study does not exhaust all aspects of the problem under consideration. Further scientific research into its solution is advisable in the following areas: development of methods for using expert systems as a means of generalization and systematization in teaching chemistry; development of adaptive systems for teaching chemistry; design of a system of cloud-based virtual chemical laboratories and development of methods for their use; theoretical and methodological foundations for designing a computer-oriented environment for the professional training of future chemistry teachers.

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Digital Learning Space to Improve the Conceptual Understanding of Mathematics of non-Mathematical Specialties Students

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Abstract: The article considers the problem of improving the conceptual understanding of mathematics of non-mathematical specialties students by means of digital learning space. The results of a survey of students on the effectiveness of their mathematical training are presented. It is established that most often students use procedural rather than conceptual knowledge, which complicates the application of mathematical methods on practice. As a result of the analysis of the most common strategies for teaching mathematics, the author's vision of teaching mathematics using digital tools is presented. Such teaching is aimed at forming students' conceptual mathematical knowledge, which is harmoniously combined with procedural knowledge. A learning space has been developed to study the topic "Derivative", where you can explore mathematical concepts and relationships between them, formulate hypotheses, experiment, ask questions, draw conclusions and discuss the results. One of the developed educational spaces is described, namely for studying the topic "Derivative". In it, you can explore mathematical concepts and relationships between them, formulate hypotheses, experiment, ask questions, draw conclusions, and discuss the results obtained. Digital tools are built into the space, which allow to implement different types of educational activities of students (individual, group and frontal) and thus ensure the effectiveness of the formation of conceptual knowledge about the derivative. On the example of studying Lagrange's theorem on finite increments and solving various applied mathematical problems, methods of forming a conceptual understanding of students' mathematics are given.

1 INTRODUCTION

In modern high-tech and digitalized society, the main trend in the development of mathematics is the process of its penetration into various sciences – the mathematization of science, which, in turn, leads to mathematization and computerization of human practice. In these conditions, a competent specialist must know the mathematical methods and models used in his profession, be able to use them, be able to use appropriate computer programs to develop new models for his/her professional needs. That is, mathematical training is a necessary and integral part of the training of highly qualified specialists at all levels of higher education.

Mathematical knowledge is dual: it is knowledge of "what" and "why" (conceptual knowledge) and knowledge of "how" (procedural knowledge). Therefore, learning mathematics will be successful if this process is aimed at understanding concepts and mastering procedures.

Many works are devoted to the definition of the content of the concepts "conceptual knowledge" and "procedural knowledge", their relationships, theoretical and methodological principles of formation (Hiebert and Lefevre, 1986; Cobb, 1988; Byrnes and Wasik, 1991). Based on them, it can be argued that conceptual knowledge involves, in addition to knowledge of concepts, facts, methods, understanding of the relationships and interdependencies between them; the ability to see the key idea of a method, to assess in what contexts it may be useful; find different solutions to one problem; analyze and evaluate the obtained result.

Procedural knowledge involves a number of steps that must be performed to solve the problem. Proce-

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Digital Learning Space to Improve the Conceptual Understanding of Mathematics of non-Mathematical Specialties Students.
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dural knowledge includes knowledge of algorithms, techniques and methods.

There are different views on the causal relationship between conceptual and procedural knowledge (Byrnes and Wasik, 1991; Rittle-Johnson et al., 2001; Forrester and Chinnappan, 2010). Most researchers believe that the effectiveness of learning is higher if conceptual knowledge precedes procedural and its knowledge is based on conceptual (Balka et al., 2012; Nahdi and Jatisunda, 2020; Forrester and Chinnappan, 2010). For example, Forrester and Chinnappan (Forrester and Chinnappan, 2010) found in testing students the dominance of their procedural skills over conceptual knowledge. All common errors were related to incorrect application of procedures due to misunderstanding of their conceptual basis.

It should be noted that the purpose of mathematical training of students of non-mathematical specialties is not to master the knowledge of higher mathematics as a value that is important in itself. The goal (and at the same time the motivation to study mathematical disciplines) is the opportunity and ability to apply mathematics in his/her field. Therefore, questions arise: 1) how do different types of knowledge (conceptual and procedural) affect this ability? 2) what should be the educational strategy aimed at forming in students of non-mathematical specialties conceptual mathematical knowledge that is harmoniously combined with procedural knowledge?

There are many methodological techniques that allow you to implement this pedagogical task. But the most effective, in our opinion, is research-oriented teaching of mathematics using digital technologies (Leung, 2006; Smetana and Bell, 2012; Astafieva et al., 2020). It involves active interaction between teacher and student, which includes identifying problems, joint search for solutions, research, discussion, consideration of alternatives, rethinking and evaluating the result. On the other hand, the use of ICT provides active communication between teachers and students, their independent research work (both individual and group), competent and effective organization of educational space and its management.

The aim of research – development and theoretical substantiation of some methodical methods of using digital learning space to improve the conceptual understanding of mathematics of non-mathematical specialties students.

Research methods:

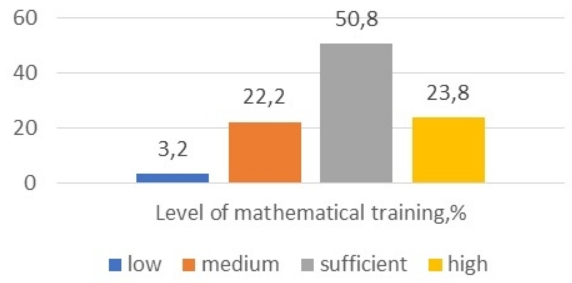
- theoretical – analysis, synthesis, systematization and generalization of scientific, methodological literature, to determine the impact of conceptual and procedural mathematical knowledge on the ability to apply mathematics and study educational strategies of mathematical training of non-mathematical specialties, definition of conceptual and categorical research apparatus (“conceptual knowledge”, “procedural knowledge”, “educational and research spaces”); generalization of progressive ideas and existing shortcomings in modern higher education to justify ways to improve the mathematical training of students by means of digital technologies that allow active learning, in particular, to conduct experiments, research and modeling;
- empirical: surveys to determine the effectiveness of mathematical training of non-mathematical specialties students.

2 RESULTS AND DISCUSSION

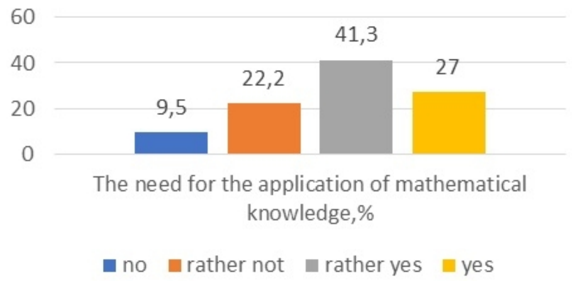
Borys Grinchenko Kyiv University trains, among others, specialists in “Computer Science”, “Management”, “Economics”, “Finance, Banking and Insurance”. These educational programs include the study of higher mathematics. In June 2022, we conducted a survey of students of these specialties on the effectiveness of their mathematical training. A total of 63 first-fourth year students took part in the survey. All students took a course in higher mathematics and had the opportunity to use the acquired mathematical knowledge in practice in the process of studying professional disciplines.

Firstly, we asked students to assess the general level of their mathematical training after studying the discipline “Higher Mathematics” (on a 4-point scale: 1 – low, 2 – medium, 3 – sufficient, 4 – high). It turned out that the vast majority of students (74.6% of respondents) believe that they have a sufficient and high level of mathematical training, 22.2% – medium, 3.2% – low. Interestingly, the answers of junior students (I – II courses) were not fundamentally different from the answers of senior students (III – IV courses). Next, we found out if they feel the need to apply mathematical knowledge in the study of professional disciplines. The majority of students, 68.3%, answered in the affirmative – “yes” and “rather yes”, 22.2% of respondents – “rather not”, 9.5% of students do not feel the need to apply mathematical knowledge in the study of professional disciplines.

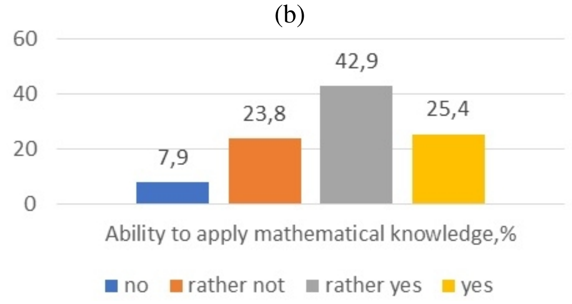
We also tried to determine whether students had to apply mathematical knowledge in the study of professional disciplines (on a 4-point scale). 68.3% of respondents answered that they use mathematical knowledge in the study of professional disciplines, 23.8% – rather no, 7.9% – no. Figure 1 shows the results of students’ survey.



(a)



(b)



(c)

Figure 1: The results of students' survey.

We compared the available empirical distributions using Pearson's test χ^2. It turned out that $\chi^2_{emp} = 1.631$ at $\chi^2_{cr} = 12.562$ (at $p = 0.05$). Thus, we can say that there is a certain relationship between the level of mathematical training of students (figure 1a), a sense of their need (figure 1b) and the real opportunity to apply mathematical knowledge on practice (figure 1c). For example, 25.4% of students do not appreciate the level of their own mathematical training, while 31.7% of respondents do not see a special need and opportunity to apply mathematical knowledge.

One of the key mathematical concepts is the concept of "derivative of a function". We asked students to comment on the essence of this concept. As a result of self-assessment it was found that only 12.7% of students believe that they remember the definition well, understand the essence of this concept and use it in the study of professional disciplines, 34.9% – remember the definition well, understand the essence of the concept, but do not use it. study of professional disciplines. The majority of students (52.4%) stated that they had some information about the derivative function or did not remember anything about it.

We decided to check the obtained results and asked students to choose the correct definition of the derivative function from the proposed options. The majority of students (34 people or 54.0%) chose the wrong answers. It should be noted that among them 14 people (22.2%), answering the previous question, thought that they well understood the essence of the concept of "derivative function".

To test the conceptual understanding of the concept of a derivative, we also asked students to explain in one word what a derivative is. Options were proposed: speed, productivity, tangent, consequence, area, work, mass. The correct options were chosen: "speed" – 46%; "productivity" – 17.5% of students. The majority of respondents (57.1%) chose the "tangent" option, which indicates a lack of conceptual knowledge, first of all, an understanding of the essence of the concept of a derivative (a derivative is not a tangent, but an angular coefficient of a tangent). Another number of students chose other wrong options: consequence (28.6% of respondents), area (11.1%), work (4.8%), mass (1.6%). It can be assumed that the reason for the incorrect answer was mainly the formal following of a certain algorithm for using the derivative in solving applied problems. In our opinion, students generally remember the rules of differentiation, can use the table of derivatives, but do not feel the main thing – the essence of the concept of "derivative function". Thus, most of them are not able to use this concept in non-mathematical contexts. Interestingly, among the 29 students who recognized the correct definition of the derivative function from the proposed ones, there were only two in which the derivative was associated with both speed and productivity, and they did not choose the wrong options. And this indicates the formality of knowledge and lack of conceptual understanding of the concept of derivative in the remaining 27 students.

The results of the survey, as well as the real experience of teaching mathematical disciplines to the authors of the study showed that students of all specialties to some extent feel the need to apply mathematical knowledge in the study of professional disciplines, as well as use this knowledge in practice. At the same time, most students are more likely to use procedural rather than conceptual knowledge. In particular, students work mechanically according to known algorithms, schemes or rules, but have a poor understanding of the essence of mathematical concepts, facts, methods and tools.

