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XII International Conference on Mathematics, Science and Technology Education

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XII International Conference on Mathematics, Science and Technology Education

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Abstract. This paper represents a preface to the Proceedings of the XII International Conference on Mathematics, Science and Technology Education (ICon-MaSTEd 2020) held at the Kryvyi Rih State Pedagogical University, Ukraine, 15–17 October 2020. Background information and the organizational structure of the meeting, and acknowledgements of the contributions of the many people who made the conference a success are presented.

1. Background

The International Conference on Mathematics, Science and Technology Education (ICon-MaSTEd) is a peer-reviewed international conference, which covers research on mathematics, science and technology education, along with technology-enhanced learning, including blended learning, E-learning, ICT-based assessment, mobile learning etc.

Since 2001, ICon-MaSTEd is the premier interdisciplinary forum for social scientists, academicians, researchers, professionals, policy makers, postgraduate students and practitioners to present their latest research results, ideas, developments, and applications. There is urgent general need for principled changes in mathematics, science and technology education elicited by promising theories, models, tools, services, networks and communications.

The background theme for this ICon-MaSTEd installation was “How learning technology changes science education in the 2020+ era”.

The rapid spread of the coronavirus that causes COVID-19 has change conference organization. In Ukraine, the Ministry of Healthcare is advising people to prepared for disruptions to daily life that will be necessary if the coronavirus spreads within communities. On March 11, 2020, the Cabinet of Ministers of Ukraine introduced a nationwide quarantine in connection with a pandemic, and all public events in the country have been canceled. As the conference organizers, in the current crisis we had to make a rational decision regarding the paper presentations: a) cancel this year conference and put presentations online; b) postpone the conference to an indefinite time in the vague future; c) change dates to Fall 2021; d) merge conferences of this and next year; e) allow the mixed participation, both real and virtual.

It seems the last choice is safe and rational, so we decided not to change ICon-MaSTEd 2020 dates and give to participants the possibility to make a real presentation using ICT augmentation. Therefore, the XII International Conference on Mathematics, Science and Technology Education (ICon-MaSTEd



2020) took place 15–17 October, 2020 at the Kryvyi Rih State Pedagogical University, Ukraine. The format was hybrid, a mix of face-to-face and online participation.

There were 110 submissions selected. Each submission was reviewed by at least 4, and on the average 4.1, program committee members. The committee decided to accept 76 papers.

Due to quarantine restrictions, we offer the in-person talk option only to the local conference organizers and participants. Unfortunately, all conference participants from overseas should present their talks only online. Despite travel restrictions and health issues, more than 230 attendees from 10 countries are joined to ICon-MaSTEd 2020 using Google Meet. The conference featured plenary, invited and contributed talks in a wide number of subject areas: Mathematics Education, Biology Education, Chemistry Education, Physics Education, Astronomy Education, Earth Science Education, Computer Science and Computer Science Education, Integrated Science Education, Technology Education, and Educational Technology.

The presentation slots were defined as follows:

- plenary talks (30 min): 20 min presentation, 10 min question answering and discussion,
- other talks (20 min): 15 min presentation and 5 minutes question answering and discussion.

The full program with video record of talks is available at <https://easychair.org/smart-program/ICHTML2020/About.html> where details of the 2 plenary sessions and 24 parallel sessions, usually headed by one or more invited presentations.

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3. Proceedings overview

3.1. Mathematics Education

This section was presented by 9 talks:

- the article of Myroslav I. Zhaldak et al [75] discusses some use of cloud technology in mathematical calculations using Remote Desktop Ulteo OVD,
- Dmytro Y. Bobyliev et al in the article [6] analyzes experience of implementing the courses *Mathematical Analysis* and *History of Mathematics* for future Mathematics teachers in the system of managing electronic academic courses at Kryvyi Rih State Pedagogical University,
- István Lénárt in the article [29] discuss the educational project called Comparative Geometry,
- the article of Valerii I. Kuz'mich et al [25] deals with issues of the metric geometry basics,
- Anna Rybak in the article [51] describe the experience of Young Explorer's Club as the environment where students can discover knowledge by making experiments,
- the article of Marina G. Drushlyak et al [10] reveals the issue of the appropriateness of training pre-service mathematics teachers to use the techniques of mnemonics in professional activities,
- Kateryna V. Vlasenko et al in the article [71] looks into the issue of online-training of master students, majoring in Mathematics for internship in technical universities,
- article of Kateryna V. Vlasenko et al [70] considers the issue of developing motivational and value-orientated readiness of Math students at teacher training universities for implementing educational innovations,
- the article of Tetiana Kramarenko et al [23] considers the issue of developing motivational and value-orientated readiness of Math students at teacher training universities for implementing educational innovations.

3.2. Biology Education

This section was presented by 2 talks:

- the Elena V. Komarova's article [21] is dedicated to the problem of true and pseudoreplication of a biological experiment, in particular in the educational process,

- Vasyl Savosko et al in the article [52] show the experience of introducing into modern biological education methods of predictive modeling which are based on relevant factual material.

3.3. Chemistry Education

This section was presented by 2 talks:

- Tetiana M. Derkach in the article [9] analyse the typical mistakes in the learning of the university course of inorganic chemistry, determine the origin of misconceptions and estimate the effectiveness of the use of computer simulations to correct false chemical concepts,
- Liliia Midak et al in the article [35] shown the benefits of study chemical disciplines, applying the augmented reality for the upcoming chemistry teachers, as far as the visualisation of the demonstration material in the 3D helps students understand various processes and phenomena, the structure of chemical compounds and the mechanisms of their correlation in a better way.

3.4. Physics Education

This section was presented by 2 talks:

- the article of Oleksandr A. Konoval et al [22] deals with the theoretical analysis of the traditional approaches to electrodynamics teaching,
- Oleg I. Pursky et al in the article [49] presents a computational method for studying the thermal conductivity of molecular crystals that can be used in the educational course of condensed matter physics.

3.5. Astronomy Education

The method of astronomy homework organization in order to increase students' cognitive activity is described by of Svitlana Malchenko in the article [33].

3.6. Earth Science Education

This section was presented by 2 talks:

- the article of Ihor Kholoshyn et al [19] is devoted to the problem of incorporation geographic information systems (GIS) in world school practice,
- the article of Petro G. Pihulevskyi et al [44] provide the information on the number of earthquakes in Kryvyi Rih and their parameters for the period 2007–2018.

3.7. Computer Science and Computer Science Education

This section was presented by 19 talks:

- the article [11] presents the novel turmite-based cryptography algorithm has been designed and implemented by Liliia Fadieieva et al,
- the conceptual and mathematical models of the agents' knowledge potential redistribution considering their constituent components are constructed in the article [42] of Volodymyr V. Pasichnyk et al,
- the main idea of the article [74] authored by Pavlo V. Zahorodko is to identify the possibility of achieving, if not quantum supremacy, then at least a quantum advantage when solving machine learning problems on a quantum computer,
- the main aim of the article [31] authored by Nadiia Lobanchykova et al is the creation of information technology for mobile (of rapid deployment) security systems of the area perimeter,
- the article of Andrii Tkachuk et al [63] describes the gravity acceleration sensor (GAS) design, the technical characteristics of which provide an increase in the static transfer constant of the GAS, the ability to determine the current static transfer constant of the GAS, reducing the level of noise effects in the output signal of GAS,

- in the article of Igor Puleko et al [48] is described a software model that allows you to study the statistical characteristics of mobile networks,
- the article of Varvara Chernenko et al [8] deals with the development of a web application on forecasting the dynamics of prices in the residential sector of Ukraine,
- the use of augmented reality-enabled scenarios in cybersecurity teaching is proposed by Yuriy Skorenkyy et al in the article [58] to respond to new requirements for the rapid adoption of new technologies and profound knowledge of cybersecurity issues by professionals,
- the article [39] authored by Viacheslav V. Osadchyi et al reviews publications on the topic of augmented reality in STEM education, describes the concept of augmented reality, the analysis of augmented reality technologies is carried out, which are adapted to the teaching of natural and mathematical disciplines,
- the article of Dmytro S. Shepiliev et al [56] deals with applying augmented reality in the web environment to solving the task of development the career guidance quests,
- Iryna S. Zinovieva et al in the article [76] analyzes various publications of scientists on the training of future IT specialists and the features of training programming using online simulators,
- the article of Olena G. Glazunova et al [14] 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 subject of the article [43] authored by Maksym Pavlenko et al is the formation of communication and teamwork skills of future IT-specialists, using project technology in teaching the administration of computer systems and networks,
- the article [4] reports Nadiia R. Balyk's et al experience of implementing educational projects in a computer modelling course offered to the students majoring in "Secondary Education (Computer Science)" at Ternopil Volodymyr Hnatiuk National Pedagogical University,
- the aim of the article [5] authored by Liudmyla Bilousova et al is to depict the functionality of the authors' mobile Android application "Petri Nets Tool-Kit", and to specify facilities and examples of its using for mastering modelling by students,
- the article of Vladyslav S. Kuznetsov et al [26] gives an overview of issues arising in connection with the organization and conduct of the course "Computer game development" in the master's program 014.09 Secondary education (Informatics),
- Yuriy V. Tryus et al in the article [67] substantiates the necessity and expediency of using the dual form of education in training specialists in the field of information technology in technical universities of Ukraine, interprets the concept of "dual education" from various sources, including UNESCO documents and the Law of Ukraine "On Education", analyzes some international experience of using dual study in higher education, in particular in Germany, considers the tasks to be solved for successful implementation of the dual form of higher education in Ukraine, and the main stages of this implementation for the period up to 2023,
- Nadiia S. Ponomareva in the article [47] emphasis that the teacher of mathematics should be capable for effective professional activity in a rapidly changing technology, educational paradigms and catastrophic educational disruptions, such as the current COVID-19 pandemic,
- the article of Serhiy O. Semerikov et al [53] is an attempt to rethink the concepts of "methodic" and "methodologic / methodical system" as basic to educational technology.

3.8. *Integrated Science Education*

This section was presented by 4 talks:

- the article of Pavlo P. Nechypurenko et al [38] analyzes the experience of implementing an integrated course "Science" in schools of Ukraine,

- the article of Leila Sultanova et al [60] considers the problem of the development of soft skills of teachers of Physics and Mathematics in higher educational institutions in the process of certification training in the system of postgraduate pedagogical education of Ukraine,
- the article of Svitlana Bodnar et al [7] highlights the problem of introducing integrated teaching the students majoring in economics in the educational process of Ukrainian tertiary non-linguistic schools,
- the article of Anna V. Iatsyshyn [17] considers factors that are influencing formation of scientists image especially: availability to inform scientist or scientific organization about the registration, scientometric indices, use of global identifiers to improve accuracy in calculating indicators, publication of papers in journals with high impact factor, publications in resources that provide visibility in global information space, involvement in global communications system, level of competence.

3.9. *Technology Education*

This section was presented by 5 talks:

- the purpose of article authored by George Abuselidze et al [1] is to investigate the impact of artificial intelligence on business education based on the experience of the world and particularly, in Georgia,
- the purpose of article [54] authored by Larysa M. Sergeieva et al is to substantiate the model of quality management of training of competitive specialists in professional (vocational technical) education taking into account the identified factors affecting the quality of training and contradictions that need to be resolved in the process of training and experimental verification of its effectiveness,
- the article of Valentyna Radkevych et al [50] discloses the peculiarities of developing professional competence in professional training teachers,
- the experience of application of methods of problem-based and project-based learning in the training of future engineers for the light industry is presented in the article [57] by Yana V. Shuhailo et al,
- the article of Viacheslav Holovnia et al [15] describes the analysis of computer-aided manufacturing systems introduction for the control program machines preparation with the numerical control into the technical students' educational process.

3.10. *Educational Technology*

This section was presented by 30 talks:

- the article of Natalya Yaremenko et al [73] deals with multimodal learning strategies aimed at transferring philological knowledge using ICT,
- the article of Oksana Babakina et al [2] is devoted to the urgent topic of using new modern information technologies in lessons in general and in the Ukrainian language lessons in particular,
- the article of Larysa Kupchyk et al [24] deals with the concept of student-centred Personal Learning Environment in the context of higher education, which is used as a means of transforming foreign language learning and teaching practices,
- Iryna Shavkun and other authors of article [55] search the solution to the practical tasks of the contemporary education characterized by the increasing role of individual work in implementation of ICT at the lessons and in the independent work, the development of new principles, strategies and methods of teaching within the framework of integrated learning,
- the article of Roman M. Horbatiuk et al [16] deals with the results of experimental work concerning the educational environment formation that is focused on the foreign language training of future energy engineering students,

- the article of Nataliia P. Volkova et al [72] addresses the issue of developing and using students' workshops in English,
- the article of Svitlana V. Symonenko et al [61] deals with the urgent issue of American English learning for IT-professionals under challenging conditions of the changeable economic situation in the world,
- to analyse what e-learning modes are used in a particular institution, to measure the efficiency of distance courses and, further, to suggest the most effective model and the ways of e-learning integration into a particular HEI according to its needs' analysis was set up as the aim of the article [64] authored by Anastasiia Tokarieva et al,
- the article of Liudmyla Bakhmat et al [3] aims at assessing the satisfaction and acceptance rate of Ukrainian lecturers with online education, as well as indicating problems and benefits they had singled out,
- the article of Tetiana Vakaliuk et al [68] substantiates the need to develop and implement a distance course "Cloud technologies in the educational process in quarantine",
- the relevance of the article [65] authored by Iryna M. Trubavina et al is explained by the necessity of developing digital competence of teachers of Humanitarian disciplines at the higher education institutions in the conditions of the quarantine measures to prevent the spread of COVID-19,
- the relevance of the Iryna M. Trubavina's et al article [66] relates to the need for continuing preschool education under quarantine conditions to prevent the spread of COVID-19 by means of distance technologies and preparation of children for STEAM-education,
- the article of Kateryna Polhun et al [46] highlights the urgency of the problem of introducing blended learning into the educational process of institutions of higher education and ensuring the quality of education using the tools of e-learning management system,
- the article of Nataliia P. Franchuk et al [13] considers the use of cloud technologies during distance learning,
- the article of Iryna K. Pokulyta et al [45] outlines both the potential of gamification and virtualization of media practices in the educational and further professional activities of a social worker, and points out the possible dangers of implementing these technologies for certain categories of people in need,
- in the article of Alla Lobanova et al [32] the actual modern problem that is pervasive minutes informatization of modern life, including the education system, which is not only positive but also negative effects on young people,
- Liudmyla V. Kalashnikova et al in the article [18] presents an overview of the main possibilities of using ICT in applied sociology, as well as the urgent need and importance of computer training of the students,
- the article of Liubov F. Panchenko et al [41] deals with the problem of PhD student training,
- the article of Mariia P. Leshchenko et al [30] devoted to the digital transformation of education and science which puts forward new requirements for training of graduate and doctoral students, in particular for development of informational and analytical competence,
- Arnold Kiv et al in the article [20] discusses the essence of lateral thinking and possible ways to test it,
- the article of Halyna M. Meshko et al [34] is devoted to the use of information technologies for pedagogical research aimed at studying the formation of key competencies and learning outcomes in higher education institutions, in particular, the professional responsibility of students of technical specialties,
- the article of Viacheslav V. Osadchyi et al [40] analyzes the possibilities of using innovative AR technologies in the process of developing the hardiness of the future specialist on the basis of the implementation of competence and subject-personal approach to the introduction of AR technologies in the educational process in the system of higher education,

- in article of Olena O. Lavrentieva et al [27] the definition of the educational institution information and consulting environment has been formulated,
- the article of Andrii V. Morozov et al [36] considers the expediency of developing and using the electronic environment of a higher education institution,
- Nataliia V. Morze et al in the article [37] highlights e-learning courses as the popular means of delivering knowledge to students in higher education institutions,
- the article of Vladyslav Ye. Velychko et al [69] looks into the effective use of open electronic educational resources,
- the article of Lidiia P. Tkachenko et al [62] touches upon the problem of introducing professionally oriented software products based on ICT into the educational process of training managers of the hotel, restaurant and tourism business,
- the novelty of the article [59] by Tetiana M. Sobchenko et al lies in determining and analyzing the levels of formation of innovative competency of students majoring in Philology,
- peculiarities of the usage of the hierarchy analysis method for the making decision on the choice of the most efficient computer mathematics system used for the preparation of the IT-sphere specialists are in the focus of the article [12] authored by Anatoliy Fedonuyk et al,
- the article of Evgeniy Lavrov et al [28] describes the problem of awakening the cognitive activity of students, arising due to revolutionary transformations in teaching technologies.

4. Conclusion

XII instalment of ICon-MaSTEd was organised by Kryvyi Rih State Pedagogical University, Ukraine (with support of the rector Prof. Yaroslav Shramko), in collaboration with Kryvyi Rih National University, Ukraine (with support of the rector Prof. Mykola Stupnik), Institute of Information Technologies and Learning Tools of the NAES of Ukraine (with support of the director Prof. Valeriy Bykov) and Ben-Gurion University of the Negev, Israel (with support of the rector Prof. Chaim Hames).

We are thankful to all the authors who submitted papers and the delegates for their participation and their interest in ICon-MaSTEd as a platform to share their ideas and innovation. Also, we are also thankful to all the program committee members for providing continuous guidance and efforts taken by peer reviewers contributed to improve the quality of papers provided constructive critical comments, improvements and corrections to the authors are gratefully appreciated for their contribution to the success of the conference. Moreover, we would like to thank the developers of EasyChair and HotCRP, who made it possible for us to use the resources of this excellent and comprehensive conference management system, from the call of papers and inviting reviewers, to handling paper submissions, communicating with the authors, and creating the volume of the conference proceedings.

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We are looking forward to excellent presentations and fruitful discussions, which will broaden our professional horizons. We hope all participants enjoy this conference and meet again in more friendly, hilarious, and happiness of further ICon-MaSTEd 2021. The next meeting in the series is the XII International Conference on Mathematics, Science and Technology Education, 12–14 May 2021, Kryvyi Rih, Ukraine (<https://icon-masted.easyscience.education/2021/>).

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Some applications of cloud technologies in mathematical calculations

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Abstract. This article discusses some use of cloud technology in mathematical calculations using Remote Desktop Ulteo OVD. To use such technologies, it is enough to have access to the Internet through a suitable browser to access an open virtual desktop on a powerful remote computer and then use the resources of the remote computer (server) to solve their problems in processing various information resources – solving mathematical problems, working out texts, translating from one language to another, help on the interpretation of different terms, their origin and more. You can organize access to Ulteo OVD from two servers (Application Server (Windows 2008R2) and Session Manager Server (Linux Ubuntu)), using the Proxmox web-based virtual environment. Gran1, Gran2D, Gran3D software can be installed on the application server. The article also examines in detail some examples of the use of the pedagogical software for educational purposes Gran1. In particular, the calculation of the approximate value of the double integral; graphical two-dimensional problem solving, the so-called linear programming problems; two-dimensional problems, including convex programming – finding the smallest value of a convex downward function (or the highest convexity of a 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 training, should be pedagogically balanced, which will allow to avoid any negative effects on the formation of personality of a future member of society, his mental and physical development.

1. Introduction

Extensive use of modern ICT in various spheres of life and activity of people provides opportunities for access to a variety of information from any field of knowledge. There are opportunities to significantly increase people's awareness of various manifestations of the world around them and, as a result, to be better prepared for a successful life and activity in today's conditions.

Educational institutions are not left out either. The introduction of modern ICT in the methodological systems of teaching [11] various disciplines, including mathematics [12], physics [3], chemistry [9], geography [1], history [5], etc., provides opportunities to significantly fundamentalize the content of education, expand and deepen the theoretical knowledge base. In addition, to provide knowledge with practical significance and applicability, to form in students the foundations of professional and general culture, to cultivate in them a sense of concern and responsibility for the safety of the world and people, to be consciously highly cultured, well-educated and polite, about his well-being and peace, the development of his culture and material well-being.

However, the use in the educational process of any technology, including modern ICT, as well as the content of education, should be pedagogically balanced, which will avoid any negative influences on the formation of the future member of society, his mental and physical development. The main thing is



the development of thinking skills, analytical-synthetic, creative [4] and critical [10] thinking of students, the ability to see the essence of various manifestations of the world and the causal links of manifestations of various phenomena and processes, to be able to correctly explain and use them for the environment and for themselves.

Of particular importance is the teaching of natural sciences and mathematics, during which students have to 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.

Of particular importance are the cloud technologies for accessing the resources of various powerful computers (servers) via the Internet [6] using not very powerful, including mobile Internet devices – smartphones, tablets, etc. [8] This allows educational institutions to use the resources of remote servers without spending money to purchase their own powerful, and therefore expensive, computers. It is enough to have access to the Internet through the appropriate browser (browser – program for reading) to get to the open virtual desktop on a powerful remote computer (Open Virtual Desktop – OVD [7]) and then use the resources of the remote computer (server) to develop solving their problems in relation to the processing of various information resources – solving mathematical problems, processing texts, translation from one language to another, information on the interpretation of different terms, their origin, and much more.

2. Cloud-based Gran

You can use Ulteo OVD to deploy Remote Desktop. To do this, you need to organize the work of two servers (application server and session manager server), which can be done using a web-oriented virtual environment PROXMOX (figure 1) [2].

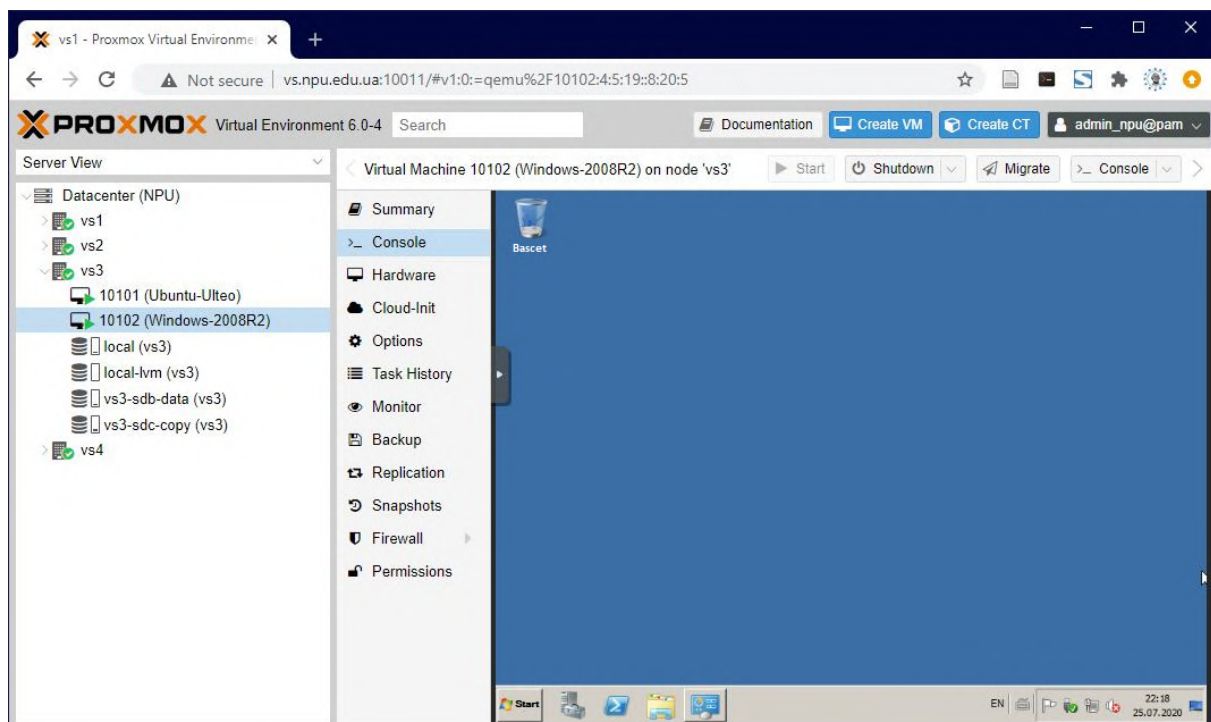


Figure 1. PROXMOX console.

One server, namely the session manager server, is configured using the Linux Ubuntu operating system. The application server is configured using the operating system Windows 2008R2, which can be installed software Gran1, Gran2D, Gran3D.

Let’s consider some possibilities of use of resources of the remote server on an example of work with cloud variants of the Gran software educational complex. To get to the virtual desktop (Open Virtual Desktop) on a remote server, you must access the browser services (such as Google Chrome) and in the input line above the desktop enter the address gran.npu.edu.ua (see figure 2), 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 (Ulteo Open Virtual Desktop) (see figure 3) 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*.

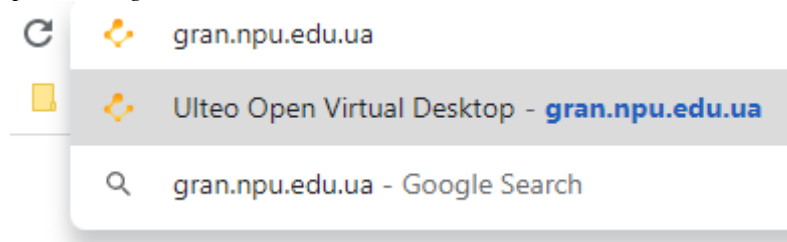


Figure 2. Access to the gran.npu.edu.ua

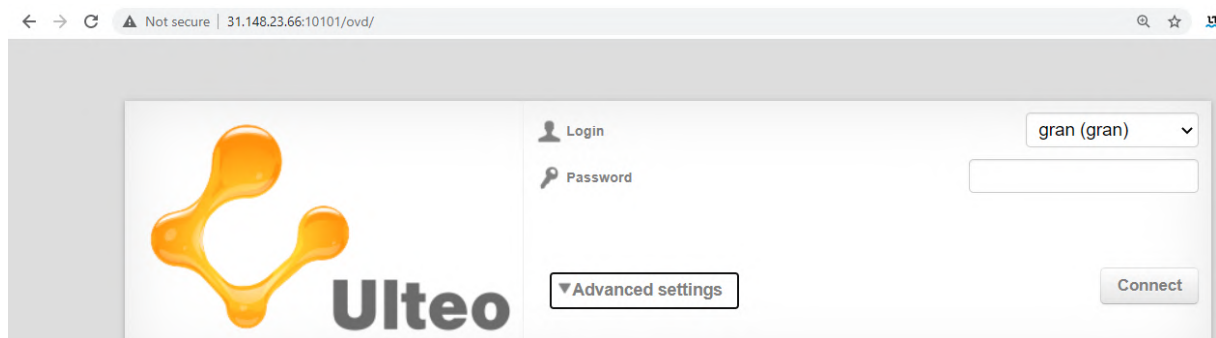


Figure 3. Ulteo OVD login page.

It should be noted that in this case, the English alphabet (ENG) must be installed on the keyboard. As a result, a window will appear with the message “Ulteo. Loading Open Virtual Desktop” (see figure 4) and soon a window will appear with the designations (through the corresponding images) of five objects: “Basket”, “Gran1”, “Gran2D”, “Gran3D”, “Local disk (D)” (see figure 5).

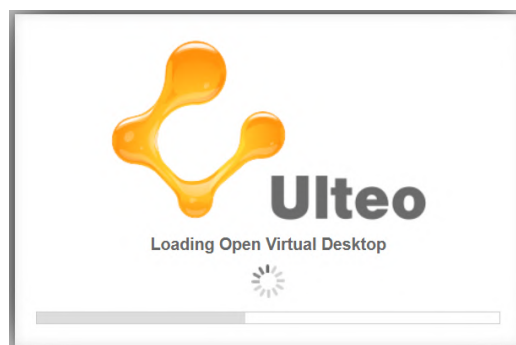


Figure 4. Ulteo OVD loading screen.

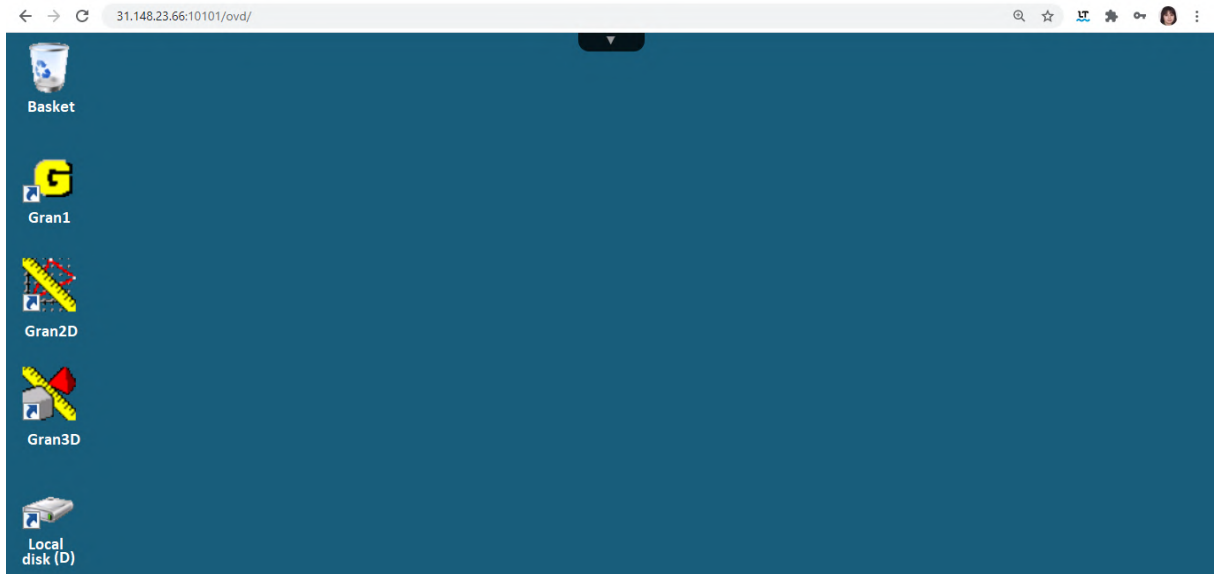


Figure 5. Cloud desktop.

To start working with Gran1, place the cursor on the “G” and double-click “left-click” (or give the appropriate instruction when using a mobile device). As a result, the Gran1 working window will appear on the screen (see figure 6). Then you can start using the services provided in the Gran1 program.

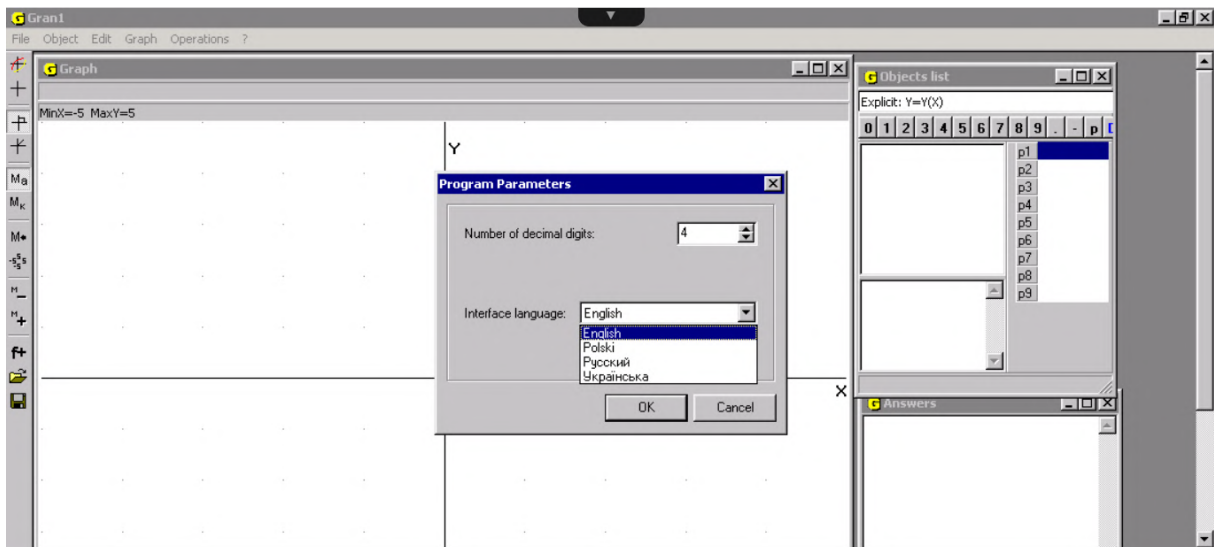


Figure 6. Gran1 starting window.

Similarly, the Gran2D program, designed to graphically process 2D objects on a plane, and the Gran3D program, designed to graphically analyze 3D objects in 3D space, are loaded.

Let's consider in more detail some examples of application of the pedagogical software of educational purpose Gran1.

3. Application of the cloud-based Gran1 in mathematical calculations

Suppose you need to calculate the approximate value of the double integral.

$$\iint_G f(x, y) dx dy, \text{ where } G = [a; b] \times [c; d] = \{(x, y) | x \in [a; b], y \in [c; d]\}.$$

Divide the segment $[c; d]$ into a number of partial intervals $[y_{i-1}; y_i]$, $i \in \{1, 2, \dots, k\}$, $y_0 = c$, $y_k = d$, $y_i - y_{i-1} = h$, where h – some step change of values y_i , and we will give approximately

$$\iint_G f(x, y) dx dy$$

through

$$\sum_{i=1}^{k-1} h \int_a^b f(x, y_i) dx + h \cdot \frac{1}{2} \left(\int_a^b f(x, y_0) dx + \int_a^b f(x, y_k) dx \right) \tag{1}$$

or, equivalently

$$\iint_G f(x, y) dx dy \approx \sum_{i=1}^k h \cdot \frac{1}{2} \left(\int_a^b f(x, y_{i-1}) dx + \int_a^b f(x, y_i) dx \right). \tag{2}$$

For each fixed value of y_i the one-dimensional integral

$$\int_a^b f(x, y_i) dx$$

is easily calculated using the corresponding services provided in the program Gran1, namely the services “Operations”, “Integrals”, “Integral” (see [12], [13], [14]). Calculating further the sum (1) for a specific value of h , we find the approximate value of the integral

$$\iint_G f(x, y) dx dy, G = [a; b] \times [c; d].$$

Consider specifically this example. Suppose you need to calculate the approximate value of the double integral

$$\iint_G e^{-(x^2+y^2)} dx dy,$$

where $G = [-5; 5] \times [-5; 5]$. We will calculate the values of one-dimensional integrals

$$\int_{-5}^5 e^{-(x^2+y^2)} dx,$$

by providing variable y_i values $0 + i \cdot h$, $i = \{0, 1, 2, \dots, k\}$. Given that the function $e^{-(x^2+y^2)}$ is even with respect to the variable y for an arbitrary value of the variable x , the resulting sum

$$\sum_{i=1}^k h \cdot \frac{1}{2} \left(\int_{-5}^5 e^{-(x^2+y_{i-1}^2)} dx + \int_{-5}^5 e^{-(x^2+y_i^2)} dx \right)$$

will need to be multiplied by 2 (or change y_i through step h , starting not from $y_0 = 0$, but from $y_0 = -5$).

Note that $f(x, y) = \frac{1}{\pi} e^{-(x^2+y^2)}$ is the density of the two-dimensional probability distribution, the coordinates of the center of which are $x_1 = 0, y_1 = 0$, and the probability scattering variance along the axis OX and along the axis OY is equal to $D_1 = \frac{1}{2}, D_2 = \frac{1}{2}$, respectively, standard deviations $\sigma_1 = \frac{1}{\sqrt{2}}, \sigma_2 = \frac{1}{\sqrt{2}}$, and $f(x, y) = \frac{1}{\pi} e^{-(x^2+y^2)}$ can be submitted as $f(x, y) = f_1(x)f_2(y)$, where $f_1(x) = \frac{1}{\sqrt{\pi}} e^{-x^2}, f_2(y) = \frac{1}{\sqrt{\pi}} e^{-y^2}$ – the densities of one-dimensional normal probability distributions along the axis OX and the axis OY , respectively. As is known, $\int_{-\infty}^{\infty} e^{-x^2} dx = \sqrt{\pi}$ (known Euler-Poisson integral).

Let us now turn to the Gran1 program and, specifying the type of dependence between the variables “Explicit”, enter the expression $\exp(-(x^2 + p1^2))$ (see figure 7), where instead of the variable y we specify the variable (dynamic) parameter $p1$. Having set some specific value of the parameter $p1$, the limits of its change “Min =”, “Max =” and the step of changing “ $h =$ ” (in the appropriate windows on the right side of the desktop), refer to the services “Graph”, “Plot”. Resulting in the window “Graph” will be the graph of function $f(x) = e^{-(x^2+p1^2)}$ at the set value of parameter $p1$ is constructed (see figures 8–13 for $p1 = 0 \dots 1.25$).

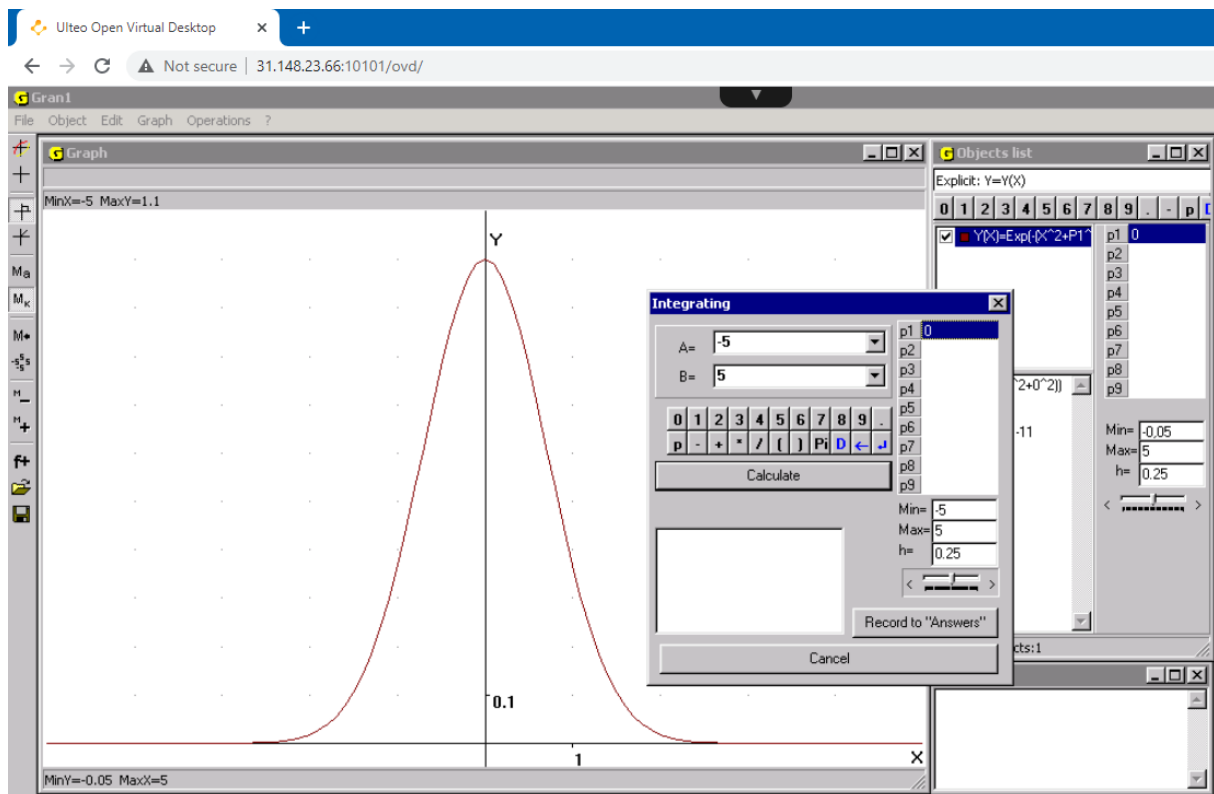


Figure 7. Plot of expression $\exp(-(x^2 + p1^2))$.

Note that the required numbers in these windows are entered by using the number pad at the top right in the working window, as usual. After entering the required numbers, you should “press” the button “←” on the specified panel.

Summarizing the obtained 14 values in the table 1, we obtain the set (on condition $h = 0.25$).

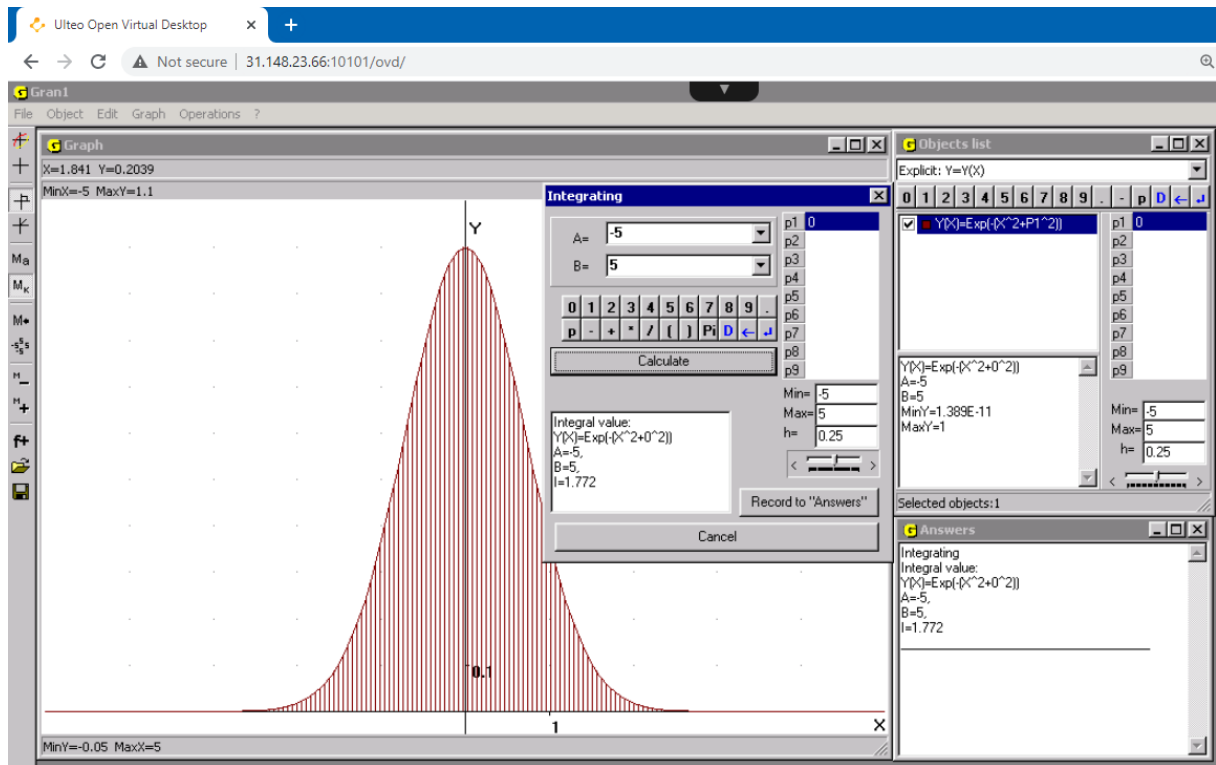


Figure 8. Graph of function $f(x) = e^{-(x^2+p1^2)}$ at $p1 = 0$.

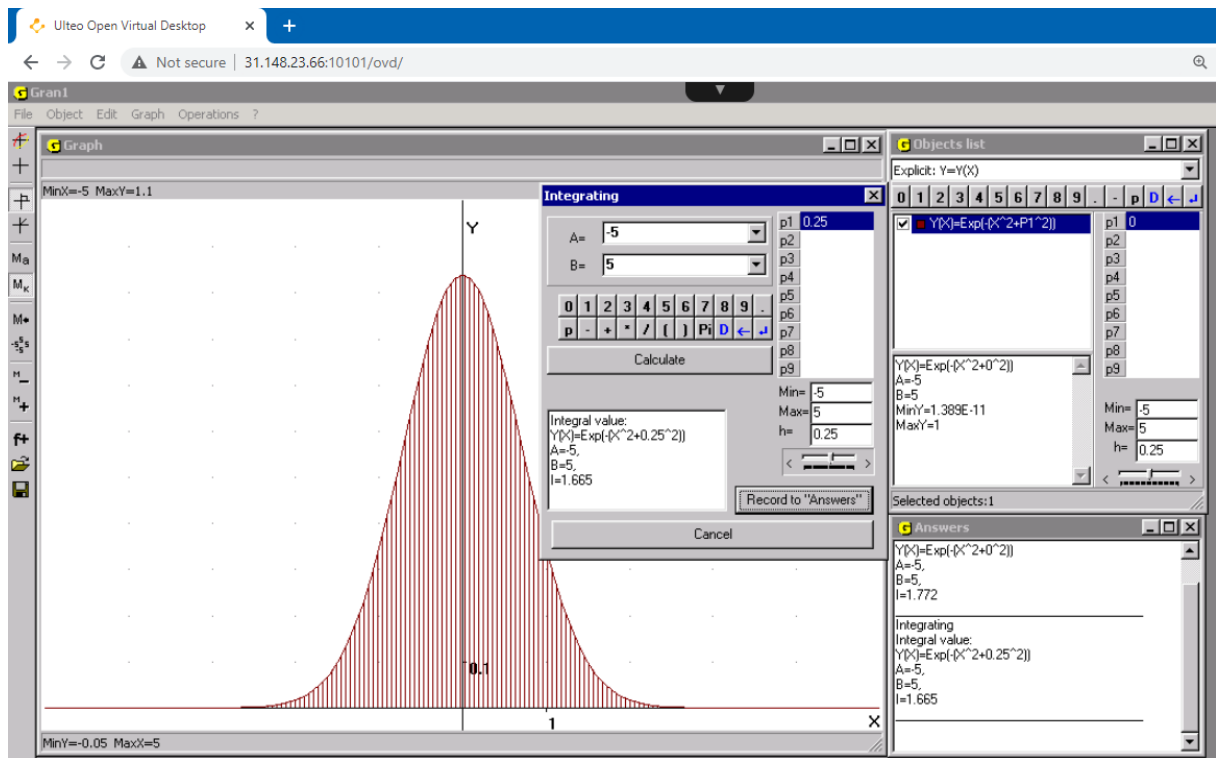


Figure 9. Graph of function $f(x) = e^{-(x^2+p1^2)}$ at $p1 = 0.25$.

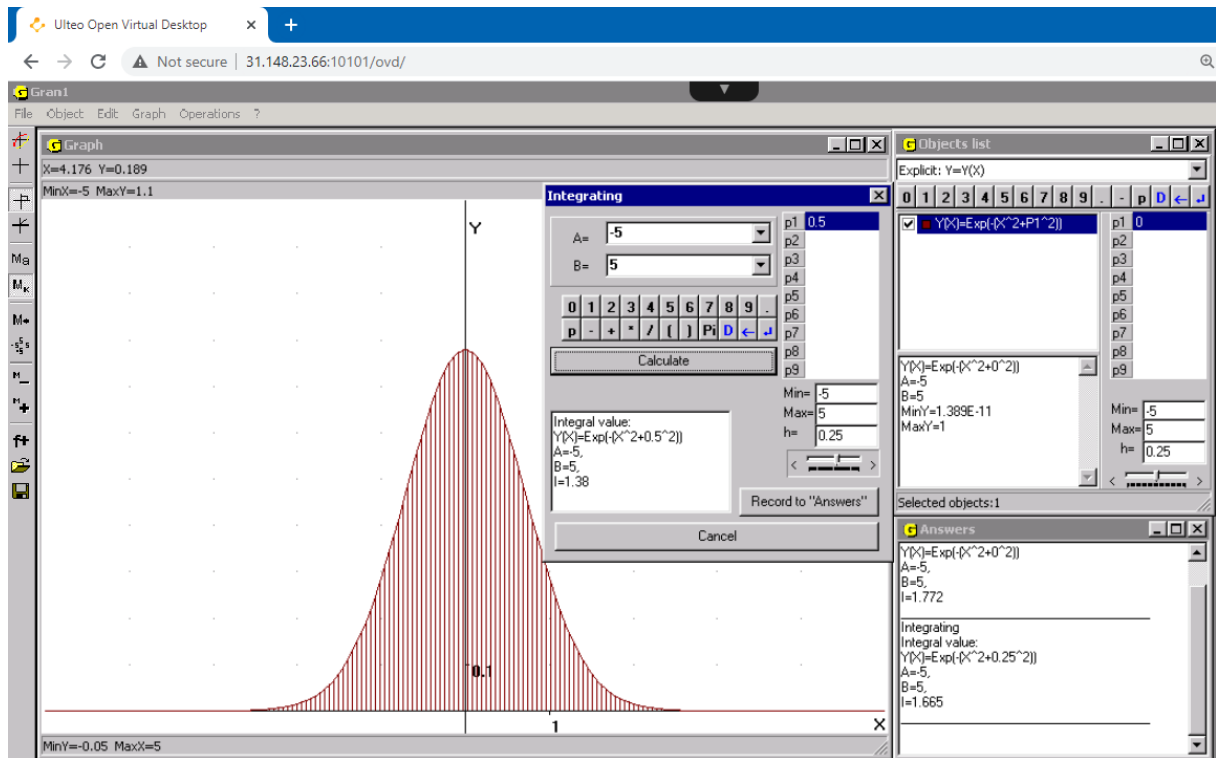


Figure 10. Graph of function $f(x) = e^{-(x^2+p1^2)}$ at $p1 = 0.5$.