The results of our survey are close to the results of the study of Aydın and Özgeldi (Aydın and Özgeldi, 2019). The authors of this study, analyzing the success of prospective elementary mathematics teachers in solving PISA-2012 problems, found that few students were able to give "mathematical explanations for conceptual knowledge items, and that their contextual knowledge was fragmented" (in this article the authors understand contextual knowledge those that allow you to connect the real world – the context in which the problem arises, with mathematics (Sáenz, 2009)). In addition, students had particular difficulty with tasks that required a combination of conceptual and procedural knowledge.

Thus, we approached the main question: what teaching of mathematics to non-mathematical specialties students will be effective, how to teach that the acquired mathematical knowledge became useful in the future professional activity?

There are two extremes in teaching mathematics to non-mathematical specialties students. The first is the desire for formal rigor of proofs of theoretical facts, formulations of definitions. Teachers are supporters of this point of view, pay too much attention to strict deductive reasoning. They, striving for formal rigor (which is still not achieved due to the limited time allocated in the educational programs of non-mathematicians to study mathematical disciplines), often have little concern about how this material will "work" in the future to solve problems that lie outside mathematics.

The second extreme is a minimum of attention to theoretical justification, learning algorithms, solving typical problems according to the instructions, the use of certain formulas, and etc. Teachers are apologists for this point of view, believing that they teach applied mathematics, do not attach due importance to the justification of certain actions, clarifying the limits of the method, and etc. Such training critically limits the ability of the future specialist to use mathematics as a tool, because the mechanical implementation of certain procedures can lead to unreasonable and incorrect decisions.

In both cases, students do not develop the ability to use mathematics to solve applied problems, which is the purpose of teaching mathematics to non-mathematical specialties students.

In our opinion, the course of higher mathematics (or a block of mathematical disciplines) for non-mathematical specialties students should have an applied orientation. But it should not be narrowly utilitarian and prescription, because applied mathematics is not a simplified version of "pure" mathematics. Courses of mathematical disciplines should be based on the necessary theoretical concepts: key mathematical concepts, facts, a set of ideas and methods that have a wide range of applications. For mathematics to be applied, deep knowledge of the essence of mathematical concepts, facts, methods is required, i.e. conceptual knowledge is required. It is also necessary to have not only (and not so much!) deductive, but also empirical thinking, which would be convincing, although not necessarily strict from the standpoint of "pure" mathematics. Rigor should be in the exact (correct) presentation of the idea, not in the fetishization of the form of presentation.

Teaching mathematics to "applicators" should, in our opinion, pursue the following goals:

1) formation of conceptual understanding of key mathematical concepts, facts, methods with illustration of their applied application, study of the corresponding mathematical apparatus;
2) developing basic skills of mathematical research and mathematical modeling.

In view of this, we consider it effective to use (as tools) digital technologies for the formation of conceptual and procedural knowledge, which make it possible to implement active learning, in particular, to conduct experiments, research and modeling.

One of the platforms that has these tools is Go-Lab. The Go-Lab project (Global Online Science Labs) is a research innovation project co-financed by the European Commission. Its goal is to bring science closer to pupils and students by providing open access to online science laboratories created by scientists and teachers from different countries (Next-Lab, 2022).

On the portal (https://www.golabz.eu) for the teacher there is an opportunity to work with the base of ready laboratories and training spaces (ILS). And also create your own learning spaces in the Graasp environment (https://graasp.eu/), using Go-Lab tools and resources.

Go-Lab Inquiry Learning Spaces (ILSs or Inquiry Spaces) are research-oriented activities structured through Go-Lab Inquiry Cycles, which can include laboratories, training resources, programs, online services and other digital tools to provide and support research learning (de Jong, 2015).

The functionality of such a space allows you to organize a special environment. Here, under the guidance of the teacher, students explore mathematical concepts and the relationships between them, formulate hypotheses, experiment, ask questions, draw conclusions and discuss the results.

In fact, with the help of ILS, the teacher can encourage students to actively learn, using methods and techniques that require students to conscious learning activities, to involve them in the process of constructing new knowledge, research skills. The active participation of the student in the educational process is the key to the formation of conceptual understanding and achievement of high results during training, as well as his ability to apply the acquired knowledge and skills in further professional activities.

An example of such a space can be created by educational and research space to study the topic "Derivative".

The learning space contains tasks that involve working with a variety of digital tools (figure 2 – 6). These tools are selected so that you can implement different types of student learning activities (individual, group and frontal) and ensure maximum efficiency in the formation of conceptual knowledge in solving the problem.

There are things that integrated into the space:

- a ready – made Go-Lab laboratory (Labs), which allows students to conduct research using computer simulations;
- built – in GeoGebra environment for research and geometric modeling;
- built – in online spreadsheets with the ability to co-edit;
- TEXT Input forms for answers (the teacher has the opportunity to see the answers of all students from his profile, and students see only their answers);
- Apps Sticky Notes, in which participants in the process can write down their ideas on stickers;
- Apps Concept Mapper for compiling problem-solving algorithms;
- Padlet board for joint work of students and teacher;
- Apps Quest 2.0 – tests to check the mastery of the topic.

Let's illustrate the use of these tools on some tasks of our educational space "Derivative".

Task 2. The motorcyclist moves in a straight line according to the law $x(t)$. When changing some parameters of the motorcyclist's movement, observe how others change. Record the results of your observations in the form below. Can you independently build graphs of speed and acceleration according to a known graph of the law of motion? And the schedule of the passed way according to the schedule of speed?

The task is performed in Go-Lab. When performing this task, students have the opportunity to conduct an experiment by changing certain parameters of the motorcyclist's movement (figure 2).

One of the most important theorems of differential calculus is Lagrange's theorem on finite increments.

Theorem. If the function $f(x)$ is continuous on the interval $[a;b]$ and differentiable on the interval $(a;b)$, then on this interval there exists a point c such that the equality (Lagrange formula):

$$\frac{f(b)-f(a)}{b-a} = f'(c).$$

The theorem has a simple (even obvious!) geometric meaning: on a solid smooth curve connecting two points, there is a point where the tangent is parallel to the chord. Students are given the task to experimentally "prove" the validity of the theorem. To do this, they should draw a line parallel to the chord AB, and then move this line parallel to itself and make sure, thus, the validity of the theorem formulated in geometric terms. The task is performed using the built – in environment GeoGebra (figure 3).

Such a geometric illustration (and argumentation!) is quite convincing, it is intuitively clear. Therefore, it is not necessary to "frighten" students, for whom mathematics will not be the sphere of their professional activity in the future, with a strict mathematical formulation of the theorem, especially – by proving it. Students will easily come to the analytical formulation when they have before their eyes the appropriate graphic image. The teacher can (if necessary) provide assistance in the form of a question: "What is the condition of parallel lines?"

With the pedagogical mediation of the teacher (or without him), students, changing the curve, just as easily establish graphically that the point c, which is discussed in the theorem, may not be one (figure 4).

To improve the conceptual understanding of mathematics and the formation of conceptual knowledge, it is important to clarify the implication links between statements. Therefore, the chance will be lost if, when studying Lagrange's theorem, we do not stimulate students to answer the question: "Are the conditions of the theorem necessary, essential, is each of them individually, sufficient?" (**Task 5**). In this particular situation, we organize the collective work of students using the built – in online Google Sheet. Students fill in the so-called. conceptual table on the topic "Lagrange's theorem" (figure 5).

What is a "conceptual spreadsheet"? A conceptual table is a summary, organized, and structured information about the content of a particular topic, ways to solve a particular problem, the results of a study, and etc. Students fill in the spreadsheet collectively, most often – working in small groups. At the same time, they must demonstrate an understanding of the essence of concepts, facts of this topic, their connection with previously studied, physical, economic,

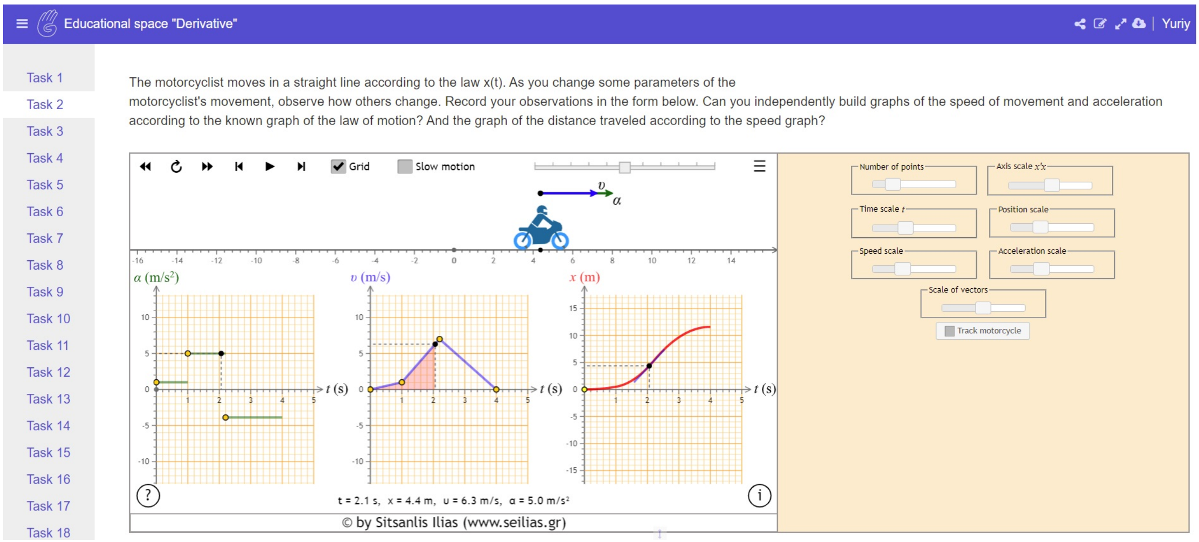


Figure 2: Computer simulation of the mechanical content of the derivative.

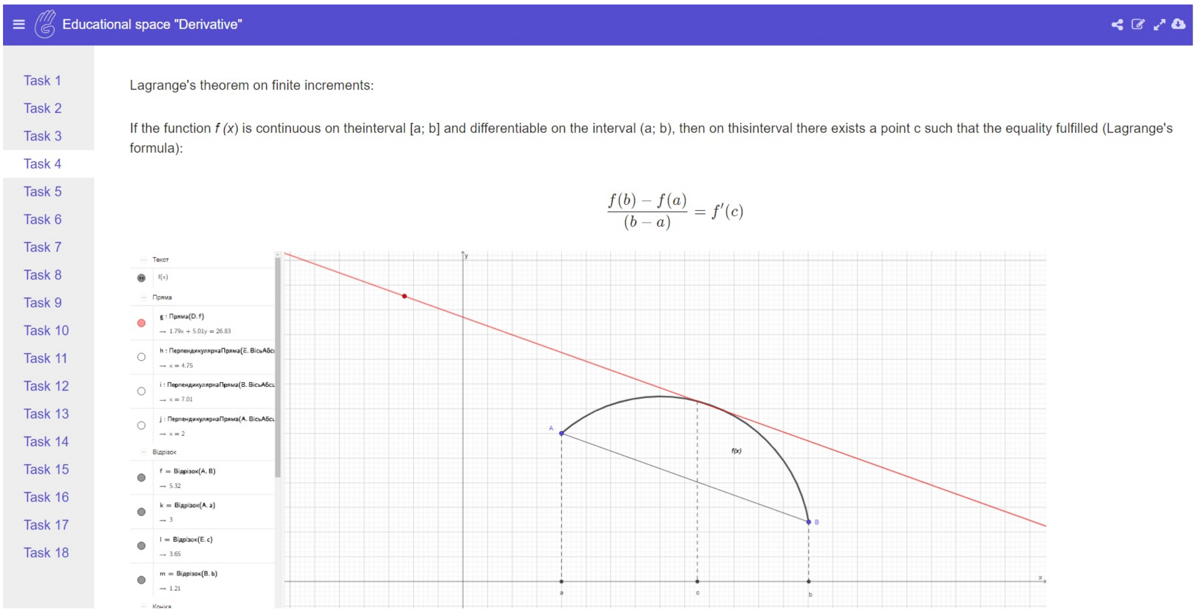


Figure 3: Graphic illustration of Lagrange's theorem (point c is one).

etc. content, the ability to correlate different forms of presentation of a mathematical content (verbal, symbolic, graphic).

The work with the conceptual spreadsheet, which summarizes the results of the study of the conditions of Lagrange's theorem (whether each of them is necessary, essential, sufficient) can be organized in different ways. For example, one group of students formulates conclusions, and another one provides a graphical argumentation of the correctness (or incorrectness) of the verbal conclusion. Or vice versa – one group gives a graphic image, and the other one makes a verbal conclusion that can be made on the basis of this image.

It will be useful to find out the mechanical meaning of Lagrange's formula (it indicates that when a body moves according to the law $s(t)$, then at some point in time the velocity of the body will be equal to its average velocity over a period of time).

Instead of a rigorous analytical proof of the theorem, which will not add any more convincing (for geometric simulation) arguments to students, it is worth considering various applications of the theorem in physics, economics, computational mathematics, and so on. It will be appropriate to draw students' attention to the fact that the number c in the Lagrange for-

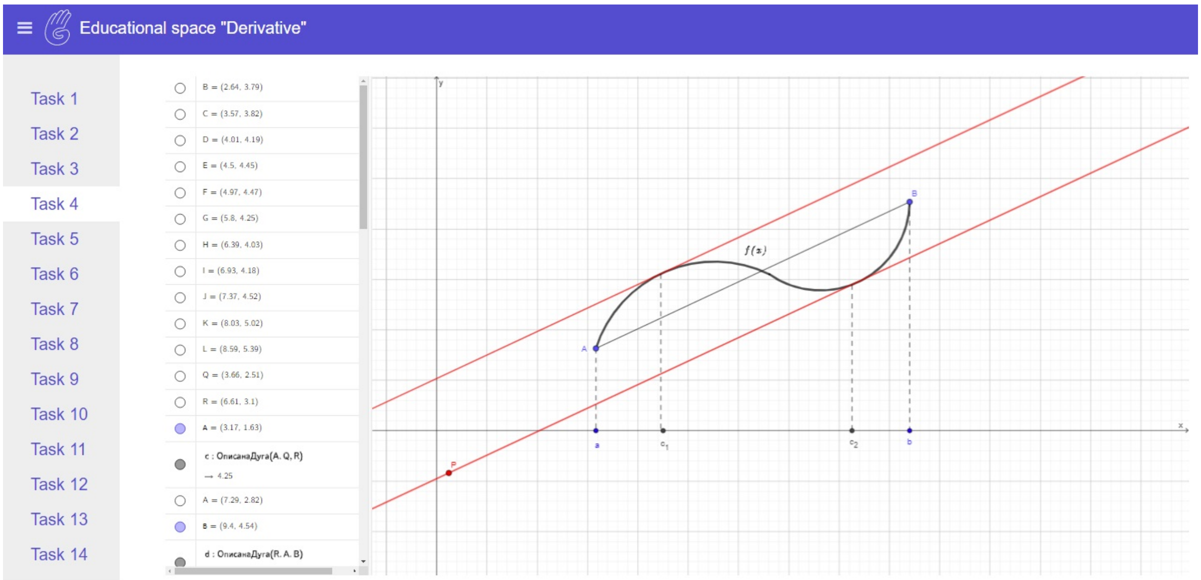


Figure 4: Graphic illustration of Lagrange's theorem (points c are two).

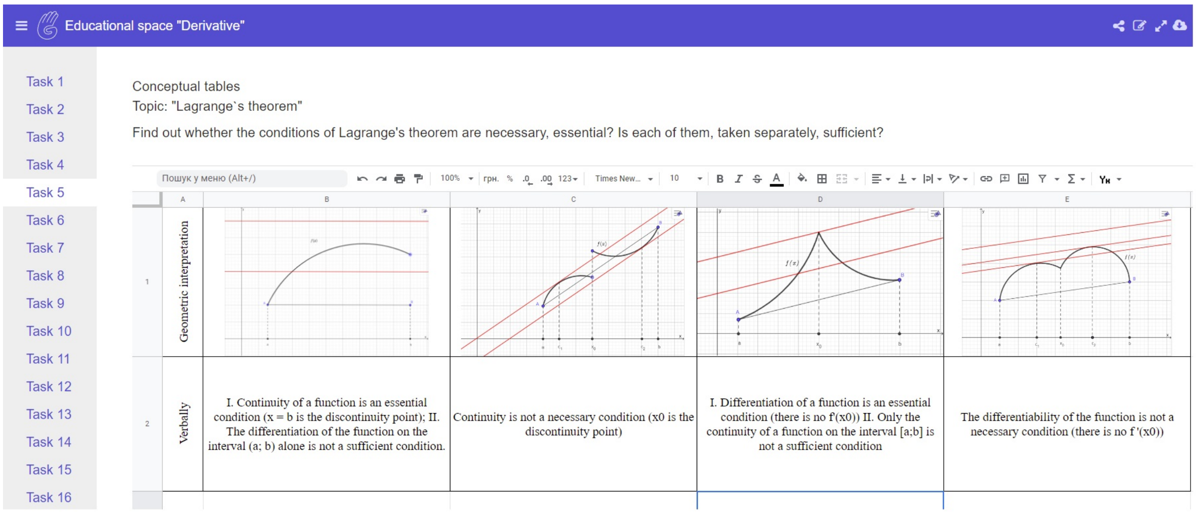


Figure 5: Conceptual spreadsheet on the topic "Lagrange's theorem".

mula is unknown, but the formula is useful in problems to estimate the difference between the values of the function, and hence – profit, work, distance traveled and other quantities.

In the context of what has been said, it will be useful, for example, to estimate the difference (**Task 6**):

$$\arctan 0.55 - \arctan 0.45$$

Solution. The function $\arctan x$ is continuous and differentiable for all real x, so Lagrange's theorem can be applied. According to this theorem, we can say that between the numbers 0.45 and 0.55 there is a number c that the equality

$$\frac{\arctan 0.55 - \arctan 0.45}{0.55 - 0.45} = (\arctan x)'|_{x=c}$$

that is

$$\arctan 0.55 - \arctan 0.45 = \frac{0.1}{1+c^2}$$

Hence, given that function $\frac{1}{1+x^2}$ decreases for positive x, we have

$$\frac{0.1}{1+0.55^2} < \frac{0.1}{1+c^2} < \frac{0.1}{1+0.45^2}$$

or:

$$0.0767 < \arctan 0.55 - \arctan 0.45 < 0.0832$$

Students were asked (**Task 8**) to formulate questions on the topic "Derivative" to this figure, which shows a graph of the function $f(x)$ (figure 6).

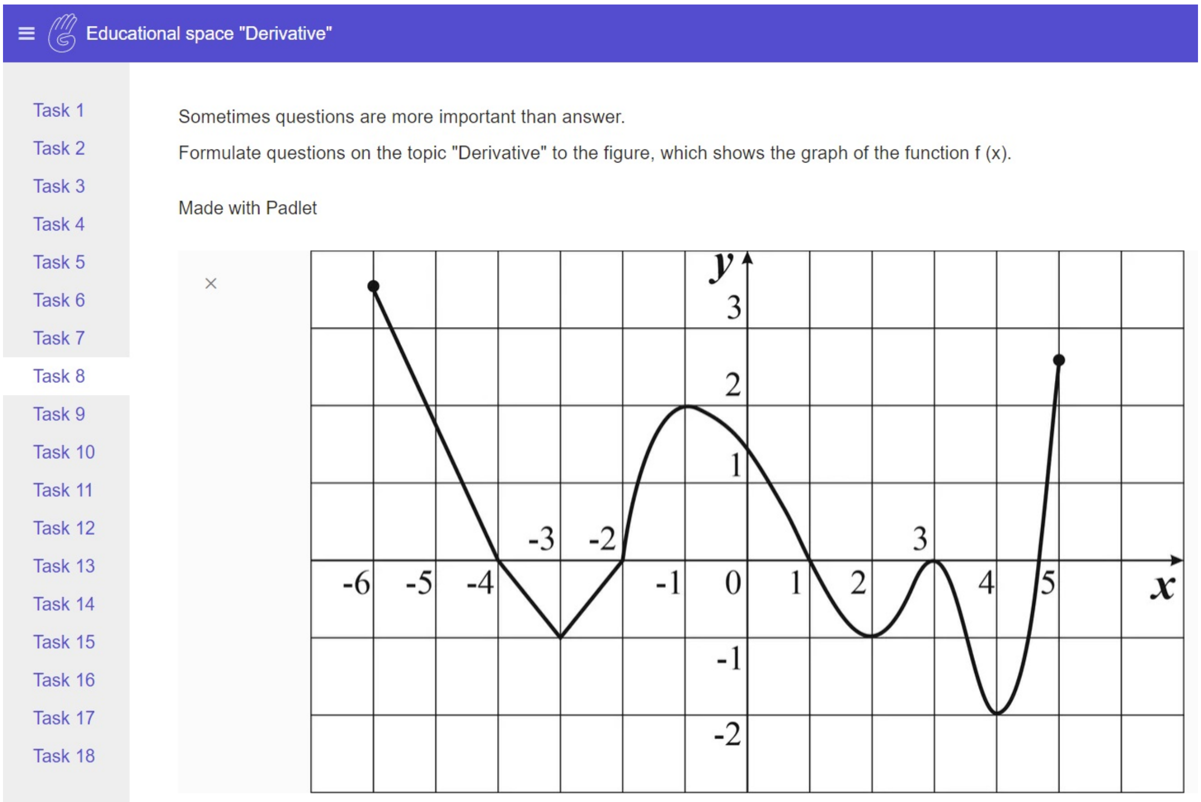


Figure 6: Task 8.

The ability to ask questions (form tasks) is one of the signs of conceptual knowledge. Therefore, the purpose of such tasks is to form a conceptual understanding of the concept of a derivative function, in particular, its geometric content, and the ability to graphically illustrate this understanding.

Students are divided into two subgroups. One formulates questions or tasks, and the other provides answers. In our space for this purpose the use of the Padlet board where each student attaches the questions – answers is provided. At the same time, an "editor" is appointed, who groups the same type of questions, "forbids" questions that are not related to the topic, and etc. Students attach the answers to the questions next to the questions themselves. Then, under the guidance of the teacher, questions and answers are discussed with a vote for the best question.

Here are the most interesting, in our opinion, questions (tasks) of freshmen:

1. Does it have the roots of an equation $f'(x) = 0$. If so, is it possible to find out: a) how much? b) which ones?
2. Solve the inequality: $f'(x) > 0$ ($f'(x) < 0$)..
3. Does the equation $f''(x) = 0$ have roots? If so, how much?
4. Does the inequality $f''(x) < 0$ have integer solutions? If so, how much? What are these solutions?
5. Does the function $f'(x)$ have a breakpoint? If so, what is the nature of these gaps?
6. Is it possible to determine the approximate value of its derivative at the point: a) -1; b) 1. If possible, explain how to find this value and find it. If not, then argue.

Task 10. Write an algorithm for approximating the value of the function $f(x)$ at the point $x_0 + \Delta x$ using a differential. Such tasks form a conscious understanding of the algorithm, i.e. the construction of procedural knowledge on the basis of conceptual.