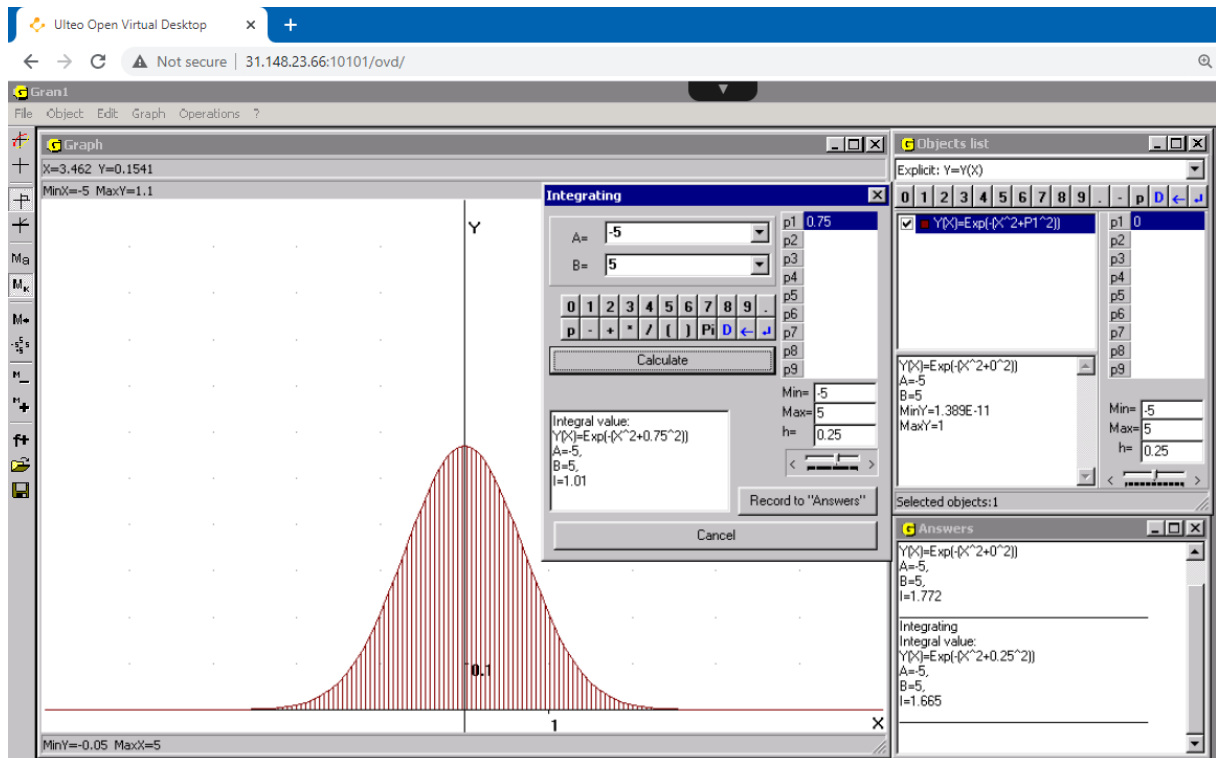


Figure 11. Graph of function $f(x) = e^{-(x^2+p1^2)}$ at $p1 = 0.75$.

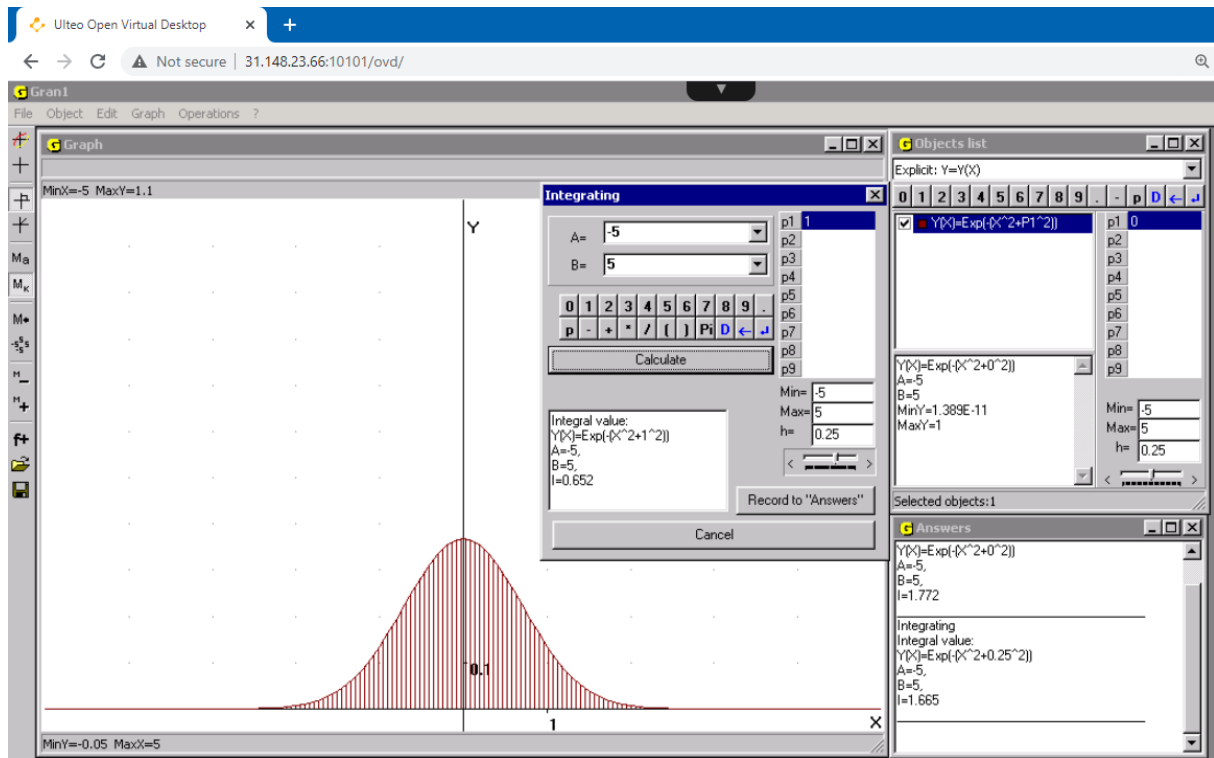


Figure 12. Graph of function $f(x) = e^{-(x^2+p1^2)}$ at $p1 = 1$.

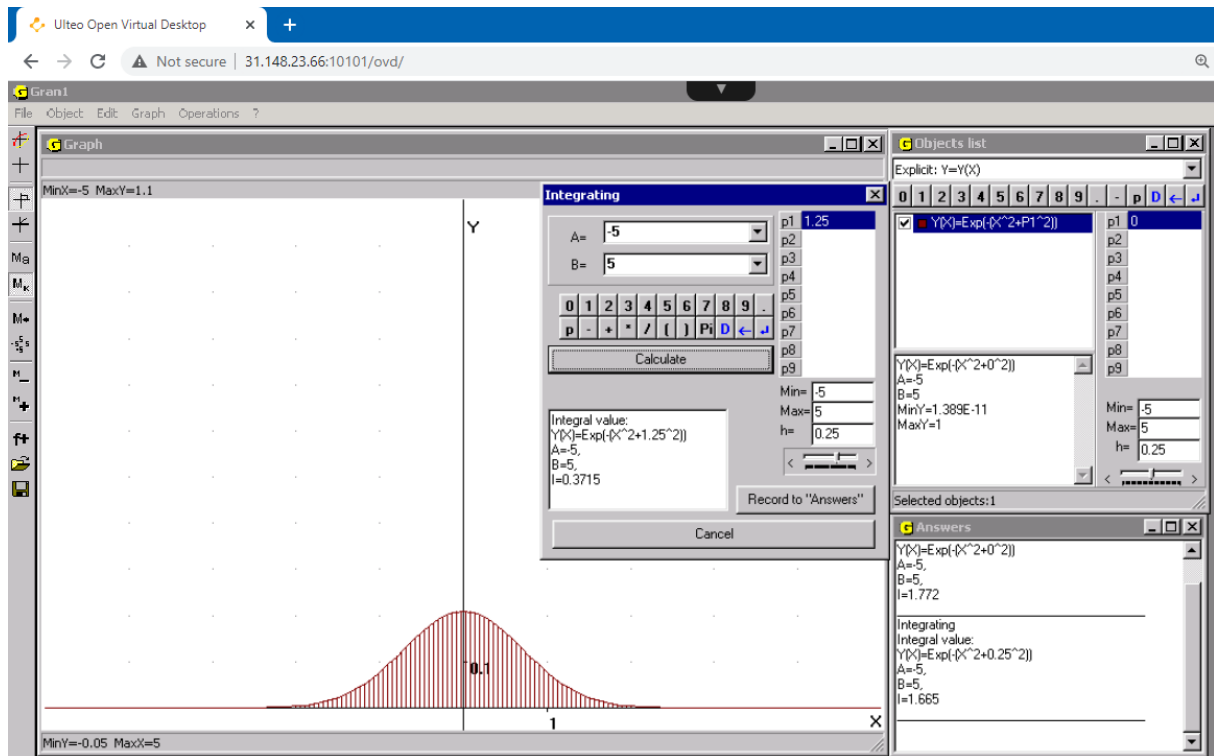


Figure 13. Graph of function $f(x) = e^{-(x^2+p1^2)}$ at $p1 = 1.25$.

Table 1. $I(p1)$ values.

$p1$	0	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
$I(p1)$	1.772	1.665	1.380	1.010	0.652	0.3715	0.1868	0.0829	0.03246	0.01122	0.003422	0.000920	0.000218	0.000046

Calculating now the sum of the found values of the integral

$$I(p1) = \int_{-5}^5 e^{-(x^2+p1)} dx$$

for different (specified in the table) parameter values $p1$, we will receive

$$\sum_{p1=0}^{3.25} I(p1) = 7.168.$$

Given formula (1) (or (2)), we find

$$\sum_{p1=0}^{3.25} I(p1) - \frac{I(0)}{2} = 7.168 - \frac{1.772}{2} = 6.282.$$

Multiplying the obtained value 6.282 by the step size $h = 0.25$, we obtain $6.282 \cdot 0.25 = 1.571$. Multiplying the obtained value 1.571 by 2 (since the parameter $p1$ was changed not from -5 to 5 , but from 0 to 5 , and taking into account that if $p1 > 3.25$ practically $I(p1) = 0$), as a result we will receive $1.571 \times 2 = 3.142$, that is

$$\iint_G e^{-(x^2+y^2)} dx dy = 3.142 \approx \pi.$$

Almost the same results are obtained in the case $h = 0.1$ or $h = 0.05$. Because,

$$\iint_{R^2} e^{-(x^2+y^2)} dx dy \approx \iint_G e^{-(x^2+y^2)} dx dy = \pi,$$

for

$$\iint_{R^2} e^{-(x^2+y^2)} dx dy = \int_{-\infty}^{\infty} e^{-x^2} dx \int_{-\infty}^{\infty} e^{-y^2} dy \approx \int_{-5}^5 e^{-x^2} dx \int_{-5}^5 e^{-y^2} dy = \sqrt{\pi}\sqrt{\pi} = \pi,$$

or

$$\frac{1}{\pi} \int_{R^2} e^{-(x^2+y^2)} dx dy = \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} e^{-x^2} dx \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} e^{-y^2} dy \approx \frac{1}{\sqrt{\pi}} \int_{-5}^5 e^{-x^2} dx \frac{1}{\sqrt{\pi}} \int_{-5}^5 e^{-y^2} dy \approx 1$$

due to the fact that with a normal probability distribution with density $f(x) = \frac{1}{\sqrt{\pi}} e^{-x^2}$ standard quadratic deviation $\sigma = \frac{1}{\sqrt{2}}$, and the probability of getting outside $(x_c - 3\sigma, x_c + 3\sigma)$ is almost zero, the probability of falling outside the set $G = [-5;5] \times [-5;5]$ is almost zero, and

$$P(G) = \iint_G \frac{1}{\pi} e^{-(x^2+y^2)} dx dy \approx 1.$$

Another variant of the approximate calculation of the double integral

$$\iint_G f(x, y) dx dy,$$

where $f(x, y)$ function of the form $f(x^2 + y^2)$, G – plural form $G = \{(x, y) | x^2 + y^2 \leq R^2\}$, can be such. Put $y = 0$ and using the services of Gran1, build a graph of the function $y = f(x, 0)$. Next, starting from the point $(0, f(0,0))$ and shifting towards the increase of the abscissa x , we embed in the constructed graph of the polyline function $f(x, 0)$, placing the vertices of the polyline on the graph as close as possible to each other and placing such vertices along the graph of the function within the abscissa x in the set G . Next, we turn to the services of the Gran1 program “Operations”, “Polygonal lines processing”, “Solid of rotation volume and surface area, axis OY ”. As a result, we obtain the approximate value of the integral

$$\iint_G f(x, y) dx dy.$$

Suppose, for example, you need to calculate the double integral

$$\iint_G \frac{1}{\pi} e^{-(x^2+y^2)} dx dy,$$

where $G = \{(x, y) | x^2 + y^2 \leq 5\}$.

Using the services of Gran1, turn to the services “Object”, “Create”, enter the expression of a clearly defined dependence and then, turning to the services “Graph”, “Plot”, build a graph of a given relationship between abscissas and ordinates of points on the graph (see figure 14). Next, set the type of relationship between the variables “Polygonal line”, refer to the services “Object”, “Create”, and in the window that appears, specify the method of specifying the vertices of the broken “Data from screen”. After that, we will indicate on the constructed graph the point – the vertex of the polygonal line, for which it is necessary to place the mouse cursor in the corresponding point on the graph and press the left mouse button. As a result, such a point will be marked, and it will be given the appropriate number. After entering the last point, click “OK” in the upper right corner of the graphics window (see figure 15) and then refer to the services of Gran1 “Graph”, “Plot”.

To obtain the desired approximate value of the double integral

$$\iint_G \frac{1}{\pi} e^{-(x^2+y^2)} dx dy, G = \{(x, y) | x^2 + y^2 \leq 5\},$$

which in the geometric interpretation is the volume under the surface $Z = f(x, y) \geq 0$ over the area G , we turn to the services of the Gran1 program “Operations”, “Polygonal lines processing”, “Solid of rotation volume and surface area, axis OY ”. As a result (see figure 16), we obtain an approximate value of the integral

$$\iint_G \frac{1}{\pi} e^{-(x^2+y^2)} dx dy - V = 0.9849.$$

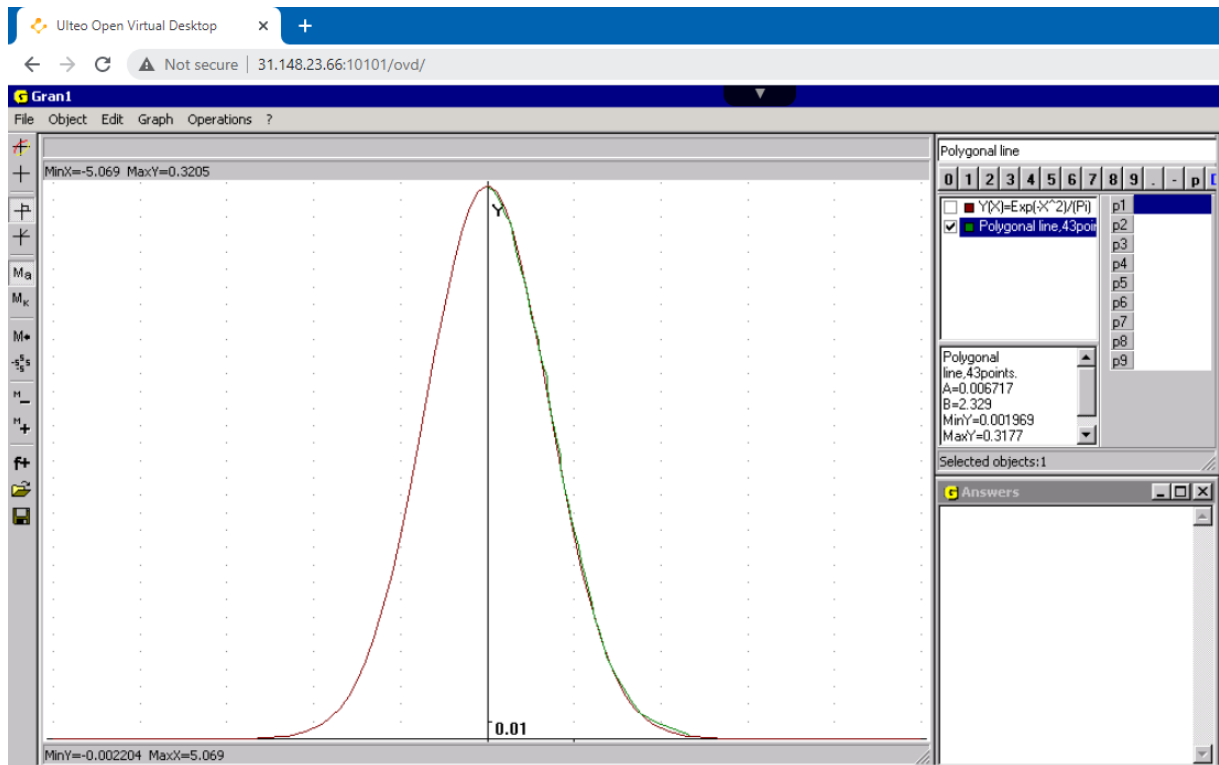


Figure 14. "Polygonal line" plot.

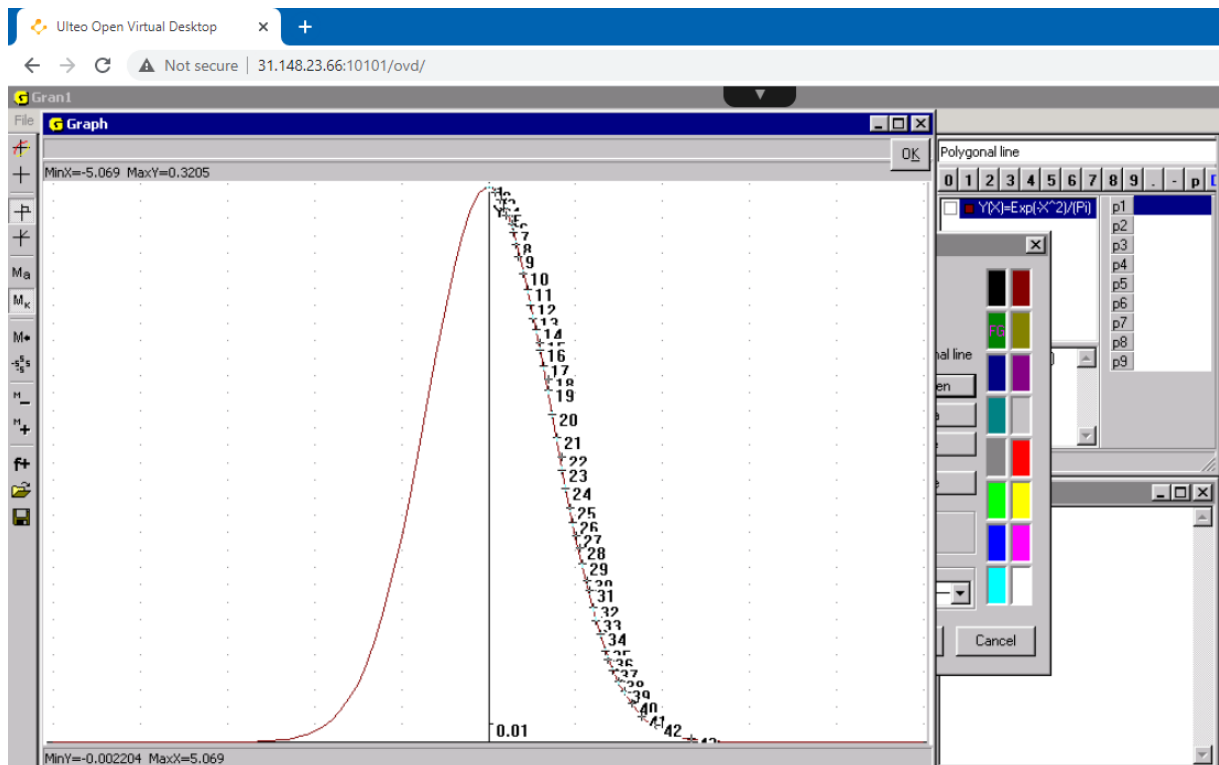


Figure 15. Plot with numerical markers.

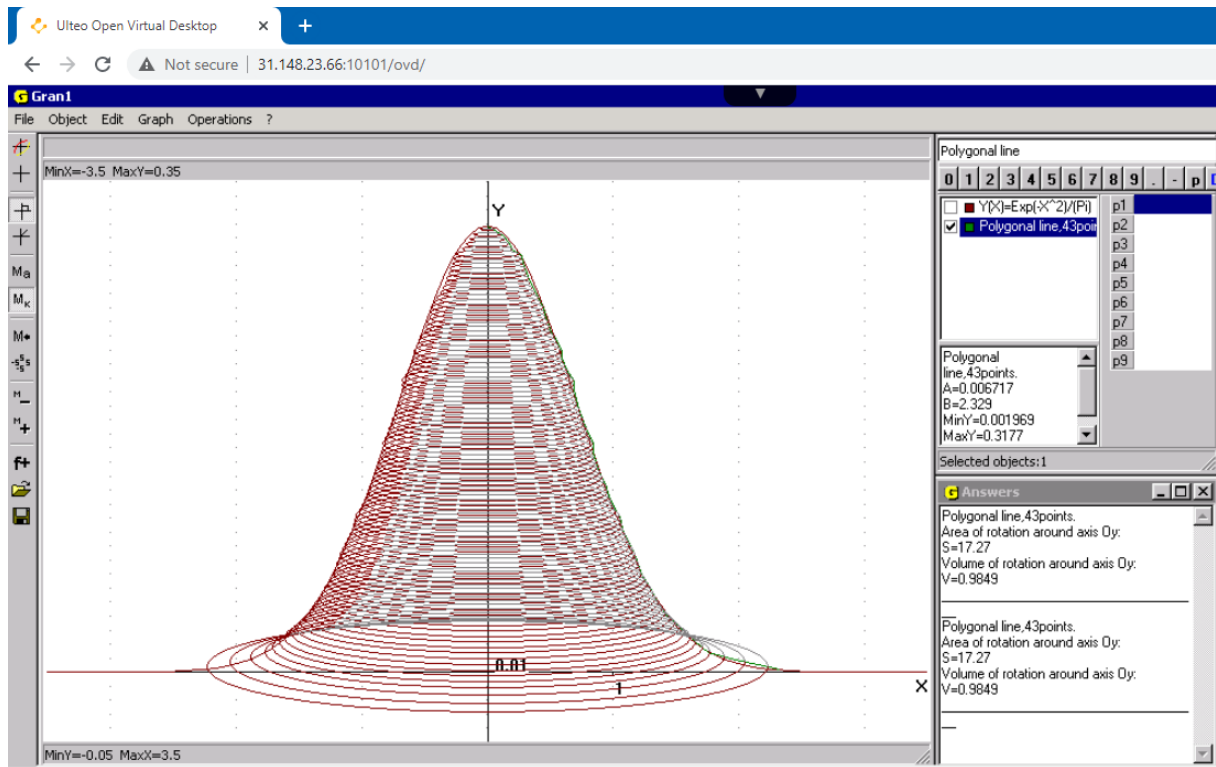


Figure 16. Approximate value of the integral $\iint_G \frac{1}{\pi} e^{-(x^2+y^2)} dx dy - V = 0.9849$.

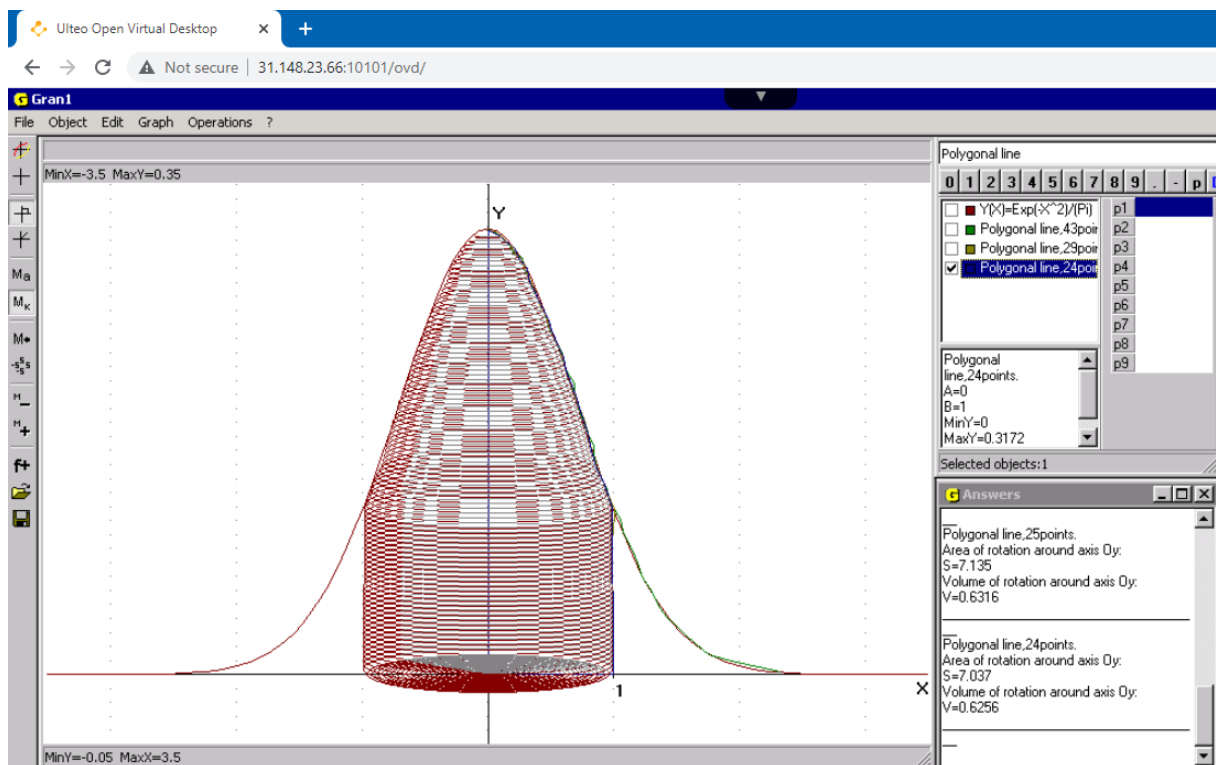


Figure 17. Example of calculating the probability of hitting a circle of radius 1 with the center.

In case, where necessary to calculate the volume of the body under the surface $Z = f(x, y) \geq 0$ over a circle of radius $r < R$, should be achieved, so that the abscissa of the rightmost vertex of the polygonal line is equal to r and further indicate another vertex on axis OX with coordinates $(r, 0)$. Then find the volume of the body of rotation of the thus formed polygonal line around the axis OY . In figure 17 shows an example of calculating the probability of hitting a circle of radius 1 with the center. Provided that on the plane XOY the probabilities are distributed with density $f(x, y) = \frac{1}{\pi} e^{-(x^2+y^2)}$. This probability is approximately equal to 0.6256.

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Problems and prospects of distance learning in teaching fundamental subjects to future Mathematics teachers

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Problems and prospects of distance learning in teaching fundamental subjects to future Mathematics teachers

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Abstract. The research analyzes experience of implementing the courses *Mathematical Analysis* and *History of Mathematics* for future Mathematics teachers in the system of managing electronic academic courses (SMEAC) at Kryvyi Rih State Pedagogical University (KSPU). To create the courses, there is a block-modular approach enabling not only structuring the process of studying fundamental mathematical subjects in the distance form of training, but also controlling the rate and depth of students' mastering the material. There are examples of laboratory works on *Mathematical Analysis* performed by students independently in the computer mathematics system CoCalc.

1. Introduction

Distance learning started in the 18th century and has been demonstrating positive dynamics for the whole period improving its forms, methods, educational resources and the content-structural component. Since the emergence and development of the Internet and global informatization of society, distance learning and online teaching have been accentuated [13]. This has been caused by the worldwide situation in the current 2019/2020 academic year.

There are three keys, in our opinion, aspects of distance learning. First, this is a learning process, which means that it is characterized by the essential characteristics of the educational process (the two-sided nature of the process (teaching – learning), joint activities of subjects, a special systematic organization of the entire process, education and development of students in the learning process). Secondly, the remoteness of this process, that is, the implementation of training can occur at a distance between the subjects. And finally, interaction, which involves the implementation of systematic feedback between the teacher and the student. In the absence of at least one of the above aspects, talking about the implementation of distance learning, in our opinion, is not entirely correct.

Today, the complicated epidemiological situation makes students switch over to distance learning, this causing intensive development of the distance learning system (DLS). Thanks to the emerged mobile information and academic medium based on modern information technologies, the DLS enables emergence of an essentially new level of availability of education while preserving its quality under pandemic conditions [4].

Subjects of distance learning involve all the participants of the joint distance learning process irrespective of their location. This learning mode results in their obtaining and creating their own system of knowledge, skills and personal features.

The DLS is a systematic aggregate of data transmission tools, information resources, interaction protocols, software and hardware tools and those of managerial and methodological support aimed to



satisfy users' academic needs. The system includes subjects directly or indirectly interacting in the academic process; the content determining the subject matter of their interaction; tools ensuring communication of a learner and a teacher who accomplishes renewed functions of management, correction and regulation [7].

The system is based on a structured set of goals, functions, tools, techniques, requirements and conditions of their effective interaction as well as factors influencing their efficiency.

Distance learning as a system of arranging a purposeful interaction of learners, teachers and learning tools can be presented as a set of three basic subsystems, each of them comprising certain components. The didactic subsystem is the primary and the basic one. It includes the components typical of traditional training – goals and the content of training, forms, methods, tools and principles of their implementation in the academic process. Yet, each of these components has its own specific features reflecting both their content and distribution of their roles and frequency of application to the academic process.

Their movement in the learner's mastering of knowledge and skills is accomplished in teacher-learner interaction through the training content and applied tools specific features of which change the character of teacher-learner interaction, their functions, the role, the place and the meaning in accomplishing the set goals [12].

It should be noted that application of distance learning to teaching fundamental subjects is efficient under the following conditions [12]:

- availability of the training and method basis in its full volume;
- expedient and competent combination of distance and contact forms of training;
- efficient control over quality of students' mastering the training material;
- an individual choice of training technologies by academic process participants.

Kryvyi Rih State Pedagogical University (KSPU) does its best to provide fulfillment of the mentioned conditions to the fullest extent. In order to improve efficiency of distance learning, students should master basic methods, ways and tools of data obtaining, storing and processing, skills of working on the computer as a means of managing information in the Internet and corporate information systems, which is finally determined as the data competence to be mastered.

Implementation of innovative information and communication technologies into the academic process enhances formation of a future Mathematics teacher's information competence.

The massive transition of all participants in the educational process to the format of distance learning undoubtedly indicates the need to study and generalize its results. First of all, the quality of assimilation of educational material by all students is important. The given paper is an attempt of systematizing experience of implementing the courses *Mathematical Analysis* and *History of Mathematics* into the system of managing electronic academic courses (SMEAC) at KSPU.

The suggested block-modular approach aims to develop and activate students' independent work through introducing Moodle as environment for electronic training, distance learning and testing [12]. Moodle aimed primarily at arranging teacher-student interaction is a center of creating learning materials and providing interaction of training participants [17].

For this reason, this article is aimed at studying problems and prospects of implementing the block-modular approach of distance learning into the process of teaching fundamental subjects to future Mathematics teachers.

2. Experience of implementing the course *Mathematical Analysis*

The fundamental subject *Mathematical Analysis* comprises six training courses:

- *Mathematical Analysis* 1;
- *Mathematical Analysis* 2;
- *Mathematical Analysis* 3;
- *Mathematical Analysis* 4 – figure 1 [3];
- *Mathematical Analysis* 5;
- *Mathematical Analysis* 6 [2].

Each of the courses corresponds to an academic term. Let us consider implementation of distance learning in the SMEAC at KSPU [9].

All these courses consist of three training modules. Each module is divided into thematic blocks containing theoretical materials with detailed examples of applying theory to solving practical tasks. Theoretical data are presented as PDF files, a block being a single file. They are based on the electronic training and method set developed by the Department of Mathematics and Methods of its Teaching at KSPU in the previous years.

Each module of the training course is finalized with self-training tests in a separate block and obligatory control tests on the training module materials. Self-training tests enable a student to evaluate the degree of knowledge mastering and, if necessary, eliminate gaps. Control tests are the same as test papers checked by University teachers manually. Test sheets containing too many mistakes are returned, while the teacher analyzes students' mistakes and tells them which themes and issues are to be revised for them to get a positive mark.

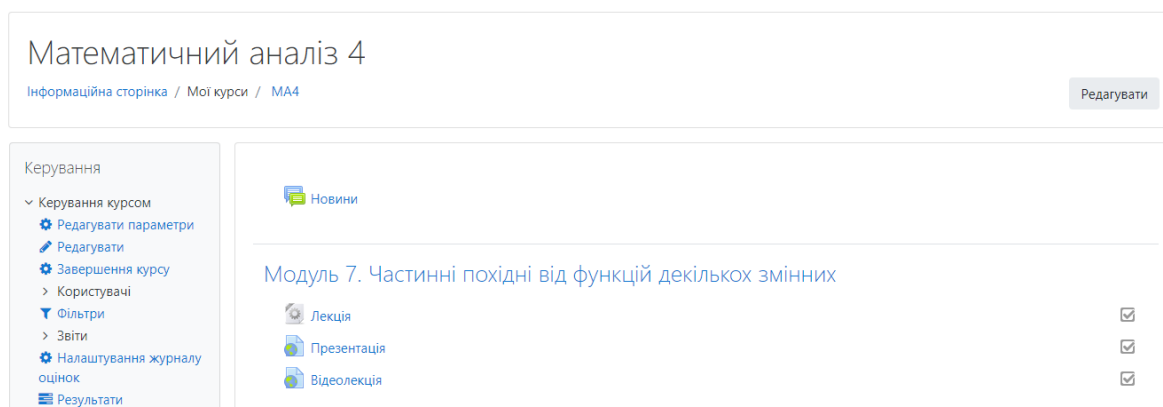


Figure 1. The fragment of the page with learning materials for the course *Mathematical Analysis 4*.

Each part of the course for both full-time and distance forms of training contains relevant test questions.

Test questions are of two types – offline tests assessed by the teacher and online tests assessed by the Moodle [10]. The number of questions per test can vary. Offline tests are a set of tasks (from 5 to 8) given entirely to a student without any answer options. The student is to send all solved tasks as a PDF file, a handwritten solution scanned being preferable. Solutions sent are assessed by the teacher.

Online tests are a form of traditional testing when tasks or questions are provided one by one to a student. There are either many answer options to select the right one (multiple choice) or just two options (True/False) or there is a space to enter the correct answer (number). There are no other task types provided like conformity or choosing a graphic answer on the current stage. Each task is assessed separately with the subsequent total score calculated [14].

Of course, offline tests are preferred as they are similar to ordinary tests used to assess students' knowledge in the traditional form of training.

To obtain objective results of current testing in each test, testing parameters are adjusted, including:

- 1) time per attempt is limited depending on the complexity of a test (time is not limited by default);
- 2) the total number of attempts is set (i.e. the ordinary test envisages one attempt, the training test – three attempts);
- 3) a passing score is set;
- 4) the time interval between attempts is set (the authors set a two-day interval as the next attempt should be made after revision only);
- 5) the method of determining the final score between the assessed attempts is chosen (i.e. the best score or the average one).

As the Moodle possesses various options to process test results (assessment scales to be set, the mechanism of result revision when the teacher corrects test tasks after a student's attempt, tools to analyze testing results), there is an opportunity to analyze the quality of test questions from the viewpoint of their efficiency in knowledge assessment. Test results are presented in the score report containing final scores for all tests of the course. The report can be detailed for each student and also each of his/her attempts can be considered separately (the answer selected or entered, time of obtaining the question and time spent to obtain the answer).

Courses on *Mathematical Analysis* are focused on application of information technologies to the training process. There is a system of laboratory practicums with students using the computer mathematics system CoCalc applied to complicated projects being suitable to perform calculations [16]. CoCalc [14] provides students with templates to perform a laboratory work. Following the instructions in commentaries, students enter their input data and, after checking out, they analyze solutions. The course *Mathematical Analysis 3* provides for the laboratory practicum developed by the authors with the following structure.

Laboratory work 1. "Calculation of a definite integral".

The example of a template:

```
integral(1 + x + x^2, x)
numerical_integral(1 + x + x^2, 0, 3)[0]
```

The result of the problem $\int (1 + x + x^2)dx$ and $\int_0^3 (1 + x + x^2)dx$ is in figure 2.

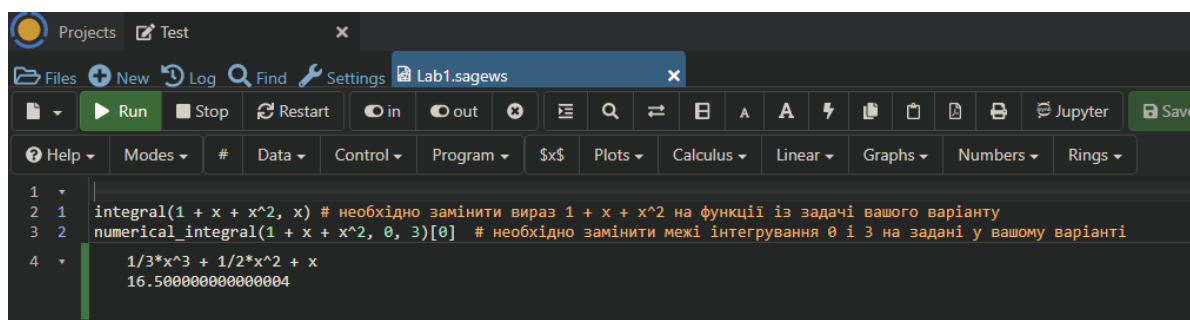


Figure 2. The fragment of the page with Laboratory work 1.

Laboratory work 2. "Calculation of a definite integral through integrating by parts".

The example of a template

```
integral(exp(x)*sin(x), x)
numerical_integral(exp(x)*sin(x), 0, 1)[0]
```

The result of the problem $\int e^x \sin(x) dx$ and $\int_0^1 e^x \sin(x) dx$ is in figure 3.

Laboratory work 3. "Integration of rational functions".

Laboratory work 4. "Integration of irrational functions".

Laboratory work 5. "Calculation of the plane curve arc length".

The example of a template

```
x = var('x')
parametric_plot((3*cos(x), sin(x)^3), (x, 0, pi), rgbcolor=hue(0.6))
numerical_integral(sqrt(diff(3*cos(x), x)^2 + diff(sin(x)^3, x)^2), 0,
pi)[0]
```

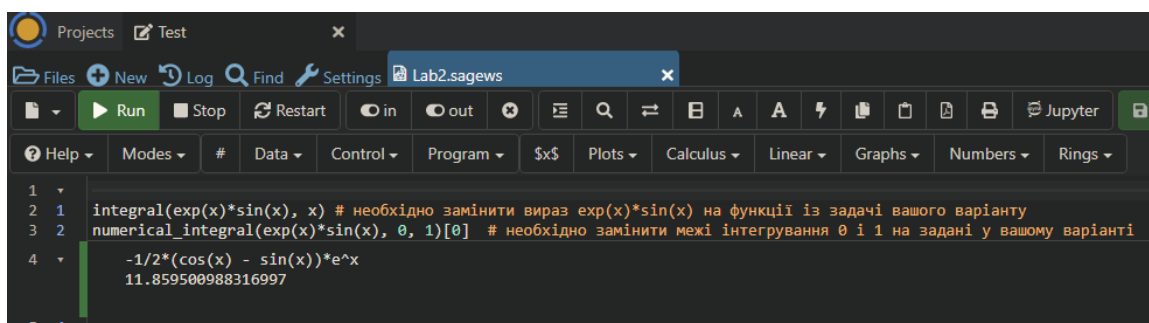


Figure 3. The fragment of the page with Laboratory work 2.

The result of the problem “Calculate curve length $\begin{cases} x(t) = 3 \cos t, \\ y(t) = \sin^3 t; \end{cases} t \in [0, \pi]$ ” is in figure 4.

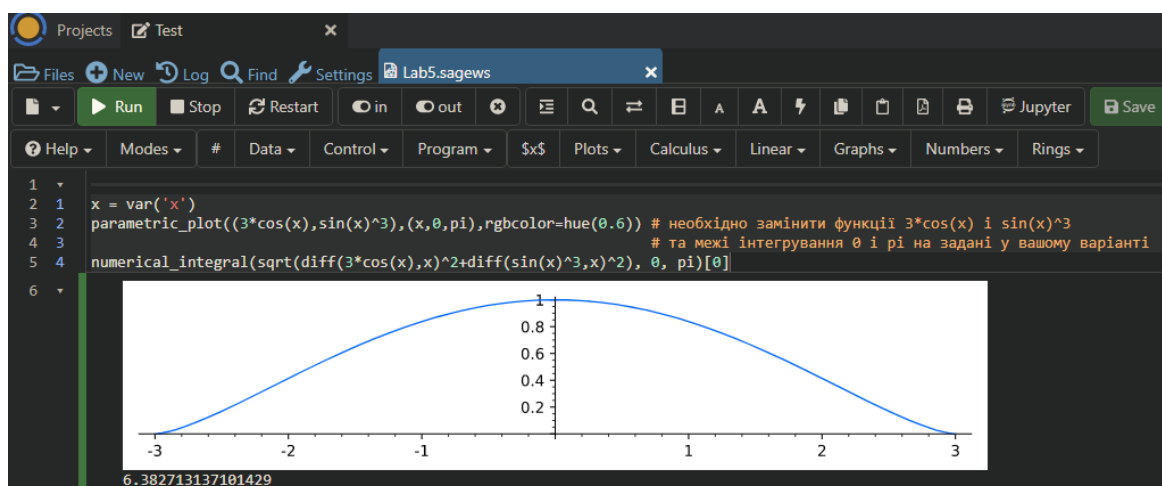


Figure 4. The fragment of the page with Laboratory work 5.

Laboratory work 6. Calculation of squares of plane figures”.

The example of a template

```
plot(sin(x)^3, (0, pi))
numerical_integral(sin(x)^3, 0, pi)[0]
```

The result of the problem “Calculate area $y = 0, y = \sin^3 x$ ” is in figure 5.

Information technologies play an essential part in developing students’ space-graphic culture. Particularly, the computer mathematics system CoCalc enables students to model 3D geometric objects and comprehend the role of information technologies in solving mathematical problems.

3. Experience of implementing the course *History of Mathematics*

Let us consider implementation of the course *History of Mathematics* in the SMEAC at KSPU [16]. Nowadays, it is impossible to imagine a Mathematics teacher’s activity without studying history of this science.

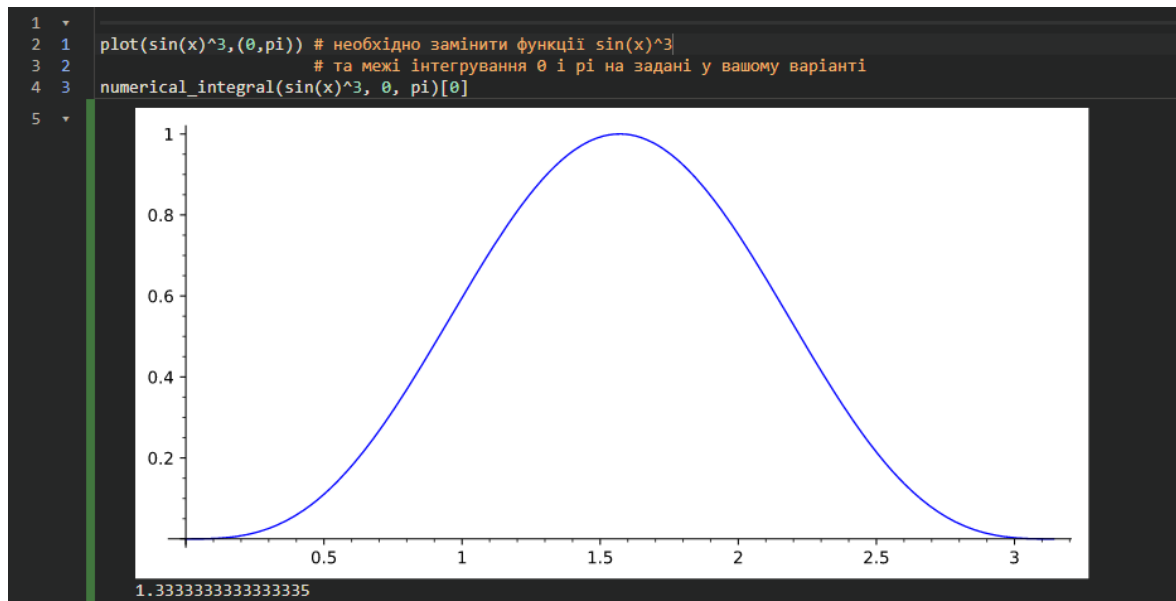


Figure 5. The fragment of the page with Laboratory work 6.

Currently, *History of Mathematics* as a historic subject is referred to humanities and applies not comparative but absolute categories (the time series “it was-it is-it will be”, the spacious characteristics “here-there”), tends to use pure descriptions and discusses the past from the viewpoint of the present [6]. On the other hand, a number of modern mathematicians, while confirming the thesis of *History of Mathematics* as a historic science, compliment it with the idea that it is also a fundamental mathematical subject. “Now, its primary task is to define regularities of emergence and development of mathematical ideas. Naturally, with this respect, people with both specific mathematical training and experience of their independent scientific work can succeed in dealing with *History of Mathematics*” [5] (hereinafter the translation is ours).

Studying *History of Mathematics* enables distinguishing general principles of developing the mathematical science, determining external and internal factors of evolution of scientific theories. Any science evolves is constantly evolving. There is continuity of ideas as new scientific theories result from criticizing the previous ones. A lively talk in class is an essential component of the training process that is difficult to be implemented in distance learning.

Besides, application of elements of *History of Mathematics* to a secondary school course is efficient for forming schoolchildren’s cognitive interest, this rising requirements to the level of professional training in this field of a future Mathematics teacher’s activity. Therefore, creation of the distance course on *History of Mathematics* at a pedagogical higher educational institution is a priority from the professional viewpoint.

Nowadays, methodological problems are highlighted in teaching *History of Mathematics* at universities. There are some criteria of selecting the course content at a pedagogical higher educational institution [15]:

- methodological orientation;
- general cultural orientation;
- professional and pedagogical orientation;
- conformity of themes with syllabuses of mathematical subjects;
- minimization.

These criteria are used as the basis for creating the distance course *History of Mathematics* in the SMEAC of KSPU, conformity of themes of the course *History of Mathematics* with syllabuses of mathematical subjects being highlighted. The course content includes issues related to the history of

development of basic sections of classical mathematics and elementary mathematics, which are part of subject training of students of Speciality 014 Secondary Education (*Mathematics*). Each mathematical course discloses to future school teachers a whole world of notions and results which should be perceived from the viewpoint of their emergence and development. This enables integration of fundamental mathematical subjects into the SMEAC of KSPU, which is to be implemented in the nearest future. *History of Mathematics* is presented as an integrating, systematizing subject taught after studying basic fundamental subjects. Students can compare Newton's "fluxions" theory and Leibnitz's theory of infinitesimal Mathematical Analysis, etc.

While creating the course, it was also important to consider the minimization criterion, which required thorough selection of the course content to achieve necessary minimum data due to time limitation accompanied by large notional load.

The content of the course *History of Mathematics* aims to form a future Mathematics teacher's competence, including:

- free operation of historical and mathematical facts, extension of historical and mathematical scope;
- mastering methodological knowledge on history of the science;
- the ability to apply historical and mathematical knowledge to new situations (pedagogical, method-related, training);
- the ability to design training content to teach students.