It is suggested to perform this task in the Concept Mapper application, which contains tools for plotting.

Task 11. The plant received an order from the cannery to produce a batch of cylindrical cans of a certain volume for canned olives. Design the shape of the tin cans so that as little material as possible is used to make them. Check out the various canned cylindrical cans at your nearest supermarket. Is their packaging economical in terms of the cost of materials for their manufacture?

This is an optimization problem "from life", which requires the use of a differential calculus to solve it. We plan to use the Sticky Notes application to solve this problem. Students describe their research on stickers, which are placed in a common field. In this way, each student sees the results of others. Then you can have a general discussion.

Conceptual understanding of mathematics involves the ability to translate a real problem into the language of mathematics and vice versa, to interpret a mathematical result in the language of a real non-mathematical context, in particular, to predict the course of the process or the end result. To develop such an ability (and, at the same time, to check its formation) we offer the following task.

Task 17. The volume of products manufactured at the enterprise is determined by the function

$$f(t) = -2t^3 + 6t^2 + 9,$$

where t is the time (in years). Give reasonable answers to questions (1 – 6), without using the graph of the function $f(t)$:

1. During what period will production increase (decrease)?
2. Indicate the periods when the growth rate of production accelerates (slows down), if any?
3. Is there a time when the nature of the rate of growth (decline) of production changes to the opposite? If so, indicate this point.
4. When will the volume of production be the largest?
5. Predict whether the volume of output may fall to zero? If so, when will this happen. If not, why not?
6. Imagine that you became the head (manager) of this company after a year of its work. Would you consider it necessary to change the production strategy (function $f(t)$)? If not, justify (for example, all is well, because production is growing, i.e. the company operates efficiently). If your answer is yes, then explaining what exactly would alarm you?
7. On the basis of conducted in pp. 1 – 6 research and analysis provide a graphic illustration of the results.

Since all questions are formulated by the teacher in advance, and the answers to them must be individual and explained, we consider it convenient to perform this task form TEXT Input. For graphic illustration (p. 7 of the task), we suggest using the GeoGebra tools.

At the end of the study of the topic it is necessary to assess the level and quality of knowledge. In the digital space, these can be tests. To test the conceptual understanding of mathematical concepts, facts, methods, the most appropriate are open tests. Because in test tasks with the choice of the correct answer among the proposed ones there is a temptation to just guess it. And, even if we exclude guessing, there is a big difference between choosing the right answer among the several given (i.e. recognizing) and formulating it yourself. Therefore, we believe that closed-type tests should be avoided or minimized.

An example of an open – ended test task with **Task 18** is: "A body moves rectilinearly according to the law $s(t) = -4 + 2t + t^2$ (s is measured in meters, t is measured in seconds). Find the speed of this body at time ($t = 3s$). In response, write a number, for example, 7".

3 CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

1. As a result of a survey of non-mathematical specialties students, it was found that students to some extent feel the need to apply mathematical knowledge in the study of professional disciplines, as well as to use this knowledge in practice. However, students do not sufficiently understand the essence of mathematical concepts and facts, the relationships and interdependencies between them. Therefore, they cannot always recognize mathematical structures in non-mathematical contexts and, therefore, apply mathematics effectively.
2. The purpose of studying mathematics by non-mathematical specialties students is to provide them with the ability to apply mathematics to solve professional problems. An analysis of the various practices of teaching mathematics has revealed that in many cases this goal is not achieved due to the lack of a reasonable balance between the formal rigor of the presentation of theoretical principles and the teaching of procedures. Therefore, the teaching of mathematics should pursue the following goals: the formation of a conceptual understanding of key mathematical concepts, facts, methods with an illustration of their application, the study of the relevant mathematical apparatus; developing basic skills of mathematical research and mathematical modeling.
3. The described methods of using the digital educational space are designed to improve the conceptual understanding of mathematics among students of non-mathematical specialties through the

study of mathematical concepts and their connections, experimentation, formulation of questions, hypotheses, conclusions, and discussion of the obtained results.

4. Prospects for further research are to develop criteria and indicators of conceptual understanding of mathematics by non-mathematical specialties students, as well as quantitative analysis of the effectiveness of the use of digital learning space for the formation of conceptual mathematical knowledge of students.

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Implementing GeoGebra as a Tool for STEM Education in Pre-Service Mathematics Teacher Training: Pedagogical Conditions and Effectiveness

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Keywords: STEM Education, GeoGebra, Pre-Service Mathematics Teacher Training, Pedagogical Conditions, Cloud-Oriented Educational Environment, Explorative Study, Motivational Measures, Pedagogical Experiment.

Abstract: This paper explores the development and implementation of pedagogical conditions for the use of GeoGebra as a tool for STEM education in the training of pre-service mathematics teachers. STEM education is discussed, and the potential and features of GeoGebra as a tool for implementing this concept are characterized. Three pedagogical conditions are proposed, including the creation of a cloud-oriented educational environment, the introduction of STEM-oriented investigations using GeoGebra, and the application of motivating measures to stimulate students. Criteria and indicators for the effectiveness of these conditions are developed, and a pedagogical experiment is conducted to test their effectiveness. The results confirm the effectiveness of the pedagogical conditions and demonstrate the potential for GeoGebra as a tool for providing STEM education in the training of pre-service mathematics teachers. This paper provides insights and recommendations for educators seeking to incorporate GeoGebra and STEM education into their mathematics teacher training programs.

1 INTRODUCTION

Improving the quality of science, technology, engineering, and mathematics (STEM) education is a key task for countries focused on strengthening economic competitiveness and developing human capital to support science-based industries and technologies (Hrynevych et al., 2021). International comparative studies of the quality of STEM education (PISA, TIMSS) are recognized indicators of the state of a country's STEM education. These studies allow for comparing a nation's educational progress with global trends in its development. The latest PISA studies have shown a significant decline in the science and particularly mathematics skills of Ukrainian high school students (Mazorchuk et al., 2021). Results of recent admissions campaigns have confirmed a decline in interest among applicants in STEM fields, which creates strategic risks for social, economic, and technological development in Ukraine. In 2020, only two of the ten most popular specialties chosen by applicants related to STEM education, and only one of them involved information technology. The need to increase the prestige of STEM education as a guarantee of the country's development necessitates improving the quality of professional training for pre-service STEM teachers.

The strategic tasks for training pre-service teachers are determined in the laws of Ukraine "On Education" (Verkhovna Rada of Ukraine, 2017), "On Higher Education" (On Higher Education, 2017) and other regulatory documents, which prioritize achieving a qualitatively new level of mathematical education through the introduction of progressive concepts, optimal combination of humanitarian and natural-mathematical components of education, the use of modern pedagogical and information technologies, and the preparation of a new generation of teaching staff. The adopted Concept of Development of Natural-Scientific and Mathematical Education (STEM Education) in Ukraine (Cabinet of Ministers of Ukraine, 2020) is based on UNESCO documents, in particular, the Incheon Declaration "Education 2030" (UNESCO, 2015), where STEM education is recognized as a key strategy for achieving sustainable development goals. The concept provides for its wide-scale implementation at all levels of education, emphasizes the key role of mathematics in

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STEM education, and emphasizes the need for significant changes in the training system, including pre-service mathematics teachers.

Therefore, there is a social demand and legislatively justified necessity to improve the quality of professional training of pre-service mathematics teachers through the implementation of the STEM education concept.

Bilousova et al. (Bilousova et al., 2022) point out the significant didactic potential of computer mathematics systems for pedagogical purposes, such as the GRAN and GeoGebra packages, in implementing STEM education in higher and secondary schools. However, the problem of effectively using these systems as tools for implementing STEM education in the practice of professional training of pre-service mathematics teachers remains insufficiently developed in both theoretical and practical aspects.

The analysis revealed contradictions between society's demand for improving the quality of natural and mathematical education and its unsatisfactory state at the key level – the level of general secondary education; recognition of STEM education as the leading direction of modernizing natural and mathematical education and the insufficient level of implementing the STEM approach in the process of professional training of pre-service mathematics teachers; the potential of the GeoGebra package for implementing STEM mathematics education and the lack of scientifically substantiated approaches to effectively using the GeoGebra package as a tool for implementing the STEM education concept in the process of training pre-service mathematics teachers.

2 RESEARCH METHODOLOGY

The relevance of the outlined problem, its insufficient development in pedagogical theory and practice, as well as the need to solve the identified contradictions, determined the *object of research* – the implementation of the concept of STEM education in the process of preparing future mathematics teachers.

The subject of research is the pedagogical conditions for using the GeoGebra package as a tool for implementing the concept of STEM education in the process of training pre-service mathematics teachers.

The purpose of the research is to theoretically justify, develop and experimentally verify the pedagogical conditions for using the GeoGebra package as a tool for implementing the concept of STEM education in the process of training pre-service mathematics teachers.

The research methods:

- theoretical – analysis, comparison, systematization, and generalization of scientific literature to identify the state of the topic's development and clarify the conceptual and terminological apparatus; analysis of the experience of implementing STEM education in the preparation of pre-service mathematics teachers; generalization and systematization of theoretical positions to justify pedagogical conditions for the use of the GeoGebra package as a tool for implementing STEM education in the process of training pre-service mathematics teachers;
- empirical – observation, survey, testing, questioning, analysis of the results obtained.

The experimental research was conducted from 2015 to 2020 at the following institutions: H. S. Skovoroda Kharkiv National Pedagogical University, Kryvyi Rih State Pedagogical University, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Lesya Ukrainka Volyn National University, K. D. Ushynskyi Chernihiv Regional Institute of Postgraduate Pedagogical Education, and the National Technical University "Kharkiv Polytechnic Institute". A total of 343 students and 26 teachers were involved at various stages of the research.

3 THEORETICAL UNDERPINNINGS OF ICT USE IN STEM EDUCATION IMPLEMENTATION AT PRE-SERVICE MATHEMATICS TEACHER TRAINING

Based on the analysis of psychological and pedagogical literature (Pylypenko, 2020; Shapovalov et al., 2020, 2022; Valko et al., 2020; Hrynevych et al., 2021; Martyniuk et al., 2021; Lukychova et al., 2022; Slipukhina et al., 2022; Mintii, 2023), it has been found that STEM education emerged as a response to the challenge posed by the rapid development of technologies, which necessitates the orientation of education towards the preemptive satisfaction of the needs of the modern economy for specialists capable of ensuring its development on a high-tech basis. The experience of implementing STEM education in the USA, France, Great Britain, Australia, Israel, China, Singapore, Hong Kong, Canada, and other countries was analised. In Ukraine, STEM education is considered a priority direction for the development of natural science and mathematics education, as declared in the corresponding Concept (Cabinet of Ministers of Ukraine, 2020).

The theoretical foundations of STEM education are being developed jointly by scientists and educators, taking into account practical experience. It has been established that despite differences in the strategies of implementing STEM education in different countries, there is a shared understanding of the purpose of STEM education (improving human capital by developing STEM competencies and a natural science worldview in students), its key principles (integrative, interdisciplinary, transdisciplinary, activity-based, competency-based, person-centered, and research-oriented approaches), and the expected result in personal (acquisition of practical natural science, mathematical, IT, and engineering knowledge and skills to solve practical problems in educational and professional activities) and societal dimensions (increasing the country's competitiveness in the international market of high technologies).

Based on the above, within the scope of the study, STEM education is understood as an innovative model of natural and mathematical education of the 21st century, and its implementation is considered a large-scale global experiment during which the content component of the model is determined (selection and structuring of educational content), the procedural component is tested (forms, methods, and means of teaching, specific aspects of organizing the educational process), and the conceptual basis is clarified (terminology, founding principles, etc.).

It is shown that mathematics has an integrative role in the complex of STEM disciplines, which is due to the universality of mathematical tools, the mathematization of various fields of knowledge, the significant influence of mathematical education on the cognitive, moral-volitional, and aesthetic development of an individual, and the exceptional importance of mathematical modeling and computational experimentation based on it as a leading method of scientific, engineering, technical, and practical human activities. The latter determines the leading role of computer mathematics systems in the implementation of interdisciplinary STEM projects.

The generalization of experience in implementing STEM education into the system of training pre-service teachers of mathematics, natural sciences, and technologies has shown the need for further research in the context of modernizing higher pedagogical education based on the implementation of the concept of STEM education. This includes the theoretical justification of pedagogical conditions for using the GeoGebra package as a tool for its implementation.

4 JUSTIFICATION OF PEDAGOGICAL CONDITIONS FOR USING THE GEOGEBRA PACKAGE AS A TOOL FOR IMPLEMENTING THE CONCEPT OF STEM EDUCATION IN THE PREPARATION OF PRE-SERVICE MATHEMATICS TEACHERS

Based on theoretical analysis, it has been proven that the special role of mathematics justifies the expediency of implementing STEM education primarily in the process of fundamental mathematical training for pre-service mathematics teachers. It is shown that the leading way to implement STEM education is through specially organized research and project activities, the main feature of which is the construction of the subject's knowledge system in the process of acquiring and comprehending their own experience in such activities. The organization of research and project activities requires the construction of communities whose members possess ICT tools for conducting theoretical and empirical research. This necessitates the need for pre-service teachers to master social-constructivist technologies for organizing computer-based STEM-oriented research and methods for forming a complex of research competencies as components of the STEM competency system.

The educational and developmental potential of the GeoGebra package as a tool for implementing the STEM education concept in the training of pre-service mathematics teachers is characterized, as well as the defining features of the package in (Kramarenko et al., 2020; Drushlyak et al., 2021). GeoGebra is positioned as a computer mathematics system aimed at supporting the educational and research activities of students and teachers. The package has a developed functionality and continuous improvement by an international team of developers, and a wide range of applications in STEM education and its branches (STEAM, STREAM, and others), scientific and practical activities of various directions. The full-featured version of the package is freely available in Ukrainian, independent of hardware and operating system, and has a cloud-based version. The large database of freely distributed educational STEM resources created by the open GeoGebra community, the possibility of visualizing computer models in virtual and augmented reality, and their materialization by 3D printing are also noted.

The 20-year history of using the GeoGebra package in mathematics education has revealed its synergetic effect – the inheritance of STEM applications. The demand for the skills and knowledge of using GeoGebra acquired by pre-service mathematics teachers is not only relevant in their professional activities but also beyond its scope.

Using the GeoGebra package as a tool for implementing the STEM education concept required the development and justification of a complex of pedagogical conditions that ensure the effectiveness of such use. Considering that STEM education is a multi-purpose concept, the focus was on the goals that the use of the GeoGebra package contributed to achieving: developing students' motivation to acquire mathematical education, forming beliefs about its significance and the effectiveness of mathematical knowledge, acquiring research competencies, and developing the ability for self-education and a desire to independently enhance their educational potential.

With these goals in mind, a complex of pedagogical conditions was developed and theoretically justified, which includes designing an educational process using GeoGebra that promotes the active involvement of students in the research and discovery process, using interactive methods of teaching and learning, and promoting self-education and research activities. The GeoGebra package also helps to develop students' mathematical thinking, creative abilities, and research skills, as well as to integrate mathematics with other disciplines.

Thus, the GeoGebra package has significant potential as a tool for implementing the STEM education concept in the training of pre-service mathematics teachers. Its effective use requires the development of a complex of pedagogical conditions, which are aimed at promoting students' motivation, developing their research competencies, and promoting self-education and research activities.

The first pedagogical condition is to create a cloud-oriented educational environment that contains software, informational, didactic, and methodological resources for organizing, supporting, and accompanying various types of student learning activities using the GeoGebra package: educational and cognitive, educational and research, scientific and research, and project-based.

The second pedagogical condition is to introduce a practical course in computer STEM-oriented research in the GeoGebra package into the educational process of training pre-service mathematics teachers, which is based on the principles of a technological approach, involving a step-by-step engagement of students in researching mathematical objects, objects from other disciplines, objects of the surrounding world, and gradually mastering the research tools of the GeoGebra package.

The third pedagogical condition is the use of a complex of tools to stimulate students' STEM-oriented GeoGebra modeling, based on the organization of their extracurricular activities, involvement in the GeoGebra community, and the use of individual and group coaching.

Within the framework of extracurricular activities, students are expected to:

- familiarize themselves with additional (non-program) materials that reveal the significance of mathematics, the value of mathematical modeling, the breadth of its applications in various areas of human activity, including creative ones;
- prepare non-standard events to popularize such information; create illustrative support for such events using the GeoGebra package;
- participate in the GeoGebra community, which promotes the transfer of pedagogical ideas and technologies, as well as the involvement of students in the development of GeoGebra models, GeoGebra projects, conducting and presenting their own GeoGebra research as a personal contribution to open world GeoGebra resources. The ability to see their own results on the site and participate in the scientific and methodological developments of teachers adds confidence to the student in the significance of the knowledge they receive in the educational process and in research and project work.

The use of individual and group coaching contributes to the development of the personal potential of pre-service math teachers, stimulates their independent cognitive activity, and increases the practical significance and demand for the results of computer STEM-oriented research using GeoGebra software. The pedagogical conditions are interconnected, interdependent, and complementary, which necessitates their comprehensive implementation.

5 ORGANIZATION, CONDUCT AND RESULTS OF THE PEDAGOGICAL EXPERIMENT

During the preparatory stage of experimental work (2015–2017), educational and methodological support for using the GeoGebra package as a tool for implementing the concept of STEM education in the process of training pre-service mathematics teachers in higher education institutions was developed. This included a textbook for mastering the dynamic mathematics GeoGebra package as a tool for implementing the concept of STEM education; sets of research tasks and educational models for conducting STEM-oriented research in GeoGebra; a cloud-based complex of interdisciplinary models presented in GeoGebra Book; tasks for individual STEM-oriented research and educational activities of students using GeoGebra modeling; STEM project topics using the GeoGebra package; and working materials for organizing extracurricular STEM-oriented student work using GeoGebra modeling in the format of a discussion club (thematic developments, scenarios, presentations, compilations of audio and video materials, etc.).

Criteria and indicators for the formation of the ability of pre-service mathematics teachers to use the GeoGebra package as a tool for implementing the concept of STEM education were also developed, including motivational-value (the awareness by pre-service teachers of the value of mathematical knowledge and the mathematical apparatus as the basis for computer research on any object; motivation to learn mathematics; readiness to overcome difficulties), praxiological (the ability of pre-service teachers to step-by-step plan computer research using the technology of its implementation; the ability to use the GeoGebra functional rationally for conducting research; the ability to analyze its results and make conclusions), and metacognitive (the ability of pre-service teachers to critically evaluate their own knowledge level for solving a problem; the ability to effectively use various ways of acquiring knowledge; the desire for constant educational growth; the ability to apply the GeoGebra package for conducting transdisciplinary research).

Each indicator is described at three levels of formation of pre-service mathematics teachers' ability to use GeoGebra as a tool for implementing the concept of STEM education: reproductive (the ability to use GeoGebra to conduct subject mathematical research according to the teacher's plan), partially exploratory (the ability to use GeoGebra to conduct independent and collaborative subject mathematical research and interdisciplinary research with the teacher's support), and creative (the ability to use GeoGebra to conduct independent and collaborative transdisciplinary research). Tools for their diagnosis have been developed.

The exploratory and formative stages of the pedagogical experiment were conducted at the H. S. Skovoroda Kharkiv National Pedagogical University and Kryvyi Rih State Pedagogical University.

During the exploratory stage (2018), experimental and control groups were formed; the absence of a statistically significant difference at the 0.05 level in the levels of formation of mathematics teachers' ability to use GeoGebra as a tool for implementing the concept of STEM education was proven.

During the formative stage (2018–2020), measures were implemented to introduce reasoned pedagogical conditions for using the GeoGebra package as a tool for implementing STEM education and testing a complex of educational and methodological materials. The stage's tasks also included testing a complex of didactic materials that provide the implementation of these pedagogical conditions, tracking the dynamics of the process of using the GeoGebra package as a tool for implementing the concept of STEM education in the process of training pre-service mathematics teachers. The pedagogical experiment was conducted in natural conditions of the educational process with the involvement of students in the experimental group. Students in the control group were taught using traditional methods.

To implement the first pedagogical condition based on the use of specially selected and developed software, informational, didactic, and methodological resources during the preparatory stage of the experimental work, a cloud-oriented educational environment was created to organize, support, and accompany various types of independent student activity using the GeoGebra package (educational-cognitive, educational-research, scientific-research, project).

To implement the second pedagogical condition, a practical course on conducting computer STEM-oriented research using the GeoGebra package was developed and implemented. The practical course provided for the sequential mastering by pre-service mathematics teachers of the technology of research and the research toolkit of the GeoGebra package in the process of step-by-step involvement in the study of mathematical objects, objects from other disciplines, real objects with the support of a specially created and constantly updated database of educational models. To support and direct the independent work of students during the practical course, a teaching and methodological guide was used. Each research project carried out by the student consisted of three stages. At the first stage, the student was involved in constructing a visual model of the mathematical object in the GeoGebra environment, guided by instructions for its construction (provided in the practical course in a table of dynamic drawing construction, which contains a step-by-step description of construction, comments, and illustrations) and mastering a certain toolkit of GeoGebra in this way. Next,

Table 1: The distribution of students in the specialty 014.04 Secondary Education (Mathematics) by the level of formation of the ability to use GeoGebra software as a tool for implementing the STEM education concept after the formative stage of the pedagogical experiment (in %).

Levels / Criteria	Control group			Experimental group		
	Reproductive	Partial-equivalent	Creative	Reproductive	Partial-equivalent	Creative
Motivational-value	37.7	39.3	23.0	19.4	38.7	41.9
Praxiological	42.6	37.7	19.7	16.1	40.3	43.6
Metacognitive	42.6	36.1	21.3	17.7	37.1	45.2

the student carried out the study of the mathematical object according to the provided step-by-step plan, which reproduced the technology of research. Each step was accompanied by questions that drew the student's attention to the essence of the obtained result. The second stage of the research was carried out by the student using the same model, but using it to study an interdisciplinary object, which required activation of knowledge from other disciplines. The questions posed were aimed at involving the student in the analysis and understanding of the results obtained, arousing his interest and initiative in satisfying it. The third stage led to a transdisciplinary level of research and concerned a real object, requiring the demonstration of a complex of acquired knowledge. The questions posed to the student aimed to arouse his natural curiosity, stimulate the development of a plan for further research, possibly with modification of the created model.

To implement the third pedagogical condition, a set of tools to stimulate students to engage in STEM-oriented GeoGebra modeling was developed and applied. In particular, extracurricular activities were organized in the form of a discussion club, where the leading method of cognitive activity was GeoGebra modeling. Students were also involved in GeoGebra community activities by developing GeoGebra models and presenting their own GeoGebra research as a personal contribution to open world GeoGebra resources, including GeoGebra Book, for the exchange of ideas and technologies, as well as the implementation and adaptation of productive international experience in the educational process of training pre-service math teachers to use the GeoGebra package in STEM education, which played a powerful motivational factor for students. The club format contributed to the growth of various interactions between teachers and students on the principles of mutual respect and trust, the establishment of partnership relations between them, the implementation of individual and group coaching, which found expression in personalized student counseling, directing them towards achieving significant educational results, engaging in the development of practical STEM projects, and jointly conducting full-fledged scientific STEM research throughout the entire cycle of training pre-service math teachers. After completing the experimental work, the level of formation of pre-service math teachers' ability to use the GeoGebra package as a tool for implementing the concept of STEM education was determined (table 1).