In the SMEAC of KSPU, the subject *History of Mathematics* consists of two training modules. Each module is divided into thematic blocks containing theoretical materials, presentations and seminar materials.

At the end of the course, there are five tests containing five tasks (two variants per test).

The screenshot shows a web interface for a course titled "Історія математики". At the top, there is a breadcrumb trail: "Інформаційна сторінка / Курси / Фізико-математичний факультет / Кафедра математики та методики її навчання / Ist_matem". A "Редагувати" button is visible in the top right corner. On the left, a sidebar menu under "Керування" includes options like "Керування курсом", "Редагувати параметри", "Редагувати", "Завершення курсу", "Користувачі", "Фільтри", "Зати", "Налаштування журналу оцінок", "Результати", "Відзнаки", "Резервна копія", "Відновлення", "Імпорт", "Очистити", and "Банк питань". The main content area shows "Новини" (News) with a "Робоча програма з курсу 'Історія математики'" (Course program for 'History of Mathematics') and a section for "МОДУЛЬ 1" (Module 1). This section lists several items, each with a checkbox: "Лекція 1 ПРЕДМЕТ І МЕТОД ІСТОРІЇ МАТЕМАТИКИ. ПЕРІОДИЗАЦІЯ РОЗВИТКУ МАТЕМАТИКИ", "Презентація до лекції 1", "Семінарське заняття 1", "Лекція 2 ПРОЦЕС ЗАРОДЖЕННЯ МАТЕМАТИКИ. РОЗВИТОК МАТЕМАТИКИ СТАЛИХ ВЕЛИЧИН. ПЕРШІ МАТЕМАТИЧНІ ТЕОРІЇ", "Семінарське заняття 2", "Презентація до лекції 2", "Лекція 3. РОЗВИТОК МАТЕМАТИКИ В ЄВРОПІ В СЕРЕДНІ ВІКИ (ЕПОХА ВІДРОДЖЕННЯ)", "Презентація до лекції 3", and "Семінарське заняття 3".

Figure 6. The fragment of the page with learning materials on the course *History of Mathematics*.

To obtain objective results of the current check of knowledge for each test, testing parameters are set:

- 1) time per attempt is limited (15 minutes by default);
- 2) the total number of attempts is set (one attempt);
- 3) the passing score is set.

4. Conclusion

The stated results are a partial generalization of the department's experience in ensuring the fundamental nature of the education of future Mathematics teachers. This approach is illustrated by the example of

teaching *Mathematical Analysis* and *History of Mathematics*. The fundamental nature of education is effectively supported by the use of Moodle. Distance learning technologies for daytime education make it possible to study independently and organize a continuous learning process in accordance with the principles of open education. The Moodle LMS, thanks to its flexible technical capabilities, meets the requirements of the modern educational process. Distance learning technology for *Mathematical Analysis* and *History of Mathematics* on the Moodle helps to develop the competencies of students. The multimedia educational material, located on the Moodle, allows you to create more favorable conditions for improving the professional competencies of students, to improve their proficiency in various types of professional activities in this and related disciplines. The possibilities of the Moodle LMS as one of the tools are substantiated: for the development of the student, self-learning and self-development, for individualized modular training and collective solution of educational tasks, for the exchange of knowledge, for the process of monitoring the level of competence formation and regular reporting.

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Comparative Geometry in distance education

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Comparative Geometry in distance education

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Abstract. I have been working on an educational project called Comparative Geometry for decades. The project is based on teaching and learning plane geometry and spherical geometry simultaneously, mainly through direct experimentation with hands-on tools, and intensive use of discussion between classmates. This work has gravely been affected by the changes that occurred two months ago because of the pandemic, still causing emergencies in many areas of education. In this article, I describe how I tried to adapt the work of a university course to an emergency; the methods by which I enabled direct experimentation and personal communication that were not possible in the given situation; my efforts to reduce the drawbacks of the situation and take advantage of the potential benefits.

1. Introduction

The fundamental idea of the Comparative Geometry project is to teach and learn two (or later more) different systems of geometry simultaneously. Students compare and contrast concepts and theorems in two or more different worlds of geometry, as in the book of David W. Henderson and Daina Taimina for university students [3], or my book for upper elementary and secondary school [4], or the book of Anna Rybak and István Lénárt for the interested layman and the professional teacher as well [5].

Comparative Geometry starts with the Euclidean geometry of the plane and the Menelaosian geometry of the spherical surface. Both of them have their origins in the antiquity.

However, in the past two millennia Euclidean geometry has maintained absolute dominance in the European cultural and educational tradition. Spherical geometry had been involved in secondary education until the middle of the twentieth century, because of its applications in geography, navigation, astronomy and art, but then gradually was pushed out of the school curriculum. Only in recent years has it returned in a completely subordinate role to plane geometry and in science popularization books such as Glen Van Brummelen's work [9].

As for hyperbolic geometry, it has only recently earned an aside in the secondary curriculum, partly due to its role in modern physics, partly as an example of "imagining the unimaginable". To this date, spherical geometry is just as strange and unimaginable for the vast majority of students as hyperbolic geometry used to be for scientists of the first half of the 19th century.

In Hungary, teaching about Comparative Geometry in colleges and universities started three decades ago at ELTE University, Budapest, in the form of an elective course, under the name "Ball geometry". Participants are prospective teachers in primary and secondary schools. During the years many future kindergarten teachers have also attended, together with many Erasmus students from



different parts of the world.



Figure 1. Erasmus students experimenting with spherical construction materials.



Figure 2. Presentation for 350 pupils in Copernicus Science Centre, Warsaw, with Anna Rybak (University of Białystok, Poland).

2. Syllabus of the course

One semester consists of about 10-11 lessons, 90 minutes each.

The material of the course has continuously been changing, but it has boiled down by now to the following list of topics:

- Basic idea and goals of comparative geometry on plane and sphere. (The ideology behind the educational project.)

- Freehand drawing on the sphere, with students' spontaneous insights about important concepts of spherical geometry that should be studied later during the course.
- Point and straight line on plane and sphere. (Perhaps it is the most difficult transition for the student to accept a new interpretation of the term "straight".) Parallels and perpendiculars.
- Distance on plane and sphere. Circles on plane and sphere. Concentric circles. Point, opposite point and equator.
- The draw-on globe: a blank map of the earth that can be drawn and wiped off, to estimate distances and areas, create illustrations to geography, history, environment, transportation, etc..
- The concept and measurement of angle on sphere and plane. (Another crucial topic that is easier to approach first on the finite sphere, only then turn to the infinite plane.)
- Polygons on plane and sphere. Biangle (or digon or lune) which is one of the big surprises for the beginner.
- Triangle and Euler triangle. Sum of sides and sum of interior angles.
- Congruence of triangles: side-side-side, side-angle-side, angle-side-angle. (Essentially the same on plane and sphere)
- Congruence of triangles: angle-angle-side. (Stark difference between plane and sphere.)
- Congruence of triangles: side- side-angle. (Essentially the same on plane and sphere.)
- Congruence of triangles: angle-angle-angle (Stark difference between plane and sphere.)
- Quadrilaterals on plane and sphere. (Trapezium, parallelogram, rhomb, rectangle, deltoid, square.)
- Measurement of area on the plane and on the sphere.

3. Background and methodology

As can be seen on the pictures above, the entire project is built on direct experimentation with hands-on natural and artificial tools. In addition, personal communication, friendly atmosphere, the right to err and to correct errors on the side of the student and (surprisingly) of the teacher is of vital importance in the course.

Before the pandemic, whenever it was possible, I have always tried to inspire students to conduct independent research, free and informal conversation in the classroom, and even a lively debate on the concept at issue. Manipulative tools were extremely helpful to reduce the leading position of the lecturer and the percentage of frontal presentation. I often hid out of sight of students, sitting in the back row of the lecture hall to help students perceive their own central role, appreciate their own results, instead of expecting the ultimate truth from the lecturer.

Another important factor was the extremely diverse knowledge of the participants, especially those arriving from another country with different curricula in mathematics. Some students admitted that they had never heard of Euclid, while others were well versed in Euclidean geometry. There was one point where everyone agreed: They had almost no knowledge about spherical geometry, let alone other geometries.

The situation changed dramatically due to the pandemic which hit the Hungarian educational network in mid-March 2020. Teachers and students had to switch to distance learning overnight, which was a largely unknown, unusual way of communication. It is worth noting that I myself participated in my first Zoom conference during these weeks.

The sudden change had a serious impact on the Ball geometry course, a total of 29 students, including 5 Erasmus students from Spain, Italy, Switzerland and Iran. The direct experimentation with hands-on tools, discussion and debate among classmates became very difficult in the unusual circumstances of distance learning.

In this emergency, the program was changed as follows: Each week, students received the elaboration of the next topic, with questions and related tasks. The received material had to be returned with students' own comments, questions, solutions, to which I answered again, with the necessary

explanations and corrections. With this indirect communication, I tried to make up for the personal encounter with the students. These elaborations were not graded.

Grading and evaluation took place at the final exam. Before the pandemic, it took a mixed form of oral and written communication in the classroom. This procedure was not feasible in an emergency situation. Instead, each student received a topic that she worked out on 1-3 pages. In addition, I put together a collection of 17 exercises from which each student solved three tasks of her own choice. (I made sure it wasn't possible to pick three that were too easy to solve.)

Students were expected to send their work to me. I commented on the tasks, but did not fully solve them (as seen below), and offered a mark that could be changed if the candidate returned an improved work.

4. Sample topic from those that I sent to the students every week

Following is a part of the topic “Angle and angle measurement”. Hopefully this detail illustrates the content and style of the descriptions. I reiterate that the text is also intended for those who have problems with the basic concepts of Euclidean geometry.

4.1. Angle and angle measurement

Summary of what we have done before:



Figure 3. Simplest line:
Plane: Straight line;
Sphere: Spherical straight line/Great circle = greatest circle on the sphere.

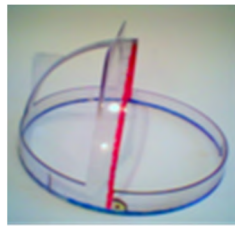


Figure 4. How to draw a simplest line: Plane: Planar ruler; Sphere: Taut string/rubber band on an orange, Scaled edges of a spherical ruler.



Figure 5. Distance of two points: Plane: Length of straight segment between the points; Sphere: Length of minor arc of great circle between not opposite points.



Figure 6. Distance of two opposite points on the sphere: Any meridian that connects the points.



Figure 7. Unit of distance: Plane: Arbitrary (finite) segment; Sphere: 1 circumference/equator, but we choose 1/360 equator = 1 degree. Full great circle 360°, opposite points 180°. Same unit on smaller or bigger spheres.



Figure 8. Circle: Plane: Locus of equidistant points from a point of centre on the plane; Sphere: Locus of equidistant points from a point of centre on the sphere.



Figure 9. Concentric circles with the same centre: Plane: No straight line among them. No two different circles with equal length of perimeter. Sphere: Circle of radius 90° is a great circle/straight line. Each small (= not great) circle has a mate of the same length (Tropic of Cancer and Tropic of Capricorn).



Figure 10. Pole and equator (also called pole and polar): Plane: This correspondence exists between points and straight lines, but much more complex than on the sphere. Sphere: Each spherical point has an opposite point and an equator. Each great circle/spherical straight line has two pole points.

Following are questions, explanations and exercises. Answers and solutions to the questions are in the text after the given question.

Important request: **DO NOT READ FURTHER** the text to the answer/solution before you think it over and write your opinion. This is the best way to really understand it. Please do not spoil the game!

4.2. *Concept of angle*

This is one of the most difficult and most obscure concepts of elementary geometry not only for kids, but also for university students and even practicing teachers – why?

Typically, the concept of measuring geometric objects begins with measuring distance, angle, and area. In plane geometry, the unit of distance is a segment, a piece of a finite line. Likewise, the unit of area (as we will see) is a finite unit square. In contrast, the unit of the angle region on the plane is an infinite region that cannot be fully displayed on a sheet of paper or a computer screen. However, the child (and the adult) only sees the finite region and derives its properties based on what he actually perceives on the image.

Question 1: What is an angle?

“An angle is a circle that we draw in the corner of the angle.” Nonsense! If the angle is actually a circle, why should we treat the angle separately? Also, where exactly is the corner of the angle where we put the circle?

READ FURTHER ONLY AFTER WRITING YOUR OPINION!

Given a flat surface or a spherical surface, we select a point on it, and draw two segments/arcs from that point. We extend them until the surface is divided into two separate regions.

On the plane, we have to extend the two segments into two infinite rays in both directions. Should we stop at a finite point, we only cut into the infinite sheet of paper, but did not split it into two separate regions.

Question 2: How far should we extend the two arcs on the sphere?

READ FURTHER ONLY AFTER WRITING YOUR OPINION!

Luckily, we don't have to go to infinity, but only to the opposite point where the two spherical straight lines meet, and the surface is decomposed into two spherical regions.

Question 3: How much larger is the area of a 90° angle region on the plane than that of a 30° angle region?

READ FURTHER ONLY AFTER WRITING YOUR OPINION!

They have no measure of area at all! The area of both domains is infinite and immeasurable, just as we cannot compare the lengths of two rays or half-lines. Therefore, angle measurement on the plane does not compare the area of angle regions. If we say, “A 90° angle region is three times as large as the 30° angle region,” this means that three 30° plane angle regions can be placed onto the 90° angle region without gaps and overlaps, but it says nothing about their measure of area. Probably the main reason of the problems with the concept of angle is that we can compare two infinite angular regions on the plane so that we miraculously get a finite number out of this comparison.

As a possible way out of this dilemma, we suggest introducing the concept of an angle first on the sphere and then turning to the planar case. The finite spherical surface precedes the infinite flat surface which makes certain angle issues easier to understand and visualize, especially for children.

4.3. *Angle region on the sphere*

Question 4: Draw a point on the sphere and two arcs of great circles from this point. Extend the two arcs until they meet again. How long will they be? How many parts is the surface of the entire sphere divided into? Try the same with an orange by cutting a piece out of the peel!

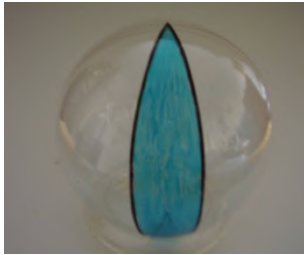


Figure 11. A biangle on the plastic sphere.



Figure 12. A biangle cut out from an orange peel.

READ FURTHER ONLY AFTER WRITING YOUR OPINION!

5. Some exercises worked out by students for the exam and my answers

Students were definitely asked to describe the steps that led to the solution rather than just delivering the end result. The Euclidean part of the exercises was correctly solved in most cases, although the clarity of the description has changed from almost childish wording to mathematically correct notation. The spherical counterpart was much more difficult, due to the adherence to the Euclidean way of thinking, and problems of orientation in another world of geometry.

In the examples below I give the full correspondence between the student and me regarding the exercise chosen by the student.

Exercise 1: What is the sum of exterior angles in a spherical triangle?

First exchange of messages:

Student: In the plane: If we take a regular triangle on the plane, all three angles will be 60° . the sum of the original angle and the additional angle is 180° , so all we need is to subtract 60° from 180° to get the number of additional angles. With this method, we see that the additional angle of one of the three interior angles will be 120° ($180-60$). The exercise asks about the sum of the supplementary angles of the plane triangle, so I multiply 120 by 3, since we have a total of three angles in the triangle. As a result, I obtained that the sum of the additional angles of a regular planar triangle is 360° .

On a sphere, I tried to indicate the supplementary angles by drawing a regular triangle out of paper (with 4-4-4 cm sides) and then redrawing it on the sphere (figure 13). I stuck toothpicks in the tops to keep the rubber bands fixed on the surface.

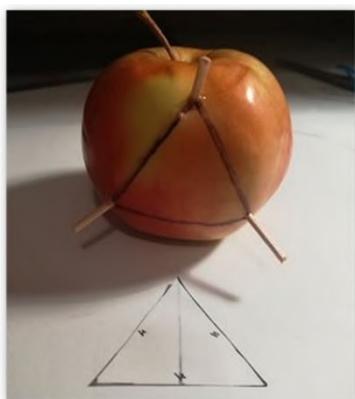


Figure 13. Student's illustration to constructing a regular triangle on plane and sphere.

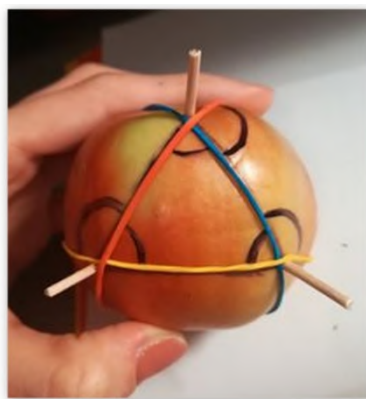


Figure 14. Student's illustration to interior and exterior angles of a triangle.



Figure 15. Student's illustration to regular spherical triangles.

The rubber bands were used to lengthen the sides of the triangle, thus helping to draw supplementary angles, as seen on my second picture (figure 14). If we add the original angle to the supplementary angle, we get 180° . The procedure will be the same as on the plane. The only difference is that the internal angles are not so easy to calculate, because the sum of the internal angles is not a fixed number. Even if I know the lengths of the sides, I can't be sure of the sum of internal angles, as their sum can range up to 540° .

I apologize because I am not sure about this solution. Maybe it was not a good idea to start from a plane triangle on a sphere. I chose this exercise as my last task because I felt it was a big challenge for me, but I might have cut more than I could chew.

Teacher: You made a huge mistake: You didn't trust yourself! The reasoning is logical, the figures are also illustrative. You wrote: "Even if I know the lengths of the sides, I can't be sure of the sum of internal angles, as their sum can range up to 540° ." What will be left for poor supplementary angles, then?

Second exchange of messages:

Student: In this case, we are talking about a regular triangle, where I think the inner angle on the sphere is also 60° , because I started from a plane triangle. Thus, the sum of the supplementary angles is 360° . For regular triangles, where all interior angles are the same on the sphere, the sum of the additional angles is 360° , but this is the minimum value. I calculate the maximum by dividing 540 by 3, and get 180° , can this be the size of an angle at all, if it's just a straight line, a great circle on a sphere?! If I continue to use this value as a basis, I won't get a supplementary angle, i.e. it will be 0° , since I don't have to add 180 to anything to be 180. The sum of the maximum supplementary angles is therefore 0° (figure 15)."

Teacher: Exactly! When the triangle is rounded to a triangle with three 180° angles, the supplementary angles flatten to zero and fit onto the equator.

Exercise 2: Each angle of a regular polygon is 120 degrees. How many sides does it have on the plane and on the sphere?

First exchange of messages:

Student: Six sides on plane and sphere. First I constructed it on a sheet of paper, and I got six sides. Then I constructed it on a sphere, and again I got six sides, but the construction did not work out exactly, that's why one side is smaller than the others. ($\alpha=120^\circ$)



Figure 16. Student's construction of a planar hexagon with angles 120° .



Figure 17. Student's construction of a spherical hexagon with angles 120° .



Figure 18. Student's construction to show that a spherical hexagon with angles 120° does not exist.

It can also be derived from the sum of the interior angles of regular polygons, e.g.: triangle: 180° , square: 360° , pentagon: 540° , hexagon: 720° , and so on. Then we multiply 120 by 3, 4, and so on. We are talking about a polygon that will be equal to that number. $6 \cdot 120 = 720$

Teacher: Oops! These angles belong to regular polygons on the PLANE – but what about the SPHERE? Maybe the construction on the apple was still correct?

Second exchange of messages:

Student: I tried again, but it is not possible to construct a regular polygon with all its angles 120° . I thought a lot (Teacher: You did it very well, that's the point!) about why it's not possible, but I didn't get an answer.

Teacher: Are you sure you can't? You started correctly by taking the sum of angles of a regular polygon, but you considered the polygons on the flat surface with fixed sum of angles. The picture is different on the sphere – remember? So, the question is: Which regular polygons with 120° angles are possible on the sphere?

Third exchange of messages:

Student: It can be a triangle, because $3 \cdot 120 = 360$ fits within the lower and upper limits of spherical triangles. It can be a quadrilateral, because $4 \cdot 120 = 480$ fits within the lower and upper limits of spherical quadrilaterals. It can be a pentagon: $5 \cdot 120 = 600$ fits within the limits of spherical pentagons. It can be a hexagon: $6 \cdot 120 = 720$ is the lower limit of the sum of angles in a spherical hexagon.

Teacher: Excellent! Two small comments: The spherical biangle is missing from your list. It is also a regular polygon and the angle $2 \cdot 120^\circ = 240^\circ$ fits well within the limits- As for the hexagon, you were right and wrong at the same time. You correctly wrote that $6 \cdot 120^\circ = 720^\circ$ is the lower limit, but such a hexagon only exists when it has degenerated to a spherical point. As soon as you leave the point to construct a larger regular hexagon on the sphere, the angles increase from 120° to 180° . Your construction on the apple was correct. The sixth side must be different!

Exercise 3: How many ways are there to cut a spherical biangle into two congruent triangles?

First exchange of messages:

Student: There is only one way for that. We cut the biangle along an axis of symmetry that is perpendicular to both semicircles. If we draw a line elsewhere that is right-angled on both semicircles, the two triangles will not be congruent, because one will be bigger than the other. If we draw a non-perpendicular line between the two semicircles, we get two different triangles again. ($a_1 = a_2$)

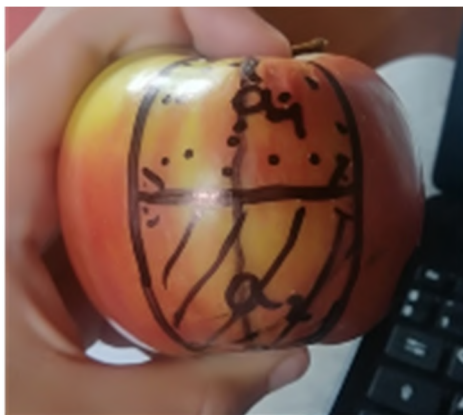


Figure 19. Student’s construction to show that there is only one way to cut a spherical biangle into two congruent triangles.



Figure 20. Student’s construction to show that there are infinitely many ways to cut a spherical biangle into two congruent triangles.

Teacher: Are you sure? Have you tried this on a real biangle? Besides, can you draw two different great circles which are both perpendicular to both sides of the biangle?

Second exchange of messages:

Student: There are an infinite number of such lines, but these lines must intersect the two semicircles so as to form the same angles. The line on the figure intersects one of the

semicircles at an angle labelled with one arc and another angle with two arcs. The same line intersects the other semicircle at two angles of the same measure respectively. Thus, two identical triangles are formed.

Teacher: Super! If you look at it more closely: Through which point of the spherical biangle does the intersecting line pass?

Third exchange of messages:

Student: The line must pass through the intersection of the two axes of symmetry, since the axes of symmetry cut the spherical biangle into two equal parts. And if the line passes through this point of intersection, the same triangle will be formed in both the vertical and horizontal directions.

Teacher: Faultless.

Exercise 4: Are there three points on the plane, any two of which have the same distance, so $AB = BC = CA$? And on the sphere?

Are there four points on the plane, any two of which have the same distance, so $AB = CD = AC = BD = AD = BC$? And on the sphere?

First exchange of messages:

Student: There exist three points on the plane where the distance of any two is the same. These points give a regular triangle.

It is also possible to find such points on the sphere. Same is the regular triangle. The distance between all its sides and all three points is equal.

There are no four points on the plane with the same distance. The square is not appropriate either, because it has two distances that are longer than the others. / the diagonals are longer than the sides of the square.

Teacher: Excellent.

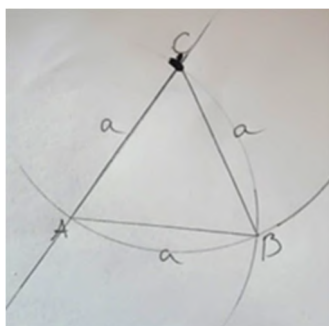


Figure 21. Student’s construction of a regular triangle on the plane.

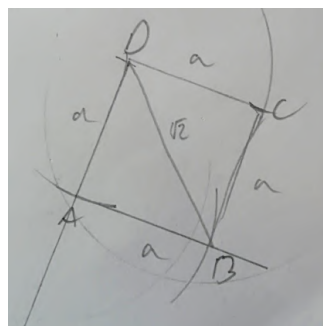


Figure 22. Student’s construction of a square on the plane.

$$AB = CD = AD = BC = AC = BD$$

Second exchange of messages:

Student: There are no four such points on the sphere either. We can nicely prove this by taking 4 points that are two by two on a spherical line, and these two points are opposite points. The two lines intersect at right angles.

At first, I thought that $AB = CD = AC = BD = AD = BC$. But on closer inspection and thought, I realized that this is not possible either, because the distance between the opposite points will be 180° , while between two adjacent points the distance will be 90° .

Teacher: You are absolutely right about this, but can you reach your goal in another way? If you still have four such points on the sphere, then surely any three of these points give a regular triangle, as you correctly proved already. So take the three vertices of a regular spherical triangle and construct the noteworthy point (centre of gravity, orthocentre, etc.) in the triangle. Fix this point and change the three vertices of the regular triangle. Does anything come out of this?

Third exchange of messages:

Student: I constructed a regular triangle, that is, $AB = BC = AC$. I constructed the orthocentre, which is also the centre of gravity in a regular triangle. Thus I get that $Am = Bm = Cm$. BUT, in this case AB is not equal to Am because $AB = AC = BC = 90^\circ$. $Am = Bm = Cm = \text{half of } 90^\circ = 45^\circ$. Thus, there are no four points, the distance of any two of which is the same.



Figure 23. Student’s first construction to show that there are no four points on the sphere so that each pair of points has the same distance.



Figure 24. Student’s second construction to show that there are no four points on the sphere so that each pair of points has the same distance.

Teacher: And if you left the point m where it is, but with the regular triangle you go BEYOND the equator?

Fourth exchange of messages:

Student: We can find four such points on the sphere if the fourth point is not the orthocentre of the triangle, but its opposite point! There must be a position when the opposite point of the orthocentre is at equal distance from each vertex of the regular triangle.

Teacher: That’s true! The four vertices of a regular tetrahedron designate four such points on the surface of the sphere which is circumscribed around the tetrahedron.

Dear Eszter, if I have any idea about math, THIS is math what you did during our correspondence. All your flawed and flawless thoughts and experiments showed the only – not royal - route to true knowledge. If you ever teach mathematics to your students, friends, or children, pass on the experience you just had. Good luck! Your exam mark is a top five!

Fifth message from the student:

Student: Dear teacher, I really enjoyed this new type of geometry. It was good to think about. Certainly it would have been even better personally in the classroom.

Exercise 5: In an isosceles triangle I found a right triangle. Then the triangle disappeared. What were the other two angles - on the plane and on the sphere?

First exchange of messages:

Student: In an isosceles triangle the angles on the base are always equal. The triangle has two identical angles and one angle which may be different or also identical. Either the angle enclosed by the legs is a right angle, or the angle enclosed by the base and one leg is a right angle, but then the angle enclosed by the other leg and the base will also be a right angle (on the sphere, as with the meridians and the equator).

Teacher: Very good start!

Second exchange of messages:

Student:

Plane:

– if the angle on the two bases is a right angle, then the triangle does not exist, because in a plane the interior angle of the triangles is always 180° , and $180^\circ - (2 \cdot 90^\circ) = 0^\circ$.

– if the angle formed by the legs is a right angle, the other two angles are equal, so that they can be calculated: $(180^\circ - 90^\circ) / 2 = 45^\circ$. Then the angles of the triangle are: $90^\circ, 45^\circ, 45^\circ$.

Sphere:

– if the angle on the two bases is a right angle, then we are talking about a triangle whose base lies on the equator and whose vertex is defined by one of the poles. Then the angle enclosed by the legs can be anything between 0° and 180° , since no matter how much we can “open” this triangle Then the angles of the triangle are: $90^\circ, 90^\circ, 0^\circ$ and 180° .

– if the angle enclosed by the legs is a right angle, then when we take the right angle, we get four equal, right-angled spherical biangles. These spherical biangles define isosceles triangles if we take the other two vertices of the triangle at equal distances from one of their vertices on both sides. Then the angles between the base and the legs will be equal and can be any size between 0° and 180° . (Teacher: But why?) Then the angles of the triangle are: 90° , anything from 0° to 180° . (In this way we can also get a triangle with three right angles that cannot exist on the plane.)



Figure 25. Student’s figure of isosceles triangle on the plane.

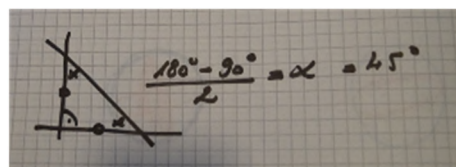


Figure 26. Student’s figure and computation of right-angled isosceles triangle on the plane.



Figure 27. Student’s model of right-angled biangle cut into two isosceles right triangles.

Teacher: That’s clear, I understand that. All you have to do is make sure that the angles can be of any size between 0° and 180° . Have you tried it on this beautiful round peach? Can it be 1° or 179° ? If the green rubber gets very close to the intersection of the blue lines, do the two angles on the green rubber seem to be almost 0° or 180° ?

Third exchange of messages:

Student: I was already thinking about this “between 0 and 180° ” when I described the problem. When all the three angles are equal, it’s 90° , but then the angle increases in one direction, decreases in the other (by pushing the green rubber away). On the other hand, I realized that if the vertices were almost coinciding at one point, they look like are almost as a planar right-angled isosceles triangle, so in this case the magnitude of the angles is actually between 45° and 135° .

Teacher: Top five!

6. Conclusions

When drawing the conclusions, one must consider the extraordinary circumstances in which the communication between the students and the teacher took place. This experiment was not a carefully planned and executed research project including the appropriate control group for an analytic-statistical evaluation. An attempt was made to deal with an unforeseen emergency situation. The question was, Can the course be completed under such conditions? Is the online form of communication suitable for achieving the fundamental objectives of the course?

For that reason, I cannot supply relevant statistical analysis to the action research described above. Although a statistical test could have been performed between the grades of a previous and the current group, the results would be irrelevant due to the large difference between the initial conditions. Still, I

give some numerical estimates regarding the current group, but these data are much more subjective than expected from the results of a planned research project.

Another interesting question is why I did not use any software to support the learning process online. One reason is that before the pandemic I did not have comparative geometry software that would fit the extraordinary circumstances of a sudden break. Besides, it would have been very difficult to organize a network overnight for students inside and outside the country. In addition, I had deeper objectives which I will describe later.

I was surprised by the perseverance of the students. Originally, there were 32 applicants, three of whom had already left the course at the beginning of the emergency. At the end of the distance learning, two students eventually did not complete the exam. One of them left without notice. The other student referred to family and financial problems, but would like to re-apply in the fall semester.

I definitely required the students not to copy-paste web pages instead of direct experiencing. There was only one student who quoted Internet sources far beyond the scope of the present syllabus, apparently without a real understanding. Of the 27 exam documents I received, 18 contained photos of self-made models, and an additional 5 contained self-made, carefully executed spherical diagrams drawn on sheets and photographed. 4 dissertations gave only written solutions without accompanying figures. (Of course, the addition of a drawing or photo was not mandatory. The point was to describe the route to the solution so that I could follow the reasoning with or without figures.)

What are the fundamental goals of the Comparative geometry project, and how were they fulfilled in distance learning?

The ideology behind the project was summarized in the article about Hungarian perspectives in mathematics education for the South African mathematics community [6].

One of the greatest problems in present-day mathematics teaching is the gap between inoperative and real knowledge that the student accumulates during the school years. Hans Freudenthal wrote in his epoch-making paper almost fifty years ago: “Geometrical axiomatization cannot be meaningful as a teaching subject unless the student is allowed to perform these activities himself. Usually he is not allowed to do so.” [2].

I apologize for thinking the same about almost all topics in geometry teaching.

Is it necessary to define a geometric concept? The answer of the majority of the students is a definite no to the question. What is a straight line, a circle, a triangle, a square? No definition is required, they say. Just look at it and you will know the answer.

One of the harmful consequences of this perception is that the student does not understand the role of definition. An even more grave consequence is the student's belief that the true acquisition of knowledge is very different from the way that you have to show in the school. You are expected to write and memorize senseless and superfluous definitions, while the real path that you followed to the acquisition of knowledge should be kept secret, in accordance with Brousseau's didactic contract [7].

Let me mention a personal experience in this regard. I was invited to give a geometry workshop for high school students. When I entered the room, I addressed them in my old-fashioned manner: “Ladies and gentlemen, I am honoured to be here. My name is István Lénárt.” Then a girl in the front row asked: “Is this already must be written?”

A similar experience can be obtained by posing questions such as: What arguments be made that a circle is a straight line on the sphere? Why is the South Pole also a centre of the Arctic Circle, in addition to the North Pole? Is there an obstacle to calling a regular spherical quadrilateral a square?

In most cases, a question about a geometric concept becomes a real challenge if and only if the same question arises on another surface, in another world of geometry. This recognition is the basis of comparative geometry.

It becomes clear when trying to answer the questions above. To decide if a planar line is straight, just look at it. However, to decide whether a spherical circle can be called a straight line, you must analyze the properties of the straight line on the plane, and check whether the specified property can be transformed onto the sphere. In short, you need to set up a definition for the planar

case if you want to solve the spherical problem, from the centre of the circle to the definition of a square or from the concept of the triangle to area measurement.

The same goes for the well-known problem of teaching about proof. To solve this problem, Freudenthal suggested the potential use of spherical and elliptic geometry [2], which actually means applying comparative geometry. This idea has been reinforced over the past few decades, as for example by Tall and others [8].

Once the student has managed to step out of the Euclidean bond into the world of spherical geometry, another step towards a third geometry becomes much easier. This is especially true for hyperbolic geometry introduced on the Poincaré hemispherical model. In this way, the knowledge gained in spherical geometry is even more useful for the student.

I deeply disagree with Alexandr D. Alexandrov who wrote, “Lobachevskian geometry can hardly be included in secondary school curricula, but it seems essential to give pupils an idea of it and to show them the greatness of the human spirit, capable of creating unimaginable concepts and theories which, in the course of time, proved to be comprehensible and fruitful.” [1]

My experience is that the plane-sphere-hemisphere route makes the basics of hyperbolic geometry understandable and enjoyable even for junior high school pupils, because they recognize not only “the greatness of human spirit” in general, but the potentials of their own spirit to understand “unimaginable” concepts and theories. My motto is that students value most their teacher’s ability to convince them about their own abilities.

Another difficult problem is the adequate grading of the achievements. The viewpoint of comparative geometry contradicts the generally accepted method of evaluation. To quote Hans Freudenthal again [2], “If teachers choose the easy way to tell right from wrong when grading test papers, geometry will be lost.” For me, the mistake that testifies direct experimentation and independent thinking is much more valuable than a correct answer copied from a printed or online material. In Exercise 2, figure 10, I highly appreciated the student’s fallacious conclusion from the figure on the apple, because it clearly showed the correct method of research: Dare to experiment, dare to draw conclusions on your own, dare to take the risk of error which can be corrected by further investigation. It is easier to correct a mistake through further research (as was the case with the apple above) than to get rid of the custom of unscrupulous takeover from uncontrolled sources.

Three decades of teaching experience suggested that direct experimentation and free informal communication were essential to achieving the goals of the comparative geometry project.

To what extent has this hypothesis been justified or refuted in the unforeseen situation caused by the pandemic? At the moment, I can only give a very subjective, partial answer to the question, which will certainly have to be reinforced by more accurate, statistically evaluated research projects.

I believe that the main goals to avoid the collapse of the course and to apply the basic forms of knowledge acquisition in the changed circumstances have been achieved.

Certainly, it would have been a great help if we could have organized the online communication for joint discussions and debates in Zoom conferences. This did not happen due to time and organization constraints and especially my own inexperience in this regard.

Still, in the correspondence with each student, I tried to maintain a relaxed tone reminiscent of peers’ conversations in the classroom. In translating the above exercises, I tried to illustrate this tone, although the language gap made it very difficult for me to convey the nuances of expression. Yet, according to the feedback from students, my efforts at least partially replaced the communication between the classmates.

It was very encouraging that direct experimental work proved to be successfully sustained under the changing circumstances. On the (more or less) spherical objects in the environment, students were able to create a system of geometry built on independent experience and observation. The most important result is that they appreciated and enjoyed this activity.

Beyond a certain level, precise spherical construction tools are of course important and even indispensable for the experiments. However, the extraordinary situation also proved that the first steps from Euclid to another system of geometry could be carried out with everyday objects and tools.

Students can conduct introductory experiments in spherical geometry at school or at home even if special construction materials are not available. In addition, these commodities will continue to remind the student of the connection between mathematical abstraction and physical reality.

I have gained an equally important experience of the benefits of online communication with students in this project, both in terms of mid-year work and exams.

During the distance learning exams, I often had the feeling that the form of correspondence provided a fairer grading for the student than a personal interview or the evaluation of a test paper. It is of great advantage that the student has the time and the opportunity to rethink the task or perform further experiments without lack of time and exam nerves. However, these benefits only apply if the teacher takes up the additional burden of multiple messages.

Admittedly, in the past I have deliberately tried to avoid the dominance of online study over hands-on experimentation, because one of the main goals of the Comparative Geometry project is to restore the student's faith in her own senses and direct experience as opposed to the virtual, filtered reality through ICT sources.

After my experience during the pandemic, I will try to incorporate online methods and communication in the semester and the exam period while still insisting on the priority of hands-on experimentation and direct personal discussion in the classroom.

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Elements of non-Euclidean geometry in the formation of the concept of rectilinear placement of points in schoolchildren

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Abstract. The paper deals with issues of the metric geometry basics. In particular, the concept of rectilinear placement of points is considered, based on the axioms of the distance between two points of metric space. This approach allows forming a modern view of the property of straightness in the pupils. This paper analyzes the content of existing mathematics textbooks for general educational institutions to acquaintance of pupils with the elements of metric geometry. The first part of the paper provides information about the rectilinear placement of points; it can be used in Geometry lessons in the 7th – 9th grades. Set of linear functions are considered as examples of points of metric space. The similar work was done in the second part of the work for geometric material of the 10th – 11th grades. In addition, some simple examples of metric spaces that may be accessible to pupils of the relevant classes are discussed. The purpose of the work is gradually introduction of pupils to the elements of non-Euclidean geometries, to form a generalized notion of the distance between the points and rectilinear of their placement. The work can be used for Mathematics teaching at school and for retraining of teachers of Mathematics.

1. Introduction

Mathematics is a fundamental science not only for engineering disciplines, but also for other disciplines. But in most cases, it is recognized “as too difficult” and students refuse to study it in favor of other sciences [1, 2, 3].

One of the advantages of mathematical education is the ability to build abstract models [4, 5]. These models are a set of graphical constructions and algebraic formulas that describe phenomena and events, and are used in forecasting. In particular, in art, the application of the properties of non-Euclidean elements allows to obtain 2D and 3D interesting results, such as tessellation, Escher's hyperbolic art and some paradoxes on Magritte's work [6, 7]. The concept of metric space in non-Euclidean geometry is the learning basis in navigation, satellite communications, phenomena that take place over very long distances [8]. At most issues study, clarity is no longer available, only analytical researches are possible, they are considered difficult. In order to interest students in the study of mathematical disciplines, it is necessary to stimulate their early motivation for analytical constructions [9, 10, 11].

Appropriate teacher training should be conducted. The curriculum of the school mathematics in the last half-century has undergone significant changes due to the widespread use of the latest mathematical research methods. In Geometry, the part of educational material is studied using vectors and the boundary transition, in Algebra and in the basis of Mathematical analysis the elements of combinatorics, probability theory and statistics, derivative of function, indefinite and definite integral are studied.



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The rapid development of non-Euclidean geometries, and their practical application in modern researches and technologies, raises the question of the need for students to get acquainted with the basic concepts and provisions of these geometries in school mathematics. It will allow students to form a critical attitude to basic mathematical concepts and postulates, and will help develop the ability to analyze them and apply them to build mathematical models of various phenomena and processes. The simplest way to achieve this goal, in our opinion, is elements of metric geometry use, as it is the closest to the classical Euclid geometry. It should be noted the simple analytical transformations in establishing the elementary facts of metric geometry, because they are based on clear axioms of the distance between the points of metric space. According to the authors of the metric geometry course, "... metric geometry remains; perhaps, it is one of the most "elementary" mathematical methods".

This paper will show how the means of metric geometry can be applied to the formation of the concept of the distance between two points and the concept of straightness, based on the school mathematics course. It will help in teaching to motivate students to study the exact sciences and further science and mathematics research, including STEM sciences.

2. Formation of notions of distance and straightness by means of metric geometry in 7th- 9th grades

As a rule, future mathematics teachers will be introduced to metric spaces in the mathematical analysis course, at studying the functions of several variables. Introducing the concept of n -dimensional of Euclidean space the generalized notion of the distance between two points of this space is presented. It generalizes the concept of the distance between two points on a numerical axis, the distance between two points on a coordinate plane, and the distance between two points of coordinate space of three-dimensional, with which students are familiar by the school mathematics. A general definition of metric space and a detailed study of specific metric spaces are offered in Functional analysis course. Here are some basic definitions of the metric spaces.

Definition 1. A metric space is a totality of a nonempty set X of elements of any nature and a single-valued real non-negative function $\rho(x; y)$ defined for any elements x and y from X , and satisfying the following conditions:

- 1) $\rho(x; y) = 0$ if and only if $x = y$;
- 2) $\rho(x; y) = \rho(y; x)$ (axiom of symmetry);
- 3) for any three elements x , y and z , the inequality is satisfied
 $\rho(x; y) \leq \rho(x; z) + \rho(z; y)$ (axiom of a triangle)

(see, the example, [12, p. 102]).

The elements of the set X are called points of the metric space, the function ρ is the metric of X space, and the numerical value of the function $\rho(x; y)$ is the distance between the elements (points) x and y . The metric space X with ρ metric is denoted by $(X; \rho)$. Terms 1), 2) and 3) of Definition 1 is also called distance axioms.

It is impractical to introduce the notion of metric and metric space in the form given in Definition 1, because the notion of function of two variables, or the functional, since points of space X can be any is used.

Note that in Definition 1, the elements of the set X can be of any nature. Euclid described the point as follows: "The point has no parts" [13, p. 11], Heron "the point has no magnitude (length)" [13, p. 224]. It is consistent with the description of the point in the school textbooks: "The point is the simplest geometric figure. It is the only figure that cannot be divided into parts" [14, p. 12]; "The point has neither length nor width, its shape we cannot determine" [15, p. 15]. Sometimes the point is described by its graphical representation: "If a well pointed pencil is pressed on a piece of paper, there will be a trace that gives an idea of the point" [16, p. 9]; "The idea of a point can be obtained by pressing a well-sharpened pencil on a piece of paper or a well-sharpened piece of chalk on a school board" [17, p. 6], or simply: "The simplest geometric figure is a point" [18, p. 6].

In our view, the concept of a point could be described in more detail, indicating that any object can be considered as a point when its structure, form, properties, etc. are not used. For example, when it is necessary to calculate the number of buildings in a certain area and to set distances between them,

without considering the size, shape, number of floors and apartments of these buildings, although each of the buildings has these characteristics and can be used in the future. At acquainting with the concept of the set, it should be emphasized that it is a set of objects (elements) united by a certain characteristic: the set of *pupils of one class*, the set of *even numbers*, etc. All the elements (points) of the set are equal among themselves, however at dealing with them it is necessary to check this points for the fulfillment of the characteristic by what they belong to this set, and you can also use this characteristic for the operations with points of this set. This concept of the point is broader than the concept of the point in Euclid's geometry, but it more accurately reflects the modern view at the point as an element of the set. The proposed point description is fully consistent with Definition 1, and prepares students for a generalized perception of point concepts and distances between points in specific metric spaces.

The first acquaintance to the concept of the distance between two points at the definition level occurs in the seventh grade at learning the basic geometric concepts: “The length of the segment AB is called the distance between points A and B. If points A and B are coincided, then the distance between them is zero” [14, p. 17]; “The distance between two points is the length of the segment with the ends at these points” [15, p. 18]; “The length of the segment AB is also called the distance between points A and B” [16, p. 17]. At this stage of studying mathematics, in our opinion, it is too early to talk about other definitions of the distance between points, although it is possible to draw pupils attention to the fact that at driving around the city, the shortest distance they have to overcome between two objects is not always measured by the length of the segment that connects these objects and may be exceeded them. Moreover, there may be several such paths. It may be the first example of the ambiguity of the notion of the distance between two points. It will help to train students for the perception of a further triangle inequality (Condition 3) of Definition 1. Pupils will also be introduced to this inequality in the seventh grade: “Each side of the triangle less then sum of the other two sides...” [14, p. 113; 15, p. 109; 16, p. 74; 17, p. 115; 18, pp. 108-109].

Due to the triangle's inequality, the characteristic property of three points belonging to one straight line is deduced, and the notion “point *B* is contained between points *A* and *C*”, which means the “rectilinear placement” of these points *A*, *B*, *C*: “if the equality $AB = AC + CB$ is satisfied for the three points *A*, *B* and *C*, then the point *C* is the inner point of the segment *AB*” [14, p. 114]; “If the equality $AB + BC = AC$ is satisfied for the three points *A*, *B*, *C*, then these points lie on one line and point *B* is between points *A* and *C*” [15, p. 109]; “... if point *C* lies between points *A* and *B* ..., then the following proportions are correct: $AB = BC + CA$, $BC < CA + AB$, $CA < AB + BC$ ” [18, p. 109]. These facts are in full agreement with the axioms of placement proposed by V. F. Kagan in constructing a straight line theory.

Purposeful and detailed introduction of students to the elements of metric geometry should begin, in our opinion, in the ninth grade. In Geometry of ninth-grade, the basic material for the elements metric geometry as trigonometry elements, cosine theorem, sine theorem, triangle's inequality, triangles solving, Cartesian coordinates on plane, scalar product of vectors is studied. In addition, the parallel study in Algebra the properties of functions gives the opportunity to begin the study of specific metric spaces, such as the space of linear (or quadratic) functions on a segment. An experienced teacher, according to the time available to study mathematics, will easily be able to divide some facts from metric geometry into those that can be learned in class and those that need to be learned in the after school.

Now let's consider the actual material that is being offered for study. First, we formulate a somewhat simplified, but more voluminous, definition of the metric space and the distance between its points. This definition uses the notion of the set and its elements studied in the eighth grade [19, p. 24].

Definition 2. *Nonempty set X of elements of any nature will call a metric space if each pair $(x; y)$ of different elements X , by some rule ρ , is matched by a single real non-negative number $\rho(x; y)$, which is called the distance between the elements x and y , and which satisfies the conditions:*

1) *for any two different elements x and y , the distance between the elements x and y is equal to the distance between the elements y and x , the equality $\rho(x; y) = \rho(y; x)$ (symmetry*

conditions) is satisfied;

2) for any three different elements x, y, z , the distance between the elements x and y is not greater than the sum of the distances between the elements x and z and between the elements z and y , the inequality $\rho(x; y) \leq \rho(x; z) + \rho(z; y)$ (triangle inequality) is satisfied.

If the conditions of Definition 2 are satisfied, then the elements of the set X will be called points of metric space, the rule ρ – metric of space. The metric space X with metric ρ will be denoted (X, ρ) .

It should be noted that this definition is reminiscent of the function which is being studied in Algebra in the ninth grade [20, p. 11]. However, there are several significant differences: the elements of set can be not only numbers, the number is matched to the two elements of the set, and this number should only be positive. In addition, the symmetry condition and triangle inequality for all pairs of elements of the set should be checked.

The Definition 2 of metric space, in the form as it is written, should be given in the senior classes, and in the ninth grades it is advisable to give it (as well as the function’s definition) in a descriptive form, using a sufficient number of examples. In this case, it is possible to divide the formulation of conditions 1) and 2) definitions into verbal and analytical forms.

Here are some of the simplest examples of metric spaces available for easy learning by pupils.

Example 1. The simplest example of the metric space is the set of all points of the numerical axis. This space is called a one-dimensional arithmetic Euclidean space, and denote R^1 . As it is known [21, p. 82], the distance between two points x and y of the numerical axis is found as the absolute value (modulus) of the difference of the corresponding numbers x and y : $\rho(x; y) = |x - y|$.