During the control stage, the results of the conducted experiment were analyzed. The obtained results allowed us to conclude about the positive effect of implementing the developed pedagogical conditions on the level of formation of pre-service mathematics teachers' ability to use GeoGebra software as a tool for implementing the STEM education concept. The verification was carried out using the Pearson correlation coefficient, which confirmed that the difference factor in the distributions of the students of control and experimental groups is statistically significant at the 0.05 level. Therefore, the research hypothesis was confirmed that the use of GeoGebra software as a tool for implementing the STEM education concept in the process of training pre-service mathematics teachers will be effective under the implementation of justified pedagogical conditions.

6 CONCLUSIONS

1. The research proposes a solution to the scientific problem of substantiating the pedagogical conditions for using GeoGebra as a tool for implementing STEM education in the training of pre-service mathematics teachers. The generalization of the results of theoretical research and the conducted pedagogical experiment allow the following conclusions to be made.
2. The analysis of psychological and pedagogical literature showed that STEM education is an innovative approach that is being implemented and developed jointly by scientists and educators from many countries of the world who are interested in the development of science-intensive production and high technologies. STEM education is being spread at all educational levels, which determines its special importance in the system of

training pre-service teachers, since the teacher is the main driving force for change in education.

3. STEM education is defined as an innovative model of natural-mathematical education of the 21st century, and its implementation is a large-scale world experiment, during which the content component of the model is determined (the selection and structuring of the content of education is carried out), the procedural component is tested (the forms, methods, means of teaching, the specificity of organizing the educational process in its specific aspects are used), and the conceptual component is refined (terminology, basic principles, etc.).

   Integrated, activity-based, and technological approaches are highlighted as key components of STEM education. Increasing the volume and significance of independent research requires its rational organization on technological principles.

   The potential of mathematics as a STEM discipline in both school and university education is analyzed. The integrative role of mathematics in the complex of STEM disciplines is determined by the universality of the mathematical apparatus, its widespread use, the mathematization of various fields of knowledge; the significant impact of mathematical education on the intellectual, moral, and aesthetic development of the individual; and the exceptional importance of mathematical modeling and computational experimentation based on it as the leading method of scientific, engineering, and practical human activity.

   The problems in training mathematics teachers for the implementation of STEM learning are outlined, which necessitate the need for theoretical justification and research regarding the modernization of higher education in the context of effective implementation of the STEM concept.

4. The educational and developmental potential as well as defining features of the GeoGebra package as a tool for implementing the STEM education concept in the process of training pre-service mathematics teachers have been revealed. The GeoGebra package is positioned as a computer mathematics system oriented towards supporting educational and research activities. The package is powerful and continuously improved by an international team of developers. It has a wide range of applications in STEM education and its branches (such as STEAM, STREAM, etc.), scientific and practical activities of different directions. The full-featured version of the package is freely available in Ukrainian. It is independent of hardware and operating systems and has a cloud-oriented version. There is a large base of freely distributed educational STEM resources created by the open GeoGebra community. The package allows for visualizing computer models in virtual and augmented reality and their materialization through 3D printing.

5. Pedagogical conditions for using the GeoGebra package as a tool for implementing the STEM education concept in the process of training pre-service mathematics teachers have been developed and theoretically substantiated. These include creating a cloud-oriented educational environment that contains software, informational, didactic, and methodological resources for organizing, supporting, and accompanying various types of student learning activities using the GeoGebra package. Introducing a practicum in conducting computer-based STEM-oriented research in the GeoGebra package into the educational process of training pre-service mathematics teachers. Using a set of tools to stimulate students to engage in STEM-oriented GeoGebra modeling based on organizing their extracurricular work, involving them in the GeoGebra community, and using individual and group coaching.

6. A pedagogical experiment was conducted to verify the effectiveness of the reasoned pedagogical conditions for the use of the GeoGebra package as a tool for implementing STEM education in the preparation of pre-service mathematics teachers. Criteria and indicators were developed for the formation of the ability of pre-service mathematics teachers to use the GeoGebra package as a tool for implementing the concept of STEM education: motivational-value (pre-service teachers' awareness of the value of mathematical knowledge and the mathematical apparatus as the basis for computer research of any objects; motivation to learn mathematics; readiness to overcome difficulties); praxiological (ability of pre-service teachers to step-by-step plan computer research using the technology of its conduct; ability to use GeoGebra functionality rationally for research; ability to analyze its results and draw conclusions); metacognitive (the ability of pre-service teachers to critically evaluate their level of knowledge for solving the problem; ability to effectively use various ways of acquiring knowledge; desire for continuous educational growth; ability to use the GeoGebra package for conducting transdisciplinary research). The reproductive, partially exploratory, and creative levels of formation were characterized for each criterion, scales

were developed for their measurement, and diagnostic tools were determined and selected. The experimental data were processed using mathematical statistics methods. The results obtained confirmed the effectiveness of the reasoned pedagogical conditions for the use of the GeoGebra package as a tool for implementing the concept of STEM education in the preparation of pre-service mathematics teachers.

7 FUTURE WORK

The research conducted does not exhaust all aspects of the analyzed problem. We consider the development of a model of professional training of pre-service mathematics teachers on the basis of an integrative approach and methodological principles for implementing STEM education in the training of pre-service physics, computer science, and technology teachers as promising directions for further scientific research.

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Didactic Terms of Shaping Pedagogical Universities Students' Digital Competence in the Process of Teaching Informatics Courses

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Abstract: In this study the results of the conducted theoretical and experimental research on determining, grounding and testing of didactic terms of shaping pedagogical universities students' digital competence in the process of teaching informatics courses have been presented. The object of the research is the process of shaping digital competency of pedagogical universities students. The subject of the research is the didactic terms that contribute to the shaping of digital competence of pedagogical universities students in the process of teaching informatics courses. The article provides insight into the essence of the conducted pedagogical experiment on the assesses of the effectiveness of didactic terms of shaping pedagogical universities students' digital competence in the process of teaching informatics courses. The conducted quantitative, qualitative and statistical analyses have identified a positive and statistically significant dynamic in the levels of formation of the competence in question in accordance with the defined criteria; in the degree of the system acquisition of this phenomenon; in general levels of the formation of digital competence of students from the experimental group.

1 INTRODUCTION

The current pace and vector of the evolution of the post-industrial world community necessitate a re-thinking of the structure of professional competencies of the students of pedagogical specialities, the inclusion in their list of the ability and readiness to function effectively in a digital society, the development and improvement of skills to competently and appropriately use models, methods and tools of informatics, the latest information technologies in professional activities and social practice.

The Strategy for the Development of the Information Society in Ukraine (Cabinet of Ministers of Ukraine, 2013) set a course for creating an education system focused on the use of the latest ICTs in forming a well-rounded personality and ensuring the continuity of education. The Concept of the New Ukrainian School (Elkin et al., 2017) calls the information and digital competencies key and essential competence for living in modern society. The Regulation on the National Educational Electronic Platform (Ministry of Education and Science of Ukraine, 2018) emphasizes the need to develop them for participants in the educational process. The concept of the Digital Agenda of Ukraine (Adz, 2016) recognized the digitalization of society, which includes future teachers, as an object of attention and integrated public administration. In the quarantine restrictions context, it is digitalization that has become the primary tool for distance and blended learning, and digital competence has been the guarantee of effectiveness.

The researches which are the basis for the study of the problem are the works examining the theoretical and methodological foundations of teachers' professional preparation as agents of social change (Honcharenko, 2012; Chernilevskyi et al., 2010; Sultanova et al., 2021; Hrynevych et al., 2022; Semychenko, 2004; Slastenin et al., 1997; Falfushynska et al., 2021; Rybalko et al., 2020; Ziaziun, 1989; Madzigon and Vachevskyi, 2011; Havrilova and Topolnik, 2017; Kuts and Lavrentieva, 2022), ways of modernizing of higher pedagogical education and updating its content and organizational forms (Aleksiuk, 1993; Bespalko,

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1960; Kodliuk et al., 2021; Lozova, 2003; Ogneviuk et al., 2020), the source developing the competence approach and reveal the essence of the teacher's professional competence (Khutorskaya and Korol, 2008; Raven, 2020; Zimnyaya, 2021; Ovcharuk, 2020; Pometun, 2003; Dakhin, 2012; Morze et al., 2022).

A lot of theoretical and experimental works of domestic and foreign scientists are devoted to the problems of implementation and effective use of ICT in education, in particular (Bespalko, 2018; Burov et al., 2020; Gershunsky and Pullin, 1990; Honcharenko, 2000; Gurevych et al., 2020; Kademiya and Kobysia, 2017; Hurevych et al., 2012; Robert et al., 2016; Sysoieva, 1998; Zhaldak, 2012). The issues of digitalization of the educational space are thoroughly considered by foreign scholars in their publications (Manovich, 2001; Polat, 2004; Stommel, 2014; Vuorikari et al., 2016) and Ukrainian researchers (Balyk et al., 2019; Kukharenko et al., 2022; Bilousova et al., 2022; Spivakovsky et al., 2013; Rakov, 2005; Teplytskyi et al., 2019; Trius and Sotulenko, 2017; Zhaldak et al., 2012).

The analysis of the current state and directions of reforming science education (STEM education) has led to the conclusion that its digitalization requires the modernization of computer science training and the cross-cutting integrated systematic design of advanced content for teaching computer science to students of pedagogical universities based on a competence approach. These problems are comprehensively addressed in the works of Hrynevych et al. (Hrynevych et al., 2021), Ramsky and Rezina (Ramsky and Rezina, 2005), Semerikov et al. (Semerikov et al., 2022).

Meanwhile, the analysis of primary sources revealed a terminological inconsistency in the use of the term "digital competence". The scientific researches which comprehensively studies the categorical and terminological field of informatics, information and communication competencies in line with our study are valuable in this context (Ovcharuk and Ivaniuk, 2021; Ovcharuk et al., 2022; Spivakovsky et al., 2022; Soroko, 2021; Vakaliuk et al., 2021a; Martyniuk et al., 2021; Bondarchuk et al., 2022; Vakaliuk et al., 2021b; Prokhorov et al., 2022; Pinchuk and Prokopenko, 2021; Riezina et al., 2022; Moiseienko, 2020; Moiseienko et al., 2020a,b).

It has been established that the Digital Competence Framework for Citizens (Carretero et al., 2017) and the Digital Competence Framework for Educators (European Commission et al., 2017) developed within the European Research Center of the European Commission have become reference models, clearly defined guidelines for creating conditions for the development of educational space, forming the digital competence of participants in the educational process, and they also laid the foundations for building an educational institution's digital learning environment. However, despite the significant achievements in the field of research, there are still contradictions such as:

- between the socially determined and state-regulated need for a high level of digitalization of all spheres of society and the insufficient level of digital competence of the key actors of the information society – students of pedagogical specialities;
- between the need for students to acquire critical thinking skills, lifelong learning, and mobility to changing technologies as the basis for their sustainable professional and personal growth and traditional approaches to teaching computer science at pedagogical universities;
- between the didactic findings, forms, methods and techniques accumulated in science and practice and the degree of substantiation and experimental verification of the didactic terms for the formation of students' digital competence in teaching computer science disciplines.

The aim of the study is to identify, theoretically substantiate didactic terms, develop and experimentally test a model that promotes the formation of digital competence of pedagogical universities students during the study of computer science disciplines.

2 THEORETICAL ASPECTS OF SHAPING PEDAGOGICAL UNIVERSITIES STUDENTS' DIGITAL COMPETENCE

Taking into account the results of the analysis of the procedural and content aspects of the competence approach as a leading educational paradigm of higher pedagogical education, the role, place and significance of digital competence have been clarified which are a key and essential component of the teachers' professional competence in a modern globalized society. It has been found that such competence allows them to creatively introduce ICT innovations into professional and pedagogical activities, to promote the development of relevant ICT competencies in students.

It has been established that in its essence, digital competence is a personality's dynamic characteristic determining the ability to secure information interaction, communication and collaboration, design digital educational resources and solve complex professional problems with the use of ICT and tools. From this point of view, it performs *motivational and incentive, gnostic and transformative, activity and methodological, evaluative and reflective, and communicative and procedural functions* in the professional activity and social practice of pedagogical institutions' students.

Given the peculiarities of informatics as a complex scientific and engineering discipline, the object of which is information processes of any nature, the subject – new information technologies, and the methodology – computational experiment, we define digital competence as a separate phenomenon that is directly related with the information competence, as well as computer, information and technological, and informatics competencies of pedagogical universities' students.

The analysis of the key and related concepts made it possible to formulate the author's vision of this multi-dimensional category. *Digital competence* is determined as the subject's ability and capacity to purposefully use ICT to create, search, process, and exchange information in the virtual space, to demonstrate information and media literacy, to comply with Internet security and cybersecurity rules, to understand and consciously adhere to ethics in working with information.

It has been found, that by its structure, digital competence is a complex and multidimensional personal formation, a professionally and personally significant integrative quality covering a set of competencies necessary for orientation and activity in the information space. These include *functional literacy in information and data, communication and collaboration competence, digital content competence, digital security competence, and problem-solving competence* (figure 1). It has been established the digital competence of pedagogical universities students can function at two qualitative levels. One is the basic level making it possible to solve educational problems by means of general-purpose computer technologies, and yet another is subject-oriented allowing the introduction of specialized digital technologies and resources into educational activities.

It has been fixed that the digital competence content reflects the structure of activities for consistent, literate and multidimensional work with information and is determined by the relevant following structural and criterion components (figure 2):

- *motivational-value component* contains the goals, motives, interests, value orientations, special abilities, focus on self-realization in professional and pedagogical activities and self-realization in the information space;
- *cognitive-informational* one as a set of knowledge and experience that ensures information processing and work with information objects on the cybersecurity and ethical behaviour foundation;
- *operational-activity* one – a set of skills and abilities for the active usage of information technology and computer equipment in professional activities as tools of learning and development, self-improvement and creativity;
- *personal-reflexive* one – features and qualities determining the student's personal reflective attitude towards themselves as a subject of activity in the information space, as well as their self-awareness, self-control, self-assessment of actions and responsibility for their results.

The article proposes to assess the formation of digital competence of pedagogical university students by the degree of manifestation of relevant indicators at four levels – elementary, intermediate, sufficient and advanced ones.

3 DIDACTIC SUPPORT FOR THE SHAPING OF STUDENTS' DIGITAL COMPETENCE

The analysis of scientific sources and the results of practical activities made it possible to clarify the essential characteristics of the educational process in pedagogical universities, to identify key disciplines and to determine didactic means (forms, methods, techniques, technologies) for the formation of components of students' digital competence in the process of studying computer science disciplines. According to the results of the analysis of educational programs, the content of teaching informatics disciplines has been presented in three content areas:

- algorithmization and programming (Fundamentals of algorithmization and data structure, Object-oriented and event-driven programming, Web programming);
- software of computer systems (Fundamentals of office technologies, Numerical methods and modelling, Multimedia);
- computer technologies in the professional activity of a teacher (School course of informatics, Methods of teaching informatics, Olympiad in informatics, Modern lesson of informatics).

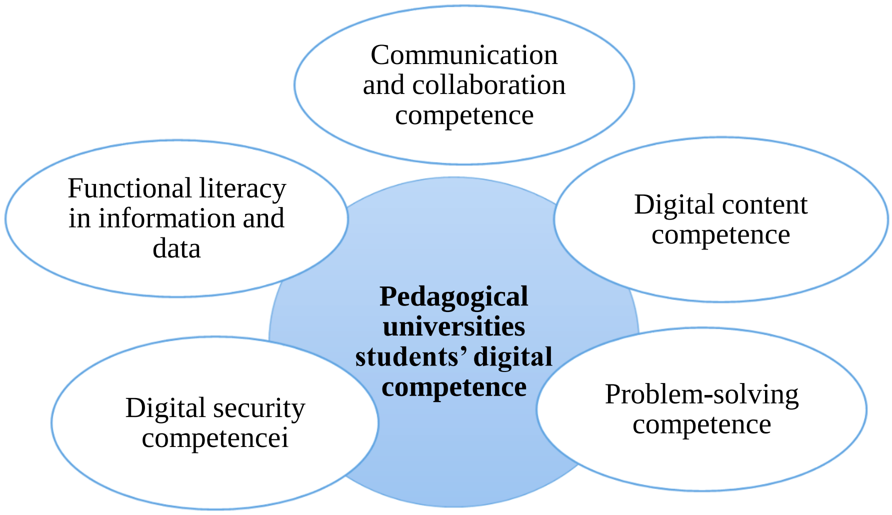

Figure 1: Components of the digital competence.

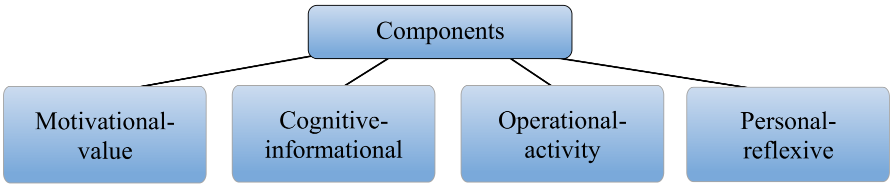

Figure 2: Structural and criterion components of the digital competence.

It has been recorded that in order to improve the students' digital competence and its separate components, the practice of pedagogical universities widely uses the possibilities of a variable block of computer science disciplines (Fundamentals of Media Literacy, Educational Smart Technologies, Network Communities, etc.), as well as the LMS of HEIs, MOOCs and open educational resources.

It has been substantiated that increasing the efficiency of the process of shaping the digital competence of pedagogical universities students is ensured by the creation of certain didactic terms that are educational procedures specially modelled as a result of the systematic selection, design and implementation of elements of content, as well as methods, techniques and organizational forms of computer science disciplines. The complex of *didactic terms* includes: the motivational conditionality of interaction of subjects' educational process in the information and digital learning environment; structuring of educational information in the form of problematic, heuristic and integrative models of learning and its translation into the project activities mode; ensuring the systemic complicating nature of students' study activities, diagnosis and timely correction of its products on the basis of modern ICT.

In the authors' opinion, the development of a structural and functional model contributes to the identification, theoretical substantiation and implementation of the didactic terms. In the model, each structural component (target, theoretical and methodological, content and procedural, criterion and diagnostic, and resulting blocks) has a specific function: orientation, analytical, formative and corrective ones serving to optimize the organization of activities for the shaping of students' digital competence during the study of computer science disciplines (figure 3).

The *target of the modelling* is to build a system of pedagogical work on the shaping digital competence of pedagogical university students during the study of informatics courses. The didactic model is based on the principles of comprehensive information support, optimality and pedagogical expediency, interactivity, comprehensive differentiation, controllability, effectiveness, proceduralism, diagnostics, gamification, adaptability, and ergonomics. The *target block* of the didactic model reflects the sequence of steps in defining goals and objectives, so it performs an orientation function in the formation of students' digital competence at each segment of the educational material. The *theoretical and methodological block* describes the content of the information and digi-

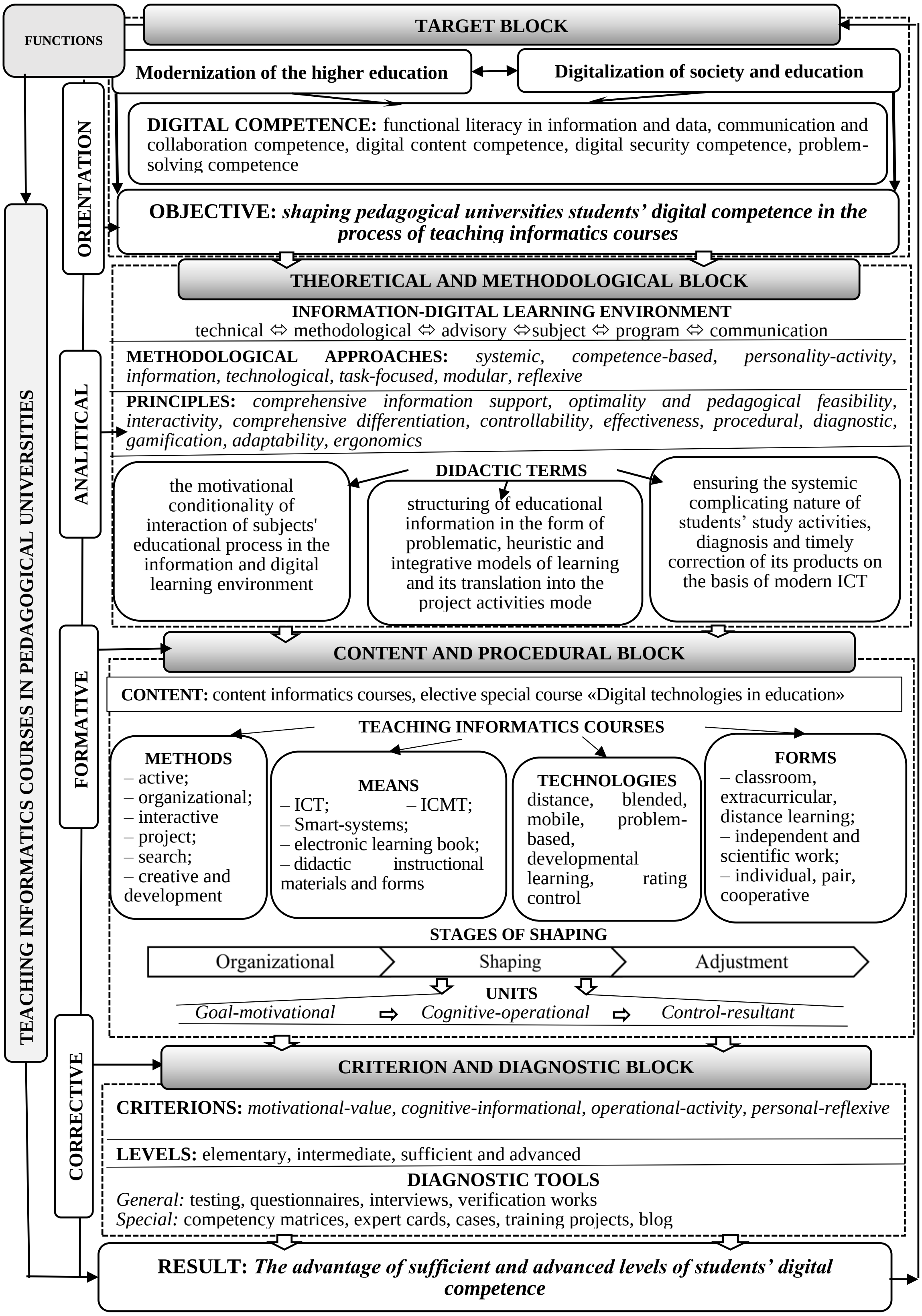

Figure 3: Didactic model of digital competence development of pedagogical university students.

tal learning environment, methodological approaches, principles and didactic terms that are the subject of analysis when designing the research process. The *content and procedural block* reflects the complex of didactic support (selected forms, methods, technologies, tools), as well as the logic and stages of forming students' digital competence and its components. The *criterion and diagnostic block* perform a corrective function, so far as shows the criteria, levels, and diagnostic tools for determining the level of students' digital competence during the study of computer science disciplines. The *result of the model implementation* is the achievement of the advantage of sufficient and high levels of digital competence at each stage of mastering computer science disciplines.