This value is always positive for different values of x and y , it follows from the definition of the number of module. The symmetry condition follows from the equalities:

$$\rho(x; y) = |x - y| = |-(x - y)| = |y - x| = \rho(y; x).$$

Checking the inequality of the triangle is always the most difficult because it is difficult enough to prove inequalities. For this case, the inequality of a triangle looks like:

$$\rho(x; y) = |x - y| \leq |x - z| + |z - y| = \rho(x; z) + \rho(z; y). \tag{1}$$

At its proving, the inequality for the modulus of the sum of two numbers is used [20, p. 60]:

$$|a + b| \leq |a| + |b|. \tag{2}$$

If in inequality (2) we put: $a = x - z, b = z - y$, then we get inequality (1).

Since all the conditions of Definition 2 are fulfilled, then the considered space R^1 is metric.

Inequality (1) can be proved in the ninth grade. However, using a number line, you can try to prove it even in the seventh grade. To do this, we have to consider six different possible cases of placement of x, y, z points on the numerical axis. A large number of analytical transformations can be offset by graphical representation of points on the numerical axis; it will make easier to understand such transformations.

For example, let the points x, y, z are placed on a number line in the following order: $x < z < y$. Then we will have:

$$\rho(x; y) = |x - y| = -(x - y);$$

$$\rho(x; z) = |x - z| = -(x - z);$$

$$\rho(z; y) = |z - y| = -(z - y).$$

Adding the last two equalities we will have:

$$\rho(x; z) + \rho(z; y) = -(x - z) - (z - y) = -x + z - z + y = -(x - y) = \rho(x; y).$$

Other placement cases of x, y, z points are observed similarly.

Example 2. An example of a metric space is the set of points of a coordinate plane. It is studied in detail in Geometry for ninth grade [21, p. 81; 23, p. 8; 24, p. 6; 25, p. 6; 26, p. 9]. This space is called a two-dimensional arithmetic Euclidean space, and is denoted R^2 .

Distance between two points $M_1(x_1; y_1)$ and $M_2(x_2; y_2)$ of space R^2 is defined as the length of the segment M_1M_2 , which is presented by the formula [21, p. 82; 23, p. 8; 24, p. 24; 25, p. 32; 26, p. 12]:

$$M_1M_2 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}.$$

For two different points of the coordinate plane, this distance is positive and has the property of symmetry:

$$\rho(M_1; M_2) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} = \rho(M_2; M_1).$$

Proving the inequality of a triangle is a bit more complicated. However, the using the Cauchy-Bunyakovsky inequality is facilitated [20, p. 209]. For arbitrary four values: a_1, a_2, b_1, b_2 it looks like:

$$(a_1b_1 + a_2b_2)^2 \leq (a_1^2 + a_2^2)(b_1^2 + b_2^2).$$

It is easy to prove this inequality by raise to the second degree in the left part of it and multiplying the expressions in brackets in the right part of the inequality. Since both parts of the inequality are non-negative, extracting from them the square root we get the inequality:

$$a_1b_1 + a_2b_2 \leq \sqrt{(a_1^2 + a_2^2)(b_1^2 + b_2^2)}. \tag{3}$$

The triangle inequality for three points $M_1(x_1; y_1), M_2(x_2; y_2), M_3(x_3; y_3)$ has the form:

$$\begin{aligned} \rho(M_1; M_2) &= \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \leq \sqrt{(x_1 - x_3)^2 + (y_1 - y_3)^2} \\ &+ \sqrt{(x_3 - x_2)^2 + (y_3 - y_2)^2} = \rho(M_1; M_3) + \rho(M_3; M_2). \end{aligned}$$

Denote by: $x_1 - x_3 = a_1, x_3 - x_2 = b_1, y_1 - y_3 = a_2, y_3 - y_2 = b_2$. These values will be substituted in the triangle inequality:

$$\sqrt{(a_1 + b_1)^2 + (a_2 + b_2)^2} \leq \sqrt{a_1^2 + a_2^2} + \sqrt{b_1^2 + b_2^2}.$$

Since both parts of the inequality are non-negative, we raise them to the square and we get the inequality:

$$(a_1 + b_1)^2 + (a_2 + b_2)^2 \leq a_1^2 + a_2^2 + 2\sqrt{(a_1^2 + a_2^2)(b_1^2 + b_2^2)} + b_1^2 + b_2^2. \tag{4}$$

Let's transform the left part of inequality (4) and use inequality (3):

$$\begin{aligned} (a_1 + b_1)^2 + (a_2 + b_2)^2 &= a_1^2 + 2a_1b_1 + b_1^2 + a_2^2 + 2a_2b_2 + b_2^2 = \\ &= a_1^2 + a_2^2 + 2(a_1b_1 + a_2b_2) + b_1^2 + b_2^2 \leq a_1^2 + a_2^2 + 2\sqrt{(a_1^2 + a_2^2)(b_1^2 + b_2^2)} + b_1^2 + b_2^2. \end{aligned}$$

The inequality (4) is presented. Therefore, the inequality of the triangle is satisfied. Since all the conditions of Definition 2 are fulfilled, then the considered space R^2 is metric.

The other metric can be selected on the coordinate plane, and thus the points of the plane will form a different metric space other than the space R^2 .

Example 3. Consider as the distance between the points $M_1(x_1; y_1)$ and $M_2(x_2; y_2)$ of the coordinate plane the number:

$$\rho(M_1; M_2) = |x_1 - x_2| + |y_1 - y_2|.$$

This number for two different points is positive. The symmetry condition is obvious due to the properties of the number module. The triangle inequality for three points $M_1(x_1; y_1), M_2(x_2; y_2), M_3(x_3; y_3)$ has the form:

$$\begin{aligned} \rho(M_1; M_2) &= |x_1 - x_2| + |y_1 - y_2| \leq \\ &\leq (|x_1 - x_3| + |y_1 - y_3|) + (|x_3 - x_2| + |y_3 - y_2|) = \rho(M_1; M_3) + \rho(M_3; M_2). \end{aligned}$$

The correct of this inequality is obvious, since each of the modules on the left side of the inequality does not exceed the sum of the modules of its terms.

All conditions of Definition 2 are fulfilled, so the considered space is metric. This space is denoted by R_1^2 .

The space R_1^2 is interesting because its essence is easy to explain even to the seventh grade pupils. By this metric, on the coordinate plane, the smallest distance between the points M_1 and M_2 can be overcome by walking parallel to the coordinate axes (along the legs of a right triangle for which the segment M_1M_2 is a hypotenuse). A similar situation occurs in a city with a rectangular street layout. This is one example where the concept of the distance between points does not coincide with the classic, as the length of the segment connecting these points.

Example 4. Consider as the distance between the points $M_1(x_1; y_1)$ and $M_2(x_2; y_2)$ of the coordinate plane the number:

$$\rho(M_1; M_2) = \max\{|x_1 - x_2|; |y_1 - y_2|\}.$$

This number for two different points is positive. The symmetry condition is obvious due to the properties of the number module. The triangle inequality for three points $M_1(x_1; y_1)$, $M_2(x_2; y_2)$, $M_3(x_3; y_3)$ has the form:

$$\rho(M_1; M_2) = \max\{|x_1 - x_2|; |y_1 - y_2|\} \leq \max\{|x_1 - x_3|; |y_1 - y_3|\} + \max\{|x_3 - x_2|; |y_3 - y_2|\} = \rho(M_1; M_3) + \rho(M_3; M_2).$$

Using the inequality for the modulus of the sum of two numbers, we obtain:

$$\begin{aligned} |x_1 - x_2| &= |(x_1 - x_3) + (x_3 - x_2)| \leq |x_1 - x_3| + |x_3 - x_2| \leq \\ &\leq \max\{|x_1 - x_3|; |y_1 - y_3|\} + \max\{|x_3 - x_2|; |y_3 - y_2|\}. \end{aligned}$$

Similarly, we get inequality:

$$\begin{aligned} |y_1 - y_2| &= |(y_1 - y_3) + (y_3 - y_2)| \leq |y_1 - y_3| + |y_3 - y_2| \leq \\ &\leq \max\{|x_1 - x_3|; |y_1 - y_3|\} + \max\{|x_3 - x_2|; |y_3 - y_2|\}. \end{aligned}$$

Comparing both obtained inequalities, we finally get:

$$\begin{aligned} \rho(M_1; M_2) &= \max\{|x_1 - x_2|; |y_1 - y_2|\} \leq \\ &\leq \max\{|x_1 - x_3|; |y_1 - y_3|\} + \max\{|x_3 - x_2|; |y_3 - y_2|\} = \rho(M_1; M_3) + \rho(M_3; M_2). \end{aligned}$$

Thus, all conditions of Definition 2 are fulfilled, so the considered space is metric and is denoted by R_0^2 . Sometimes such a space is more convenient than the space R^2 . The space R_0^2 can also be an example of space in which the distance between points is not always the length of the segment connecting these points.

Example 5. Consider in the space R_0^2 four points: $M_1(0; 1)$, $M_2(0; -1)$, $M_3(-1; 0)$, $M_4(1; 0)$. Let's find by the metric of space the distance between these points:

$$\rho(M_1; M_2) = 2, \rho(M_1; M_3) = 1, \rho(M_1; M_4) = 1, \rho(M_2; M_3) = 1, \rho(M_2; M_4) = 1, \rho(M_3; M_4) = 2.$$

It is necessary to pay attention to the equalities that are fulfilled:

$$\begin{aligned} \rho(M_1; M_2) &= \rho(M_1; M_3) + \rho(M_2; M_3) = 1 + 1 = 2; \\ \rho(M_1; M_2) &= \rho(M_1; M_4) + \rho(M_2; M_4) = 1 + 1 = 2; \\ \rho(M_3; M_4) &= \rho(M_1; M_3) + \rho(M_1; M_4) = 1 + 1 = 2; \\ \rho(M_3; M_4) &= \rho(M_2; M_3) + \rho(M_2; M_4) = 1 + 1 = 2. \end{aligned}$$

Geometrically, on the coordinate plane, the points M_1, M_2, M_3, M_4 are the vertices of a square, its side length is $\sqrt{2}$. In Euclid's geometry, the length of the diagonal of the square is less than the sum of the lengths of its two sides, but in this example they are equal. Moreover, in Euclid's geometry there are all three points involved in equality must lie on one straight line.

This example clearly demonstrates the difference of the concepts of distance between points of the same set at different attributes. In addition, this example points to the ambiguity (relativity) of the concept of rectilinear placement of points of metric space. In particular, in his axiomatic, D. Hilbert, in contrast to Euclid, did not give specific definitions of basic geometric concepts: point, line, plane, but he only described their properties because of the correlation between them [27, pp. 3-4].

Let's consider the notion of rectilinear placement of points of metric space. It is a special case of Definition 2, at the inequality of a triangle becomes equality.

Definition 3. *Let's say that the points x, y, z of the metric space (X, ρ) are rectilinear placement in this space if the equality is satisfied:*

$$\rho(x; y) = \rho(x; z) + \rho(z; y). \tag{5}$$

At equality (5) solving, it is natural to say that the point z "lies between" points x and y , or to call it "internal" for points x, y, z . At the same time, the point x (point y) can be said to be "beyond" points y and z (points x and z), or "external" for points x, y, z (compare [14, p. 16]).

For the pupils it may be noted that equality (5) must be executed for some two points from three given points (for example, for points x and y). For other pairs of points the equality $\rho(x; z) = \rho(x; y) - \rho(z; y)$ will be executed, or the equality $\rho(z; y) = \rho(x; y) - \rho(x; z)$, they can also indicate the rectilinear placement of the points x, y, z .

Let's define a rectilinear placement of the set of points of the metric space as the rectilinear placement of any three points of this set.

Definition 4. *Let's say that the set of points of a metric space is rectilinear placement if any three points of that set are rectilinear placement.*

Definitions 3 and 4 make it possible to study the individual properties of rectilinear placement without using a straight line definition and without introducing straight line axioms. They can be used to construct the rectilinear placement sets of points in the arbitrary metric space. The properties of such sets will largely depend on the metric in the corresponding space.

Now let's look at some examples of rectilinear placement of the points in different metric spaces.

Example 6. The simplest example of the set with a rectilinear placement is the space R^1 . Indeed, from the properties of the set of real (natural, integer, rational) numbers, it follows that one out of three different numbers x, y, z will be the smallest, the second – the largest, and the third – the intermediate. For example, a double inequality is executed: $x < z < y$. As in Example 1, by the space metric R^1 , we find the distances:

$$\rho(x; y) = |x - y| = y - x, \rho(x; z) = |x - z| = z - x, \rho(z; y) = |z - y| = y - z.$$

Since equality:

$$\rho(x; y) = y - x = (z - x) + (y - z) = \rho(x; z) + \rho(z; y),$$

is executed, then by Definition 3 the points, y, z are rectilinearly placed in the space R^1 . These points were arbitrary, so Definition 4 is executed and the entire space R^1 is rectilinearly placed.

Example 7. Here is a more complicated example of a rectilinearly placed set. To do this, we consider the set of linear functions $y = kx$ given on the segment $x \in [0; 1]$. The graphs of these functions are straight lines passing through the beginning of coordinate. The pupils get acquainted with the properties of functions quite thoroughly in the ninth grade [20, p. 24; 22, p. 65; 28, p. 72; 29, p. 68; 30, p. 73]. However, with some elementary functions and their simplest properties, in particular with a linear function, acquaintance begins in the seventh grade [31, p. 137; 32, p. 139; 33, p. 103; 34, p. 96; 35, p. 130; 36, p. 141]. The two functions defined at a certain interval will be considered different if they have different values at least at one point in that interval. Provided that these functions are continuous on a numerical gap, they will have different values on the some numerical gap.

Let's introduce a metric in this set by choosing the distance between its two different elements $y = k_1x$ and $y = k_2x$ number:

$$\rho(k_1x; k_2x) = \max_{x \in [0; 1]} |k_1x - k_2x|.$$

Let's show that with this choice of the distance between the elements, the set of functions $y = kx$ is the metric space. In the future, for convenience, we will use the notation:

$$k_i x = y_i, \rho(k_i x; k_j x) = \rho(y_i; y_j) = \rho_{ij} \quad (i, j = 1, 2, \dots).$$

For two different functions, the distance ρ_{12} is positive due to the definition of the number module. If we assume that this distance is zero, then at each point in the segment $[0; 1]$ the values of both functions must be the same, that is, the functions must be coincided.

From the property of modulus of the number the distance symmetry property follows:

$$\rho(y_1; y_2) = \max_{x \in [0;1]} |k_1 x - k_2 x| = \max_{x \in [0;1]} |k_2 x - k_1 x| = \rho(y_2; y_1).$$

Consider on the segment $[0; 1]$ three functions: $y_1 = k_1 x, y_2 = k_2 x, y_3 = k_3 x$, where k_1, k_2, k_3 are different numbers. For example, let's the inequalities $k_1 < k_2 < k_3$ are executed. Let's find the distances between functions:

$$\rho_{12} = \max_{x \in [0;1]} |k_1 x - k_2 x| = \max_{x \in [0;1]} |k_1 - k_2| |x| = k_2 - k_1,$$

$$\rho_{13} = \max_{x \in [0;1]} |k_1 x - k_3 x| = \max_{x \in [0;1]} |k_1 - k_3| |x| = k_3 - k_1,$$

$$\rho_{23} = \max_{x \in [0;1]} |k_2 x - k_3 x| = \max_{x \in [0;1]} |k_2 - k_3| |x| = k_3 - k_2.$$

From the obtained values, the equality follows:

$$\rho_{13} = k_3 - k_1 = (k_2 - k_1) + (k_3 - k_2) = \rho_{12} + \rho_{23}. \tag{6}$$

Thus, the triangle inequality for the points y_1, y_2, y_3 is satisfied, and the chosen distance is a metric. Consequently the set of functions $y = kx$ on the segment $x \in [0; 1]$ is a metric space.

Since for points y_1, y_2, y_3 , equality (5) is executed, and the points are choose arbitrarily, then from the equality (6), by Definition 4, the rectilinear placement of the whole set of functions is followed.

Example 8. The space R^1 considered in Example 1, as well as the space R_1^2 considered in Example 3, are partial cases of a more general metric space – R_1^n . This space consists of ordered groups n real numbers: $x(x_1, \dots, x_n)$. The distance between two points $x(x_1, \dots, x_n)$ and $y(y_1, \dots, y_n)$ of this space is given by the formula:

$$\rho(x; y) = \sum_{k=1}^n |x_k - y_k|. \tag{7}$$

The fulfillment of all axioms of the distance for this metric is executed in the same way as in Example 3.

Consider the set P of points of space R_1^n such that for arbitrary three points $x(x_1, \dots, x_n), y(y_1, \dots, y_n)$ and $z(z_1, \dots, z_n)$ of this set the inequalities are executed: $x_k \leq y_k \leq z_k$ for of all values of $k = 1, 2, \dots, n$. Such a set is rectilinear placement in the space R_1^n . Indeed, using equality (7) we have:

$$\begin{aligned} \rho(x; z) &= \sum_{k=1}^n |x_k - z_k| = \sum_{k=1}^n (z_k - x_k) = \sum_{k=1}^n ((z_k - y_k) + (y_k - x_k)) = \\ &= \sum_{k=1}^n (z_k - y_k) + \sum_{k=1}^n (y_k - x_k) = \sum_{k=1}^n |z_k - y_k| + \sum_{k=1}^n |y_k - x_k| = \\ &= \rho(z; y) + \rho(y; x) = \rho(x; y) + \rho(y; z) \end{aligned}$$

Therefore, for points x, y, z the equality (5) is executed, so by Definition 3 they are rectilinear placement in the space R_1^n . Since we have taken these points arbitrarily from the set P , then by Definition 4 this set is rectilinear placement in the space R_1^n .

Rectilinear placement of the points in Examples 6-8 may be intuitively associated with rectilinear placement of the points in Euclid's geometry, however, this is not always true. The following example demonstrates this peculiarity of rectilinear placement of points in metric space.

Example 9. In Example 5, we found that for any three points, of the considered four M_1, M_2, M_3, M_4 in this example, the equality (5) is executed, and therefore every three points, by Definition 3, are rectilinear placement, and hence, by Definition 4, all four points are rectilinear placement in the space R_0^2 . This result is somewhat different from the intuitive perception of the notion of a straight line in Euclid's geometry, since these four points are the vertices of the square, as noted above.

We considered some basic concepts of metric geometry and some of the simplest metric spaces which you can introduce middle-class pupils. The teacher can choose the level of validity of the results – intuitive, graphic or rigorous analytical. In the senior classes, more complex metric spaces that require concepts of continuity, differentiation, and integration of function can be considered.

3. Formation of notions of distance and straightness by means of metric geometry in 10th -11th grades

Opportunities for the use of elements of metric geometry in the senior grades are increasing. This is due to a more detailed and thorough study of the properties of functions, in particular on the basis of differential and integral calculus. For example, familiarity with the properties of functions continuous on a segment makes it possible to consider the corresponding metric space. It should be noted that in the senior grades, such material should be considered only if the study of mathematics is at an advanced level.

After acquaintance with continuous functions, their properties and the second Weierstrass theorem [37, p. 318] on the existence of the largest and smallest values of the function continuous on a segment, we can consider the metric space $C_{[a;b]}$ – the set of functions continuous on a segment $[a; b]$ for which the distance between the functions $f(x)$ and $g(x)$ of the set is determined by the formula:

$$\rho(f ; g) = \max_{x \in [a;b]} |f(x) - g(x)|. \tag{8}$$

At this choice of metric, the set of functions becomes a metric space because all axioms of distance are fulfilled (see Example 7).

First, the right side of the equality is always non-negative. If the functions $f(x)$ and $g(x)$ on the segment $[a; b]$ at least in one point have different meanings (these functions are different), then the right side of the equality (8) is positive. The symmetry property is executed due to the property of the number module: $|f(x) - g(x)| = |g(x) - f(x)|$. The execution of the triangle inequality is followed from the obvious inequalities:

$$\begin{aligned} |f(x) - g(x)| &= |(f(x) - h(x)) + (h(x) - g(x))| \leq |f(x) - h(x)| + \\ &+ |h(x) - g(x)| \leq \max_{x \in [a;b]} (|f(x) - h(x)| + |h(x) - g(x)|) \leq \max_{x \in [a;b]} |f(x) - h(x)| + \\ &+ \max_{x \in [a;b]} |h(x) - g(x)| = \rho(f; h) + \rho(h; g). \end{aligned}$$

Since these inequalities are satisfied for an arbitrary value of x from the segment $[a; b]$, we finally obtain the inequality:

$$\begin{aligned} \rho(f ; g) &= \max_{x \in [a;b]} |f(x) - g(x)| \leq \\ &\leq \max_{x \in [a;b]} |f(x) - h(x)| + \max_{x \in [a;b]} |h(x) - g(x)| = \rho(f; h) + \rho(h; g). \end{aligned}$$

It should be noted that all the maxima that are part of the inequalities are due to the continuity on a segment $[a; b]$ of the corresponding functions [37, pp. 305-308].

Since all the basic elementary functions studied in a school mathematics course are continuous in their fields of definition, then metric (8) can be used to study the same functions (linear, quadratic, degree, trigonometric), and to establish metric correlations between different functions. It is possible to use the properties of monotone functions [20, p. 35]: “if the function f increases on a segment $[a; b]$, then $\min_{x \in [a;b]} f(x) = f(a)$, $\max_{x \in [a;b]} f(x) = f(b)$; if the function f decreases on a segment $[a; b]$, then $\min_{x \in [a;b]} f(x) = f(b)$, $\max_{x \in [a;b]} f(x) = f(a)$ ”. These two properties can be combined into one and be more broadly formulated: “monotonic function on the segment takes its smallest and largest values at the ends of that segment”. This formulation may make it somewhat easier to find the extremes of a function on a segment.

Here is an example of finding the distance between two linear functions in the space $C_{[a;b]}$.

Example 10. Consider two points y_1 and y_2 of space $C_{[a;b]}$, which are linear functions: $y_1 = k_1x + b_1$ and $y_2 = k_2x + b_2$. Let's find the distance between these points by the space metric $C_{[a;b]}$. In Example 7, we have already considered the particular case of linear functions: $y = kx$. Due to the absence of a free term on the right side of the equality, find the distance between such functions was easy enough. In our case, consider the function:

$$y = |y_1 - y_2| = |(k_1x + b_1) - (k_2x + b_2)| = |(k_1 - k_2)x + (b_1 - b_2)|.$$

May be the following cases of the plot the graphs of the functions $y = k_1x + b_1$ and $y = k_2x + b_2$. Let's the equalities $k_1 = k_2 = 0$ be satisfied. In this case, the graphs of both functions are parallel to the OX axis. Then by the equality (8) we have:

$$\begin{aligned} \rho(y_1; y_2) &= \max_{x \in [a;b]} |y_1 - y_2| = \max_{x \in [a;b]} |(k_1 - k_2)x + (b_1 - b_2)| = \\ &= \max_{x \in [a;b]} |(k_1 - k_2)x + (b_1 - b_2)| = \max_{x \in [a;b]} |b_1 - b_2| = |b_1 - b_2|. \end{aligned}$$

We consider the different points of space, so $b_1 \neq b_2$.

Now let's at least one of the numbers k_1 or k_2 is non-zero, for example, $k_1 \neq 0$. Suppose that the graphs of the functions y_1 and y_2 on the segment $[a; b]$ do not intersect. In this case, one of them is higher than the other at each point in the segment. For example, if the inequality $y_1 > y_2$ at every point of the segment $[a; b]$ is executed then we have:

$$y = |y_1 - y_2| = y_1 - y_2 = (k_1 - k_2)x + (b_1 - b_2).$$

Since the function $y = (k_1 - k_2)x + (b_1 - b_2)$ is linear and therefore monotonous, it takes its smallest and largest values at the ends of the segment. Therefore, we will have:

$$\begin{aligned} \rho(y_1; y_2) &= \max_{x \in [a;b]} |y_1 - y_2| = \max_{x \in [a;b]} ((k_1 - k_2)x + (b_1 - b_2)) = \\ &= \max \{(k_1 - k_2)a + (b_1 - b_2); (k_1 - k_2)b + (b_1 - b_2)\}. \end{aligned}$$

This maximum can be reached not only at the end of the segment. In particular, if case of equality $k_1 = k_2$, the maximum is reached at each point of the segment $[a; b]$, in this case the graphs of the functions are parallel to each other.

Now consider the case when the graphs of both functions are intersected. It will mean that the function $y = (k_1 - k_2)x + (b_1 - b_2)$ intersects the OX axis (or touches it) at the point x_0 of the segment $[a; b]$, where

$$x_0 = \frac{b_2 - b_1}{k_1 - k_2}.$$

In this case, the function

$$y = |(k_1 - k_2)x + (b_1 - b_2)|$$

will take non-negative values on the throughout segment $[a; b]$, this function will be monotone on each of the segments $[a; x_0]$ and $[x_0; b]$, and will be value zero at the point x_0 . Therefore, this function can take the largest value only at the ends of the segment $[a; b]$.

Since we have considered all possible cases of the mutual placement of both functions, we can conclude that the distance between two linear functions by the metric of space $C_{[a;b]}$ is equal to the greater of the absolute values of the differences of the values of both functions at the ends of the segment $[a; b]$.

To generalize of Example 10 in the case of arbitrary two monotonic and even continuous functions is impossible.

According to the results Examples 6-8 may suggest that a rectilinear placement of points of a metric space requires a certain "monotony" of the placement of these points. However, this is not always true.

Example 11. On the segment $[0; 1]$ we consider the functions:

$$y_1 = x, y_2 = -x, y_3 = -x + 1, y_4 = x - 1.$$

We show that in space $C_{[a;b]}$ these functions are rectilinear placed. For this we find by the space metric $C_{[a;b]}$ the distances between these functions (points). By the formula (8) we have:

$$\rho_{12} = 2, \rho_{13} = 1, \rho_{14} = 1, \rho_{23} = 1, \rho_{24} = 1, \rho_{34} = 2.$$

Since the equality is executed: $\rho_{12} = 2 = 1 + 1 = \rho_{13} + \rho_{23}$, then the points y_1, y_2, y_3 are rectilinear placed in the space $C_{[a;b]}$, and the point y_3 lies between the points y_1 and y_2 , that is, the point y_3 is internal for points y_1, y_2, y_3 . Similarly, from the equality $\rho_{12} = 2 = 1 + 1 = \rho_{14} + \rho_{24}$ it follows that the points y_1, y_2, y_4 are also rectilinear placed and the point y_4 is internal to them.

On the other hand, the equality $\rho_{34} = 2 = 1 + 1 = \rho_{13} + \rho_{14}$ indicates that the points y_1, y_3, y_4 are rectilinear placed and the point y_1 lies between the points y_3 and y_4 . In addition, from the equality $\rho_{34} = 2 = 1 + 1 = \rho_{23} + \rho_{24}$ we get the points y_2, y_3, y_4 are also rectilinear placed and the point y_2 is internal to them.

Since we have consider all possible triples of points and all of them are rectilinear placement, then, by Definition 4, all four points are rectilinear placement in space $C_{[a;b]}$.

Note that each of the four points lies between some two of them, that is, there are no extreme points between these points. This situation cannot be in Euclid's geometry. There, from the four points lying on a straight line, two will be extreme and two will be internal to those points. Therefore, in this example, as in Examples 5 and 9, we are dealing with elements of non-Euclidean geometry.

The peculiarity of placement of points y_1, y_2, y_3, y_4 can be explained by moving away from the intuitive perception of straightness. It can be illustrated by the example of the space of points of a single circle. If the distance between the two points of the circle is the length of the smaller of the two arcs of the circle connecting these points, it is easy to make sure that the space becomes metric. In this case, the points y_1, y_2, y_3, y_4 will be the ends of two mutually perpendicular diameters of the circle.

The concept of rectilinear in metric space is ambiguous. In Euclid geometry, two points define the only direct line containing these points; this fact is established by the corresponding axiom [27, p. 3]. In metric space, the situation is different. Let's demonstrate by the example of linear functions the ambiguity of the notion of a rectilinear placement of points in space $C_{[a;b]}$.

Example 12. Consider the functions: $y_1 = x + 1, y_2 = x, y_3 = x - 2, y_4 = -x$, given on the segment $[0; 1]$.

Find the distances between these functions by the formula (8), taking into account the results of Example 10:

$$\rho_{12} = 1; \rho_{13} = 3; \rho_{14} = 3; \rho_{23} = 2; \rho_{24} = 2; \rho_{34} = 2.$$

From the obtained equalities, it follows that the points (functions) y_1, y_2, y_3 are rectilinear placed, since equality is executed: $\rho_{13} = 3 = 1 + 2 = \rho_{12} + \rho_{23}$. In this case, the point y_2 lies between the points y_1, y_3 .

On the other hand, the points y_1, y_2, y_4 are also rectilinear placed because the equality is executed: $\rho_{14} = 3 = 1 + 2 = \rho_{12} + \rho_{24}$. In this case, the point y_2 also lies between the points y_1, y_4 .

Since in both cases the points y_1, y_2 are present in each of the equalities, then in Euclid's geometry, all four points y_1, y_2, y_3, y_4 must belong to one straight line. However, from the obtained values of the distances between them, it follows that the points y_2, y_3, y_4 cannot belong to one straight line, since distances between them are equal (they form an equilateral triangle whose lengths are 2). At the same time, the graphs of the functions are arranged one below the other, that is, at each point of the segment $[0; 1]$, the following inequalities are executed:

$$y_1 \geq y_2 \geq y_4 \geq y_3. \tag{9}$$

This fact indicates that in the space $C_{[a;b]}$ the concept of rectilinear placement differs in its properties from the concept of straightness in Euclid's geometry. Below we show that when you change the space metric, the property of placement monotony can be preserved.

The results obtained can be explained by the fact that the properties of the rectilinear placement of points in Euclid geometry are fixed by the corresponding postulates (axioms) [27, pp. 3-5]. In the metric space there are only axioms of the distance between the points, and therefore a certain ambiguity of the notion of straightness is possible.

Assuming a slightly different interpretation of rectilinear placement, then the obtained results are easy to understand. For example, moving around the globe as straightness, we however moving in a circle centered at the center of the Earth. Therefore, by imposing certain restrictions on the path that you can move from point to point, and for the distance between points by taking the shortest path length between points, you can get a non-Euclidean interpretation of the rectilinear placement of points.

Consider another example that demonstrates another feature of the space $C_{[a;b]}$. If you place three points on a straight line in Euclid's geometry, and move one of the two end points along that line in the direction of the other two points, then moving continuously, this point first coincides with one of the other two points (internal point), and then with the second (other outside) point, after which it will continue to move along this line. In the space $C_{[a;b]}$ this is not always possible to do.

Example 13. Consider the functions: $y_1 = 0, y_2 = x, y_3 = C$, where C is a constant. In Example 6, we have shown that all points of the space R^1 are rectilinear placement, so by changing the constant C we move this point in a straight line, both in this space and in the space $C_{[a;b]}$ (see Example 10).

First, consider the case where the constant C satisfies the inequality: $0 < C \leq 0,5$. In this case, we will found the distance between the points (functions) y_1, y_2, y_3 by the formula (8), we have:

$$\rho_{12} = 1; \rho_{13} = C = |C|; \rho_{23} = 1 - C = 1 - |C|.$$

Since the equality is executed:

$$\rho_{12} = 1 = |C| + (1 - |C|) = \rho_{13} + \rho_{23},$$

then the points y_1, y_2, y_3 are rectilinear placement in the space $C_{[a;b]}$.

At $C < 0$ the distances between points (functions) y_1, y_2, y_3 will be:

$$\rho_{12} = 1; \rho_{13} = -C = |C|; \rho_{23} = 1 - C = 1 + |C|.$$

Since the equality is executed:

$$\rho_{23} = 1 + |C| = \rho_{12} + \rho_{13},$$

then points y_1, y_2, y_3 are rectilinear placement in the space $C_{[a;b]}$.

Now let the constant C satisfy the inequality: $C > 0,5$. In this case, the distances between the points (functions) y_1, y_2, y_3 will be: $\rho_{12} = 1; \rho_{13} = \rho_{23} = C$. With these values of distances, the points y_1, y_2, y_3 form an isosceles triangle with a length of base which equal to ρ_{12} and with sides whose lengths are equal to C (constant C exceeds 0.5). Thus, for the points y_1, y_2, y_3 , the rectilinear placement in the space $C_{[a;b]}$ was broken, although the point y_3 moved straightforwardly.

Example 13 indicates that, despite the equality of all points of the metric space, in specific spaces not only the metric, but also the intrinsic properties of each point (element) of the space can significantly affect the geometric properties of the entire space.

After studying the definite integral and its applications, it is possible to acquaint the pupils with another metric space related to the geometric content of the definite integral. These topics are studied in the eleventh grade [38, pp. 254-256; 39, pp. 373-374; 40, pp. 235-238; 41, pp. 112-113].

Consider the set of functions continuous on the segment $[a; b]$. For the distance between the two functions $f(x)$ and $g(x)$ of this set we take the number which is given by the formula:

$$\rho(f; g) = \int_a^b |f(x) - g(x)| dx \tag{10}$$

With this choice of metric, the considered set of functions becomes a metric space denoted by C_L .

To test the distance axiom in this space, it is necessary to know a number of properties of a defined integral that are not actually mentioned in current textbooks. In particular, it is not mentioned the monotonicity property of a defined integral:

“If the functions $f(x)$ and $g(x)$ are continuous on the segment $[a; b]$, and inequality $f(x) \geq g(x)$ is executed at every point in this segment, then the inequality

$$\int_a^b f(x)dx \geq \int_a^b g(x)dx$$

is executed.”

This property is quite simple to obtain the defined integral is determined as the boundary of the integral sum [39, pp. 367-368; 40, pp. 225-226; 41, pp. 112-113]. Such a definition is historically justified and makes it quite easy to obtain various applications of a definite integral. For calculating defined integrals of functions is more convenient to use the Newton-Leibniz formula.

It should be noted that, as a rule, only the arithmetic actions over integrals are mentioned among the properties of a defined integral in the existing mathematical textbooks, and the condition of the existence of the integral is not actually paid attention. Therefore, pupils should be emphasized that function which is continuous on the segment is integrated, that is, continuity of a function on a segment is a sufficient condition for exist its integral on that segment. In our view, it will greatly enhance the importance of studying the concept of continuity of function. The condition of continuity of the integrand function can be included when familiarizing with the Newton-Leibniz formula [39, p. 360; 40, p. 223].

Let’s make verification of distance axioms for the metric given by formula (10). From continuity of the functions $f(x)$ and $g(x)$ follows continuity, the function $|f(x) - g(x)|$ is existed, so the distance defined by formula (10) exists. Any integral sum for the function $|f(x) - g(x)|$ on the interval $[a; b]$ is the sum of the nonnegative terms, and therefore its boundary cannot be negative. The triangle inequality for the functions $f(x)$, $g(x)$, $h(x)$, continuous on the segment $[a; b]$, is obtained using the monotonicity property of a defined integral:

$$\begin{aligned} \rho(f; g) &= \int_a^b |f(x) - g(x)|dx = \int_a^b |(f(x) - h(x)) + (h(x) - g(x))|dx \leq \\ &\leq \int_a^b (|f(x) - h(x)| + |h(x) - g(x)|)dx = \int_a^b |f(x) - h(x)|dx + \int_a^b |h(x) - g(x)|dx = \\ &= \rho(f; h) + \rho(h; g). \end{aligned}$$

Geometrically, the distance between the two functions $f(x)$ and $g(x)$ of the space C_L defines the figure area which is bounding by the graphs of these functions on the segment $[a; b]$.

In school textbooks the less general formula of the area of a figure bounded by the graphs of the functions $f(x)$ and $g(x)$, which satisfy the inequality $f(x) \geq g(x)$ on the segment $[a; b]$ is used:

$$S = \int_a^b (f(x) - g(x)) dx$$

[38, p. 261; 39, pp. 373-374; 40, pp. 236-237; 41, p. 115].

The metric defined by formula (10) is less sensitive to the features of the structure of an individual element of space. It can be illustrated by the following example.

Example 14. Let us return to Example 12 and consider the functions: $y_1 = x + 1$, $y_2 = x$, $y_3 = x - 2$, $y_4 = -x$, given on the segment $[0; 1]$. Previously, we found that all four functions are not rectilinear placement in $C_{[a;b]}$. Let’s find the distances between them by the metric of space C_L . By the formula (10) we have:

$$\rho_{12} = \int_0^1 |(x + 1) - x|dx = \int_0^1 dx = 1 - 0 = 1;$$

$$\rho_{13} = \int_0^1 |(x + 1) - (x - 2)|dx = \int_0^1 3dx = 3(1 - 0) = 3;$$

$$\rho_{14} = \int_0^1 |(x + 1) - (-x)|dx = \int_0^1 (2x + 1)dx = (1^2 - 0^2) + (1 - 0) = 2;$$

$$\rho_{23} = \int_0^1 |x - (x - 2)|dx = \int_0^1 2dx = 2(1 - 0) = 2;$$

$$\rho_{24} = \int_0^1 |x - (-x)|dx = \int_0^1 2xdx = 1^2 - 0^2 = 1;$$

$$\rho_{34} = \int_0^1 |(x - 2) - (-x)|dx = \int_0^1 (2 - 2x)dx = 2(1 - 0) - (1^2 - 0^2) = 1.$$

Since the equality is executed: $\rho_{13} = 3 = 1 + 2 = \rho_{12} + \rho_{23}$, then the points y_1, y_2, y_3 are rectilinear placed in the space C_L , and the point y_2 lies between the points y_1 and y_3 .

From the equality $\rho_{14} = 2 = 1 + 1 = \rho_{12} + \rho_{24}$ it follows that the points y_1, y_2, y_4 are also rectilinear placement, and the point y_2 lies between the points y_1 and y_4 .

Since the equality is executed : $\rho_{13} = 3 = 2 + 1 = \rho_{14} + \rho_{34}$, then the points y_1, y_3, y_4 are rectilinear placement in the space C_L , and the point y_4 lies between the points y_1 and y_3 .

From the equality $\rho_{23} = 2 = 1 + 1 = \rho_{24} + \rho_{34}$ it follows that the points y_2, y_3, y_4 are also rectilinear placement, and the point y_4 lies between the points y_2 and y_3 .

We considered all four possible triples of points, and each of them turned out to be rectilinear placement. By Definition 4, all four points are rectilinear placement in C_L , and the points y_1, y_3 are external, and the points y_2, y_4 are internal to the points y_1, y_2, y_3, y_4 . All points are placed in the following order: y_1, y_2, y_4, y_3 . This placement of functions coincides with the order of their placement on the coordinate plane.

Example 14 is a consequence of the more general property of C_L space. Comparing the results of Examples 12 and 14, we can conclude that the metric of the space C_L is more “stronger” than the metric of the space $C_{[a;b]}$, since even the “monotonicity” of the placement of functions could not ensure their rectilinear placement in the space $C_{[a;b]}$. In the space C_L , unlike the space $C_{[a;b]}$, the rectilinear placement of points can provide them with a certain “monotonicity of placement”, as evidenced by the following example.

Example 15. Consider the set F of functions continuous on a segment $[a; b]$. Let’s for any function $f(x)$ and any function $g(x)$ of this set, the inequality $f(x) \geq g(x)$ is executed at every point of this segment.

We show that the set F is rectilinear placement in the space C_L . To do this, we consider arbitrary three elements $f(x), g(x), h(x)$ of this set. Let for them, at each point x of the segment $[a; b]$ are satisfied, for example, inequalities $f(x) \geq g(x) \geq h(x)$. By formula (10) we will find the distances between these elements:

$$\rho(f; g) = \int_a^b |f(x) - g(x)|dx = \int_a^b (f(x) - g(x))dx = \int_a^b f(x)dx - \int_a^b g(x)dx ;$$

$$\rho(f; h) = \int_a^b |f(x) - h(x)|dx = \int_a^b (f(x) - h(x))dx = \int_a^b f(x)dx - \int_a^b h(x)dx ;$$

$$\rho(g; h) = \int_a^b |g(x) - h(x)|dx = \int_a^b (g(x) - h(x))dx = \int_a^b g(x)dx - \int_a^b h(x)dx.$$

From the obtained equalities follows the equality:

$$\rho(f; h) = \int_a^b f(x)dx - \int_a^b h(x)dx =$$

$$= \left(\int_a^b f(x) dx - \int_a^b g(x) dx \right) + \left(\int_a^b g(x) dx - \int_a^b h(x) dx \right) = \rho(f; g) + \rho(g; h).$$

The obtained equality means that the elements $f(x)$, $g(x)$, $h(x)$ of the set F are rectilinear placement in the space C_L .

Since we have chosen elements arbitrarily, by Definition 4, the whole set F is rectilinear placement in the space C_L . Now, the result of Example 14, due to inequality (9), becomes a special case of Example 15.

4. Conclusions

The current state of development of non-Euclidean geometries, and the level of their application, indicates the need to introduce into the educational process of the basic school of the basic concepts and elements of these geometries. This paper presents examples of such implementation in geometry lessons, as well as in extracurricular work in mathematics. These examples are based on the school mathematics course, and form generalized notions of point, distance between points, and rectilinear placement of points. It is proposed to introduce these concepts throughout the course of school mathematics, starting from the 7th grade.

Formation of generalized notions of distance between points, and straightness of their location, can be started in the seventh grade with advanced study of mathematics. At the same time, examples of ambiguity of these concepts should be used to make understandable for students of the appropriate age.

Systematic introduction to non-Euclidean geometry students can begin in the ninth grade with advanced study of mathematics. Such elements can be demonstrated when studying the numerical straight and coordinate planes.

In senior classes with advanced study of mathematics, at the profile level, it is possible to introduce the notion of metric space, and as examples of such spaces we can consider the spaces of continuous and integrated functions on the segment. However, in our opinion, this material should be considered in elective classes in mathematics.

The material presented in this paper can be considered as the first acquaintance with the basics of metric geometry. Following these examples, you can develop and solve a large number of different problems about the mutual placement of basic elementary functions in different metric spaces, and build, explore different geometric forms in these spaces. In [42, 43] the question of rectilinear placement of points of metric space was applied to the study of geometric properties of this space.

Further research will focus on the application of the generalized concept of angle formed by the points of the metric space, and the concept of flat placement of points of this space. The research is planned to be limited to discrete cases of rectilinear and flat placement of points.

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Learning by experimenting as a good way to effective and student friendly mathematics education – experiences from Young Explorer's Club

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Abstract. Students in many countries have problems with learning of mathematics. Many students do not like mathematics. Teachers and parents are mostly aware that the style of teaching of mathematics and “the atmosphere” around mathematics are the main reasons for this state. For the society it is clear that something must be changed. Maybe methods of teaching, maybe the whole system? Copernicus Science Centre in Warsaw 18 years ago proposed the idea of Young Explorer's Club (YEC) as the environment where students can discover knowledge by making experiments. Learning by experimenting, by own activity of learners makes the whole educational process more interesting and less frustrating for students. This also applies to mathematics education. Experiences from mathematical Young Explorer's Clubs established at the Centre for Creative Mathematics Learning at the Faculty of Mathematics University of Białystok as the possible way to more effective mathematics education will be presented in the paper. Experimenting and using functional strategy of teaching of mathematics is the basic form of activity in the Clubs.

1. Introduction

Students in many countries have problems with learning of mathematics. A lot of students do not like mathematics. It is necessary to answer the question: Why does mathematics education cause so much problems? Why students do not like to learn mathematics?

At the Faculty of Mathematics, University of Białystok, Poland, lecturers cooperate very strongly with teachers and students from schools of all types on all educational levels and during this cooperation some problems with mathematics education were identified. The main of them (from students' point of view) are the following:

- too abstract (for many students) character of mathematics;
- lack of convincing about the usefulness of mathematics;
- image of mathematics as a set of separate theorems without any connections between them;
- learning to the memory;
- superficial learning, lack of the ability of the concentration on the text;



- lack of the self-confidence and lack of belief in the possibility of successful learning mathematics;
- the style of the lessons where teachers play the leading role with spoon-feeding teaching methods; students' role is to memorize knowledge and solve exercises;
- dissonance between freedom of access to information in everyday life and the school environment where modern technologies are still much less frequented among teaching/learning resources.

Conclusion from this list of students' opinions? It is necessary to change the style of mathematics education.

2. How to change the style of mathematics education – a proposal

At the first edition of The Cognitive Adventures Conference [11] organized by Copernicus Science Centre in Warsaw in 2015 there was given good proposal for this. One of the speakers proposed to arrange education (not only mathematics education) according the following:

- inspiration versus information;
- exploration versus explanation;
- self-motivation versus obligation.

It is known very well that now in schools mostly information, explanation, obligation is given our students. What will happen if we give them inspiration (to discovering knowledge), good conditions for exploration (in order to discover knowledge) and self motivation (instead of fear of exam or bad mark)? What will happen if we propose our students diversity of experience instead of learning theorems and formulas in memory? What will happen if we arrange educational process according the schema: observe, measure, compare, conclude? What will happen if we propose our students “learning by doing”, learning by activities – different activities, both physical and mental?

“Teaching is really about inspiration, not information. Effective teaching focuses on *why* and *how*, not what. The goal should be to spark each student’s imagination, to find a hook in their heart and mind so that they feel a need to learn the material. The rest is easy, because the student then drives his or her learning. My role as a teacher is to ask provocative questions, and to help the students make a path toward the answers. If they are motivated to find the path, they will carve it themselves. If I have to pull out a mental machete to expose the path, then I haven’t done my job.” – Tina Seelig says in the interview “Teaching – it's about inspiration, not information” [7].

Is it possible at all?

3. Strategy of functional teaching of mathematics

Experiences show that it is possible, especially that we have strong theoretical, scientific bases for learning by doing. As the theoretical background of this kind of mathematics education the following theories can be taken: theory of constructivism; strategy of functional teaching of mathematics; problem solving method.

Many teachers and organizers of educational process forgot already about strategy of functional teaching of mathematics, created by Zofia Krygowska, Polish great specialist in didactics of mathematics, and strongly popularized by Helena Siwek, also specialist in mathematics education. It is a pity, because this strategy is a very good methodological background for recommended changes in mathematics education (and sometimes in other subjects of education too).

In one of her most important books „Outline of the didactics of mathematics” Zofia Krygowska gave some advices that can lead to raising students' creativity and independence in learning mathematics, for example: “Putting the student in conflict situations in which the adopted patterns of conduct fail and in which the student must transform (adapt) the old pattern or develop a new one. (...) Consistent learning of free use of known operations and getting the student accustomed to the fact that only specific action, not just passive contemplation and waiting for "inspiration" leads to the solution of the problem”. [5]

Strategy of functional teaching of mathematics recommends using three kinds of activities in the process of formulating mathematical concepts [5], [8]:

- concrete activities (on real objects) – enactive representation (action-based) in Bruner's Learning Theory in Education;
- imaginary activities (on pictures, patterns and other graphic images of ideas) – iconic representation (image-based) in Bruner's Learning Theory in Education;
- abstract activities (on mathematical symbols) – symbolic representation (language-based) in Bruner's Learning Theory in Education.

In such approach to mathematics education student participates in the whole process of formulating particular concept, so understands this concept and will remember it, because will remember process and reasoning that led his/her to constructing this concept.

And such approach fits very well to “observe, measure, compare, conclude” method: “observe, measure” – concrete activities; “compare” – very frequently activities on pictures, patterns and other graphic images of ideas; “conclude” – abstract activities.

Strategy of functional teaching of mathematics is strongly connected with problem solving method and realistic mathematics teaching. Concrete activities means experimentation. We do experiments in order to solve some problems; that means that we use problem solving method and organize investigative work for students. Doing experiments leads to discussions, arguing and making conclusions. It means also using research method – it can be useful in education of many school subjects.

Using problem solving method requires very frequently correlations between school subjects; we solve not only mathematical problems, but problems from other fields of science that often need mathematics. It is very good way to make our students convinced that mathematics is useful everywhere, also in making analysis of the results of experiments and concluding about trends.

Of course using strategy of functional teaching of mathematics, implementing problem solving method, inspiring students to investigative work requires from teachers creating proper didactic situation that consists of properly selected didactic tools (research tools for students) and atmosphere of scientific work, full of inspiring questions, discussions, arguing, concluding. As for research tools, we can use any proper tools, both manual and technological. Usually the main aims of using technology are to make simulations in research work and to make analysis of the results of experiments in order to conclude about trends. [6]

4. Mathematical experiment

Many teachers ask: what is “mathematical experiment”? We can imagine experiment in biology, chemistry, physics, but in mathematics? Is it possible to make experiments at the lesson of mathematics?