4 ORGANIZATION AND METHODOLOGY OF EXPERIMENTAL WORK

The investigation of the state and analysis of the problem in the practice of pedagogical universities made it possible to diagnose the goals and content of teaching computer science disciplines at the bachelor's level. First of all, it has been found that mastering the basics of algorithmization and programming, software of computer systems is provided only for the main or additional speciality "Informatics" (15% of the total curriculum). For the rest students, elective and integrated courses are offered covering the issues of computer technology in the professional activities of a subject teacher. Evidently, it does not contribute to the full and purposeful digital competence formation as one of the key competencies for a teacher. At the same time, other contradictions and a number of objectives, conceptual and procedural difficulties have been identified, and the superiority of the primary and secondary levels of digital competence in more than 52% of students has been stated both by separate criteria and in general.

Experimental testing of the effectiveness of the identified didactic terms was carried out in stages. At the organizational stage, on the basis of systemic, competence, personal activity, information, technological, task-focused, modular, and reflective approaches, the empirical research program was developed, the content was clarified and the electronic educational content of computer science disciplines ("Event-driven programming" and "3D modelling") was updated, the author's electronic special course "Digital Technologies in Education" (3 ECTS credits) was prepared, didactic support for teaching computer science disciplines (lectures, multimedia presentations, electronic textbooks, instructional materials and forms, tests, a system of educational tasks for the formation of digital competence and its components) was selected.

The components of the information and digital learning environment – methodological, consulting, subject, programmatic, and communication were developed and filled with content in accordance with the components of the didactic model of students' digital competence formation. The guideline was the prepared structural and logical scheme of teaching computer science disciplines with a system of classroom work and independent and self-educational activities of students with the support of the LMS of HEIs, open educational resources, specialized departmental websites and teachers' personal websites (blogs, pages, etc.), and digital communication tools.

The testing of such didactic term as the *motivational conditionality of interaction of subjects' educational process in the information and digital learning environment* carried out at the formative stage of the experimental work provided for the use of the advantages of such an environment to organize effective cooperation and co-creation in the system "teacher-student-class" during the study of computer science disciplines. The development of students' learning motivation in mastering digital competence was facilitated by the use of problem-based and developmental learning technologies, the creation of success situations, the introduction of emotional stimulation, and rating control with elements of gamification. The projects implemented (individual or group) were aimed at developing motivation, forming cognitive readiness for digital activities, practising leading digital activities, and integrating computer science knowledge.

Students' progression from motives in mastering digital activities to knowledge, skills, abilities, and evaluative judgments to digital competence was ensured by creating a didactic term such as *structuring of educational information in the form of problematic, heuristic and integrative models of learning and its translation into the project activities mode*. Based on the logic and stages of the studied activity, a technological scheme for the formation of students' digital competence was developed, namely:

entrance and introductory diagnostics $\rightarrow$ *goal-motivational module (formation to students of a system of motives and an approximate basis for activities in the virtual space)* $\rightarrow$ *cognitive-operational module (solving a system of educational tasks to develop components of digital competence, forming of constituent elements of digital competencies, inputting them into*

Table 1: Comparative results of experimental work.

Criteria and indicators	Experimental group	Control group
Motivational-value criterion	*+25.26%*	*+10.75%*
Formation coefficient / χ^2 – Pearson's criterion	+0.09 / 79.28	+0.04 / 7.43
Cognitive-informational criterion	*+35.79%*	*+13.98%*
Formation coefficient / χ^2 – Pearson's criterion	+0.11 / 143.48	+0.04 / 9.54
Operational-activity criterion	*+23.16%*	*+7.53%*
Functional literacy in information and data	+0.11%	+0.04%
Effective communication and cooperation competence	+0.11%	+0.02%
Creation of digital content competence	+0.07%	+0.01%
Security competence	+0.08%	+0.03%
Problem-solving competence	+0.07%	+0.02%
Formation coefficient / χ^2 – Pearson's criterion	+0.09 / 63.58	+0.03 / 3.21
Personal-reflexive criterion	*+17.89%*	*+13.98%*
Formation coefficient / χ^2 – Pearson's criterion	+0.06 / 31.73	+0.04 / 9.95
The level of digital competence	*+26.32%*	*+10.75%*
Elementary	–17.89%	–9.68%
Intermediate	–8.42%	–1.08%
Sufficient	+16.84%	+8.6%
Advanced	+9.47%	+2.15%
Formation coefficient / χ^2 – Pearson's criterion	+0.09 / 113.95	+0.04 / 9.74

the metastructure of digital competence during the creation, search, processing, exchange of information) → control and result module (control, evaluation, self-assessment, correction of the formed constructs via information and digital learning environments).

This work was supported by a system of study tasks, contextual, game and problem situations, and web quests created by, which in their content covered motivational and value, cognitive and informational, operational and activity, and personal and reflective aspects of students' activities in the virtual space. The content of the tasks was aimed at both understanding, comprehension, and memorization, structuring the learned tools in the student's memory, actualization and reflection on their own activities.

Ensuring the systematic complication of students' study activities, diagnostics and timely correction of its products based on modern ICTs, as the next didactic term, involved the introduction of virtual space tools that together optimized and intensified the learning of students of computer science disciplines. These include new ways of organizing classes, technological models of mobile, distance, and blended learning, game design, video and teleconferencing, web forums, and workshops in synchronous and asynchronous modes.

The corrective stage involved monitoring and correcting the results of students' learning activities using both general (testing, questionnaires, interviews, tests) and specific methods (competency matrices, expert cards, cases, learning projects, blog).

According to the results of quantitative, qualitative and statistical analysis of the experimental work results, a tendency towards positive changes in the levels of students' digital competence formation both by separate criteria and in general has been established (table 1).

The comparative analysis revealed a positive dynamic of achievements of pedagogical university students of both groups, which, however, is more pronounced and statistically significant for students of the experimental group. According to the research results, the cognitive-informational (+35.79%) and motivational-value (+25.26%) structural-criterion components have turned out the most developed. Changes in the control group's indicators are due to the influence of the educational process and the overall development of students. The non-randomness of the obtained changes was proved with the use the mathematical statistics methods.

5 CONCLUSIONS

1. The study analyses the procedural and substantive aspects of the competence approach as a leading paradigm of higher pedagogical education, clarifies the role and importance of informatization and digitalization in the development of the educational space, highlights the need for digitalization of science education (STEM education) and the urgency of end-to-end

integrated systematic design of advanced content of teaching computer science disciplines to students of pedagogical universities. On this basis, the place of digital competence in the structure of the professional competence of future teachers is determined as a key and essential component in performing motivational and incentive, gnostic and transformative, activity-methodological, evaluative and reflective, and communicative and procedural functions in their professional activities and social practice. At the same time, it is established that the problems in the formation of students' digital competence during the study of computer science disciplines in traditional approaches are associated with the prevalence of a knowledge-oriented paradigm in the organization of the information and digital learning environment, the focus on the one-sided mastery of the basics of algorithmization and programming and software of computer systems. Yet another reason is the insufficient level of educational innovations introduced in the teaching of computer science disciplines.

2. It has been found that the digital competence of pedagogical university students is inherently a dynamic characteristic of a personality determining the ability and capacity to purposefully use ICT to create, search, process, and exchange information in the digital space, to demonstrate information and media literacy, to comply with Internet security and cybersecurity rules, to understand and consciously adhere to ethics in working with information, to creatively introduce ICT innovations in professional and pedagogical activities, to promote the development of relevant their students' digital competence.

Digital competence is an integrative quality that encompasses a set of competencies necessary to navigate and operate in the information space in order to fulfil personal and social needs and carry out professional activities. These include functional literacy in information and data, communication and collaboration competence, digital content competence, digital security competence, and problem-solving competence.

The structural and criterion components of digital competence are motivational-value (indicators: interest in mastering information in the subject area; motivation to use ICT to search for information), cognitive-informational (indicators: knowledge of information sources, methods of working with information, methods of presenting information, knowledge of security and cybersecurity), operational-activity (mastery of methods of obtaining, storing, processing and transmitting information, ability to use information technology in working with sources), and personal-reflexive (indicators: a reflection of information activities, the ability to evaluate information differently and critically select it). It allows monitoring of their formation during the study of informatics disciplines according to the signs of elementary, intermediate, sufficient and advanced levels.

3. The didactic support of shaping pedagogical university students' digital competence in the process of teaching informatics courses has been developed. By analyzing educational programs, the content basis for the formation of the studied phenomenon is represented by three areas in the study of computer science disciplines (algorithmization and programming, computer system software, and computer technologies in the teacher's professional activity), as well as the possibilities of a variable block of the curriculum, in particular, using the LMS of HEIs, MOOCs and open educational resources.

The set of didactic terms for shaping pedagogical university students' digital competence in the process of teaching informatics courses has been determined and justified. Among them are the following ones: 1) motivational conditionality of interaction of subjects' educational process in the information and digital learning environment; 2) structuring of educational information in the form of problematic, heuristic and integrative models of learning and its translation into the project activities mode; 3) ensuring the systemic complicating nature of students' study activities, diagnosis and timely correction of its products on the basis of modern ICT.

4. The effectiveness of creating the system of didactic terms is ensured by the substantiation and experimental verification of the didactic model, which schematically reflects the system of work on the formation of the digital competence characterizing the hierarchy, sequence, components, stages, blocks and applied tools, connections between them and performs orientation, analytical, formative and corrective functions in the organization of teaching students of computer science disciplines.

The implemented didactic modelling led to the content, specification and correction of the educational goals of the components of teaching the pedagogical universities students (target, theoretical and methodological, content and processual and criterion and diagnostic blocks), structuring of educational material into functional modules (goal-motivational, cognitive-operational and control-resultant ones); made possible the logic and gradual introduction of didactic terms for the formation of digital competence in the educational process, in the classroom and students' independent study work.

The motivational conditionality of the interaction of the subjects of the educational process in the information and digital learning environment contributed to a shift in emphasis from the mentoring model of communication between teachers and students to the partnership model.

Structuring educational information in the form of problem-based, heuristic, and integrative learning models and transferring it to the project activity mode made it possible to transform students' reproductive activities into creative ones, which contributed to the skills development to navigate the information space, generalize and integrate knowledge, and choose effective ways and methods of solving problems.

Ensuring the systematic complication of students' study activities, diagnostics and timely correction of its products based on modern ICTs made it possible to gradually increase the complexity of the learning tasks performed, contributed to students' confidence in their abilities and building-up motivation and interest in learning.

Apart from traditional study means additional academic modules were created including special and elective courses in Digital Technologies and 3D Modelling.

According to the results of the empirical research in the experimental groups, there is a statistically significant dynamics in the levels of students' digital competence, namely a 17.89% decrease in the number of students with an elementary level, an 8.42% reduction in the number of students with an intermediate level, 16.84% increase in the number of students with a sufficient level, 9.47% – with a high level. The cognitive-informational, operational-activity and structural-criterion components of digital competence have developed the most.

The paper does not exhaust all aspects of this problem. Further research is reasonable to update the content of educational programs of pedagogical universities in accordance with the needs of the information society and the goals of STEM education; modernization of computer modelling training based on the use of modern tools and software, factors of improving the content and mechanisms for organizing students' activities in the information and digital learning environment, ways to develop and apply educational SMART systems.

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