Yes, it is. Probably the first man-made experiments are due to the time of Galilei (for instance experiments with pendula). In mathematics, models and instruments became important in the 19th century. In the last years, some mathematical exhibitions (and not only mathematical ones) have been developed and science centers have been opened. Mathematics is typically not presented there in the traditional way using the mathematical language. Visitors find there exhibits, in which they may see or explore mathematics. Visitors are challenged to perform “mathematical experiments”. Also some mathematical experiments have been known for a long time, mostly under the name of “mathematical games”. [1]

All of us know some of these experiments related to mathematics, for example Pythagoras puzzle (in order to prove Pythagoras theorem), origami (in order to create beautiful models of solids) etc. But many people (especially mathematicians who deal with pure mathematics, but also teachers and parents) ask two fundamental questions:

- 1) Are these experiments at all?
- 2) Is this at all mathematics?

Albrecht Beutelspacher in [1] asks these questions and answers first question in the following way:

“One of the main features of mathematics is that the truth of an assertion is obtained by a proof, that is by purely logical arguments, and not, for instance, by experiments. This distinguishes mathematics from sciences such as physics or chemistry, where experiments are used to verify a theory or to falsify a wrong hypothesis. Also, mathematical experiments are not used to simply illustrate a definition or a theorem. The role of a mathematical experiment is quite different. Its basic property is to stimulate thinking. In science centers, experiments do not come second (after a theory), but experiments come first. They provide a strong impulse. Basically, a person working with a mathematical experiment is challenged by a mathematical problem. As in research, one has to get the right conception, the right idea of what’s going on. And sometimes, after a while of thinking, and sometimes with luck, one finds the solution. (...) To put it short, a mathematical experiment works “bottom-up”: starting from experience, leading to insight. It is an impulse. If the experiment is good, this impulse is so strong that it enables the visitor to ask the right questions, to get the right conceptions and, finally to get by an “Aha-moment” the right insight.”

As the answer the second question he writes: “Certainly, it does not look like mathematics, in particular not like school mathematics. In fact, in Mathematikum we explicitly stated at the beginning that we want to make a place that doesn’t look like school. Mathematical experiments do not show the mathematical language: no point is called “P”, no variable is called x, in fact, there are no formulas. Also, no definitions, no theorems, no proofs. On the other hand, an important part of mathematical activity is clearly present, namely problems. And, if visitors solve the problems, they activate mathematics-related competences, such as arguing, and communicating. (...) To sum up, working with mathematical experiments is *a first step into mathematics*.”

Let’s repeat our question asked at the beginning of the section: Is it possible to make experiments at the lesson of mathematics?

Strategy of functional teaching of mathematics recommends starting from experimenting by doing concrete activities. In teaching “school mathematics” all activities of students and teachers must lead to possessing mathematical knowledge and skills. In this situation (according to the theory of functional teaching) experiments (concrete activities) are arranged in order to solve some mathematical problem and acquiring some new knowledge. In this sense of the whole process experiment means the beginning of investigative work of student, the beginning of research process. The structure of the research process (observation – curiosity – problem formulation – assumption – hypothesis verification – application) fits very well to the strategy of functional teaching: curiosity leads to setting problem, then students set the hypothesis, then verify their hypothesis by making experiment on real objects, then formulate conclusions in the language of mathematics (construct new knowledge) with the help of iconic representations, symbols and abstract thinking.

5. The idea of Young Explorer's Club

Teachers say that they have no time for such way of teaching, because of many pupils in the group, too less number of lessons per week, necessity of good preparing to exams... They often say: “How can I change the style of lesson if I have to prepare my students to exams, to explain them everything, to teach them how to solve exercises of types that occur in tests and have so little time for this?”

But it is necessary to change something if we want to make students not to be afraid of mathematics and (it would be so good!) to like mathematics.

In this situation extracurricular classes organized in the schools or in any other places can be some solution of the problem.

Copernicus Science Centre in Warsaw 18 years ago proposed the idea of Young Explorer's Club (YEC) as the environment where students can discover knowledge by making experiments.

“Young Explorer Club means meetings, gripping classes and atmosphere! Children and young people together experiment under the watchful eye of Supervisors. They gain knowledge on their own. All over Poland and abroad there are several hundred clubs. The Copernicus Science Centre, the coordinator of the programme, enhances the development of the YEC with the support of the Strategic Partner, the Polish-American Freedom Foundation.” – we can read at the website of this program. [2]

What is important in the idea of Young Explorer Club?

- During meetings a personal commitment is most important.
- Members of the Clubs are seeking subjects interesting for them by themselves, instead of looking into the textbooks.
- Participants are looking for solutions of the problems by experimenting.
- Research method is a core method; it helps to develop a lot of competence and abilities in the same time, allows for crossing school borders between objects and shows that making mistakes is valuable and teaches to solve problems.
- It is possible to examine phenomena from different fields.

In Poland there are more than 700 Clubs, in Georgia – more than 100, now this idea starts in Ukraine and Armenia. Most of these Clubs are based on biology, chemistry and physics.

6. Mathematical Young Explorer's Clubs at the University of Bialystok

In order to give some support for those children and young people who are interested in discovering mathematics by themselves in June 2019 we (lecturers from Faculty of Mathematics) established at the Centre for Creative Mathematics Learning (Faculty of Mathematics, University of Bialystok) two Clubs: “We, trackers of mathematics” (for kids from primary schools) and “We, mathematicians” (for students from secondary schools). During meetings participants do manual activities in order to explore new for them topics or applications of mathematics.

For the first meeting kids came with parents, grandparents or teachers. Especially parents and grandparents were very happy that in Bialystok will be the place where their children/grandchildren will be able “do something concrete in mathematics, not only solve exercises from textbook” – as some of them said.

Meetings of Clubs at the Faculty of Mathematics, University of Bialystok, take place one time per month for each Club. Parents participate very often in the meetings of children from primary schools and solve the same problems that kids solve. And they have a fun from this and very often say: “I never learned mathematics in that way! I had new experience today and understood the topic!”

Books by Ian Stewart are very good source of topics for investigative work that leads to mathematical discoveries [9], [10].

There are two main principles of arranging workshops in the Clubs at the Centre of Creative Math Learning:

- 1) to inspire students to discover mathematics by experimenting with using real objects;
- 2) to help them in learning “school mathematics” – it means that all their activities in the Clubs are somehow connected to the topics from school mathematics and help them to understand these topics better.

There are two reasons for these principles:

- 1) to convince students, parents and teachers that mathematics can be learned by experimenting and thinking, not only by listening and solving exercises from textbooks;
- 2) to start the process of transfer methods of learning and teaching from YEC to the lessons of schools, because we want to help teachers and students in more effective and less frustrating mathematics teaching and learning.

Now Copernicus Science Centre pays big attention to the process of transfer methodology of experimenting from YEC to schools.

At the beginning our intention was to arrange workshops for students from secondary schools on more advanced topics, so first topic was the introduction to topology, but during the school year these students found out topics of workshops for kids from primary schools, found them very interesting and asked to work on the same topics, so some topics were proposed for participants of both groups. Also it happened that students asked to explain them topic from the lesson of the school (for example after first lesson in the school about trigonometric functions they were so interested in the topic that asked to tell them about practical applications of these functions and we devoted all meeting of the Club to this matter).

7. Selected topics of Clubs' meetings

Bellow the selected topics of workshops with methodical comments and illustrating pictures are presented. In two cases using Strategy of functional teaching of mathematics is described in more detailed way. The workshops for Club “We, mathematicians” were conducted by author of this paper, for Club “We, trackers of mathematics” by author and Dr. Justyna Makowska, lecturer in Faculty of Mathematics together. Presented materials are structured in chronological order.

7.1. *Is the coffee mug always different from bagel? – introduction to topology.*

The sketch of scenario for the workshop for YEC “We, mathematicians”, carried out on June 11, 2019 at the Centre for Creative Mathematics Learning at the University of Białystok. Students of secondary schools (technical schools) from Białystok participated in the classes.

Aim of the workshop:

Who has not heard the term "computer network topology"? We know from computer science lessons that it's just a way of connecting computer devices. What does the word "topology" mean? During the workshop, we will investigate whether diametrically opposed – it would seem – different subjects have something in common and in this way we will learn the basics of a very important branch of mathematics, i.e. topology. Next, we will consider if the topology is visible around us.

Materials: plasticine, drawing supplies (a sheet of paper and a pen will be enough).

Introduction (arousing cognitive curiosity): A topologist is jokingly described as a mathematician who cannot distinguish a coffee mug from a bagel. Why? – a short discussion on this topic, leading to interest in the topic rather than answering the question, because the very definition of the topologist was very surprising for the students.

Short introduction to the concept of topology: Topology is a branch of mathematics that studies properties that do not change even after objects have been radically deformed (geometric figures, solids, and objects with more dimensions). Such properties are called topological invariants, and deformation is understood as meaning any deformation (bending, stretching, twisting), but without tearing and sticking together various parts. The deformation process is easiest to imagine assuming that the object is made of rubber.

Problem 1: How can you find out if a bagel is the equivalent of a cup (topologically)? Brief brainstorming on research strategies and working with plasticine. This stage of work is illustrated by the photo below:



Figure 1. Students try to transform mug into bagel with using plasticine.

Discussion and conclusion: Yes, we can turn a plasticine cup into a bagel without tearing it apart and sticking the parts together! We know how to make topological transformations!

Problem 2: Geometric concepts such as length, area, parallelism, and perpendicularity are not topological properties. Why?

Discussion on this topic supported by experiences with plasticine. The answer to the question was not a problem for the students. They quickly discovered that, for example, when stretching an object, the original dimensions were not preserved.

Problem 3: The dimension is the topological property. Why?

And here problems appeared – mainly with understanding the concept of dimension, which was a surprise to me. We explained to ourselves, using sheets of paper, pens, a blackboard, chalk, drawing appropriate figures, that a point is a zero-dimensional figure (it has no dimensions, we do not measure it in any way), a straight line, a half-line, a line segment are one-dimensional figures (we measure one dimension of the segment, i.e. length, in the case of a straight line or a half-line this "length" is infinite), a rectangle is two-dimensional (we measure its length and width, i.e. it is characterized by two numbers), a cuboid is three-dimensional (we measure its length, width and height, i.e. it is characterized by three numbers). Of course, we also talked a bit about 2D and 3D. Once we explained the concept of dimension, the following problem arose: can plasticine still be a good research tool for us in this exercise, if a point has no size, a straight line has only one dimension, and we can only create three-dimensional material objects from plasticine – yes, even if we they tried very hard, we will not create a completely flat object without thickness. The conclusion from the discussion was as follows: here plasticine will not be useful to us. We have to use our imagination and think abstractly. Using just abstract thinking, students said that dimension is a topological property, because with the transformations allowed by the topology, we will not obtain an object with a given dimension of an object with a different dimension: the straight line will always remain one-dimensional, and the rectangle will not “grow” a cuboid.

Problem 4: Are the circle and the triangle topologically equivalent? And the circle and the triangle? Why or why not?

There was no trouble here anymore. Plasticine came in handy, the circle was quickly transformed into a triangle, both figures are two-dimensional, so they are equivalent in a topological sense. In the case of the circle and triangle, the answer was no. Perhaps the Readers will wonder why?

At the end of the class, we talked a bit about topology applications and it turned out that students were familiar with the term "topology" in relation to, for example, the GIS system, but they never had any associations with mathematics on this occasion.

Summary of the lesson (from the students' side): We were discovering strange mathematics today, but it was interesting!

Methodical note:

During the classes a clear application of the strategy of functional learning of mathematics appeared: there were concrete activities (on objects made of plasticine), imaginary activities (in drawings, when we explained the issues related to the concept of dimension) and abstract activities (performed only in our minds when explaining why dimension is a topological property and we did not need concrete activities because it was not possible to use plasticine). All three kinds of activities were necessary for the students to discover new knowledge and draw conclusions. Overall: It is strongly encouraged for teachers to use a functional strategy. Students of all ages like to do concrete activities. Expecting from them only abstract activities often causes a lack of understanding of the subject and builds a picture of mathematics as a field inaccessible to the average student.

7.2. How to make “perpetual calendar” from two cubes?

Workshop for kids from primary school, participants of the Club “We, trackers of mathematics”, September 30th, 2019.

In 1957, John Singleton patented a desktop calendar that was supposed to show each day of the month from the 1st to the 31st with two cubes, but allowed that patent to expire in 1965. There are six figures on each cube, one on each side. You can place cubes with any face facing forward and in any order. What should the numbers on each of the cubes be? [9]

From mathematical side of view the problem is connected to combinatorics.



Figure 2. Children solve the problem of eternal calendar. The main problem is: what digits should be on the sides of cubs if we want to express number of each day from each month?

After the workshop one father said: “My son has at home such calendar, but he never wondered what the mathematical principle of its construction was. Now he experienced this on his own.”

7.3. Is it possible to transform Greek cross into a square?

Workshop for kids from primary school, participants of the Club “We, trackers of mathematics”, October 23rd 2019.

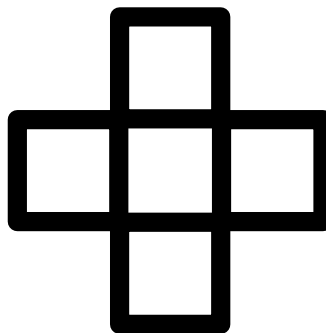


Figure 3. Greek cross.

Problem: Is it possible to transform it into a square?

Problem solving objectives:

- deepening students' knowledge of geometry;
- training problem-solving skills;
- developing the ability to build a strategy, plan implementation, critical approach to the result of your actions;
- developing the ability to discuss, argue, justify one's opinion.

Concrete activities:

First, students try to make a square from the cut parts of the Greek cross:

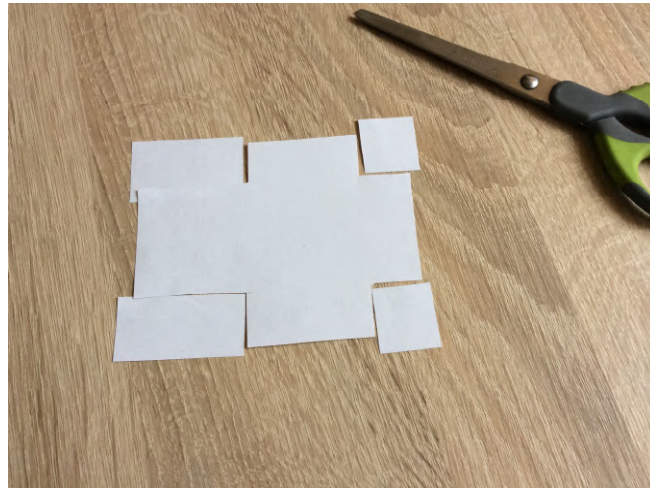


Figure 4. Concrete activities at first.

Imaginary activities:

Students present their ideas on the blackboard and try to justify that the presented "puzzle" is indeed a square (the figure on the right side of the blackboard):

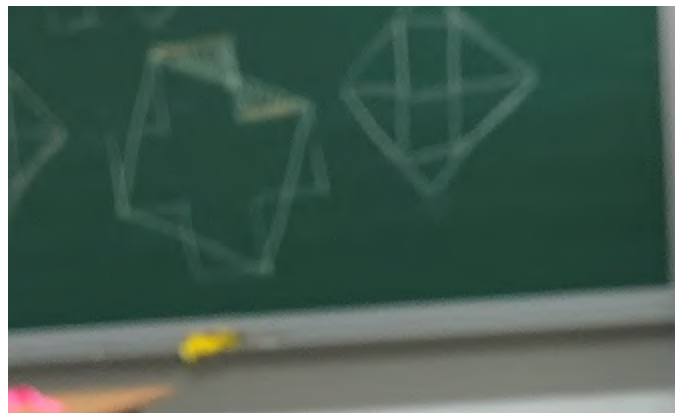


Figure 5. Activities on the pictures and discussion about proving our thesis in next steps.

Abstract activities:

We are discussing the transformation that actually leads to the formation of a square (figure in the center of the board). We have to show that the "cut" fragments "fit" to the places where we want to place them, that is – mathematically – that the two triangles are congruent. And here the problem arises if we conduct classes in a group of different age groups. During the reported classes, students aged 7 to 13 were present, so not all of them knew the concept of congruent figures. This concept had to be introduced on the basis of everyday situations, close to the kids. And it really happened: the participants assimilated the concept of congruent figures (alternatively: identical) on the example of patterns of the part of the dress that the tailor sews, closely matching the template placed on the fabric. Determining the congruence properties of triangles was already simple (What does it mean that the triangles are identical? What does it mean for their sides and for their angles?) Based on the formulated congruence properties, we reasoned that the two triangles shown in the figure are identical.

Now it had to be justified that the "puzzle" was a square. We had to show that all sides of the resulting quadrilateral are equal and all angles are right. In the case of justifying the equality of the sides, the situation is simple: we use the congruence of triangles. With angles, the situation is more complicated. For children in younger age, intuition and measuring can be used, and for the older ones, operations on the measures of angles expressed generally, with the help of symbols.

Classes on the same topic were also conducted with secondary schools students, members of the Young Explorer's Club "We, mathematicians". Generating ideas for turning the Greek cross into a square did not go any better here than it did for primary school children, but justifying that we got a square was much smoother because the students knew the concept of congruence, the Pythagorean theorem, and were more skilled at angular measurements. Moreover: one of the students proposed to prove that both figures (the original Greek cross and the resulting square) have the same fields, which of course we did.

Reflection:

No student came up with the idea of how to turn a Greek cross into a square – despite being prompted at some point. The drawing in the center of the board was made by the teacher (AR) at the time when it was already known that there were no new ideas from the participants. Why was it so difficult for the participants to develop the concept of transformation? Probably because they are used to drawing geometrical figures in such a way that some sides are parallel to the edge of the page or board, so then "the drawing is decent". This is what they wanted to get the square on the table. Meanwhile, here we got a "slightly rotated" square, that is, it was necessary to break with the stereotype.

7.4. What common have knot tied in the ribbon or strip of paper and an apple?

At the next stage of workshop conducted in October 23rd 2019 we researched what is the result of tying the ribbon? And the paper ribbon? What does a cut apple have to do with a knot on the ribbon?

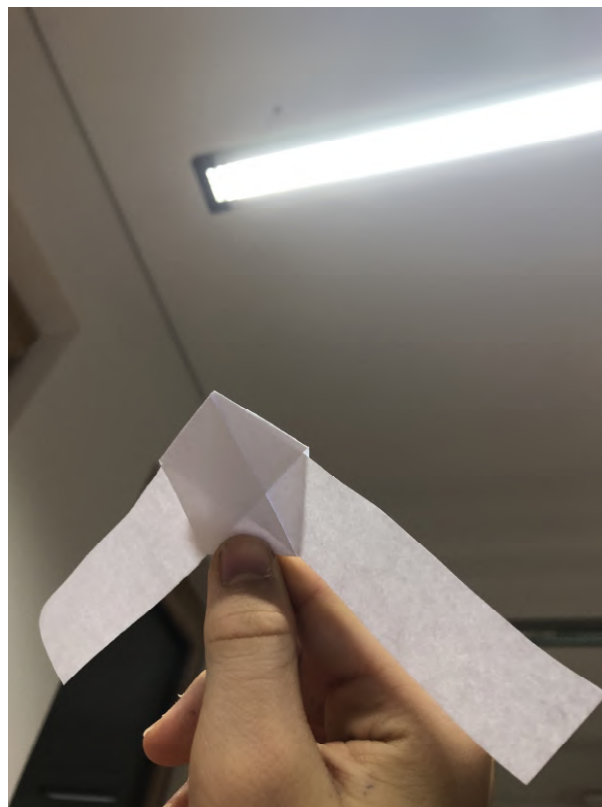


Figure 6. Pupils discover pentagon in the knot made from strip of paper.



Figure 7. Pupils discover pentagon in the apple. Mathematics in the apple? Yes!

Of course, for students from secondary schools it was necessary to prove that this knot on the strip of paper is a regular pentagon. For some kids from primary school it was first meeting with pentagon, so they counted sides, angles and vertices of the figure and created the name of it (by analogy with the triangle that has three sides, three angles and three vertices).

But for all participants it was really surprise that mathematics can be discovered on the knot made on the ribbon and the same figure is present in the nature.

7.5. Moving butterfly that is we are searching for the centre of gravity

On February 19th, 2020, another class of the “We, trackers of mathematics” Club took place. This time it concerned physics and mathematics and was led by the Dean of the Faculty of Mathematics, prof. Alina Dobrogowska. We used a sheet of paper, coins and a match to build a butterfly, which not only stayed on the fingertip or the blade of scissors, but also moved in this position without losing its balance. Of course, it was necessary to find the center of gravity of the object, and we learned to look for this center by first considering the centers of gravity of various geometric figures. By the way, we discovered several properties of the triangle that were not so obvious “at first glance”.

And the most beautiful thing was that the parents worked and discovered mathematics with the same enthusiasm as their children.



Figure 8. I did this! Butterfly flies on the tip of my finger!

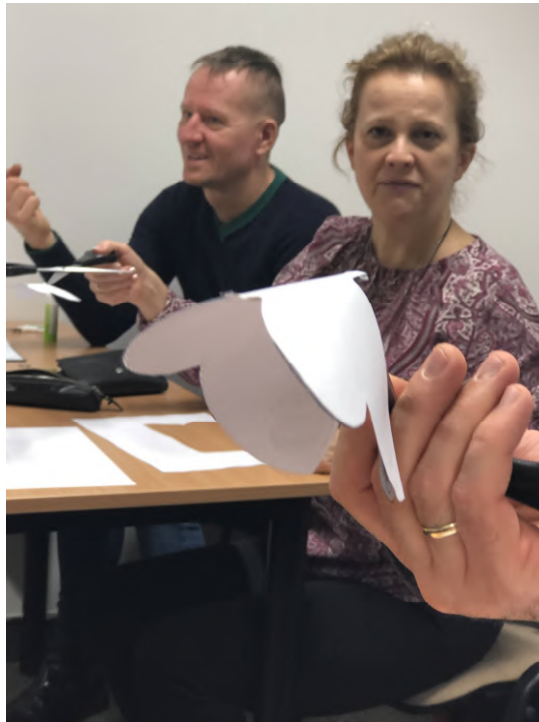


Figure 9. Parents of members of the Club are working with full commitment.

This workshop showed the participants that there are correlations between mathematics and physics and that mathematical discoveries can be useful in physics. Also it is very important that even 7-years-old kids discovered center of gravity of triangle and other figures with using functional learning method, not from definition.



Figure 10. We are looking for the center of gravity of a triangle.

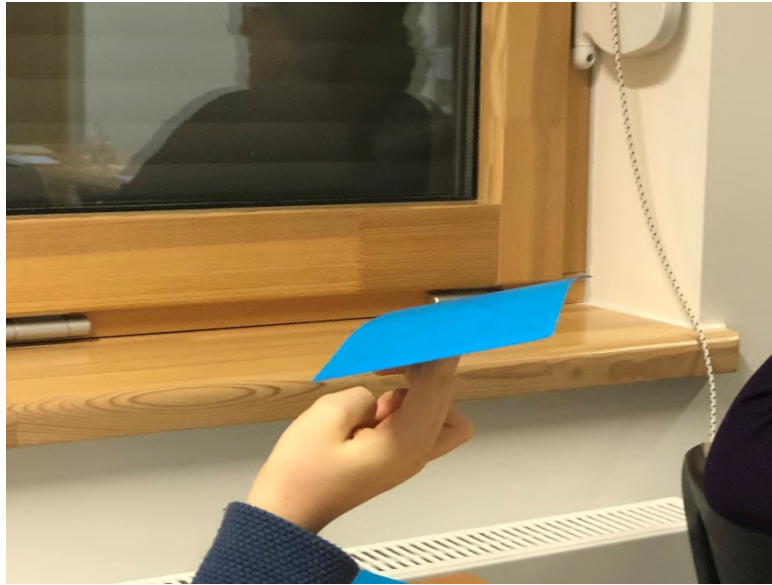


Figure 11. I found the center of gravity of a rectangle!

7.6. Clubs during pandemic

During pandemic and quarantine we couldn't have our normal meetings, so each month materials for work in families were sent to the members of our Clubs. Topics of these materials: Geodesic lines; We improve our mathematical intuition and the sense of observation; You can create art as Escher; You can discover properties of polyhedrons as Euler.

Some of these materials were published at the website of YEC as inspiration for all teachers and students from the whole Poland who are interested in the topic [4].

Online meetings of the Clubs were not arranged, because there were many problems in families with online school lessons, so we did not want to overload kids and their parents with additional online activities.

8. Research

We did not conduct any well prepared research on effectiveness of mathematics education in this style that we propose in Centre for Creative Learning of Mathematics – more precisely in our mathematical Young Explorer's Clubs. Our Clubs are relatively young, also pandemic broke our normal functioning, so we even had no time to prepare and conduct full research process. During these few months we observed great interest and enthusiasm of the members of our Clubs and their parents.

On the website of Copernicus Science Centre the report from big research carried out in 2015 “School of experience. Report of study on Young Explorer's Clubs” has been published. There were twelve research questions in this investigation related to different aspects of functioning of YEC: their members, leaders, parents, cooperation with schools, society etc. Among the conclusions we can read that “YEC is the place of meetings of children active and curious about world, interested in original educational methods, not necessarily pupils having the highest evaluations and standing out during normal lessons.” Also “Participants of the study expressed the belief that the participation in YEC can have a positive effect on results in the learning of science in the school and the self-confidence transferring pupils to the higher activity both during lessons, as well as in competitions of different kind.” [3]

We (lecturers from the Centre for Creative Mathematics Learning at the Faculty of Mathematics, University of Bialystok) plan to conduct research on effectiveness of proposed educational method, but at first students have to be allowed to come back to regular meetings in the schools and at the University. Before that we have time to prepare methodology of the research.

9. Conclusions

During several months of operation of our Clubs about 30 members participate in workshops in two groups. Interest of this kind of activity is big, even methodologists from methodology centers for teachers invited the author of the paper to the regional conferences for teachers that always take place before new school year to give some talks on this topic in the autumn 2020, so we expect more participants next school year (if pandemic will stop, of course).

Our experiences gathered at our mathematical Young Explorer's Clubs show that style of learning based on different activities (including manual activities) and investigative work help students to discover mathematics, to understand mathematics and to enjoy mathematics. They start to look at mathematics from quite new side: not as at the domain accessible only for selected people, but as at the domain that can be discovered and is present everywhere around us – even in apples and knots. Also parents are happy that their children found enjoyable way to mathematics and could feel themselves as discoverers.

Now great task before us: to convince the teachers that such methods can be used at the lessons in the schools and to inspire them to implement this style of teaching in their everyday work with students.

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Training pre-service mathematics teacher to use mnemonic techniques

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Abstract. The article reveals the issue of the appropriateness of training pre-service mathematics teachers to use the techniques of mnemonics in professional activities. This issue 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 learned by a particular person. It is established that in the process of teaching mathematics, mnemonics should be used as a way of perceiving new information due to the formation of associative connections using special methods and techniques. The expediency of training pre-service mathematics teachers to use various methods of mnemonics (“Binding”, “Transformation”, “Amplification”) is substantiated. A positive attitude of mathematics teachers towards the use of mnemonics techniques was revealed, as well as a low level of students' understanding of the advisability of using mnemonics techniques in professional activities. The classification of software used to create visual models is presented. A training was developed and introduced into the practice of university education on the development of mnemonic techniques for the presentation of educational mathematical material. The prospects of scientific research through the development of methodological support for the training of pre-service mathematics teachers to use the techniques of mnemonics in professional activities are determined.

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 specific 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 cognitive load of the subjects of training 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.

In the process of teaching mathematics, only memory has a special load. The success of training depends on the level of development of mnemonic processes that ensure the memorization, preservation, and reproduction in the brain of information obtained during human interaction with the outside world. Therefore, the introduction of effective approaches to memorizing a variety of mathematical 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 disappointing results of External Independent Evaluation in mathematics in recent years, the results of the international study of the quality of education PISA – 2018 [11], which determine the level of mathematical literacy of Ukrainian students as such, which are lower than average, clearly demonstrate the level of mathematical preparation of school students. For today's mobile and computerized students, the assertion that mathematics is the queen of all sciences, which develops their thinking, is no longer an authority. School teachers need updated methodological tools that will make students interested in mathematics. Therefore, there is a need for a certain reboot, modernization of the existing system of methodological training of pre-service mathematics teachers at universities.

The basis for the implementation of our work was the results of scientific research on the mathematical preparation of students at the university by a number of authors: Mogens Allan Niss and Tomas Højgaard [10], Todd R. Kelley and J. Geoff Knowles [6], Xueli Wang [18], Barbara Jaworski [5], Kateryna Vlasenko, Olena Chumak, Iryna Lovianova, Daria Kovalenko and Nataliia Volkova [17] as well as the authors of this study ([1], [15]), which disclose the theoretical and methodological foundations for the implementation of mathematical education at the university.

The issue of using mnemonics in the educational process is presented in the works of several authors. (Thomas E. Scruggs and Margo A. Mastropieri [14], Jerome A. Yesavage, Javaid I. Sheikh, Leah Friedman and Elizabeth Tanke [19], Franziska R. Richter, Avi J. H. Chanals and Brice A. Kuhl [12]), in particular in the process of studying mathematics (Susan Peterson Miller and Cecil D. Mercer [8], Peter M. Nelson, Matthew K. Burns, Rebecca Kanive and James E. Ysseldyke [9], Emmanuel Manalo, Julie K. Bunnell and Jennifer A. Stillman [7]).

In the above-mentioned works, 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. Such information requires long-term storage and subsequent reproduction, for example, a sequence of numbers, phone numbers, historical dates, formulas. It is established 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.

At the same time, our studies made it possible to argue that the issue of training pre-service mathematics teachers for the use of mnemonic techniques and methods has not been the subject of special studies yet.

The aim of research: to reveal the content of training future mathematics teachers to use mnemonic techniques in professional activities.

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-conceptual apparatus of the study; synthesis, generalization, systematization for the theoretical justification of the appropriateness of training pre-service mathematics teachers to use the of mnemonic techniques and methods in professional activities; empirical: diagnostic (conversation, questionnaire), statistical (McNemar's test) to assess the appropriateness of using mnemonic techniques in teaching mathematics.

The experimental base of the study is the institutions of general secondary education in Kiev, Sumy, Dnipro and Irpin, A. S. Makarenko Sumy State Pedagogical University, Borys Grinchenko Kyiv University, Alfred Nobel University (Dnipro).

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.

Effective in the study of mathematics is the timely use of memos, tables, instructions, visual supports that help students gradually, without overload, to perceive and remember significant objects.

An essential characteristic of the process of memorization is a measure of understanding the memorized. Therefore, meaningful and mechanical memorization is usually emphasised.

Mechanical memorization – 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.

Comprehended 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 processes and relies mainly on generalized relationships between parts of the material at the level of the second signaling system.

In the process of training pre-service mathematics teachers, it is worth paying attention to the comprehended 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 comprehensive memorize educational material, methods and techniques of mnemonics are determined. The work of G. A. Chepurnoi and L. V. Bura on educational mnemonics as a technology of effective assimilation of information became a reference point for us [2].

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), *Mnemonics* (using music, rhyme, chants, poems, songs, counting out rhymes, etc.), *Sequential Associations* (sequential associative connections are created), *Bonding Method* (combining information units into a single holistic image with preservation of the main features and functions), *Synthesis Method* (information units are combined into a single integrated image with a common associative connection), *Key Letters Method* (an associative connection is created between the first letters of words, you need to remember, and the first letters of words of a specially created sentence), *Logical Questions Method* (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).

Consistent Associations Technique. When studying the construction rules for remembering the order of changing the name of a function, one can suggest the following association: the angles $\frac{\pi}{2}$, $\frac{3\pi}{2}$, are located on the vertical axis, therefore, we shake our heads in the affirmative, that is, we change the function, the angles π , 2π are located on the horizontal axis, therefore shake our head negatively, that is, we do not change the function.

Key Letters Method. In the study of the topic *Disclosure of brackets. Similar terms and their construction* it are 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:

- $-(a + b)$ – «**Minus**» – **Miniaiemu** znaky (in Ukrainian), **Minus** – **Change** the signs; in Ukrainian, the words *minus* and *change* begin with the letter **m**;
- $+(a + b)$ – «**Plus**» – **Perepysujemo bez zmin** (in Ukrainian), **Plus** – **Rewrite** without changes; in Ukrainian, the words *plus* and *rewrite* begin with the letter **p**.

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), a 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), 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)

An example of receiving a *Neologism* is shown in figure 1.

Order of Operations Mnemonics
 Please **E**xcuse **M**y **D**ear **A**unt **S**ally

P arenthesis	()	
E xponents	5^2	
M ultiplication	}	<i>Use whichever one comes first</i>
D ivision		
A ddition	}	<i>Use whichever one comes first</i>
S ubtraction		

X ÷ + -

Figure 1. Neologism Technique.

Analogy Technique. When solving mathematical work word problems, students have more complications than when solving motion word problems. The analysis of complications showed that students do not understand the content of the concept of *productivity*. Let us draw an analogy between the values of the motion problems and work motion word problems.

As a result of the analogy between the values, the term “productivity” and its load become clear to students (see Table 1).

Table 1. Analogy Technique.

Dimensions of motion problems	Dimensions of work problems
<i>S</i> – speed of movement – is the distance an object travels per unit of time <i>T</i> – time <i>D</i> – distanse Key formula: $D = S \cdot T$	<i>P</i> – work speed – the amount of work per unit of time <i>T</i> – time <i>V_p</i> – the amount of work to be done Key formula: $V_p = P \cdot t$

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 2a, 2b, 3a, 3b.

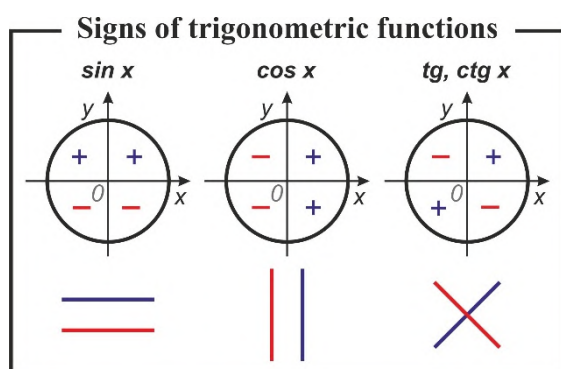


Figure 2a. Visualization technique “Signs of trigonometric functions”.

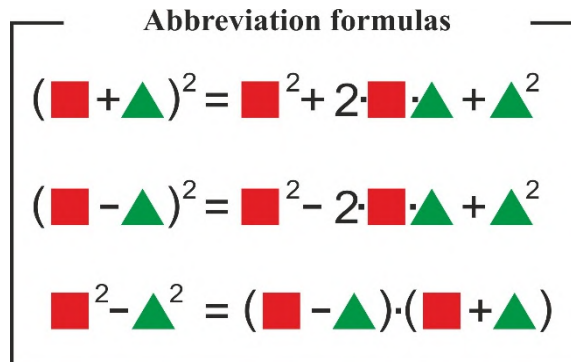


Figure 2b. Visualization technique “Abbreviation formulas”.

To confirm the appropriateness of mastering the techniques of mnemonics, future teachers conducted a pedagogical observations. During March – May 2019, we conducted a survey of 32 working mathematics teachers in Kiev, Sumy, Dnipro and Irpin. 52 students of the specialties “Mathematics” and “Secondary Education (Mathematics)” of the A. S. Makarenko Sumy State Pedagogical University and Borys Grinchenko Kyiv University, as well as individual students of the Alfred Nobel University (Dnipro) also acted as respondents. The results of the survey of teachers were distributed as follows: 87% of teachers noted the feasibility of using mnemonic techniques, and their answers to the most effective were distributed differently (choosing one of three, figure 4).

Method name	Method idea		Compression features
	Output data	Output	
Bit compaction	Bit representation ab : 0110001 01100010	11000011100010	Compression ASCII = $\frac{1}{8} = 12,5\%$ UNICODE = $\frac{9}{16} = 56,3\%$ Compression techniques used for text
Frequency method RLE (Run Length Encoding)	a a ... a b b ... b 30 40	a30b40	Compression $\frac{70}{6} \sim 1200\%$ Compression techniques used for images
Method KWE (Key Word Encoding)	Четыре черненьких чумазеньких чертенка чертили черными чернилами чертеж	Четыре 1н2 чумаз2 1тенка 1тили 1ны3 1нила3 1теж + Library: 1-чер, 2-еньких, 3-ми	The percentage of compression depends on the length of the text and its speech, since the attached library takes a fixed amount

Figure 3a. Color accent technique.

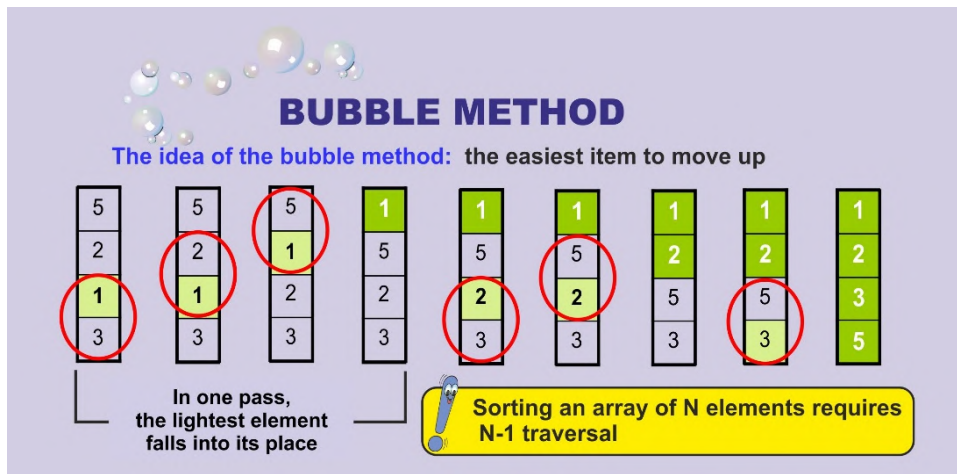


Figure 3b. Color accent technique.

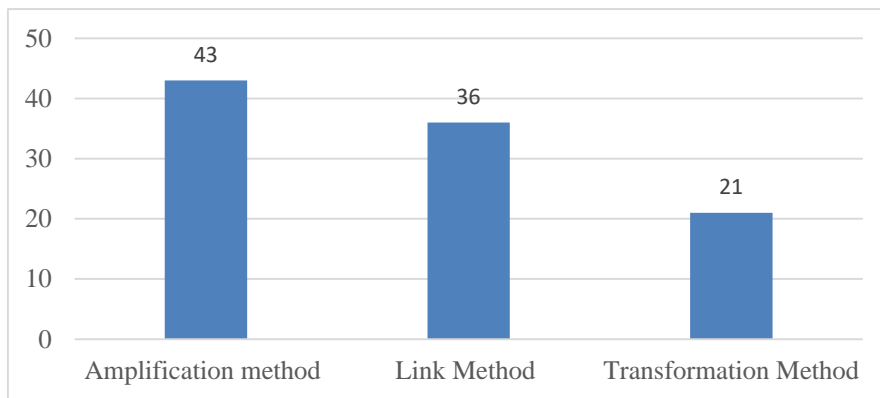


Figure 4. The opinion of teachers regarding the most effective mnemotechnical method (in%).

Moreover, among the receptions, visualization, color accent, comedian, analogy and plot were noted to a greater extent (figure 5). The remaining 17 methods that we proposed for evaluation are of poor popularity among teachers of mathematics.

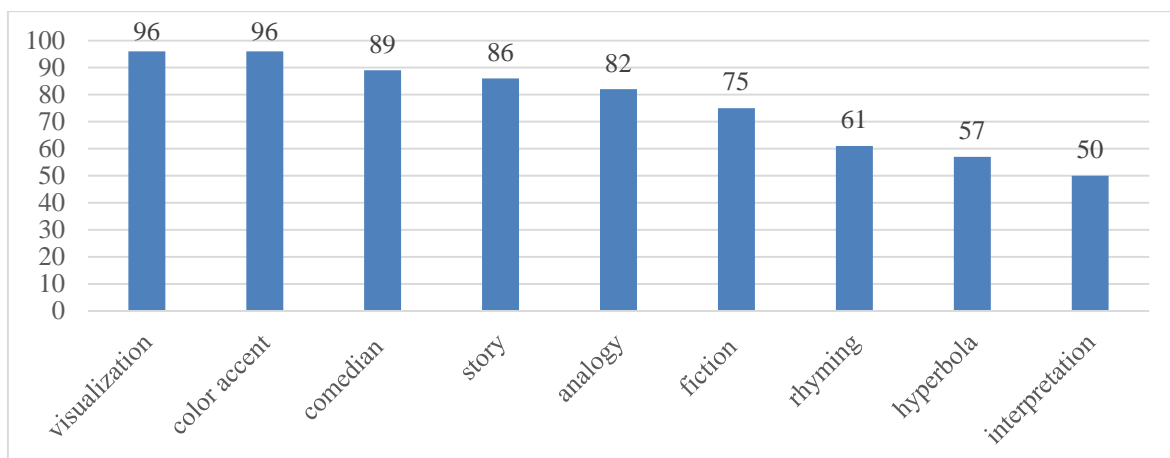


Figure 5. Teachers' opinion on the effectiveness of the mnemonic method (in %).

Unfortunately, the number of students who believe that it is advisable to use the mnemonic techniques of is a little, only 38%. This clearly demonstrates the importance of improving university training in this regard.

Based on the teachers' opinion that the *Amplification* method and the *Visualization* method are the most effective, which contribute to the meaningful memorization of educational material through its structuring and compaction, we drew attention to the software tools used to create visual models. Their study was implemented as part of the work of scientific student groups of the A. S. Makarenko Sumy State Pedagogical University. Conventionally, software can be divided into four groups:

- 1) office software products with Smart objects;
- 2) mindmapping programs;
- 3) services for creating scribing presentations;
- 4) programs for creating infographics.

We describe these groups. So, 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).

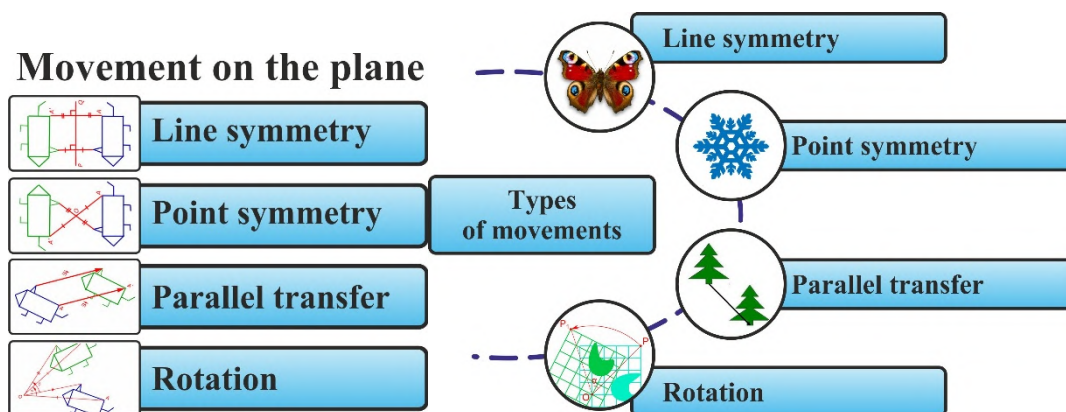


Figure 6. Mnemovisual models created using Smart objects.

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 70s of the twentieth century. Interesting ideas and technologies for creating smart cards in the process of teaching mathematics are presented in the works of modern scientists: Pui Kun Choo, Zhi Ning Lou, Bradley A. Camburn, Kristin L. Wood, Ben Koo and Francois Grey [3], Halyna I. Ivanova, Olena O. Lavrentieva, Larysa F. Eivas, Iuliia O. Zenkovych and Aleksandr D. Uchitel [4], Riccardo Solmi [16].

To build intelligence cards use the program X-Mind, Free-Mind, Coggle, Mind-Meister and others. Such programs help to fix ideas, organize them into various diagrams, use these diagrams together with other users. The mentioned programs allow you to build intelligence cards (figure 7), Ishikawa diagrams (fishbone diagrams or cause-effect diagrams), tree diagrams, logic diagrams, tables.

The main areas of application of intelligence cards in the professional activities of mathematics 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.

Both scribing technique is used to activate the cognitive and mnemonic activity of subjects of learning, and 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 scribing is associated with the British artist Andrew Park, who proposed this technology to popularize scientific knowledge. Sudeep Sarkar 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 and sees about the same thing, while the graphic series is fixed on key moments of the audio sequence [13].

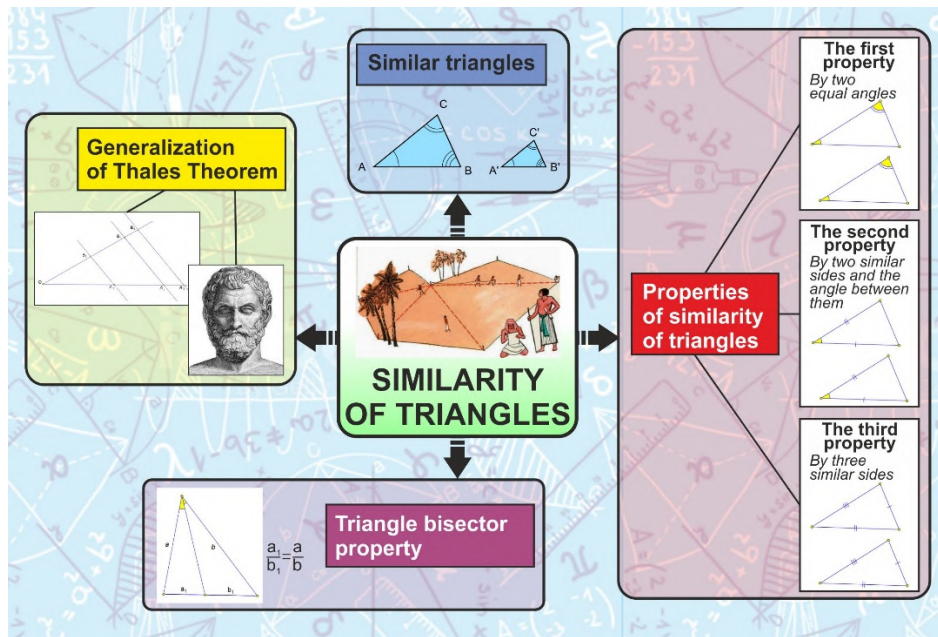


Figure 7. Memory card for the theme “Similar triangles”.

Among a large number there are several useful for creating scribing presentations such as: Sparcol Video Scribe (www.sparcol.com, figure 8), Pow Toon (www.powtoon.com), Go Animate (www.goanimate.com), Plotagon (www.plotagon.com).

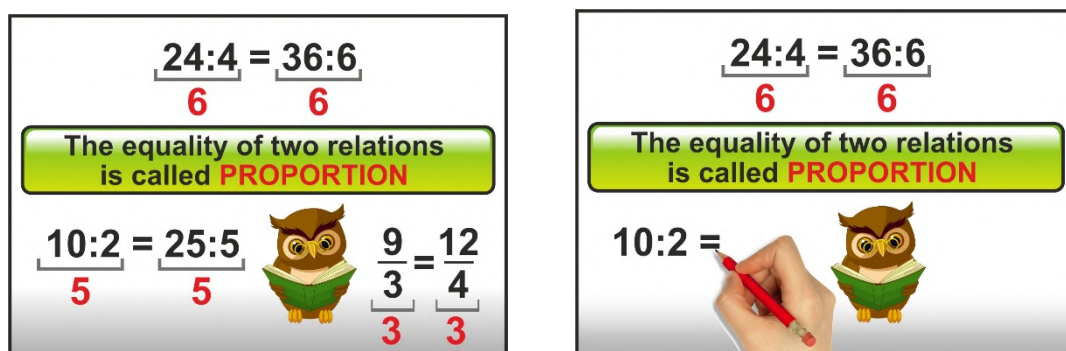


Figure 8. Scribes for the theme of Proportion.

In accordance with infographics, the technology of educational material is presented 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 9). Resources for creating infographics include: Infogr.am, Easel.ly, Vizualize.me, Venngage more.

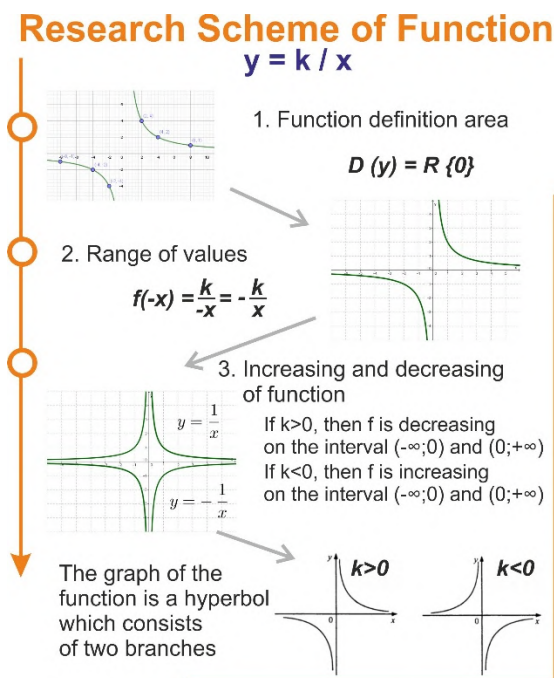


Figure 9. Infographics on function research.

During September – November 2019, at the A. S. Makarenko Sumy State Pedagogical University with various groups of students specializing in secondary education (mathematics), we conducted trainings on the development of mnemonic methods for presenting educational mathematical material. The training lasting 3 hours was aimed at training future mathematics teachers to use of mnemonic techniques in professional activities, the result was achieved through acquaintance with the existing mnemonic techniques and the formation of these skills to implement them using specialized software environments. More details are presented in table 2.

At these trainings, students had the opportunity not only to develop their own products to accompany professional activities, but also to evaluate the development of other students, to analyze their effectiveness taking into account their own educational experience and practical activities. During the organization of the experiment, we are primarily interested in efficiency and, in connection with this, before the start of training, a survey was conducted on the appropriateness, in the opinion of students, of using mnemonics. Then, a survey was again conducted on the appropriateness of using mnemonic methods. A total of 41 students took part in the survey. Since students' answers may or may not have changed, the McNemar's test was used to confirm the effectiveness of the training. The results of the first and second surveys are shown in table 3.

The statistical hypothesis was constructed: the special course does not affect the students' opinion on the appropriateness of using mnemonic techniques in teaching mathematics. For the McNemar's test with $n = 2 + 10 = 12$, the statistic value is $T = \min \{2, 12\} = 2$, therefore, according to the hypothesis acceptance rule, we have $0.019 < 0.025$. Therefore, the null hypothesis must be rejected and an alternative hypothesis should be adopted on the effectiveness of training for future teachers to master mathematics techniques of mnemonics.

4. Conclusions and prospects for further research

In the process of analysis of scientific literature, it was found that the level of development of mnemonic processes that ensure the memorization, preservation and reproduction of information in the brain depends on the success of training, in particular, mathematics. In order to introduce effective ways to memorize a variety of mathematical information, mnemonics are considered as a way of perceiving new information due to the formation of associative connections using special methods and techniques. The

expediency of preparing pre-service mathematics teachers to use the methods of mnemonics: *Binding, Transformation, Amplification*, as well as appropriate techniques.

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)	Power Point, X-Mind, Free-Mind, Pow Toon Easel.ly	Knowledge of specialized software examples, knowledge of software tools (MS Power Point, X-Mind, Free-Mind, Pow Toon, Easel.ly), the ability to use specialized software tools to accompany mnemonic techniques; ability to analyze created products; development of teacher professional competence

Table 3. Distribution of students' answers before and after the training.

Survey results	Effective	Ineffective	
Effective	23	2	25
Ineffective	10	6	16
	33	8	41

According to the results of a survey conducted by experts, a positive attitude of mathematics teachers to the use of mnemonic techniques was established and the most popular of them were identified. At the same time, a low level of students' understanding of the appropriateness of using the mnemonic techniques in professional activities was recorded, which requires the development of appropriate pedagogical tools (methods, technologies, etc.) to train pre-service mathematics teachers for use mnemonics.

The classification of software tools used to create visual models is presented: office software products with Smart objects; mining mapping programs; web resources for creating scribing presentations; programs for creating infographics.

A training was developed for mastering of mnemonic techniques for the presentation of educational mathematical material and introduced into the training process for future teachers of mathematics. The effectiveness of the training was confirmed using the McNemar's test.

We see the prospects for further scientific research in the development of methodological support for training pre-service mathematics teachers to use the mnemonic techniques in professional activities and introduction of mnemonics in the practice of university training of future teachers.

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The arrangement of on-line training of master students, majoring in Mathematics for internship in technical universities

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Abstract. This article looks into the issue of online-training of master students, majoring in Mathematics for internship in technical universities. This study is focused on arranging students' learning activities with the help of an on-line course "Methods for teaching Mathematics to students in technical universities". The study considers the issues that students face during the internship in technical universities and debates a possibility to factor in the students' needs while designing the course content. The present study gives a description of the activities that students do while working with the course materials, requirements, and recommendations on facilitating the learning process through this course. Active participation of students and their contribution to discussing the course, its content and the facilitation of the learning process presume that introduction of the on-line course and its integration into the program of training master students enhances their readiness for internship.

1. Introduction

Would-be Mathematics teachers in universities are being trained within a master's program. Before writing a master thesis students (the qualification code of the program "014.04. Secondary Education. Mathematics") are to do assistant internship. The objective of the internship is to build the undergraduate students' readiness for teaching in colleges and universities. Among undergraduate students there are always those, who are willing to teach in a technical university, but most of them lack in adequate preparation for such kind of internship and need remote support of their pursuits. The matter is, that in ever-changing educational environment and due to academic mobility, a student who plans to teach Mathematics in a technical university must be able and ready to adapt to the environment, to upgrade and master their skills at all times. This, in turn, urges the development of a



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learning environment, aimed at those students who possess self-discipline and are able to develop their own skills.

Currently on-line courses are being launched and introduced in universities all over the world. About 65% of American universities have already introduced distant learning into their development strategies. In May 2012, Harvard and MIT representatives announced launching a joint project in on-line learning EdX (<https://www.edx.org/>). Two more successful projects of 2012 are Coursera (<https://www.coursera.org/>) and Udacity (<https://www.udacity.com>) that opened up opportunities for thousands of students.

Numerous scientific sources bring into the open certain issues of distant learning (MOOC). Gaytan and McEwen [10], Barakabitze et al. [2] look into learning and assessment strategies, considering them to be the most efficient in the on-line learning environment. Dixon [6], Verschaffel et al. [33] research motivation issues in students who are involved into taking on-line courses. Scott [28] studies a teacher's role in high quality intensive on-line courses. Holzweiss et al. [16], Austin and Gustafson [1], Vlasenko et al. [34] summarize the students' and teachers' experience in on-line learning.

The analysis of these scientific resources proves the necessity of life-long learning and expansive use of information technologies in training specialists for various lines of work. On-line courses are widely used within the system of vocational education in European countries and worldwide.

The demand for on-line platforms, which are actively used by the students, is increasing. For instance, the platform "Teachers of Tomorrow" [30] is used to train teachers who strive for being kept updated on educational processes. On-line format gives teachers an opportunity to develop professionally at their own pace. On-line courses make self-development possible and accessible.

From the experience of researchers Gardner and Gail Jones [9], Yen et al. [38], arranging the activity in any on-line course involves careful selection of content, methods and modes of learning in order to develop students' skills and abilities, required by the objectives of the course. When studying the process of training of students, who major in Mathematics, Vlasenko et al. [35] noted that while designing a course it is important to identify the types of activities specific to the work of a higher school mathematics teacher. Learning the objectives of the internship, according to researchers [35], will allow to choose the types of activities that meet the course objectives. The researchers [35] also advise learning more about the experience of teacher training courses in place.

On-line courses in French offer training for teaching on different educational levels. The course "Graduate Studies" [13] is aimed at life-long learning of teachers. "Teacher Training" [26], "MOOCs Adapted to All Actors in Education" [24] and "Training" [31] help teachers get ready for teaching on all educational levels. The course "Training to Teach in the Superior" [23] offers content for educators, working in universities.

It must be noted, that the above mentioned courses do not contain modules, which would support students in their preparation for teaching career in technical universities. That is why creating a learning platform "Higher School Mathematics Teacher" [14] was regarded as a way to effectively train would-be Mathematics teachers. Undergraduate students in teacher training universities became target audience and users of the platform. The platform concept encompasses developing courses, which might help students get on-line consulting. One of the modules of the platform contains a course "Methods for Teaching Mathematics to Students in Technical Universities" [15], aimed at the students, obtaining their master's degree and who plan to teach at technical universities.

Necessity and timeliness of developing and introducing such a course was discussed at the International Conference on Sustainable Future: Environmental, Technological, Social and Economic Matters (ICSF 2020) [36]. As a conclusion, ultimate need for providing distant support in professional education of students, obtaining the master's degree in Mathematics (the qualification code of the program "014.04 Secondary Educational. Mathematics").

The objective of this research is to look into the description of the activity arrangement in the on-line course "Methods for teaching mathematics to students in technical universities" [15], designed for students who are trained to be Mathematics teacher. Added to that, the present paper displays the outcomes of the process of developing educational content for the on-line course, that is, the selection

of the content, effective forms of developing the learning material, with reference to a preliminary survey of master students and further discussions on the forum.

2. Materials and methods

Prior to drafting the course, the developers found out the problems and difficulties in training would-be Mathematics teachers, which undergraduate students most frequently encounter. For this purpose, questionnaires and pedagogical observation methods were used.

57 master students, in Mathematics (the qualification code of the program “014.04 Secondary Education. Mathematics”) took part in the survey. The respondents are the students of the following universities: Kryvyi Rih State Pedagogical University, Sumy State Pedagogical University named after A. Makarenko, National Pedagogical Dragomanov University, Berdyansk State Pedagogical University, Vinnytsia Mikhailo Kotsiubynskyi State Pedagogical University.

To deal with the issues, which students face during assistant internship, the course developers devised a questionnaire using a free-to-access on-line resource and uploaded it to the platform “Higher School Mathematics Teacher”. The questions were aimed at defining the most typical problems that students encounter while having their internship. Taking account of the students’ willingness to actively and directly participate in selecting and adapting the course topics and materials, the developers engaged undergraduate students into discussion of the course content on the platform “Higher School Mathematics Teacher”. Analysis of the survey and active students' participation in the forum discussion, which contributed to improving the learning materials and choosing topics for the course, is to be presented in the research findings.

Launching the on-line course also means defining the learning activities of its users. For this purpose, Inductive Content Analysis Method of the Internship Programme for master students, majoring in Mathematics (“014.04 Secondary Education. Mathematics”) in Ukrainian Universities was applied. The findings of the analysis are presented in table 1.

Table 1. Analysis of the objectives of the Internship Programme for master students.

Assistant Internship Program in Kryvyi Rih State Pedagogical University [20]
To learn about the basic principles, modes and methods of teaching special disciplines at University; to develop the ability to plan and manage educational and methodological activity of a teacher; to master the methods of designing educational materials in order to use them in the process of training students, who obtain a Bachelor’s degree; to master the methods of running various types of classes at University and managing students’ self-study work; to develop professional teacher competencies; to develop personal qualities, necessary for the job.
Scientific and Pedagogical (assistant) Internship Program in the Bohdan Khmelnytsky National University of Cherkasy [32]
To prepare and run seminars, tutorials and to draft their plans; to do methodological analysis of the educational material in order to anticipate possible difficulties in its acquisition by students; to draft educational materials for seminars, tutorials and self-study work of students.
Scientific and Pedagogical Internship Program in National Pedagogical Dragomanov University [25]
To develop own skills and abilities in future scientific pedagogical activity: to draft plans of lectures, to give the lectures in Mathematics; to draft notes and run tutorials, seminars or laboratory works according to the notes
Internship Program for master students in Berdyansk State Pedagogical University [3]
To develop relevant professional teaching competencies in University teachers; to develop the ability to manage the basic modes of arranging the learning process at University, using modern technologies and teaching methods; to refine the teaching experience, ethical qualities in a University teacher, to develop individual creative teaching style as well as willingness to pursue life-long learning.

The analysis of internship programs at the above-mentioned universities allowed the authors to highlight the types of activities that will ensure the arrangement of the learning process of users of online course.

The course is aimed at giving students an opportunity to learn better various teaching methods, used by Mathematics teachers in technical universities.

The course program consists of three modules.

I. Didactical basics of Mathematics teacher training in technical universities.

II. Basic content of the course “Mathematics” for students of technical universities.

III. Modern technologies for teaching higher Mathematics to students in technical universities.

The duration of the course program is three weeks, the total number of hours – 30. Each week students spend up to 10 hours, allocating 2-4 hours for covering all the activities and exercises. The timeframe is a rough estimate and can be adapted to the students’ needs and capacity. The weekly material is considered to be fully covered, if a student has done all the activities and exercises, allocated for this week and the results are presented on the week’s forum. Video is used to introduce the course and to assess the students’ plans.

The learning process is arranged in the following way: a tutor-presenter outlines tasks for the week, sets timeframes. The start of the first week on the course is chosen by students individually, from the moment of registering for it. Each participant has their own deadlines for the week.

Various resources and activities make the individual work more efficient. Short videos accompany all the documents, which are in a text format and used in order to present the main theoretical points through graphs and tables. The videos show examples of teaching mathematical concepts and notions, giving lectures and tutorials to the students of technical universities.

Covering theoretical material during each week finishes with assessment and taking a test. All the tests in the course are aimed to train the skill, so the number of tries is not limited. A test is passed, when a student gives 60 % of correct answers.

To get prepared for a tutorial, a student has an opportunity to watch a video with guidelines on taking lecture notes, or preparing a set of exercises to be done in class. After watching the video students choose a part of Mathematics they would like to cover and create their own product in line with the weekly task, uploading it to the weekly forum. One of the tasks is checking their course-mates’ tasks and peer assessment, along with discussing it on the forum. Students are provided with assessment criteria to complete this task.

The course also contains resources that can help students to familiarize themselves with examples of using modern technologies in teaching Mathematics in technical universities. Participation in a weekly forum is the main criterion of mastering the course.

3. Results

Master students in their first year of studying made up 35.7%, students in their second year made up 48.2% and students, who recently obtained their master’s degree made up 16.1% of the survey respondents. The question posed was “What are you plans career-wise?” and 41.1% of the respondents answered they would like to pursue a teaching career in a technical university. Most of them are considering obtaining a PhD in this sphere.

The respondents were offered to assess their level of qualification and readiness to teach Mathematics and related subjects in a technical university. The results showed that 10.7% of the respondents consider their level of qualification to be insufficient, 30.4 % of the undergraduates have doubts as to own qualification and readiness to teach Mathematics-related subjects, 25% lack in confidence as to their professional skills for teaching Mathematics.

The findings prove that master students in the final year, willing to work in technical universities, assess own level of qualification as inadequate. 58.9% of the survey respondents have a need to improve their level of professional qualification for future work, which urged developing the on-line course.

The survey respondents joined in a discussion on the course content and materials (see figure 1), as 45.6 % of the respondents consider their theoretical background insufficient to pursue a teaching career in a technical university; 68.4% confirmed their willingness to know more about the concept of computer-aided tutorials and laboratory work classes in Mathematics; 40.4% want to familiarise themselves with a possibility to manage individual work; 59.6% of the respondents see it as a central need to know more about activities and methods, used by a Mathematics teacher, such as preparing lecture notes, exercises and activities for tutorials, etc.

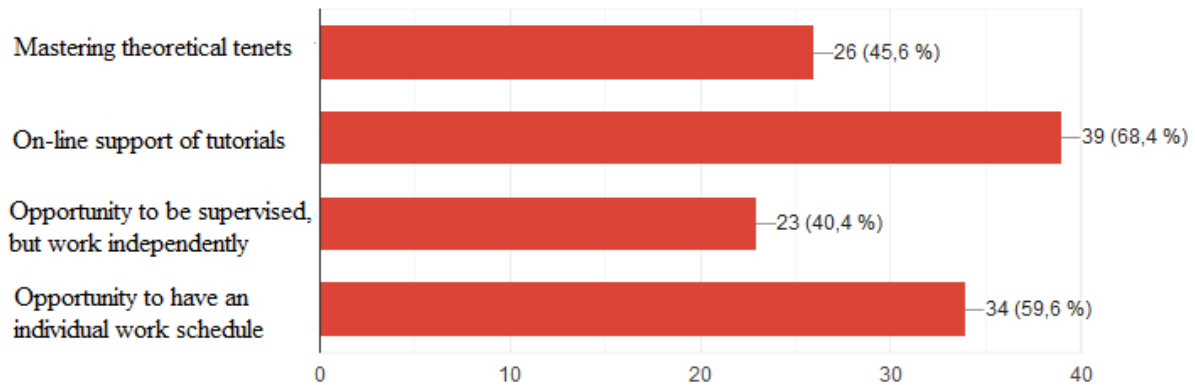


Figure 1. Allocation of the students’ preferences who enrolled in the on-line course.

The respondents’ preferences as to the choice of the forms of learning are allocated as follows (see figure 2): 78.9% of the students emphasize the necessity to have an individual, flexible work schedule; 80.7% of the respondents would like to enjoy the tutor’s support throughout the learning process; 10.5% need support only while mastering theoretical tenets of the course and for 30.4% of the respondents doing internship in a technical university, the tutor’s support becomes a motivator to learn.

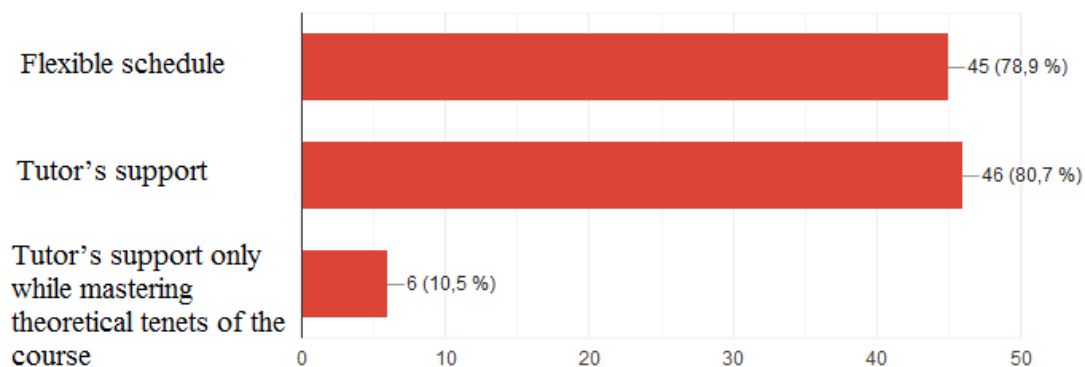


Figure 2. Allocation of the students’ preferences as to the choice of the learning forms.

The students’ responses also helped make corrections to the list of topics (table 2). The students were asked to look into the content of the course “Methods for teaching Mathematics to students in technical universities” and rank these topics according to their relevance: 1 – “The topic is not of relevance for my methodological competence”, 2 – “The topic does not require any special theoretical course”, 3 – “The topic is not relevant in terms of modern requirements for a university teacher”, 4 – “The topic is a must for a would-be teacher”, 5 – “The topic is crucial for my methodological competence as a university teacher”, 6 – “Lack of this topic makes the teacher’s qualification inadequate”.

Table 2. Results of students’ ranking of the topics of the course “Methods of teaching Mathematics in technical universities”.

No.	List of topics for the course	Selection of topics, done by students					
		1	2	3	4	5	6
1.	Course definition and content	12	8	9	16	2	10
2.	Basics of the design of methodological framework	3	5	1	19	20	9
3.	Implementation of the project of a methodological framework	1	2	2	8	19	25
4.	Psychological and pedagogical basics of teaching higher Mathematics to university students	1	4	3	12	15	22
5.	Didactical basics of training Mathematics teachers in the system of higher education	0	2	3	13	15	24
6.	Arrangement of the educational process in the system of training Mathematics teachers	0	3	2	8	22	22
7.	Methodological basics of teaching Mathematics in tertiary educational level.	0	1	1	5	22	28
8.	Teaching methods to give a lecture in Mathematics	1	1	2	13	13	27
9.	Methodology for running tutorials, seminars, laboratory work classes.	1	0	1	9	13	33
10.	Methodology for using Systems of Computer Mathematics when teaching higher Mathematics to students.	0	2	1	14	14	26
11.	Methodology for arranging individual work of students	2	5	3	10	24	13
12.	Methodology for designing a Mathematical project	10	12	12	6	8	9
13.	Cloud technologies in teaching Mathematics	1	3	4	15	16	18
14.	Methods of monitoring and evaluation of the students’ qualification level	15	22	1	10	1	8
15.	Methodology for creating a teacher’s portfolio with the help of cloud services tools.	2	5	4	13	20	13

If, according to the results of the ranking, a topic scored 4, 5, 6 points in most respondents, it became a part of the course program. Thus, master students selected topics 2, 3, 4, 5, 6, 11, 15 as central to enhancing their methodological competence. Topics 7, 8, 9, 10, 14 were also embedded into the course, being selected as important. This allowed the developers to identify 3 modules, aimed at covering methodological, content and technical constituents of training would-be Mathematics teachers in technical universities.

The students’ offers as to the outcome of the training helped choose a certification procedure option (see figure 3). Thus, 38.6% of the respondents offered issuing a certificate of participation according to academic achievements; 19.3% were in favour of pitching a creative project and receiving a certificate of participation; 40.4% of the respondents chose doing internship in a technical university and receiving a certificate of participation.

The course development was accompanied by the comments of the forum participants on the platform “Higher School Mathematics Teacher” [14]. The forum contributed to establishing a two-way connection with the students, who were willing to participate in drafting the course. Upon uploading the course program and materials to the platform, a discussion started on the forum, which played a significant role in making changes and adapting the program and materials in line with the users’ needs. The insights from students helped the course developers select proper forms of learning

and assessment. Moreover, the respondents’ comments on the content of the units to be studied by the Mathematics students in technical universities were taken into account as well.



Figure 3. Allocation of answers to a question “What should be an outcome of training?”

Feedbacks on the methods of assessment, given by the users of the platform also proved to be of use (see figure 4).

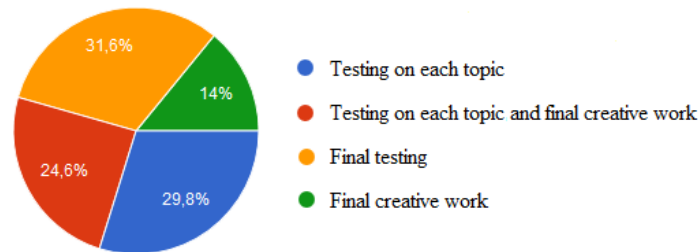


Figure 4. Allocation of respondents to estimation methods of their training at the course.

The study of the impact of the designed course on the efficiency of the arrangement of the students’ learning activities during their assistant internship in technical universities took place over 2019-2020 academic years. The study involved the master students of the second year of study in the above mentioned universities, who had the assistant internship during that period. The experimental group (EG) of students was invited to sign up for the course “Methods of teaching Mathematics in technical universities” [15] while doing their internship. Students of the control group (CG) did the assistant internship without involving the course. The assessment of the internship was done by the same tutors. The internship in technical universities was assessed by the type of activities in accordance with the scoring system developed in the provision ([3], [20], [25], [32]).

The 1st type – to prepare and hold a tutorial on topics “Matrices. Actions with Matrices” (20 points), “Derivative of Function. Physical Content of the Derivative” (20 points);

The 2nd type – to draft a plan of consulting students on the topics of tutorials, to draft assignments for individual work of students on the topic “Derivative of Function. Geometrical Content of Derivative” (20 points);

The 3rd type – to select and prepare learning materials on the topic “Matrices. Actions with Matrices” (20 points);

The 4th type – to make a list of topics for a special course or a workshop “Applied Problems of Linear Algebra”, using systems of computer Mathematics (20 points).

The average score for a definite activity in the control and the experimental groups was calculated as an average of scores of each student in this group.

A student-intern scored 20 points for:

- showing Mathematical literacy in presenting the content of a tutorial, maintaining students’ motivation in class;
- showing applied aspects of studying a topic, interdisciplinary connections between Mathematics and other professionally-orientated subjects of the cycle;

- striking the balance between scientific rigour of teaching abstract mathematical content and its practical applicability;
- managing the audience, skills in using cutting-edge learning technologies.

Figure 5 presents the average score of the selected activities of students of the control and experimental groups.

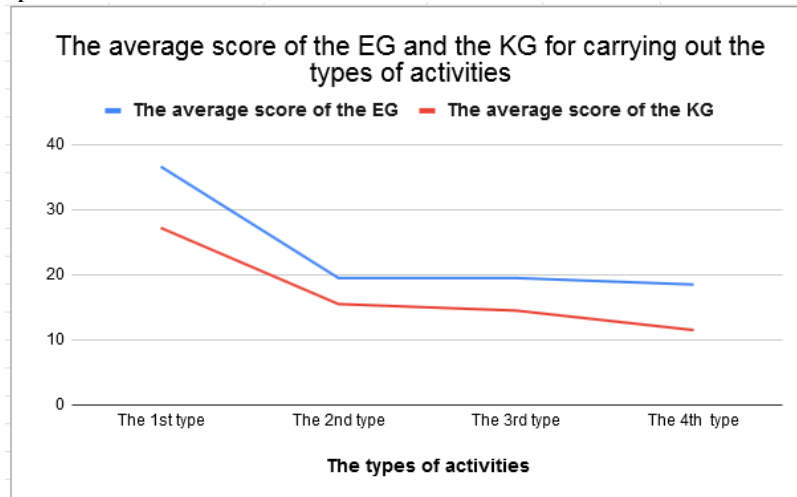


Figure 5. Comparison of average scores of students in the experimental and control group by types of activities during the assistant internship.

Percentage of the indicators in the experimental group and the control group according to the abovementioned types of activities is 34.6%, 25.8%, 34.5% and 60.9% respectively in favour of the experimental group. This fact proves the efficiency of engaging students into enrolling for the on-line course when doing the internship.

4. Discussion

Analysis of the blogs and on-line platforms, such as Inclusive Education [17], Job Test Prep [18], Teacher Certification Degrees [29], and Mathematical Association of America [22] proved our assumption concerning the necessity to consult master students majoring in Mathematics (the qualification code of the program “014.04 Secondary Education. Mathematics”) to be correct. The scientists, looking into the issue of providing the students with support through on-line courses, prove that students tend to learn on-line ([8], [9], [12], [19]).

Before designing the on-line course “Methods of Teaching Mathematics in Technical Universities” [15], the authors of this article studied the guidelines on preparation, structuring and design of on-line materials for courses, the developers studied the guidelines on preparation, structuring and development of on-line materials for courses, devised by FAO [11], DIGICOMP [5] and Leicester Learning Institute [21]. Based on these recommendations (Burgess et al. [4], Donnelly and Agius [7], Vlasenko et al. [37]), we looked at the development of the teaching material for the course from a different perspective. We had to take into account all the demands and desires of the students as users of training. A survey was conducted with the students, who obtain their master’s degree majoring in Mathematics (the qualification code of the program “014.04 Secondary Education. Mathematics”) in order to find out the problems or difficulties they encounter during their assistant internship. Upon receiving the students’ agreement to work with on-line courses and analyzing the Internship Programme for master students, majoring in Mathematics (“014.04 Secondary Education. Mathematics”) in Ukrainian Universities, the developers defined the content, structure, modalities, and materials in order to organize the students’ activities on the course.

The works of researchers, who define the quality benchmarks for on-line courses (Yen et al. [38], Peters et al. [27]), the developers engaged into drafting the high-quality content some educators-experts on Mathematics.

The importance of using imagery (graphs, schemes) and animation was taken account of and helped combine different formats of presenting the materials. To select relevant resources, only verified sources of information, approved by the Ministry for Education and Science of Ukraine were used. Students' comments and feedbacks on the course materials, which were uploaded to the platform, proved the course to be popular with the undergraduate students.

5. Conclusions

Absence of a special program for training master's students to prepare them for assistant internship was one of the decisive factors to develop the on-line course "Methods for teaching Mathematics to students in technical universities" [15]. Students' willingness to get on-line support while doing internship added significantly to its value.

The types of learning activities of the master students majoring in Mathematics were designed based upon the analysis of resources of Ukrainian Universities that provide with objectives of the internship for master students. The content of the course and the learning process are based around the principles of personal orientation, practical implementation, flexibility, independence and voluntariness. It can be easily adapted to the learners' needs. Learners' forum helped improve the course, as through questions, posed on the forum, we found out its flaws. Discussing and taking into consideration the learners' comments and offers helped adapt the course to the learners' needs. Analysis of the feedbacks from the forum participants and their willingness to work with the course shows that the course can be used by the master students to get prepared for assistant internship in a technical university. The effectiveness of involving students in the course during their assistant internship in technical universities was confirmed experimentally. Master students, engaged in the course, showed mathematical literacy and a better understanding of how to motivate learners. They also showed better results in applying active learning tools and techniques to present the applied aspects of the topics and interdisciplinary connections between Mathematics and professionally-orientated subjects of the cycle. The master students in the experimental group exceeded the students in the control group in terms of managing the audience with the help of information technologies and communication strategies.

The findings also make it possible to outline certain lines of work in future research, such as the implementation of the on-line course "Methods for Teaching Mathematics to Students in Technical Universities" [15] into practical training of the 2nd year Master students in teacher training Universities.

6. Data Availability

The [RESULTS OF SURVEY] data used to support the findings of this study have been deposited in the repository https://docs.google.com/forms/d/106_BvuExmTBg6u-QhxzV-RglMIe2K8ZZmBVQc_02iLA/edit?usp=sharing

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Methods for developing motivational and value-orientated readiness of math students at teacher training universities for implementing educational innovations

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Abstract. The present article considers the issue of developing motivational and value-orientated readiness of Math students at teacher training universities for implementing educational innovations. The method, chosen for the present research is the analysis of the scientists' viewpoints, on-line resources and reports regarding the issue of designing and using Rich Tasks when teaching Mathematics, methods and means for developing students' motivation for implementing educational innovations. This paper describes the methods, aimed at developing in students motivation and ability to systematize, devise, use Rich Tasks in their professional activity and to combine them with other innovational learning methods and means. The analysis of the teacher training internship results and the surveys in the experimental group give ground to make a conclusion about efficiency of the methods offered.

1. Introduction

1.1. Problem statement

When characterizing current situation in education in Ukraine and its development strategies, United Nations Children's Fund (UNICEF) [29] highlights the necessity of implementing innovations into educational process. Constant improvement of educational technologies, as well as higher societal demands regarding a Math teacher are among the factors that encourage introducing innovations into mathematical education at schools. Meanwhile, a significant part of Ukrainian Math teachers, when introducing new syllabi, tools, technologies, methods of learning, face various challenges at the stage of the adaptation to the demands, needs of a concrete group of students and own possibilities. As a result, the effectiveness of implementing innovations into school mathematical education decreases. This, in turn, urges universities in Ukraine not only to develop a theoretical background for devising educational



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innovations, but also to prepare Mathematics teachers for making an informed choice, approbation, adjustment and implementation of innovations into the educational process.

1.2 Literature review

When devising a theoretical background for developing readiness of Mathematics students in teacher training Universities for introducing innovations, it was central to define, what is meant by “educational innovations”. Such researchers as Kirkland and Sutch [18], Christensen et al. [7], Warford [36] consider innovations to be a dynamic process, which results in new approaches to achieving the goals.

As it is highlighted by Kerke et al. [21], no matter from which perspective you look at innovations, factor connections between innovations and educational system development are maintained. Other scholars also put emphasis on the issue of innovative educational activity of teachers. Aguiar et al. [1] look into developing and implementing innovations, based on information technologies, into university education, examine various approaches to applying innovative activities by teachers. The scholars believe that the key prerequisite for holding Mathematics student’s professional training is an adequate level of their motivation for innovative educational activity.

Various didactical aspects of developing motivation in students are considered in a number of research papers. For instance, Andrade et al. [3] describe motivation as an educational strategy for teaching Mathematics in different educational institutions in Ecuador. Mercado et al. [20], Vlasenko et al. [35] focus on using ICT in order to foster motivation for self-teaching Mathematics in first-year students. Barrientos Jiménez et al. [4] analyze the issue of developing internal motivation for learning, as well as correlation between academic excellence and level of motivation in place in law students.

Irrespective of the area of research, all the scholars adhere to the opinion that developing motivation in course of learning depends on their values formed. Hence, it was paramount to analyze the scientific papers on developing values in course of obtaining education in universities. We join the scholars, who believe that nowadays it is virtually impossible to implement innovations efficiently into mathematical education in secondary and high schools without developing values and beliefs. Vlasenko et al. [33] consider the issue of motivational readiness to be all-important, as motivation of a Mathematics teacher results from their professional interests, values and beliefs.

Markova et al. [19] classify motivation, based on the source of instigation into external and internal, the latter depending heavily on a personality’s stimulus. We share this point of view and consider that the central incentives for innovative educational activity are financial incentives, need for self-affirmation, professional incentives and need for personal development. Added to that, we agree with Barrientos Jiménez et al. [4], that internal motivation is more efficient and sustainable, it prompts an individual to search for novelties, to face challenges and overcome them. In order to develop internal motivation for creating and introducing innovations, the counselors of the platform “Technology & Innovation in Education” recommend us to develop a technology that enables using an intrinsic approach to learning. As far as Ruppel and Harrington [22] are concerned, efficiency of such a technology implies engaging each and every student into devising an innovative solution. According to a research by Gojak [12], engaging students into devising an innovative solution can occur in the process of solving certain types of problems.

The findings by Gojak [12], and Yeo [37] confirm, that Math problems can change students’ attitude to studying the subject and contribute to developing creative thinking. The researchers indicate that developing of creative thinking in students is a basis for students to search new approaches to learning and to be open to innovations. Rich Tasks are among the means that contribute to developing creative thinking in students. Moreover, such tasks are considered by researchers to be innovative, since they allow not only to showcase non-conventional, creative thinking in the course of searching a solution, but also give students an opportunity to “construct” their own product (problems devised). This idea complies with the findings in a research by Vlasenko et al [31]. The researchers consider that Rich Tasks in Elementary Mathematics boost interest to learning Math as a science, owing to the fact that students have an opportunity to “re-discover” Math rules (notions, regularities), to act in a non-conventional way, to develop creative thinking and interest to devising own mathematical product. According to Gojak

[12], solving such types of tasks must be accompanied by engaging a certain system of methods, modes and means of learning. When choosing the learning methods, the authors of the present paper draw on a research by Sato and Rogers [24], who justify the efficiency of applying the case-study method in the course of training teachers for doing research work. The opinion of Kadir [17] concerning a shift in attitudes of primary school Math teachers to the learning process and overcoming the fear of failures with the help of micro-teaching, is of importance for the authors of this paper as well. Kadir [17] considers, that this fear hampers teachers to modify their activity, to introduce new modes of arranging the learning process. Căprioară, Frunză [5] use individualized and differentiated learning through arranging individual and group work to help students cope with such problems and improve their mathematical and methodological competence. In order to implement an individual approach, Sullivan [25] chooses the means of learning, that factor in students' preferences, and students get satisfaction from the process of studying Mathematics. According to the researcher, only under this condition can the means of learning boost students' motivation for studying the subject.

Therefore, the analysis of the experience and expertise of the scientists helped to develop the methods, that will engage students into the process of devising innovative solutions and give them the feeling of accomplishment and satisfaction from this process.

The objective of the present article is to present the methods for developing motivational and value-based readiness of Math students at teacher training universities for implementing innovations; to describe their implementation into the process of teaching Elementary Mathematics, Methods and Technologies of Teaching Mathematics. In order to reach the objective, it is necessary to take the following steps:

1) to analyze the scientists' opinions, on-line resources and reports, which present developing students' motivation for implementing innovations;

2) to devise the methods, using thereof comprises 2 stages:

– in the course of teaching Elementary Mathematics students are propelled to learn how to solve and devise various types of systematized Rich Tasks;

– in the course of teaching Methods and Technologies of Teaching Mathematics, students are propelled to devise Rich Tasks for certain topics of secondary school Mathematics and to justify using each type of Rich Tasks, combined with the active learning methods and means of learning.

3) to check experimentally the efficiency of the developed methods in the course of teacher training internship.

2. Methods

The stage of developing the methods was accompanied by using the method of the analysis of the recommendations by the Organisation for Economic Co-operation and Development (OECD) [16] and reports by Open University Innovation [16]. As a result of this analysis, the basic principles of developing students' motivational and value-orientated readiness were singled out. Based on these principles, the authors of the present paper selected types of Rich Tasks in Elementary Mathematics, singled out open-ended and integrative problems. In turn, open-ended problems were divided into situational problems, open-ended problems, research problems. When solving the situational problems, students have to choose the mathematical apparatus and apply it to solving a certain problem. Solving an open-ended problem, students have to add a certain condition (conditions) to the existing ones, pose a problem and solve it. Using research problems means that students single out the methods for solving it and apply them. Integrative tasks are divided into three types. When solving the problems of the first type, students have to understand and use the content and conceptual link between separate sections of secondary school Mathematics (for instance, between Algebra and Geometry). Solving the tasks of the second type, students understand and use the links between Elementary Mathematics and sections of Higher Mathematics. Using the problems of the third type means that students apply mathematical methods to solving problems that occur beyond the scope of Mathematics. Table 1 presents some examples of a system of Rich Tasks, which are systematized for the purpose of teaching Elementary Mathematics.

Table 1. The examples of a system of Rich Tasks in Elementary Mathematics

Principles	Categories and sub-categories of Rich Tasks in Elementary Mathematics	Examples of Rich Tasks
Problematic nature	<i>Open-ended problems</i> Situational problem	In order to renovate the house, the owner has to measure the internal diagonals of a brick. He forgot Pythagoras theorem, but there were enough bricks and the problem was quickly solved with the help of a ruler. How to do this?
	Research problem	Based on the analysis of manuals in Elementary Mathematics and secondary school manuals, single out the methods for solving trigonometrical equations and tentative tenets for applying these methods.
Ambiguity	<i>Open-ended problems</i>	The height of a parallelogram equals 8 and 12 m respectively. Devise 2 problems of different levels of difficulty, using these conditions (no more than 1 condition can be added) and solve them.
Integrative nature	<i>Integrative problems</i> Problems of the first type, based on using the content and conceptual link between separate sections of secondary school Mathematics	Using the Square Coordinates application, formulate and describe a general instruction for the construction of a square when you are given two: 1) adjacent angles; 2) opposite angles. Decide, whether any of the sets of points given below, are vertices of the square. If so, which ones? Can you do this without plotting the points on a grid? <ol style="list-style-type: none"> 1. (8,3), (7,8), (2,7), (3,2). 2. (3,3), (7,4), (8,8), (4,7). 3. (16,19), (18, 22), (21, 20), (19, 17). 4. (4, 20), (21, 19), (20, 2), (3, 3). How can you check by means of Vector Algebra that the resulting figure is a square? Draft an action plan for constructing a square, if specified: <ol style="list-style-type: none"> 1) only one vertex of the square; 2) only two vertices, if it is known that they are adjacent; 3) only two vertices, if it is known that they are not adjacent; 4) three vertices. Is it always possible to find the fourth vertex? Why? How do you set three vertices to make this possible? What figure might these three given vertices form? How to check this fact by means of Vector Algebra?
	Problems of the second type, based on using the links between Elementary Mathematics and sections of Higher Mathematics	Given two positive numbers which do not exceed 2, find the probability that the sum of these numbers is not less than two. Analyze what questions can be asked in the context of this problem in order to use information from Geometry to

solve it. The following question can serve as an example: find the probability that the difference between these numbers does not exceed 1.

Are there any possibilities to solve the problem, applying knowledge of Higher Mathematics? Draft variants of such tasks. The following question can be an example: find the probability that the product of these numbers does not exceed 2.

Think carefully and give variants for problems with this specification, but with more tasks. For example: find the probability that the sum of these numbers is greater than 1 and the product is less than 2.

The following is an example: find the probability that the sum of these numbers is greater than a and the product is less than b . Find the conditions under which the problem will have no solution.

Problems of the third type, based on applying mathematical methods to solving problems that occur beyond the scope of Mathematics

One of the students in the group started coming to the first lesson too tired. When the teacher asked why that was happening, the girl replied that she had started taking another way to school. She said, the road is much shorter than the first one, but very steep. The teacher decided to give the students a task to find out how steep the student's new way to school is. The students found that the sidewalk on which the girl walks every morning is a staircase consisting of small stepping stones. They counted the number of stepping stones, their depth and height. Using the information about right triangles, similarity of triangles, information from trigonometry, students easily determined the inclination of the road.

Think carefully and give general instructions for solving this problem. It is advisable to present several ways to solve this.

Give variants of tasks in the context of this problem. The following can be an example: stepping stones on the sidewalk of a fairly steep street have a height of 7 cm and a depth of 52 cm. Find the inclination of the sidewalk. Now let the sidewalk be designed for 25 m of road with an angle of 12 degrees. Build a scale diagram of the corresponding section of the road. Find the depth of the stepping stones, if each of them has a height of 10 cm. How many steps must be taken on this part of the road? How many 15 cm high stepping stones will it take to cover this section of the sidewalk if the angle is 8 degrees? What depth of the 15 cm high stepping stones will be needed for a street with a gradient of 0.25 or 0.3?

At the next stage the authors of the present paper used the Deductive Approach to Content Analysis of the resources, that present developing students' motivation to implementing innovations. Selecting methods, modes and means of learning, a focus was placed on the ones that ensure students' value-orientated attitude to implementing innovations (table 2).

Table 2. Analysis of the resources presenting the on-line courses, focused on motivating students to innovate.

The on-line courses	Methods of learning	Modalities of learning	Tools for learning
Technology & Innovation in Education [27]	Case study, projects, microteaching	Group work	Cloud services
Disruptive innovation [15]	Case study, projects	Individual work	Cloud services
Centre for Innovation in Mathematics Teaching [6]	Microteaching, simulation games	Group and individual work	Programs of dynamic Mathematics and cloud services
Teaching mathematic with technology [28]	Projects, role-plays	Group work	Programs of dynamic Mathematics and cloud services
Creativity, Innovation, Motivation and new Teaching Methodologies [11]	Case study, business projects, games,	Individual work	Cloud services
Specialization Innovation Management and Design Thinking [9]	Microteaching, case study	Individual work	Programs of dynamic Mathematics and cloud services
Innovation Essentials [14]	Case study	Individual work	Cloud services

The analysis of the recommendations, developed by the experts (table 2), contributed to working out the methods. The authors of this study took into account not only experts’ opinions but also their own experiences.

Using a vast array of interactive learning methods, such as “Microphone”, “Brainstorm”, “Situational Analysis” the authors in the present paper consider that changing those methods in the course of solving and devising open-ended Rich Tasks adds an element of surprise, develops readiness for changes in learning and further on – in future professional activity. Case study and microteaching were also used in course of teaching students. To arrange the learning process with the help of the case study method, a problem situation was devised. This situation meant using Rich Tasks, combining them with active learning methods and innovative means of learning; it also had at least two solutions. The realistic nature of the problem situation allows to design the content of the future educational activity. Using the method of micro-teaching meant that students had to devise a fragment of a Math lesson, using integrative Rich Tasks, active learning methods and information technologies.

Innovative learning implies transition to group and individual work of students, so we arranged group work in homogeneous and heterogeneous groups of variable composition and individual work of students during tutorials and laboratory work classes, for which teachers used the method of creating a team product. It aimed at arranging group activity of students mainly in homogeneous groups.

One of the innovative learning modalities, which boosted students' activity, was running an experimental counseling point "The First Session". In October-December undergraduate students counseled freshmen on a group and one-to-one basis. Within the framework of a vertical interaction of students, we arranged collaboration between freshmen, studying Elementary Mathematics and undergraduates. Undergraduates also did peer assessment for the first-year students.

Information technologies, such as dynamic Mathematics software (GeoGebra), graph constructors (Advanced Grapher); cloud services (Google+ and Google Classroom) were used to make the learning process visual and to boost students' motivation.

The key constituent of our research was integration of mathematical and methodological training of students in course of teaching Elementary Mathematics. Developing motivational and value-orientated attitude towards Mathematics as a science and a learning subject, getting familiarized with the potential of innovative learning methods, modalities and tools, developing willingness and ability to introduce changes into own activity were the central objectives of learning Mathematics in first and second-year students. Later on, students in year three and four, while learning Methods of Teaching Mathematics and Technologies for Teaching Mathematics fostered a positive attitude to innovations thanks to complementing the content with topics, related to devising and implementing innovations. The topics were chosen by the students themselves from a list of 3-4 topics. More often students chose topics "Innovations in School Mathematical Education" and "Innovative Technologies for Teaching Mathematics".

3. Results

The experiment took place from 2014 till 2019, the number of respondents totalling 211 students from major Ukrainian universities: Berdyansk State Pedagogical University, H. S. Skovoroda Kharkiv National Pedagogical University, Uman State Pedagogical University named after Pavlo Tychyna, Glukhiv National Pedagogical University, East-European National University named after Lesia Ukrainka and East-Ukrainian National University named after Volodymyr Dal.

At the beginning of the experiment the participants were divided into two groups – the control group (105 students) and the experimental group (106 students). In the control group (CG) teaching was done, following a traditional methodology. The academic staff, working in the experimental group (EG), were briefed on the methodology, developed by the authors of this paper and were provided with the guidelines on teaching each of the three methodological subjects.

To prove the homogeneity of the groups, the Ryan and Deci questionnaire [23] was used at the beginning of the experiment. The students had an opportunity to take part in the survey with the help of a free on-line service. Figure 1 presents the results of measuring the level of motivational and value-orientated readiness of students in the experimental and the control groups for implementing innovations at the beginning of the experiment.

As can be seen on the chart, there is almost no difference between the students' motivation for success and for failure in the control and the experimental groups at the beginning of the experiment. The biggest number of students (almost 56% in the experimental group and 55% in the control group) had ulterior motivation.

At the end of the experiment in order to study the impact of the developed methods, certain types of activities, done by the students during their internship were assessed. The students in the experimental and in the control groups received the same tasks and the academic staff, working with the students at the second stage of the experiment were at the same time supervisors.

The assessment of the students' motivational and value-orientated readiness was done, based on doing the following tasks.

1. Analysing the experience of the university, where the students did their internship (the most recent, innovational works of the academic staff) – 10 points.

2. Applying innovations in Math class and after-class activities. The assessment criteria were – students' initiative in using innovative learning methods, modes, means, technologies (Rich Tasks

included); the students’ activism, consistency, coherence in using innovations, their readiness for experimenting, changes in own activity – 20 points.

3. Devising learning materials in the course of doing the internship. The usage of innovations was assessed (designing Rich Tasks, using cloud services, programs of dynamic Mathematics, web-quests, excursions, etc.) – 10 points.

4. Participation in arranging training research activity of secondary school students. The students’ activism and initiative in preparing the secondary school students for Math contests, developing the research topics for the Junior Academy of Sciences and helping to get the research papers published were assessed – 10 points.

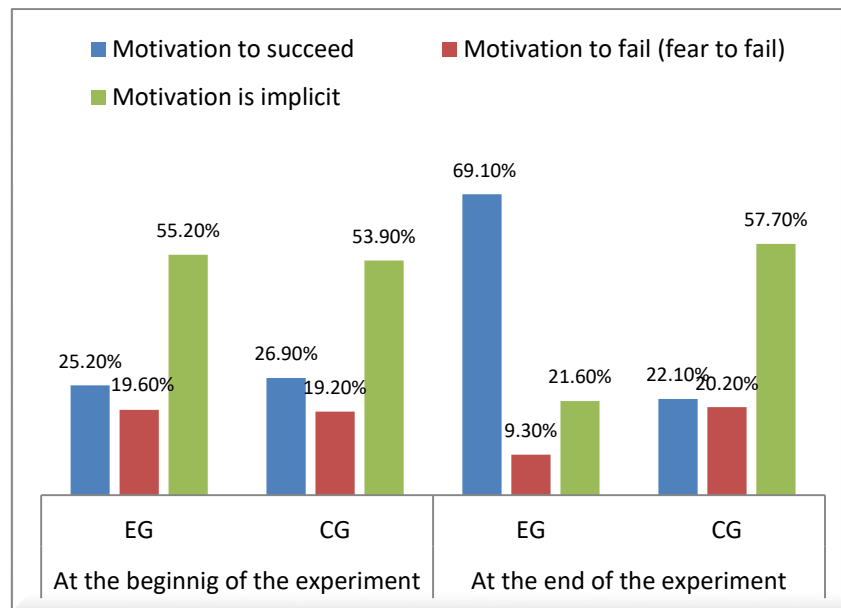


Figure 1. The results of the students’ answers to the questions in the Ryan and Deci questionnaire [23].

The average score for a definite activity in the control and the experimental groups was calculated as an average of scores of each student in this group.

An intern could score 50 points, if he or she:

- got actively interested in, analysed, compared the innovative experience of an institutions, where the internship was done, with the methods and techniques, already known to this intern;
- proactively, consistently and systematically tried to implement innovations into the process of doing the internship; had no fear to experiment with the learning methods, modes and techniques;
- proactively designed educational materials, using innovations;
- got actively engaged into arranging the training scientific activity of secondary school students; came up with proposals concerning topics and content of research papers for secondary school students, as well as methods, modes and means of preparing them for contests.

The assessment results of the students’ motivational and value-orientated readiness in the control and the experimental groups are shown in figure 2.

The average score of all four internship tasks in the experimental group (10.0 points) is higher than in the control group (6.4 points) by 56%. This proves the effectiveness of the developed methods of forming the motivational and value-orientated readiness of students, majoring in Mathematics, for implementing innovations. EG students more actively studied and more consciously analyzed the innovative pedagogical experience of the of the university, where they did their internship. They showed

more initiative in introducing Rich Tasks and other innovations into teaching, and more actively and creatively helped students in preparing research papers, in preparing for mathematical competition.

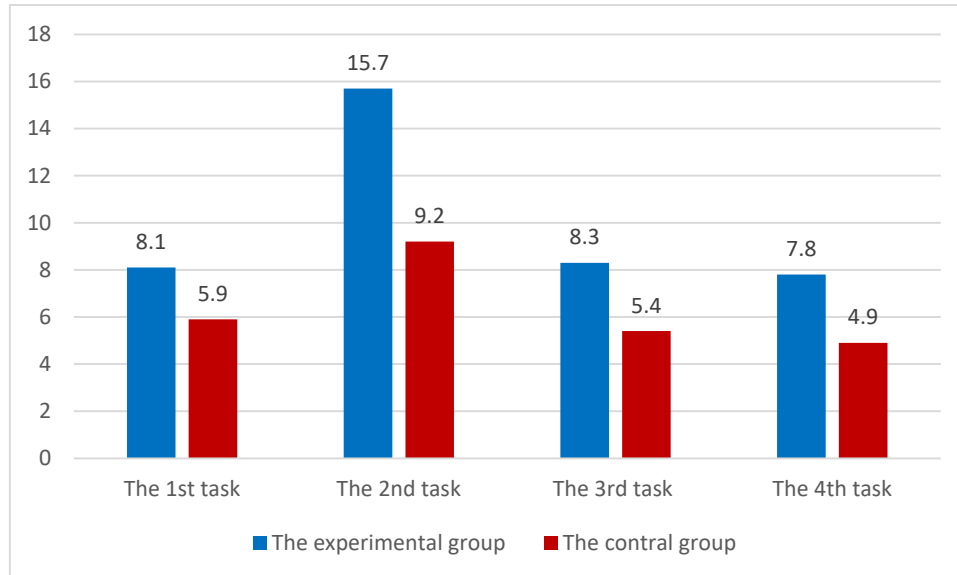


Figure 2. The results of assessing the internship tasks in regard to motivational and value-orientated readiness for implementing innovations.

A repeat survey, using the Ryan and Deci questionnaire [23] was done at the end of the experiment. The questionnaire was uploaded to the platform “Higher School Mathematics Teacher” [13]. The results of assessing the teacher training internship tasks are proved by the analysis of the students’ responses (figure 3).

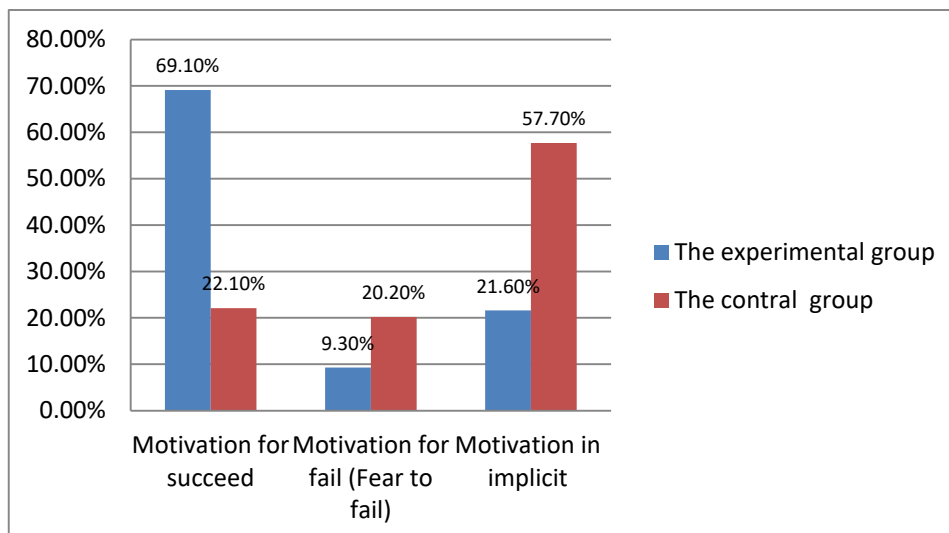


Figure 3. The results of the students’ responses to the Ryan and Deci questionnaire [23] at the end of the experiment.

As can be seen in figure 3, the students in the EG have three times higher motivation for success, than the students in the control group. Meanwhile, the number of students with ulterior motivation is 2.5

times lower than in the CG.

During the International Conference on Sustainable Futures: Environmental, Technological, Social and Economic Matters (ICSF 2020) [32] we presented the above mentioned methods. The idea of its introduction into the process of teaching in order to develop motivational and value-orientated readiness of Mathematics students for using innovations received approval.

4. Discussion

Research done by *Merke et al.* [21], *Álvarez Aguilar* [2], *Dyczkiwska* [10] prove significance of the issue of implementing innovations by students, who choose teaching as their future job. The expert opinions were taken into consideration, when developing the methods for facilitating the students' motivational and value-orientated readiness for implementing innovations. The scholars emphasize, that training teachers for implementing innovations is based on their motivation and values. Thus, *Merke et al.* [21] look into psychological aspects of developing teachers' motivation for implementing innovations. *Álvarez Aguilar* [2] highlights the necessity of value-orientated attitude of a University teacher to implementing innovations, analyses the factors, which hamper training teachers for implementing innovations.

Of interest for us was a research done by *Dyczkiwska* [10], who devised a technology for developing students' internal motivation for implementing innovations in infant schools. Devising the methods for developing motivational and value-orientated readiness of Mathematics students in teacher training Universities for implementing innovations was based on views of *Clewell and Villegas* [8], who came up with an innovative program of training teachers. In the program the researchers offered to value diversity of opinions, methods, ways of achieving a goal, to establish a connection between theory and practice, which was taken into consideration.

We also share the opinion of *Tarasenkova and Akulenko* [26] and *Vlasenko et al.* [34] concerning the necessity to integrate mathematical and methodological training of students, majoring in Mathematics in teacher training Universities. At the same time, we believe that the training is to start in year one, as it is a key prerequisite for improving motivational and value-orientated readiness of students for implementing innovations. Teaching students how to solve, systematize, devise Rich Tasks in the course of learning Elementary Mathematics provides the basis for the methods, developed by the authors of this research. When studying Methods and Technologies of Teaching Math, students must learn how to devise and apply Rich Tasks in their professional activity, how to combine them with other active learning methods and innovative learning means. Reasonable alternating of teaching methods, modeling future professional activity of students, contributes to creating an effect of novelty, increasing internal motivation, providing a role model for students in their future job, which is why a method of microteaching was used alongside case studies. Using microteaching and combining it with case studies during laboratory work classes and tutorials, added to developing a steady interest and psychological orientation at implementing innovations, improving students' self-esteem.

5. Conclusions

Analysis of scientific and methodological papers proved relevance of the research into the issue of developing motivational and value-orientated readiness of Mathematics students in teacher training universities. The key prerequisite for this is integration of Mathematical and methodological training of students in course of learning Elementary Mathematics, Methods of Teaching Mathematics, and Technologies for Teaching Mathematics.

The joint activity of the academic staff, teaching Math and methodological subjects contributed to developing requirements and guidelines, following thereof added value to positive dynamics of the interest in and focus on implementing innovations

1. Consolidated efforts of all the teachers, engaged into teaching in experimental groups shall be aimed at devising guidelines on innovative teaching. Those teachers, who take part in the experiment, are to be familiarized with all the materials well in advance. To meet this requirement, the teachers shall undergo a series of seminars and workshops so as to get answers to all the questions that might arise.

Searching the answers to those questions, as well as reviewing curricula and materials shall be done in collaboration with all the teachers, engaged in the experiment.

2. The first step to take in the experiment must be surveying students, using the Ryan and Deci questionnaire [23], combined with assessing their motivational and value-orientated readiness for implementing innovations, as well as ensuring the homogeneity of the experimental and the control groups. At the end of the experiment, it is advised to assess the tasks, done by the students during their internship in regard to their motivational and value-orientated readiness for implementing innovations

3. Introduction of the methods is to take place during the whole four-year period of learning. It comprises two stages: an introductory stage (years one and two) while learning Elementary Mathematics and the main stage (years three and four), while learning Methods of Teaching Mathematics and Technologies for Teaching Mathematics.

4. During the first stage, the academic staff should use both, group and individual mode of work in order to solve and devise Rich Tasks, to change reasonably active learning methods, means of information technologies. Also, the teachers should arrange innovative modalities of supporting students, such as “The First Session”.

5. It makes sense to use the same methods, modes and means of innovative learning at both, the first and the second stages, channeling them to developing the students’ motivation and ability to apply Rich Tasks, combined with other innovations. Added to that, it makes sound sense to use case study, microteaching in course of running tutorials, laboratory work classes and extra-class work.

Following the above mentioned recommendations and requirements, while implementing the methods in experimental groups, contributed to increasing the level of development of motivational and value-orientated readiness of students, majoring in Mathematics for implementing innovations.

Further research work in this domain will be focused on developing a module on the educational platform “Higher School Mathematics Teacher” [13], which will present the materials devised for implementing motivational and value-orientated readiness of students for implementing innovations.

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The ICT usage in teaching mathematics to students with special educational needs

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Abstract. In the article, authors have considered the implication of ICT into mathematics educational strategies in the inclusive class of secondary school. The research includes also a presentation of a teacher's tool, prepared by an author group, on the use of ICT in teaching planimetry and stochastics of children with special educational needs (SEN) in secondary schools. The research has introduced the model of implication ICT and the influence of effective strategies and methods of inclusive education on the math studying process by children with hearing disorder. The possibilities of using the method of educational projects as one of socialization directions are described. The efficiency of the distance learning was discovered that facilitates the self-representation of students with SEN.

1. Introduction

The world standard of inclusive education strategy is based on the idea that students with special educational needs (SEN) require support in getting key life competence such as cognitive, non-cognitive skills, and the acquiring of "functional literacy" for independent life and socialization [71]. The "literacy" in this context implies the ability to recognize, understand, interpret, create, transmit, and assess information based on documents printed and handwritten having relation to various issues of lives to make daily decisions and guide their actions ([9], [23]). The "functional literacy" of mathematics includes basic skills: numbers, fractions, four operations, geometrical shapes, problem-solving, and measurement for students to solve daily problems [71]. Particularly, the success of the students' targeted acquisition of these key math competencies depends on class management, teaching approaches and methods such as the universal design of learning or differential instruction [13].

The philosophy of inclusive education requires the provision of the qualitative education for all children through the development of appropriate curricula, the accomplishment of organizational measures for school and class universal design, preparation of teaching strategies, use of resources, and partnerships with key stakeholders (administration, families, service staff, assistants and other specialists from the team) [70].

The success of using strategies of teaching mathematics in secondary school emanates from the concept of "normalization" in inclusive education which based on individualized learning and determines the specific educational approaches [32]. For this concept, we need to provide for the relevant conditions of overcoming the educational and environmental barriers to the process of studying mathematics by students with SEN. It means that children with SEN are able to acquire math skills in general class only when they are supported in an appropriate educational environment and conditions based on their needs [36]. This task of overcoming educational barriers means the



preparation of individual programs in respect of individual particularities of the educational cognitive activity, for each student with SEN ([32]; [36], pp. 5–7). Particularly speaking, these conditions are attained through integration of ICT strategies in studying mathematics into the education curriculum of secondary school [67].

The current reform of the educational system in Ukraine foresees the development of inclusive education to create conditions for children with special needs to study together with their peers. Consequently, the basic principle of inclusive education aims to minimize external differences in the implementation of learning and to incorporate specific methods and techniques into internal aspects of its implementation. Today, there are several issues in inclusive education in Ukraine. Firstly, at the local level, the pedagogical staff of schools may lack the necessary competencies needed to implement inclusive education in their educational institutions. Although generally supported by the government, coherent practical approaches are lacking as stakeholders in the field of inclusive education act rather independently from region to region with lack of coordination. Secondly, teachers are not psychologically prepared to work in an inclusive class, although pre-instruction is provided to inform a teacher what is necessary to work with a child with special educational needs. It means, that the psychological readiness of working in inclusive education declares that the modern rehabilitation should be directed not at “repair”, and “correction” of defects of a sick child, but at providing conditions and opportunities for its active life and involvement in all social processes of the community life. Thirdly, at the same time in Ukraine educational space there is several wrong formal ways of inclusion: “normalized” and ignore the special education needs of a child (structure and functions of the body, factors of the environment, difficulties), a concentration on correctional education (cognitive, emotional spheres and speech development) without socialization.

Children with SEN have typical for this group features of cognitive and non-cognitive activity inherent in each child. Such special needs of the child require reasonable adaptation and organization of the educational environment, modification of educational tasks, giving more time to think about tasks, and self-fulfillment [32]. We need to highlight the children with hearing impairments (especially students with cochlear implants, hearing aids) most need of using of technical gadgets and time-controlling over their working conditions, assignment modifications, adaptation of educational facilities (improvement of acoustic conditions, additional sound amplification) [13], [44]. Peculiarities of cognitive activity of children with hearing impairment (HI) are presented in the publications of Janet F. Fletcher [15], Wayne M. Garrison [14], Annette Majnemer [33], Terezinha Nunes [44] and others. Learning difficulties of this category of children are related to speech delay and specific problems in conceptual and figurative thinking [6]. 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 [13]. Of course, these features of cognitive activity become the subject of correctional and developmental activities of correctional psychologists. At the same time, the greatest fears about this category of children arise in teachers of mainstream schools when teaching the physics and mathematics cycle.

That's why the purpose of our research is the modification teaching strategies for children with SEN: to study the possibilities of optimal use of interactive exercises LearningApps and GeoGebra Dynamic Geometry system in order to provide methodical and didactic support of training sessions, independent study, implementation of monitoring activities. Consequently, some aspects of the problem of math teaching students with SEN can be eliminated through the use of ICT as a provider of training materials adapted, assistive devices, and support. There are two benefits of using ICT: technology usage in studying is beneficial in the self-representation of students with SEN; it gives more opportunities for getting a quality education. However, there are some problems with ICT for students with HI. Firstly, ICT as a provider of training materials adapted usage technique for math teaching students with HI is not firmly established and needs further accommodating research and testing. Secondly, there is a problem with the way of learning material representation for students with SEN using ICT technologies as information and communication technologies and support.

2. Literature review

Most researchers agree that the access to appropriate ICTs can reduce differences in inclusive education, and children with SEN must have access to ICT-based programs being a part of the schedule of school [72]. That is why digital inclusion in math education as a process is a system of a student's empowerment through participation in education processes with ICT programs [6]; individual curricula of studying math [44]; providing with reasonable accommodation of materials [6].

Various aspects of digital inclusive education in math have been considered by researchers the problems of social and psychological support of the educational process of students with SEN (Janet Muscutt [41], Alla A. Kolupaieva [22], Sangeeta Singh [63]); the role of information and communication technologies in education of persons with special educational needs (Beatrice Hope Benton-Borghi [1], Antonia Cascales-Martínez [6], Alistair D. N. Edwards [72], Adriana S. Fachal [10], Tamila H. Kolomoiets [21], Yekaterina A. Kosova [8], Yuliia H. Nosenko [77], Hanna B. Varina [47]); inclusive mathematics education (Annemarie Fritz [13], David Kollosche [20], Paula Maccini [32], Terezinha Nunes [44]); preparation for work in inclusive educational environment (Julie Forster [12], Mary A. Mendenhall [34], Josef Slowik [64]); the process of inclusive education establishing in Ukraine (Alla A. Kolupaieva [22], Olena P. Shestopalova [3]).

The scientific analysis articles of the issue teaching mathematics of students with special educational needs in secondary school has shown that the research was conducted in the following areas: the best practices of NCTM standards such as promote hands-on learning and critical thinking [32], diagnosing students' mathematical competences [3], examples of adaptations for an individualized educational plan (tabletops, calculators, ICT) ([6], [32], [44]), cases of behavioral management, types of assignment modification ([6], [20], [32], [41]), effective instruction ([20], [44]). Few general notions have interest for our research in chapters of the handbook edited by Annemarie Fritz, Vitor Geraldi Haase and Pekka Räsänen. It's the analysis of the implementation of competence models as a basis for defining, understanding, and diagnosing students' mathematical competencies ([13], p. 44) and comparative analysis of mathematical learning and its difficulties in Eastern Europe ([13], p. 147). The basic idea of educational standards "functional literacy" of mathematics in secondary inclusive class we highlight in article by Paula Maccini and Joseph Calvin Gagnon [32]: math as problem solving, communication, reasoning and math connections.

In training course for teachers [72] by Alistair D. N. Edwards notes the ideas of assistive technologies for educational purposes concerning the needs of hearing of impairments: design of SNE curriculum content based on ICT usage and model of ICT-based educational/pedagogical skills (skills of general use of ICT hardware and software, learning-to learn skills of using Internet resources on specific subjects). The article by Kateryna M. Bondar and Olena P. Shestopalova explores the pilot project of implementation of the supervision as a model of inclusive educational retraining. The research project includes: 1) training the team to work with the objectives of the individual development plan of a child with SEN; 2) key features of performing observations of the learning process in the class and analysis of school environment factors; 3) team interaction supervision [3].

The article of Yuliia H. Nosenko outlines the main changes in the education system in recent years; reflects the new educational opportunities for children with disabilities; identifies the possible ways of use of ICT to improve the quality of inclusive education [77].

The manual [43] presents the results of studies on ICT support for inclusive education at different levels of education – preschool, secondary, higher. This is one of the first attempts to systematize the experience of domestic specialists in this aspect, in particular on supporting inclusive learning for hearing impaired children ([43], pp. 152–177).

The leading concept "as promote hands-on learning and critical thinking" in article [6] analyzed through the dynamics of studying math by using a multi-touch tabletop system like using technology as an "object-to-think-with" and as a tool to increase the motivation of students with SEN. Svitlana V. Lytovchenko notes that most students with HI face some difficulties in studying disciplines with a large number of abstract concepts, in particular, the disciplines of the mathematical cycle. Therefore, analogies should be applied and case studies should be supported by specific examples [30].

As Kateryna O. Kolchenko [19] notes, the rational combination of verbal and visual means the influences the effectiveness of the studying process of students with HI. Accordingly, it is better to duplicate audio information by visual one. It is advisable for the teacher to provide the students with HI with the printed lecture notes and written explanations of demonstration material in advance so that the students are able to understand its contents. It is appropriate to use some tables, diagrams, graphs with visual comments. All this will eliminate the ambiguity in the perception of oral speech [43].

Problems of distant technologies usage in teaching students (e.g., Mathematics training) were covered by Dmytro Ye. Bobyliev [2], Irina A. Getman [66], Liudmyla H. Havrilova [16], Anna V. Iatsyshyn [80], Hennadiy M. Kravtsov [25], István Lénárt [29], Larysa M. Petrenko [50], Dmytro A. Pokryshen [51], Kateryna V. Polhun [52], Tetiana V. Prydacha [54], Svitlana V. Shokaliuk [61], Myroslav J. Syvyi [65], Iryna M. Trubavina [69], Tetiana A. Vakaliuk [73], Vasyl V. Yahupov [76], Myroslav I. Zhaldak [79], and other researchers. Thanks to combined and e-learning it's allowed to have direct communication and constant interrelation between a student and a teacher.

Problems in teaching students stochastics and preparation of mathematics teachers to present this topic were covered by Myroslav I. Zhaldak, Vasyl M. Franchuk and Natallia P. Franchuk [79]. For solving the problems of mathematical statistics, researchers suggest using the Gran1 software. It is very convenient when constructing polygons of relative frequencies or histograms, to determine the numerical characteristics of the sample.

The paper of Svitlana H. Lytvynova and Oleksandr Yu. Burov [31] is discussed some methods, forms and safety issues of social network usage for school students. Taking into consideration the growing interest of students to electronic communication in social networks (ESN), it was described their place in the information educational environment. There were made the classification of objects and use of ESN to help teachers and school authority to teach students in the corporate social network. The basic components of corporate social networks were revealed: forms of learning activity (individual, group, and collective), forms of learning (quiz, debates, discussions, photo-story, essay contest, a virtual tour, mini design web quest, and conference video-lesson), and database. They were defined particular aspects of the use of certain forms for students training in ESN according to the type of social objects (messages, individual messages, video files, photos, audio files, documents, comments, and blitz-survey).

The use of ICT in mathematics teaching creates additional opportunities for students with SEN: perception of material through different sensory organs (multimodal or polysensory perception), activation of information perception by focusing on the work of stored analyzers; scaling objects on an interactive whiteboard, dynamic polysensory demonstration of environment objects and phenomena of any complexity degree; personalization of educational products by formatting the data view (changes in color, fonts, graphics, sound) etc. [43].

The theoretical analysis of previous studies reveals the following trends:

1. Online delivery has become the most prevalent way of presenting the up-to-date information to students in the quickest, most flexible, and innovative ways possible. Educational courses can utilize a variety of training of ICT specialists in SNE integration of ICTs.

2. The arrangements for successful inclusion of students with SEN of ICT to facilitate effective learning and interaction between participants of pedagogical process: asynchronous and synchronous communication and collaboration tools (e-mail, bulletin boards, whiteboards, chat rooms, videoconferencing, and teleconferencing), interactive elements (simulations, immersive environments, and games), various testing and evaluation methods (self-assessment, multiple choice testing, etc.) ([72], p. 30; [77]).

3. The educational content can be presented in various media: text on a website, multimedia, such as digital audio, digital video, animated images, and virtual reality environments ([5], [42], [45], [68]). This content can be created in a multiplicity of ways, utilizing a variety of authoring tools.

4. As a result, ICTs transform educational dynamics providing alternative, authoritative sources of information, which requires teachers to become facilitators and, in some cases, intermediaries between specific information sources and a learner.

5. The basic components of corporate social networks were revealed: forms of learning activity (individual, group, and collective), forms of learning (quiz, debates, discussions, photo-story, essay contest, a virtual tour, web quest, and conference video-lesson), and database. They were defined particular aspects of the use of certain forms for students training in ESN according to the type of social objects (messages, individual messages, video files, photos, audio files, documents, comments, and blitz-survey).

6. At the same time, the use of online services and the system of dynamic Mathematics through mobile phone applications for students with SEN has not been explored enough yet.

7. The didactic principles in distance learning remain the same. But they are implemented taking into account the specifics of new tools and organizational forms of learning, the possibilities of using modern information resources. It makes it possible to organize distance learning support for Mathematics teaching, in particular through the Moodle learning management system ([37], [38], [40]). One more way is using Google Classroom as a supplement to the traditional methodological teaching system and, as a result, improving, and updating it [4].

The studies above do not consider properly the use of distance technologies and modern technologies for mobile communication in schoolchildren teaching.

3. Method

Developed visuals for teaching students with SEN were partially implemented in the learning process in the pilot project of retraining 12 school teams who work with children with HI (Project “Supporting inclusive education in Kriviy Rih”, GIZ, 2017-19) and at a course of mathematic the multidisciplinary training and rehabilitation center “Suziria” (conducted with Karyna O. Shavyrina).

The work of the research team was aimed to developing a concept for supporting inclusive math education in Kryvyi Rih in cooperation between Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, Department of Education and Science of the Executive Committee of the Kryvyi Rih City Council and the Kriviy Rih State Pedagogical University. The first step was the analysis of the answers to the needs for visuals for teaching students with SEN of key stakeholders (teachers, tutors, and other staff: $N=18$). According to the distribution of the needs of educational training of working with children with HI, the selection is as follows 35% have experience of support children with SEN, 65% – specialists-beginners in using ICT programs into mathematics educational strategies. The second step was implementing ICT programs into educational strategies of studying math in 6-7 class inclusive classes (students of 6-7 classes: $N=21$ children with SEN). There were children with HI, children with speech and HI, autism, and others in inclusive experimental classes.

4. Results

The appropriate methodological approach to educate students with SEN takes consideration of the key principles of learning and teaching as well as the identification of individual learning styles. According to the formulation in the Law on Education, inclusive education is a strategy based on the model requires to identify the following components of the lesson in teaching: objectives of the lesson, type of the performance, type of submitting the material, working space [36]. An inclusive model for students with SEN requires the creation of a set of specific learning conditions and contains four interrelated components: the target-oriented component, the content-oriented component (applying the different didactic material – to give a realistic task), the operation-and-action-oriented component (also using various forms of interaction contribute to the development of communication skills) and the control-and-evaluation one [32].

4.1. *The principles and methods of mathematics education in an inclusive class*

The principles and methods of math education in an inclusive general class of the secondary school based on the determination of needs the child with SEN: 1 step – to determine the current level of knowledge and skills of the student; 2 step – to determine the effective teaching style (visual, kinesthetic, poly-sensory and an-other one, especially if one of the styles dominates); 3 step – to

determine particularities of the child's adaptation to the educational institution and peer group; 4 step – to identify specific aspects of the child's learning activities, where it needs the outside help during the educational process ([13], [41]).

We need to highlight, that for teaching children with special educational needs, 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 children with SEN to work independently and to take initiatives.

There are specific methods of class management and teaching were studying students with HI ([10], [44], [63]). Firstly, teachers need to use alternative forms of communication are being actively formed and the strategy of studying math based on non-verbal intelligence, and competences (seriation, analogy, systematization) [44]. Secondly, studying math need an adaptation of training facilities (improvement of acoustic conditions, additional sound amplification means). For example, it's using technical equipment and controlling its operating status (cochlear implants, hearing aids). That is why, the teacher needs some tips for classroom management: never talk while facing the board, try not to speak when handing out extra material, present the topic of the lesson in front of the class, give up the habit of going along the class [72]. Thirdly, socialization children with HI mean that they need to support the establishment of relations with other persons [20]. The ignorance of special needs in socialization students with HI leads to increased anxiety and distrust of others, separation from the hearing collective group. That is why the student with HI needs collaborative group work and cooperative learning and a little more time to process the information and prepare for the answer.

Conceptually, difficulties of children with HI in secondary school on math 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 [72]. Generally, the main purpose of studying math 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 SEN 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 ([32], [44]).

Students with HI have difficulties using conventional sources of information like books and that is why they have the piecemeal knowledge is formed [44]. Consequently, they need supporting to form ideas about the world around (the basic competencies are child can investigate length, width, area, and perimeter; can determine the time by a clock; understands the relationship between days, weeks, and months; navigates the value of coins and banknotes; compares volume and weight), orientation in open space (child determines flat and volumetric shapes in the environment; uses words that indicate the position and direction; uses a system of coordinates; creates geometric patterns).

There are some species of typing of the performance and submitting the math material for students with HI. Generally, all adaptations are noted in the individual development program of the student. The adaptation of the education math content to the cognitive abilities of the students for children with HI, this is the removal of complex verbal material. Firstly, it's visual learning. Taking into account the specificity of the SEN, the types of showing objects are additionally selected. For example, for children with HI, the visual manuals should be specific, with details that concentrate on the perception of main things. Secondly, slowing down the educational process. Communication of the information for children with HI is carried out with consideration of the slower perception of the verbal information. For children with HI, more time is given to think about the answer ([44], [63]). Thirdly, repeatability in teaching. The repetition variability should be used to fill the gaps in the perception of students with HI especially if we use ICT [10]. Fourthly, optimization of the work pace and fatigue dynamics student with HI. 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, visualization, modeling, extrapolation examples in classroom environment); using interesting facts, examples, and details in the process of presentation of the

material; emotional presentation; organizing the minutes of rest at the lessons; creating success situations for the child [10].

4.2. Online service LearningApps usage for teaching the students with SEN

Based on the conducted research the writing team developed the teaching aid [28]. The first part covers general guidelines for teaching pupils with special educational needs using ICT and tools of distant 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 ([7], [17], [18], [24], [35], [39], [49], [56], [75], [78]). 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 (see figure 1). A significant advantage of this service is the ability of task integration Moodle into learning management systems.

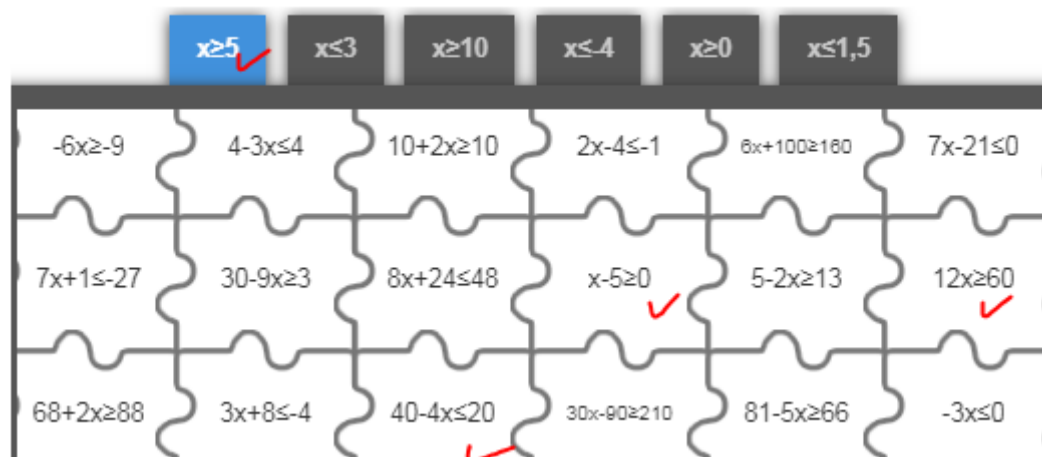


Figure 1. Task: to find equal inequalities.

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.

Let's demonstrate how LearningApps service interactive exercises can be applied at different stages of learning mathematics. For example, at the stage of learning about the concept of an event, an impossible, accidental, and probable events, 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 reasonable to introduce exercises to children with HI in such 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 memorize 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. Students with SEN can easily find both 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. Calculate the probability of an accidental event.

Task 3. Determine the likelihood that a certain event will occur.

Task 4. Choose the name of the formula to be used to solve the problem.

The purpose of exercise 5 is to test the students' ability to attribute the suggested signs, definitions, or examples to the two indicated concepts. This exercise is useful for students with SEN because it develops students' logical thinking and memory.

Task 5. "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 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 6. "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 corresponds 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 student with SEN 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.

We have found that the LearningApps learning environment can be applied at different stages of a lesson: during the organization of independent, individual activity and in joint research activities. Due to interactive exercises, students with special educational needs 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. Because, while carrying out the task, a student with special educational needs makes much more effort than a perfectly healthy peer, the system of evaluating the educational achievement of such students can be stimulating. After each student has completed each exercise, the teacher must analyze and compare the expected results with the actual results of the students' works. A prerequisite for teaching students with special educational needs in mathematics is to provide feedback: to find out if the students are satisfied with their work and the knowledge they have acquired and whether they understand the importance of this knowledge for further study of the subject.

4.3. Using GeoGebra in mathematics teaching

The third section of the teaching aid focuses on the usage of GeoGebra Math Apps ([11], [26], [28]). The Mathematics teacher is offered several visuals for visualization of geometric constructions, hypothesis concerning the properties of geometric figures, and the proof of theorems. GeoGebra (<https://www.geogebra.org/>) visuals include the usage of mobile phones applications such as Geometry, 3D-Calculator, Graphing Calculator, and the visuals demonstrating stochastic experiments in 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 socialization, especially for students with SEN. As our research has shown, Mathematics teachers practically do not use them in their work. Partly because of 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 ([27], [46], [57], [58], [60], [59], [62], [74]). We consider it reasonable to use the GeoGebra Math Apps in teaching students with SEN. The authors offered a mathematics teacher a teaching guide and tasks for students to use GeoGebra in teaching Planimetry and Stochastics [26]. 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 Manuel Sada [55].

To present an experiment demonstration, a teacher can use the GeoGebra dynamic geometry 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 Manuel Sada. We have upgraded the set of visuals offered by Manuel Sada [55] to adapt it to students learning in Ukrainian. For example, one of the exercises allows 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 on the lesson should be structured for a student with special needs in the form of clearly formulated actions, algorithm 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: modeling and counting the results when throwing two, three or more dices and calculating the sum of the falling numbers, etc. By practicing 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 developed by us the lessons of planimetry, the library of electronic visibility.

Research Task 7. How the position of the center of a circle described around a triangle is related to the view of a triangle (see figure 2).

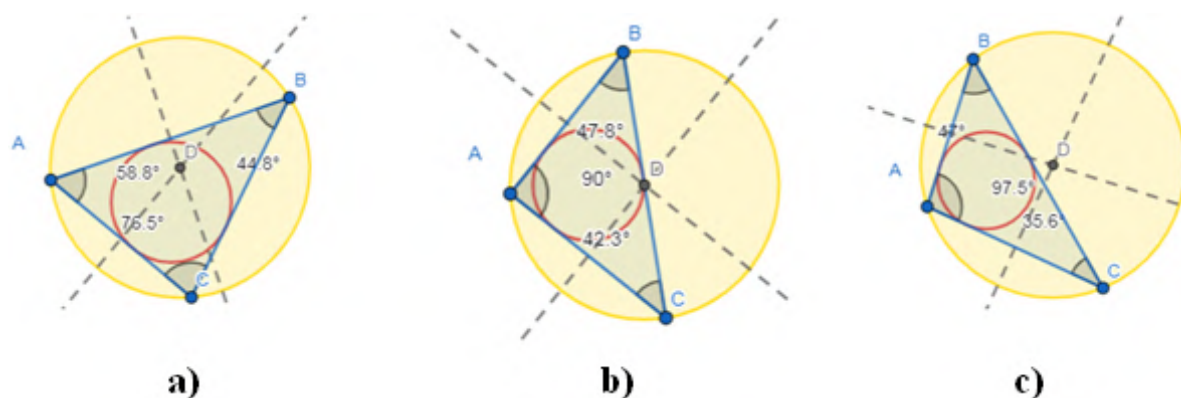


Figure 2. Investigation of the position of the center described around a triangle of a circle (GeoGebra Geometry): (a) an acute-angled triangle, (b) rectangular, (c) obtuse.

It should be taken into consideration that GeoGebra Dynamic Mathematics system can be installed on smartphones. So, the students with SEN 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 below. These are two open-ended tasks with a detailed answer, which are evaluated by examiners according to special rules (EIE-2018).

Task 8. In a regular quadrangular pyramid SABCD, the side of the base ABCD is equal to c , and the side edge SA forms an angle α with the plane of the base. A plane π is drawn through the base of the height of the pyramid parallel to the plane ASD. Construct a section of the pyramid SABCD plane π , justify the type of section and determine its perimeter (see figure 3).

Task 9. Solve the inequality depending on the values x of parameter a :

$$\frac{\log_a x}{x^2+(a-4)x+4-2a} < 0 \tag{1}$$

In preparation for the external independent assessment, students will be able to use GeoGebra Graphing Calculator to identify all possible ramifications for the parameter and to evaluate visually possible solutions of the inequality (see figure 4). This will provide visualization, help students better understand the process of solving such complex problems.

Using the suggested refinements will help a student with special needs better to understand the material. Thus, a student receives full information if it is supported by visual perception of the text, tables, diagrams.

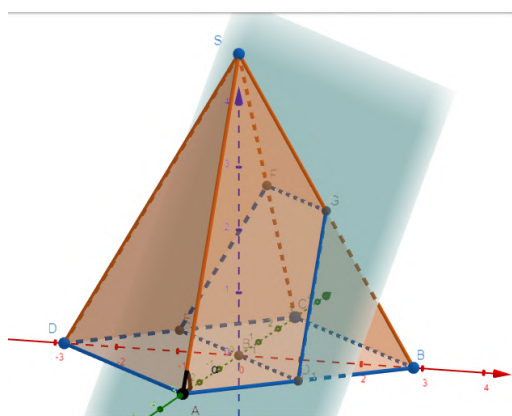


Figure 3. Examples of open-ended tasks (EIE-2018). GeoGebra 3D Calculator.

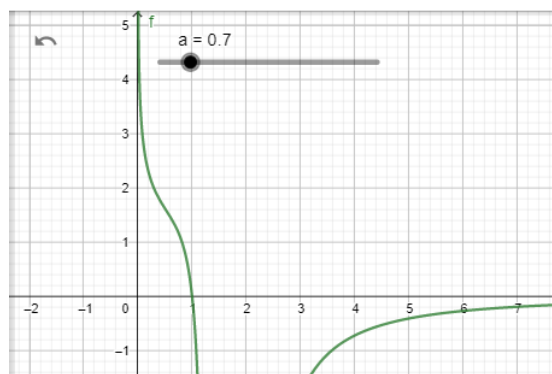


Figure 4. Examples of open-ended tasks (EIE-2018). GeoGebra Graphing Calculator.

4.4. Educational projects method usage as one of the directions of students with special educational needs socialization

As we have already noted, inclusive education involves the education and upbringing of students with special needs in secondary school with a view to their social adaptation in society. The right of such children to integrate into society is a fundamental principle of international standards, and providing them with access to quality education is the basis of real integration. Therefore, the main purpose of the new standards is to reveal the child’s personality, his/her talents, ability to self-study, teamwork, responsibility for his actions, creation of a comfortable environment.

The fourth section of the teaching aid focuses on the usage of project-based learning technologies in Mathematics, in particular STEM projects, to enhance, first and foremost, the socialization of students with SEN. Students can use cell phones to access the developed materials.

The project activity is a joint educational-cognitive and creative activity of a student, a teacher and parents of a child with special needs. It has a common purpose, agreed methods, methods of activity and is aimed at achieving a general result. The purpose of the project is to form and develop the ability to find solutions to the problem; to teach students with SEN to organize individual work; to develop communicative competences and critical thinking of students with SEN; to develop their research skills, observation, the ability to hypothesize and generalize.

The peculiarity of STEM education is that it helps to master these areas not in isolation, but by integrating all disciplines into a single system of learning. The project activity is organized correspondently – the chain “from theory to practice” is the opposite: first thinking and designing, and only then, in the process of this activity – mastering theory and new knowledge. The study object is not studied separately, but in combination with other subjects. Therefore, STEM projects that aim to address the goals of different areas prepare a student for real life better.

Working on a STEM project causes students with SEN to desire thinking independently, to get to know the world and to make discoveries. It also generates non-standard, engineering thinking, nurtures an interest in the exact sciences, develops inventive abilities, since when combined with knowledge, their practical application is created. teaching. When using STEM projects, it is important to focus not on memorizing, but on understanding and applying new knowledge in practice, and the focus should be on the practical task or problem.

At the preparatory stage, a teacher selects the content of the subject, develops tasks for students, means of assessing the quality of knowledge and educational products, involving students in this activity. It is important for a teacher working in an inclusive classroom to anticipate the nuances of implementing project technologies in the learning environment of students with special educational needs.

When planning a teacher’s work, it is advisable to offer the student with special educational needs to choose the feasible, interesting tasks for him / her, according to his / her abilities. With this personal approach, the student develops cognitive interests, the desire to find new facts, which intensifies the intrinsic motivation, and ultimately, promotes the formation of a positive self-image of the student, adds confidence in their abilities.

Especially important in a control is assessment - the process of establishing a student’s educational achievement in mastering the subject knowledge and skills, in accordance with the curriculum. The assessment is expressed in the evaluative judgments and conclusions of a teacher, which are qualitative (verbal) indicators, or in points, that is, quantitative indicators.

In an inclusive class, it is reasonable to maintain a teacher’s portfolio and a student’s portfolio. A teacher’s portfolio is considered as a way of recording, accumulating and evaluating a student’s individual achievements during a certain period of study.

In order to investigate progressive shifts in the study of mathematics students with SEN using ICT tools, it is advisable to compare the shifts in the scores of the diagnostic test and the test. Statistical groups can be analyzed for two G-test and Wilcoxon tests. These algorithms involve the use of small volumes of samples. So, they used it and tested it for individual academic groups. We observed a trend of increasing values of the trait (points scored) in the transition from training exercises to controls.

5. Conclusions

1. Based on the analysis of psychological-pedagogical, educational and methodological literature, it was concluded that the problem of using distant technologies in teaching children with special educational needs is urgent. Inclusive education is not just the coming of a child with special educational needs into a secondary school.

2. The study of problems of Mathematics teaching of students with SEN (with hearing impairment) by means of distance technologies have made the following conclusions: it is reasonable for students with hearing impairments to emphasize each word so that they know how to read those words correctly; one of the tasks of the teacher and a teacher assistant is to encourage children with SEN to study.

3. The most important thing is to socialize children with hearing impairments. It can be done by engaging hearing impaired children in group work or in pairs, both at home and during lessons. The effectiveness of teaching Mathematics depends to a large extent on software tools that allow to apply a fresh approach of teaching Mathematics, exempting students from routine computing, providing them with effective and visual methods of solving a rather wide range of problems.

4. Forms, methods, techniques of teaching processes have been examined that ensure the formation of mathematical competence in students with special needs. The expediency and the necessity of using the research method of learning, the heuristic method, the method of the problem statement, the method of projects, the method of learning by cooperation, as well as information and communication technologies along with adaptive ones have been proven.

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Replication, pseudoreplication and model experiment in the study of population genetics

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Abstract. The paper is dedicated to the problem of true and pseudoreplication of a biological experiment, in particular in the educational process. It was found that this issue is relatively new and actual for the methodology of biological experiments in general. Its solution in science ensures the veracity of the results obtained and the relevancy of the formulated conclusions. In biology teaching methods at school, the problem of true and pseudoreplication of the experiment was not reflected. The author covers an issue of true replication teaching when setting up a model experiment to study genetic-evolutionary processes in populations. The paper discloses the experience in evolution of a model experiment and its development aimed at formation of ideas about technical and biological replication by the example of study of the genetic structure of an ideal population in generations. For this purpose, there was developed a web page that allows to automatically implement technical and biological experiment replication. There was described an experience of approbation of the proposed variant of the experiment, and its difficulties and advantages were revealed.

1. Introduction

The educational subject “Biology” is a didactically adapted system of scientific biological knowledge. As came about from Aristotle times, the natural sciences, and the biology is undoubtedly one of them, have an experiment as one of the main research methods. It is this that allows, on the basis of the various factual material obtained, to make wide generalizations, to proceed to the establishment of connections, patterns that allow deeper penetration into the essence of the phenomena under study. A lot has already been said about the experiment in biological science, about its types, methods, requirements for organization, limitations and difficulties of application. A huge number of scientific works are dedicated to the issues of experimental method history in biology. We, however, were interested and are interested, at this point in time, in the experimental method from the point of view of the possibilities of its use in biological education. In addition, having narrowed the subject field we are interested in, it is worth pointing out that a model experiment occupies a special place in high school. It allows to create models of real objects and to prototype the processes occurring with them in reality. In previous works, the author highlighted some aspects of this issue [16].

In the process of studying the topic of the display of experimental method at the level of school biological education, transformation of ideas about how it is possible to implement the experimentation with complex biological systems, including those inaccessible to the student for direct study, we initially



started out from the following. An educational biological experiment should maximally meet the requirements that are put forward for scientific biological experimentation. These, in particular, are the reliability in essence, the rule of single difference, replication, mass nature. From the mid-20th century, a lot of attention has been paid to the organization of a school biological experiment, moreover to its various types, differing both in the object of research (botanical, zoological, physiological tests, functional tests, etc.), and in the form of carrying out under the conditions of school laboratory, class (demonstrational, laboratorial, mental) [3], [4], [5], [6], [8], [11], [24], [25], [29]. Regardless of the type and form of carrying out, all various types of educational biological experiment must meet the abovementioned requirements in order that the results obtained were maximum consistent.

The biggest difficulties in the educational process are caused by the observance of such requirements as replication and mass nature. In other words, to ensure the veracity of results, the educational experiment should be conducted several times using a sufficiently large number of objects.

It is difficult to implement both the first and the second condition in the educational process due to the following reasons:

- firstly, the temporal limitations of the educational process;
- secondly, due to the inaccessibility of objects for study in the required quantity;
- thirdly, in the principle of inaccessibility of some objects and processes for direct study, primarily due to their objective specificity: either too small (organic molecules, cells, viral particles), or too large (populations).

Let's turn our attention to these reasons, possible ways of their elimination.

Analysis of scientific literature in regards to the experimentation in biology showed that since the end of the 1980s, one of the actively discussed problems became the problem of pseudoreplication in ecological and biological research. In the classical variation, from the moment of publication of the first paper on this topic, pseudoreplication was considered as a negative experimental practice [13]. Even now, one of the criteria by which reviewers evaluate the submitted paper for a journal indexed in the authoritative international scientometrical Scopus and Web of Science databases is the true and pseudoreplication of the experiments conducted [7]. Please note that at the moment the scientific community is still not so categorical in regards to pseudoreplication of experimental research. Discussions are being conducted on the issue of reality and contrivedness of the problem [18], [22], [23].

We proceed from the assumption that the biology teaching methods cannot stay on the sidelines of the problems actively discussed in biological science. Moreover, this question lies in the plane of the science methodology. The mastery of methodological knowledge and the ability to apply them is the basis for the formation of a system of biological knowledge for senior high school students. The author's early works were devoted to this question [15]. So, we consider the question of to what extent in school experimentation in biology it is necessary to take into account the requirements that Stuart H. Hurlbert identified as the problem of pseudoreplication of experimental research in science, as definitively solvable in the direction of their observance. At the same time, given that the educational subject still differs from the basic science in that it is a didactically adapted version of it, it is necessary to achieve a double effect in organization of a school biological experiment. The first effect is that the results of the educational experiment should be maximum consistent, obtained by true replication. The second effect is that the use of true replication should be maximum ergonomical. Ergonomic in time, cost and complexity.

The purpose of this paper is to demonstrate the capabilities of the school model experiment in study of the genetic structure of populations in time while meeting the requirements of true technical and biological replication of experimental objects. Or, in another way: to consider the possibilities of solving the problem of pseudoreplication in the school biological experiment aimed at study of the genetic-evolutionary processes in populations.

We consider it logical to state the essence of the declared problem in the sequence of answers to the following questions: what is the essence of replication in biological research? What kind of experimental replication occurs, what goals does it pursue? What is the essence of pseudoreplication in biological

research, what is the history of the problem? Is pseudoreplication as scary as it might seem? How to ensure true replication in a model experiment by studying complex ideal and real biological objects in school biology (by the example of genetic structure of the population)?

The answers to the set of the abovementioned questions make sense if we answer one of the most important questions: “Why should we conduct at school a model experiment in study of the genetic structure of the population?” It can be concretized in the following way: what is the purpose of this experiment, if it is possible manage without it, to replace it? What fundamental knowledge and skills do pupils acquire when performing this experiment? Why the model experiment in study of population genetics is considered by us as the most important instrument for the formation of not only genetic-evolutionary concepts, but also of metasubject skills?

2. Technique and methods

2.1. *Main issue. Why should we conduct at school a model experiment in study of the genetic structure of the population?*

Study of the issue of model experimentation with the genetic structure of the population during 2015-2020 convinced us that its goal is the obtention by the pupils of a direct subject and mediated activity result. Subject result – 1) mastery of the essence of the law of genetic balance and the conditions under which it is consistent; 2) understanding of the mechanism of influence of evolutionary factors, such as natural selection, gene drift, gene flow, mutation process on the genetic structure of the population; understanding of the mechanisms forming the basis of micro- and macroevolutionary processes. The fundamental significance of the law of genetic equilibrium (Hardy-Weinberg) is that it is the central law of population genetics, it is based on the application of statistical methods in genetics [10].

Activity result – mastery by pupils of the method of the result achievement maximally approximate to the consistent value. In other words, this refers to the formation of a metasubject ability to plan and set up an experiment methodologically correctly, to collect data, to process them and to formulate reasonable conclusions.

Before the development of methods of the model experiment in study of the genetic structure of the population, we posed two questions:

1. Is it necessary to conduct a model experiment when studying the law of genetic equilibrium and the conditions for its consistency?
2. Can a model experiment be replaced with other educational methods?

The answer to the first question is: no, not necessarily. It is possible to limit to the demonstration of the multimedia presentation and video on this topic.

The answer to the second question is: yes, it is possible. An alternative is familiarization with theoretical material on a printed basis about the factors of change in the genetic structure of a population, overlearning of Hardy-Weinberg equations, teaching of the solution of problems on determination of the genetic structure of a population.

The answers to both questions demonstrate that in the alternative version, at the best, only one result will be achieved – a subject one. Without performing experimental actions, it is extremely difficult to form such elements of methodological knowledge as a variant of experience, replication, sampling. In addition, it has to be considered that the law of genetic equilibrium is a law, the substantial part of which consists of abstract categories not attached to a specific biological object (abstract homozygotes and heterozygotes, dominant and recessive alleles, conditions for the veracity of the law). And the law itself is applicable to some really non-existent ideal object, or, conversely, is not applicable to any really existing object (real population).

The abovementioned reasons are the answer for us to the main question, namely: 1) model experimentation contributes to the mastery by the pupils of abstract biological categories on concrete material objects; 2) allows to visualize the processes in an ideal population non-existent in reality; 3) allows to simulate the changes taking place in real populations over several generations. Thus, for educational purposes, the time frame of the actually occurring processes is condensed; 3) allows to vary

the replications and variants of the experiment with minimal material costs; 4) allows to teach true replicates (replications) of the experimental impact; 5) allows to artificially quickly change the conditions (factors) affecting the population, including acting stochastically [20].

2.2. *Issue No. 2. What is the essence of replication in biological research?*

A person possessing a basic level of biological knowledge within the scope of the school curriculum of complete secondary education, the term “replication” is known as a process related to the molecular level of organization of a living being. In the English-language scientific biological literature, the term “replication” is used not only in the meaning of the synthesis of new nucleotide sequences, but also in the meaning of the replicate of experimental attempts. In other words, the principle of replication in experiment is the well-known principle of replication. The last term is more widely used in domestic scientific works.

Replication in biological research can be technical and biological [26].

Technical replicates give us these things:

1. They give us an accurate measurement they give this particular object.
2. If we want to tell more about this object or we do not want to generalize the data and transfer it to the population – a technical experiment is what we need.
3. They will also tell us how accurately we performed the measurements.
4. “If we wanted to publish a paper about how awesome our new method is, we’d use technical replicates” [26].
5. If the experimental technique is transformed, different samples are taken simultaneously from one object, then technical replication will also take place, since they tell us about an individual.

In the biological replicates each measurement comes from different sample that comes from different objects.

Biological replicates give us these things:

1. Biological replicates tell us about a trait that occurs in a group. In biological replicates, each measurement comes from different samples or is obtained differently from one object.
2. You can mix biological and technical replicates, but the wisdom of doing this depends on the type of the experiment. Sometimes you get more bang for your buck if you add more biological replicates and ignore technical replicates.

So, the difference between technical and biological replication is as follows:

- a) technical replicates are just repetition of the same experiment on the same person;
- b) biological replicates use different biological sources of samples (i.e. different people, different plants, and different cell lines) [26].

When choosing the type of replication of a biological experiment, it is necessary to proceed from the purpose in view. If it is planned to describe a specific object, whether it be an individual, a population, or to research a method, it is necessary to use technical replication. If the goal is to study a group of objects, it is necessary to choose biological replication.

2.3. *Issue No. 3. What is the history of the problem of pseudoreplication in biological research?*

The problem of pseudoreplication was raised for the first time in 1984 by Stuart H. Hurlbert, who published a critical analysis of 156 experimental scientific papers in English-language editions published in 1960-1980. He came to the conclusion that in 27% of cases there was one of two variants: 1) the experimental influence was applied in one replication; 2) the experimental replications were not statistically independent. Such errors were called pseudoreplication by Stuart H. Hurlbert. Mikhail V. Kozlov notes that in Russian academic journals in 1998-2001 the part of papers based on pseudoreplication turned out to be twice as high (47%) than in the English-language periodicals for 1960-1980, i.e. before the publication of Stuart H. Hurlbert’s paper. This situation was considered as non-normal, at the same time it was pointed out that the reason for the pseudoreplication lies not only in errors in experiment planning, but also in the incorrect application of statistical analysis to the results of a well-planned experiment [17].

After the publication of Stuart H. Hurlbert's paper in 1984 during the period from 1987 to 2001, according to Mikhail V. Kozlov: 1) the term “pseudoreplication” firmly came into the ecological scientific lexicon of foreign authors, the problem of pseudoreplication in foreign ecological studies is actively discussed; 2) the number of foreign publications based on pseudoreplication began to decrease.

Back in 2003, Mikhail V. Kozlov paid attention to the fact that the concept of pseudoreplication is completely unknown to the overwhelming majority of Russian ecologists. In addition, the author emphasized that Stuart H. Hurlbert's work was never cited in Russian-language periodicals, against the background of more than 2000 references (2015 references as of 2001) in English-language publications. Mikhail V. Kozlov repeatedly published his works on standing up for the position that the problem of pseudoreplication is a problem of the world scientific community, which should be treated with all possible seriousness [17], [18].

The English term “pseudoreplication” does not have a direct analogue in Russian, since it primarily denotes a process – an erroneous choice of replicates for assessment of intragroup variability in statistical analysis [13], [18]. In this regard, direct translation of terminology is difficult enough; the authors provide English equivalents of key concepts. “In medical experiments, where they are designated to as “spurious replication”, “trial inflation”, or “the unit of analysis problem or error” [1], [2], [30]. Although the concept of “pseudoreplication”, which is most adequately translated as “statistical analysis based on pseudoreplication”, is not found in all works listed above, and we do not agree with all the conclusions of the indicated authors, all the cited studies are united by a serious approach to the problem” [18].

2.4. Issue No. 4. Is pseudoreplication as scary as it might seem?

In Russian-language sources, the attitude to the problem specified by Stuart H. Hurlbert and supported by Mikhail V. Kozlov can be characterized as far-fetched and already well-known and studied (Vasilii V. Nalimov, Alexander A. Lyubishchev, Aleksandr I. Bakanov, Nikolai A. Plokhinskii, Tatiana I. Golikova). The Russian-speaking authors agree that there are two indisputable theses in the ideas of Stuart H. Hurlbert:

1) “it is not always correctly to extend the conclusions, obtained in the study of private samplings, to the entire general population;

2) assessment of the degree of factor influence may turn out to be erroneous if the studied effect is not properly localized, and the compared data are taken from insufficiently randomized sources” [22].

The conducted analysis of literary sources [21], [9], [27], [28], [14], [19], [12] on the problem allowed us to single out the “pros” and “cons” of the consideration of the problem of pseudoreplication as significant for biological research. The analysis results are presented in table 1.

2.5. Issue No. 5. How to ensure true replication in a model experiment in school biology?

In previously published materials [15], [16], we described the method of model experimentation developed for senior high school students to study the supraorganismal levels of life organization, namely, population-specific.

The development of a model experiment methodology aimed at the study of the essence of genetic-evolutionary changes in the population by pupils, and its improvement during 2015-2020, was carried out by us in a staged manner. This was dictated by the objective and subjective difficulties of implementation of a model experiment into teaching practice.

At the first stage, we used only material models of gene alleles, created models of genotypes in a manual way, and, respectively, models of parental and daughter populations in generations. Mathematical calculations were performed without the use of a computer, the participants in the experiment manually calculated the frequencies of genotypes and alleles in populations, and presented the results obtained in the graphical representation.

At the second stage, we combined material modelling and use of the computer. Work with material models consisted of carrying out of the experiment itself, creation of a model of the parental population in manual way, and combination of the gene alleles at random (this is how panmixia was simulated).

The participants entered the results of the experiments into a table on the developed web pages. With the help of a computer, the obtained frequencies of alleles and genotypes were automatically calculated. In automatic mode, the results of the experiment were optionally presented in the graphical representation.

Table 1. Pseudoreplication – a real problem in biological research.

“Pro” arguments	“Con” arguments
<p>1. Each object in the sampling is a functional part of the whole, and not a separate element of a set. In a number of studies, the results and conclusions obtained for discrete objects apply to the entire population, which does not correspond to one of the requirements for biological experimentation – consistency in essence.</p> <p>2. During the experiment, there is a multiple determination of reaction of the same organism in the course of sampled counts. As an alternative, the same sampling is studied in different time intervals. In this case, living objects (their populations) are pseudoreplications.</p> <p>3. Two main problems of pseudoreplication are an insufficient mass nature of experimental objects and their initial incomparability with each other. In the first case, the researcher receives insufficient data for the consistent statistical result. In the second case, the problem has an objective causality due to the initial uniqueness of living objects.</p>	<p>1. Each object in the sampling is discrete and individual.</p> <p>2. Factors acting independently on the sampling, act on a set of separate biological objects, and not on an integral object. The specificity of a biological experiment lies in the uniqueness of the objects and, in certain cases, in the impossibility of repeating the experiment in an accurate manner.</p> <p>3. Living objects react to the actions of factors independently on a physical level, and thus they are statistically independent. In a majority of research variants, living objects are true replications.</p> <p>4. The specificity of living objects in their uniqueness and originality. Some ecological research involves study of the reactions of individuals or parts to the impact. In a number of studies, it is not possible to repeat a unique biological object, whether it be an individual or a population.</p> <p>5. The problem of pseudoreplication is artificial, since technical and biological replication is distinguished in biology. The attempt to apply the goals and requirements of technical replication to biological is a prime cause of the issue of pseudoreplication in biological experiments.</p> <p>6. According to one of the points of view, the attention of English-speaking authors to the problem of pseudoreplication is explained by several reasons:</p> <ul style="list-style-type: none"> – the desire to join the campaign of criticism and to incriminate colleagues in pseudoreplication; – the attempt to divert the stigma of pseudoreplication from their work and the work of colleagues; – as a warning signal to the reviewer that the author is acquainted with the work of Stuart H. Hurlbert, therefore there should be no comments on the paper [6].

But both variants did not allow to work with a large number of experimental objects. That is, it was impossible to comply with the condition of mass nature. The reasons are as follows:

1. It is physically impossible in the course of the educational process to explore a large number of material model objects – homozygous dominant, homozygous recessive and heterozygous individuals. The work was accompanied by the enormous time spent on manual modelling and counting of randomly formed pairs of alleles. Such a calculation had to be carried out both within one generation, and in several replications. Note that in this variant we are talking about the difficulties with the technical replication of the experiment.

2. The use of material models was limited to elementary material costs for the manufacture of model elements. The maximum number of individuals whose genotype models were used in the experiment was equal to 50. In the case of diallelic inheritance of a trait (as the simplest variant of inheritance), the number of alleles was equal to 100. Let's point to the fact that in the classrooms there were carried out parallel experiments on the study of influence of different factors of the dynamics of the population genetic structure, the work was carried out in small groups, each of which worked with a separate set of elements for modelling. There were 5 such groups. The first group studied the genetic structure of an ideal population in generations. The second group studied the effects of gene drift. The third group studied the essence of the gene flow phenomenon. The fourth group studied the influence of natural selection on the genetic structure of the population. The fifth group studied the role of the mutational process in the dynamics of the genetic structure of the population. In total, at least a set of 500 material elements was needed for modelling.

We place the emphasis on the fact that even with 50 simulated members of the population, we obtained results that allowed to illustrate the essence of genetic transformations in populations in the absence of any factors and in their presence.

In work on the improvement of the experimental methodology, we tried to: 1) get closer in school modelling of genetic-evolutionary processes to the real process taking a course in populations; 2) take into account significant differences and commonality between scientific and educational experiment. Particularly, this was expressed in the fact that it was necessary to:

1. Cover by the experiment the maximally large number of individuals. It has been assumed that the hundreds and thousands of individuals could be the experimental objects.

2. Reduce the amount of routine work for pupils on the calculation of the resulting genotypes and alleles in one generation.

3. Simulate a larger number of replications (replicates) of the experiment, which would increase the veracity of results and their closeness to the mathematical formula of Hardy-Weinberg. We also set the task to provide the possibility for technical and biological replication of an experiment on one topic.

3. Results

Taking into account the abovementioned tasks, we have developed a web page <http://mybio.education/mod/exp6/en/index.html#> (Model experiment 1. Study of the genetic structure of the ideal population (third variant)).

Using the tools of this web page, we can conduct an experiment on the modelling of a structure of an ideal population in the absence of such factors as natural selection, gene flow, gene drift, mutations. Note that this is the third variant for conduction of a model experiment on the stated topic. The first two are displayed on the following pages: <http://mybio.education/mod/exp1/en/index.html> and <http://mybio.education/mod/exp2/en/index.html>.

What is the difference between the proposed third variant?

First. In two early variants, the number of individuals was limited by the physical ability to manually count the resulting pairs of alleles and the number of material elements for modelling. The studied population in the proposed variant can be very large – several hundreds, thousands, millions of individuals. This contributes to the implementation of the first of the tasks pursued by us – an increase in the number of objects used in the model experiment. And in this case, it can be considered as a step towards the increase in the veracity of the experimental results. And thus, the maximum convergence with the actually occurring genetic and evolutionary transformations in the population. For example, for an experiment, you can take several tens of thousands of individuals and several million (figures 1, 2).

Second. The user (student) can independently enter the initial allele frequencies in the graph for the parental population. In the first two variants, the allele frequencies were calculated automatically after data entering by the manual calculation of the randomly obtained genotypes. This function opens up an opportunity to demonstrate the essence of **biological replication of experiments**. This function is especially remarkable in the lesson during the simultaneous work of several groups of students with different populations in number and frequency of alleles occurrence (figures 1, 3).

Model experiment 1. Study of the genetic structure of the ideal population (third option)

1. In column 2 for the parent generation P, we introduce the number of pairs of two-body gene alleles (in other words, the number of individuals).
2. We are determined by the ratio of the dominant (A) and recessive (a) alleles, and we introduce their values in columns 9 and 10 for the parent generation P.
3. Click the "Calculate" button.
4. Click the "Calculate" button opposite the lines F1, F2, F3, F4, F5.
5. Click on the "Show Graphs" button.
6. Based on the analysis of the obtained graphs and diagrams, formulate the conclusions of the plan:
 - Change in the frequency of genotypes in generations;
 - Change in the ratio of gene frequencies in generations;
 - The direction of evolutionary changes in the population.

Table 6. Genetic structure of the ideal population

Generation	Number of Individuals	Distribution of genotypes						Gene frequencies		
		AA		Aa		aa		A(p)	a(q)	
1	2	3	4	5	6	7	8	9	10	
P	20000	10910	0.545	6180	0.309	2910	0.145	0.7	0.3	Calculate
F1	20000	10893	0.545	6214	0.311	2893	0.145	0.738	0.380	Calculate
F2	20000	10883	0.544	6234	0.312	2883	0.144	0.738	0.380	Calculate
F3	20000	10890	0.544	6220	0.311	2890	0.144	0.738	0.380	Calculate
F4	20000	10823	0.541	6354	0.318	2823	0.141	0.736	0.376	Calculate
F5	20000	10869	0.543	6262	0.313	2869	0.143	0.737	0.379	Calculate

[Show Graphs](#)

Figure 1. Results of a model experiment with a number of 20000 individuals, allele frequencies p (0, 7) and q (0, 3).

Model experiment 1. Study of the genetic structure of the ideal population (third option)

1. In column 2 for the parent generation P, we introduce the number of pairs of two-body gene alleles (in other words, the number of individuals).
2. We are determined by the ratio of the dominant (A) and recessive (a) alleles, and we introduce their values in columns 9 and 10 for the parent generation P.
3. Click the "Calculate" button.
4. Click the "Calculate" button opposite the lines F1, F2, F3, F4, F5.
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Table 6. Genetic structure of the ideal population

Generation	Number of Individuals	Distribution of genotypes						Gene frequencies		
		AA		Aa		aa		A(p)	a(q)	
1	2	3	4	5	6	7	8	9	10	
P	2000000	1087149	0.544	625702	0.313	287149	0.144	0.7	0.3	Calculate
F1	2000000	1087690	0.544	624620	0.312	287690	0.144	0.737	0.379	Calculate
F2	2000000	1087753	0.544	624494	0.312	287753	0.144	0.737	0.379	Calculate
F3	2000000	1087745	0.544	624510	0.312	287745	0.144	0.737	0.379	Calculate
F4	2000000	1087290	0.544	625420	0.313	287290	0.144	0.737	0.379	Calculate
F5	2000000	1087641	0.544	624718	0.312	287641	0.144	0.737	0.379	Calculate

[Show Graphs](#)

Figure 2. Results of a model experiment with a number of 2000000 individuals, allele frequencies p (0, 7) and q (0, 3).

Third. The number of generations of the population has been increased. In the proposed variant, it is equal to 5. I.e. together with the parental population, the total number of replications of the experiment is equal to 6. In previous variants of the experiment, the number of replications was equal to 3 (one parental generation and two daughter generations). In addition, note that it is technically possible to increase the number of replications by times. This will offer an opportunity, first of all, to quickly get a picture of the genetic structure of the population, without bothering students with mechanical work on mixing and distribution of genotypes, since there is an automatic distribution of genotype frequencies

within the limits of the ideal population. Secondly, it contributes to the implementation of one of the tasks pursued by us – an increase in the number of replications of the experiment within the limit of one sample (population). This function opens an opportunity to conduct the **technical replication of experiments**.

Model experiment 1. Study of the genetic structure of the ideal population (third option)

1. In column 2 for the parent generation P, we introduce the number of pairs of two-body gene alleles (in other words, the number of individuals).
2. We are determined by the ratio of the dominant (A) and recessive (a) alleles, and we introduce their values in columns 9 and 10 for the parent generation P.
3. Click the "Calculate" button.
4. Click the "Calculate" button opposite the lines F1, F2, F3, F4, F5.
5. Click on the "Show Graphs" button.
6. Based on the analysis of the obtained graphs and diagrams, formulate the conclusions of the plan:
 - Change in the frequency of genotypes in generations;
 - Change in the ratio of gene frequencies in generations;
 - The direction of evolutionary changes in the population.

Table 6. Genetic structure of the ideal population

Generation	Number of individuals	Distribution of genotypes						Gene frequencies		
		AA		Aa		aa		A(p)	a(q)	
1	2	3	4	5	6	7	8	9	10	
P	20000	2295	0.115	3410	0.171	14295	0.715	0.2	0.8	Calculate
F1	20000	2261	0.113	3478	0.174	14261	0.713	0.336	0.844	Calculate
F2	20000	2310	0.116	3380	0.169	14310	0.716	0.340	0.846	Calculate
F3	20000	2274	0.114	3452	0.173	14274	0.714	0.337	0.845	Calculate
F4	20000	2221	0.111	3558	0.178	14221	0.711	0.333	0.843	Calculate
F5	20000	2285	0.114	3430	0.172	14285	0.714	0.338	0.845	Calculate

[Show Graphs](#)

Figure 3. Results of a model experiment with a number of 200000 individuals, allele frequencies p (0, 2) and q (0, 8).

The visualized replication results are displayed on the user's screen by clicking the "Show graphs and diagrams" button. Note that in one session the user can only see the results of technical replication, i.e. distribution of alleles and genotypes in generations with initially specified parameters (number of individuals and allele frequencies). The generations of the population will act as technical replications. In order to simulate biological replication, it is necessary to load the page once again without closing the previous one and enter other initial data (the number of individuals, allele frequencies). Within each session, generations of a population in relation to each other will act as technical replications, but in relation to the first population and its generations – biological replications.

In 2019/2020 academic year, the developed web page was tested with the participation of 6 students of the 3rd year of the Institute of Living Systems of Immanuel Kant Baltic Federal University, in specialty "Biology" and 12 students of the 11th form of the Municipal Budgetary General Education Institution General Secondary School "School of the Future" of Guryevsky district of Kaliningrad Region (Russian Federation). The approbation took place within the framework of carrying out by Municipal Budgetary General Education Institution General Secondary School "School of the Future" together with the National Research University Higher School of Economics of the conference "Effective High School" (January 23-25). Within the framework of the conference, there were organized practical classes for pupils of 11th forms on the topic "Modelling of the genetic evolutionary processes in the population". One of the proposed experiments for carrying out was a model experiment "Study of the genetic structure of an ideal population" according to the methodology updated by us without using material objects.

In approbation, the participants were divided into 2 groups (3 students and 6 pupils). One group was asked to start with an experiment at <http://mybio.education/mod/exp1/en/index.html#>, and then at <http://mybio.education/mod/exp6/en/index.html#>. Another group was asked to click a link to the web page <http://mybio.education/mod/exp6/en/index.html#> (Model experiment 1. Study of the genetic structure of the ideal population (third variant) and simulate the genetic structure of a population of any

number more than a thousand with an arbitrarily given combination of allele frequencies. It was proposed three times to the participants to carry out model experiment in the third variant with different initial data (number of individuals of the population, allele frequencies). Each of the participants of the approbation both in the first and second groups in carrying out of the third variant of the experiment worked separately. The participants were asked to use the “Show graphs and diagrams” function, and also to formulate conclusions at the end of the experiment.

The goals pursued by us were as follows:

1. To find out the availability of understanding by users of the tasks and results of experiments.
2. To find out the main difficulties faced by users when working with a web page <http://mybio.education/mod/exp6/en/index.html#>.

During the oral survey of the participants in the experiment, it was found:

1. Participants of the first group, when conducting an experiment with material objects at the beginning of work, hardly understood the essence of the performed similar actions. Only after data entering into the table, calculation of the frequencies of alleles and genotypes, the understanding of the meaning of the uniformity of actions came.

2. Participants of the first group complained about the routine of the performed actions, increased fatigue during their performance. Participants sought to complete the experiment more quickly, which increased the error rate in calculation of the absolute number of genotypes. The latter was displayed at the frequency of genotypes calculated by the program. Thus, the obtained results in several cases were erroneous, the experimental actions had to be performed over again.

3. Participants of the first group, after passage to the second experiment, which, in fact, duplicated the first variant, but did not require manual counting, expressed great approval of the possibility to operate only with numbers.

4. Participants of the second group completed the assigned task more quickly. However, in both groups, there arose questions about the purpose of three-time replicate of the experiment (with different number of population and allele frequencies). Note that practically no questions arose in both groups regarding the advisability of repeating the experiment in generations of the same population. It follows that the essence and necessity of technical replication is recognized and accepted by the participants.

With biological replication, the situation is different. Its objectives were not clear to the participants, most likely due to a lack of methodological awareness of this type of replication.

5. Before the performance of the experiment, we deliberately did not focus the participants' attention on the goals of repeated replicate of experimental actions. This was done in order to find out whether the participants understood the conditions for the veracity of the results of the biological experiment. Since among the examinees there were both students of a biological specialty and pupils of graduating profile chemical and biological classes. We assumed that the participants already possess the necessary methodological tools for planning, conduction of biological experiments and interpretation of the results. The results of approbation showed that teaching the methodology of a biological experiment should be started with distinguishing between technical and biological replication of experimental effects. We can only assume that a lack of understanding of the differences between them (for purposes, methodology) could initiate the spread of the problem of pseudoreplication in biological research in principle. We believe that in order to confirm this assumption, it is necessary to conduct additional studies aimed at a retrospective analysis of biological scientific literature, primarily of scientific papers, conference materials containing a description of the methods and results of experiments. The question is, is it worth doing? Or to accept the fact that even if we consider the problem of pseudoreplication as far-fetched, then the issue of distinguishing between technical and biological replications and teaching this in the secondary school and in higher educational establishment definitely deserves further study.

4. Conclusions

As a result of work on the topic of true replication by means of a school biological experiment, we came to the following conclusions:

1. The question of the artificiality and reality of the problem of true replications in biological science

remains open.

2. One of the reasons for the artificiality of the problem may be an implicit distinction between the purpose and methods of technical and biological replication.

3. Model experiment on the study of genetic-evolutionary processes in populations by means of computer modelling is ideal for demonstration of the essence of technical and biological replication.

4. Computer modelling of genetic-evolutionary processes in populations allows to take into account the requirement of mass nature of experimental impact, which is one of the necessary for obtention of consistent results.

5. In the educational model experiment, it is impossible to take into account all the requirements for a scientific biological experiment, therefore, it is necessary to rely only on its essential features: replicativity, mass nature, principle of single difference, veracity in essence.

5. Outlook

Continuation of approbation of the effectiveness of the proposed method for studying the law of genetic equilibrium and the essence of technical and biological replication of the experiment is scheduled to be conducted in 2020/2021 academic year. Elective courses “Population Biology” and “Fundamentals of Theoretical Biology” for students of 3rd and 4th academic years of the Institute of Living Systems of Immanuel Kant Baltic Federal University will be used as an experimental site, as well as the course “Olympiad Biology” for pupils of 10-11 forms of the School of the Future of Guryevsky district of Kaliningrad region.

Further work on studying the possibilities of a model experiment in training of the pupils of 11 forms and students-biologists in true replication, as well as the essence of technical and biological replication, we can see in the following. It is necessary to develop and approbate web pages to model the structure of a very large population under the influence on its numerous generations of such factors as natural selection, gene flow, gene drift, mutations.

The modelling of the genetic structure should be fully automated. The initial platforms for improvement of methodology will be the existing web pages <http://mybio.education/mod/exp3/en/index.html#> (Model experiment 2. Study of the genetic structure of the population under the influence of natural selection), <http://mybio.education/mod/exp4/en/index.html#> (Model experiment 3. Modelling the effect of gene flow on the genetic structure of the population), <http://mybio.education/mod/exp5/en/index.html#> (Model experiment 4. Modelling the effect of random processes on the genetic structure of the population, modelling the drift of genes*), providing one of the stages of work with material objects.

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Predictive model of heavy metals inputs to soil at Kryvyi Rih District and its use in the training for specialists in the field of Biology

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Abstract. The importance of our research is due to the need to introduce into modern biological education methods of predictive modeling which are based on relevant factual material. Such an actual material may be the entry of natural and anthropic heavy metals into the soil at industrial areas. The object of this work: (i) to work out a predictive model of the total heavy metals inputs to soil at the Kryvyi Rih ore-mining & metallurgical District and (ii) to identify ways to use this model in biological education. Our study areas are located in the Kryvyi Rih District (Dnipropetrovsk region, Central Ukraine). In this work, classical scientific methods (such as analysis and synthesis, induction and deduction, analogy and formalization, abstraction and concretization, classification and modelling) were used. By summary the own research results and available scientific publications, the heavy metals total inputs to soils at Kryvyi Rih District was predicted. It is suggested that the current heavy metals content in soils of this region due to 1) natural and 2) anthropogenic flows, which are segmented into global and local levels. Predictive calculations show that heavy metals inputs to the soil of this region have the following values ($\text{mg} \cdot \text{m}^2/\text{year}$): Fe – 800-80 000, Mn – 125-520, Zn – 75-360, Ni – 20-30, Cu – 15-50, Pb – 7.5-120, Cd – 0.30-0.70. It is established that anthropogenic flows predominate in Fe and Pb inputs (60-99 %), natural flows predominate in Ni and Cd inputs (55-95 %). While, for Mn, Zn, and Cu inputs the alternate dominance of natural and anthropogenic flows are characterized. It is shown that the predictive model development for heavy metals inputs to soils of the industrial region can be used for efficient biological education (for example in bachelors of biologists training, discipline “Computer modelling in biology”).

Introduction

Heavy metal (HM) pollution of atmospheric air, surface / groundwater and, especially, soil cover is an urgent problem for all industrial regions. It should also be noted that the gradual accumulation and very long finding of these pollutants occurs exclusively in the soil [1], [5], [8], [15], [18]. It is generally accepted that the accumulation in soils of a significant amount of anthropogenic HM poses a serious threat to the state of the biosphere and to human health [3], [4], [6], [41].

By now, researchers have thoroughly and in detail considered the features of HM content in soils in industrial regions. At the same time, identification of regularities of total metals inputs to soils at ore-mining and metallurgical regions remained without their proper attention [4], [5], [11], [14]. While, understanding the philosophy and details of metals inputs to soil at industrial regions can become



a methodological basis for environment protection of these regions. It should also be noted that, measures effectiveness is determined by the successful streamlining of soil ecosystem functions as a biosphere indispensable component [11], [25], [37], [38].

Recently, biological education is increasingly using modern computer technology and a variety of computer models [23], [24]. However, in most cases, these models are created by either mathematicians or computer scientists. Therefore, such models do not reflect biological processes well enough. That is why it is so important for effective modern education that models of biological phenomena and processes are made by biologists [19], [30], [36], [40].

The object of this work: (i) to work out a predictive model of the total heavy metals inputs to soil at the Kryvyi Rih ore-mining & metallurgical District and (ii) to identify ways to use this model in biological education.

Materials and methods

Our research was performed in the Kryvyi Rih Ore-mining and Metallurgical District (named as Krivbas, Kryvorizhzhia, Kryvorizsky region). This district is located in Central Ukraine and its center is in the city of Kryvyi Rih. The geographical coordinates of its extreme points are: north – 48⁰19 ' N, south – 47⁰48 ' N, west – 32⁰58 ' E, east – 33⁰47 ' E. (Figure 1).

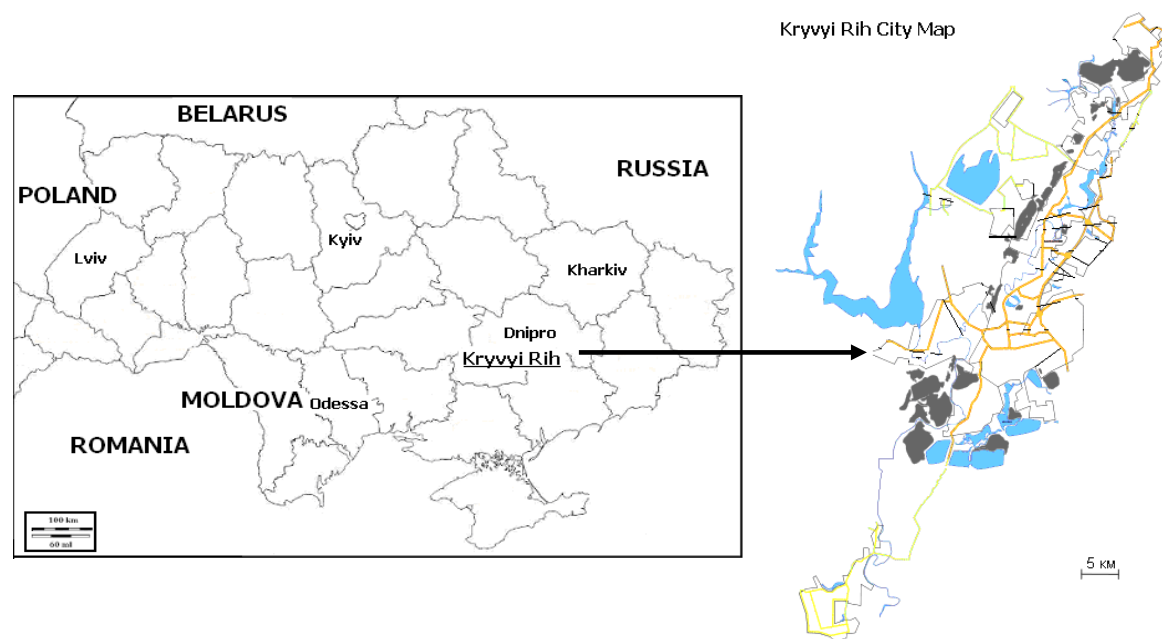


Figure 1. Location of study areas.

By the beginning of the XXI century Kryvbas – it is the largest ferrum ore and mining and metallurgical region in Europe. The full-cycle metallurgical plant, five mining and processing plants, and nine mines have been operating in this region for more than 50 years. In this region, 95-105 million tons of ore are mined annually, 60-70 million tons of enrichment products (agglomerate, pellets, concentrate) are produced, 6-7 million tons of pig ferrum and 5-6 million tons of steel are smelted [6], [32], [34].

Methods of research are analysis and synthesis, induction and deduction, analogy and formalization, abstraction and concretization, classification and modeling. Principles, methodology and formulas for forecasting of heavy metals inputs to soils are detailed in this publication [32].

Results and discussion

The concept of model of HM inputs to soil

In our opinion, the total metals’ inputs to soils at Kryvyi Rih District can be represented in the coordinate axes: the x-axis is the source of inputs to and the Y-axis is the flow levels. Figure 2 manifests the concept and philosophy for our predictive model [32].

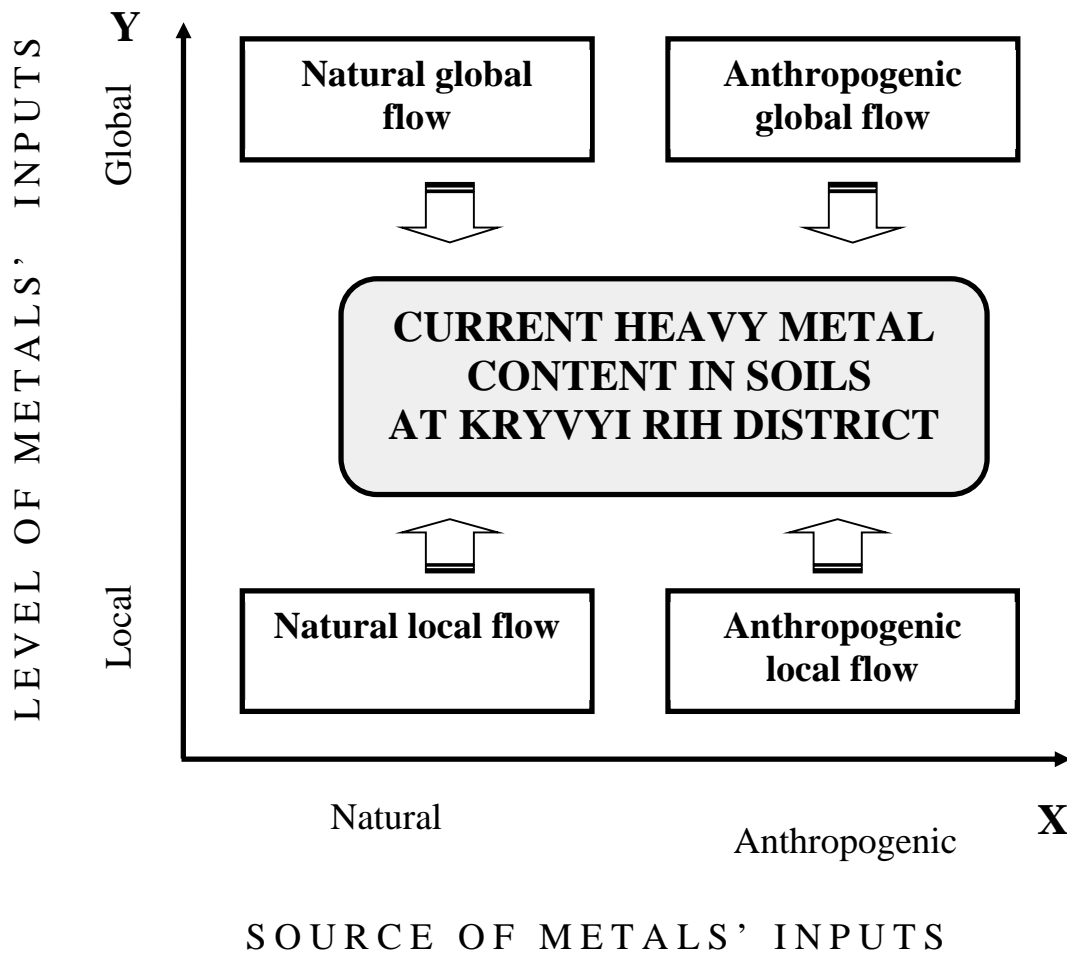


Figure 2. Concept pattern of heavy metals inputs to soil at Kryvyi Rih District.

The main sources of natural metals inputs to soils are the products of rock hypergenesis, soil formation and the products of biosphere genesis. While the main sources of natural metals inputs to soils are the arena for emissions from iron ore and mining enterprises (anthropogenic flows). In turn, these flows are segmented into two levels: global and local. Global flows of metals inputs cover all areas of the earth's surface. Therefore, these metal flows have the same values. Local flows of metals strictly timed to a specific industrial area. Therefore, these metal flows have different values for every area.

Predictive model of HM inputs to soils at Kryvyi Rih District

Published data of metals biosphere cycles [2], [7], [14], [16] we used to calculate the indicators of natural HM flow to soils at Krivbass (table 1). In this case, we a priori assumed the following prerequisites for our calculations. First, this flow of metals was formed by continental dust and oceanic precipitation.

Second, all the metals from this flow were naturally evenly distributed throughout the landmass of the planet Earth.

Table 1. Natural local flow of heavy metals to soil at Kryvyi Rih District.

Metal	Sub region	Inputs, mg · m ² /year						Total
		by underground phytomass			by aboveground phytomass			
		Min	Max	M	Min	Max	M	
Ferrum	North	262,5	337,5	300,0	113,8	146,3	130,0	430,0
	Southern	227,5	292,5	260,0	61,3	78,8	70,0	330,0
Manganese	North	72,0	88,0	80,0	18,0	22,0	20,0	100,0
	Southern	49,5	60,5	55,0	13,5	16,5	15,0	70,0
Zinc	North	45,5	54,5	50,0	9,1	10,9	10,0	60,0
	Southern	41,0	49,1	45,0	4,6	5,5	5,0	50,0
Nickel	North	18,4	21,6	20,0	7,4	8,6	8,0	28,0
	Southern	16,6	19,4	18,0	4,6	5,4	5,0	23,0
Copper	North	5,78	6,62	6,20	2,61	2,99	2,80	9,00
	Southern	4,94	5,66	5,30	1,58	1,82	1,70	7,00
Lead	North	1,98	2,22	2,10	0,47	0,53	0,50	2,60
	Southern	1,70	1,90	1,80	0,28	0,32	0,30	2,10
Cadmium	North	0,457	0,503	0,480	0,029	0,031	0,030	0,510
	Southern	0,390	0,430	0,410	0,019	0,021	0,020	0,430

Min – minimum value, Max – maximum value, M – arithmetic mean.

According to predictive calculations, it was established that in the soils of the Kryvyi Rih mining and metallurgical region with continental dust, ferrum is introduced as much as possible – 540-550 mg · m²/year. An order of magnitude less manganese, two orders of magnitude less – nickel and zinc, three – less copper and lead, five – cadmium. In the soils of this area with ocean precipitation lead and zinc are the most sedimented, respectively 2,0-2,5 mg · m²/year and 3,6-3,9 mg · m²/year. Ferrum, manganese and copper are an order of magnitude less and two orders of magnitude less – cadmium.

We found that the phytomass of herbaceous vegetation is the main source for the metal natural local flow to soils of Kryvyi Rih area. As our calculations have shown, in the soils of this area with a natural local flow, ferrum is sedimented in the largest amount 330-960 mg · m²/year (table 1). The intensity of flows of manganese, zinc was one and a half time less, copper and lead – two orders of magnitude. For cadmium, the minimum values of sedimentation in the soils of this area were revealed – 0,430-0,800 mg · m²/year. The values of the natural local flow of HM to the soils at Kryvyi Rih area are comparable with the data of the scientific data [10], [27], [28], [44].

It should also be noted that the natural flow of ferrum, zinc and nickel to the soils of this district is by 2,5-3,0 times higher than similar indicators of their flow to the soils at steppe reserves of Ukraine [32]. Our results show that the amount of metals introduced to the soils of this region by vegetation precipitation (local level) is 3-4 orders of magnitude higher than by general biosphere input.

Our calculations indicated that according to the levels of anthropogenic global inputs to soils at Kryvbas, metals form a decreasing series (mg · m²/year): ferrum (180), zinc (15,0), manganese (11,0), copper (6,00), lead (5,00), nickel (2,25), cadmium (0,200). This series differs significantly from the ordering of metals flowing into the soils of the Kryvyi Rih area by natural and global fluxes. This fact manifests the dominance of anthropogenic flow of metals into the soils of this region.

Predictive calculations have determined that at Kryvyi Rih District by anthropogenic local flow annually ferrum is sedimented to the soils from 1,800 to 80,000 mg · m²/year (table 2). Sedimentation rates of manganese, zinc and lead are two and a half orders of magnitude lower than ferrum. Sedimentation rates of manganese, zinc and lead are two and a half orders of magnitude lower than

ferrum. The flux intensities of copper and nickel are at about the same level, which are three orders of magnitude less than ferrum. It should also be noted that the minimum flux values detected for cadmium – 0,0050-0,3000 mg · m²/year. These values are four orders of magnitude lower than ferrum.

Table 2. Anthropogenic local flow of heavy metals to soil at Kryvyi Rih District.

Metal	Inputs, mg · m ² /year								
	Buffer area			Sub Impact area			Impact area		
	Min	Max	M	Min	Max	M	Min	Max	M
Ferrum	1 575	2 025	1 800	26 250	33 750	30 000	70 000	90 000	80 000
Manganese	9,00	11,00	10,00	180	220	200	468	572	520
Zinc	7,10	8,51	7,80	127	153	140	328	392	360
Nickel	0,37	0,43	0,40	6,35	7,45	6,90	16,4	19,2	17,8
Copper	1,02	1,18	1,10	17,7	20,3	19,0	46,6	53,4	50,0
Lead	2,35	2,65	2,50	42,3	47,7	45,0	113	127	120
Cadmium	0,0048	0,0053	0,0050	0,11	0,13	0,12	0,28	0,32	0,30

Min – minimum value, Max – maximum value, M – arithmetic mean.

A comparison of the metals anthropogenic local flow to the soils at Kryvbas with their sedimentation to the soils at industrial areas of the world showed the following. Indicators of ferrum inputs, in general, are comparable with the data from other mining and metallurgical regions, but in the impact area were by 5-15 times higher than these values [11], [26], [31], [42].

As our calculations have shown, the maximum levels of anthropogenic sedimentation of manganese, zinc, copper and lead to the soils at Kryvbas exceed their entry to the soils at other mining and metallurgical regions at the world. Lead was by 4.5 times, zinc and copper were by 2.5 times, manganese was by 2 times. While, the values of nickel and cadmium anthropogenic local fluxes to the soils of this area are comparable with the intensity of these metal flows to the soils from other industrials and agricultures areas [22], [29], [35], [39].

According to our predictive calculations, the metals natural global flow to the soils at Kryvyi Rih District is characterized by a negligible share. It is only 0,001-0,03% of the total amount of metals (figure 3). According to the structure of the HM total inputs to the soils at Kryvbas, metals are united into three groups: “technophilic”, “technophilic-biophilic”, “biophilic” [32], [33].

The first group of “technophile elements” includes ferrum and lead. For these metals, the antropogenic component predominates in their total soil uptake. Thus, at minimum levels of anthropogenic impact, the natural flow is: 5-35% for ferrum and 10-30% for lead. With increasing intensity of anthropogenic impact, the natural flow is reduced to zero.

The second conditional group of “technophilic-biophilic elements” includes manganese, zinc and copper. These metals are characterized by the alternating dominance of both natural and anthropogenic flows in their total entry into the area soils.

Thus, with minimal anthropogenic impact of natural substances, the flux of these metals is: manganese 50-90%, zinc 45-85%, copper 45-75%. With minimal anthropogenic impact, anthropogenic flux dominates in total intake: 55-90% for manganese, 60-90% for zinc and 55-90% for copper.

The third group of “biophilic elements” includes nickel and cadmium. The total inputs of these metals to the soil of district were exclusively due to the natural local flow. Thus, in the area of minimal anthropogenic impact, the natural flux of these metals has very high values by 85-95% for nickel inputs and by 65-80% for cadmium inputs. Despite the increase in the intensity of anthropogenic impact, the importance of natural flow in the entry of these metals into the soils of the Kryvyi Rih mining and metallurgical region remains very significant: 55-90% – nickel and 45-70% – cadmium (figure 3).

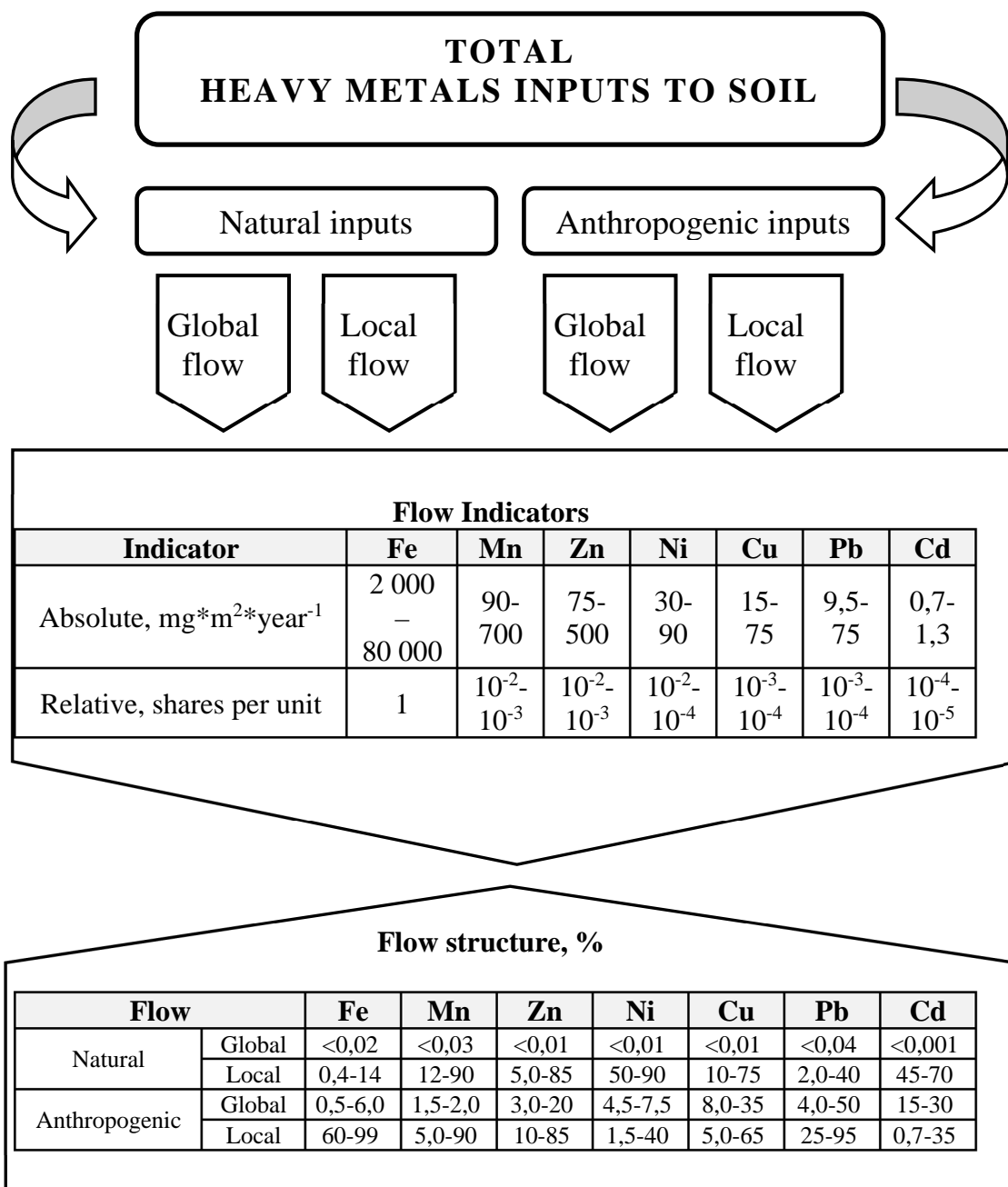


Figure 3. Predictive pattern of heavy metals inputs to soil at Kryvyi Rih District.

The predictive model and biology education

Recently, modeling has been widely used as an effective tool for research, design and training, including in biological education. The created models, displaying the basic contours of biological phenomena and processes, help to better understand the philosophy of modern biology. That is why the created models of biological processes and phenomena are actively used also in biological education. It should also be noted that the use of computer technology significantly improves the models of biological processes and phenomena [13], [19], [20], [21], [36].

It is generally accepted that one of the effective methods of using computer technology is the use of elements of modeling phenomena and processes of the surrounding reality. At the same time, it is necessary to emphasize that models should be created by biologists to solve biological problems and

problems. Since, there are currently a very large number of diverse biological models that have been developed by mathematicians and computer scientists. However, unfortunately, such models are very difficult for biologists to understand and are very far from solving biological problems and from understanding biological processes / phenomena. That is why it is so important to involve professional biologists to create a computer model of biological processes and phenomena [9], [12], [17], [30], [40], [43].

The model of heavy metals flow to soils at Kryvyi Rih Ore-mining & Metallurgical District made by us is very important and relevant. First of all, this model helps to understand the philosophy of soil contamination by heavy metals. Moreover, this model reveals the shares of natural and anthropogenic flows in soil pollution. It should also be noted that this model will allow predicting anthropogenic flows of heavy materials to soils at various mining and metallurgical activities in this district. In addition, the algorithms of the model and the model itself can be used in biological education. For example, the predictive model development for heavy metals inputs to soils of the industrial region can be used for efficient biological education (for example in bachelors of biologists training, discipline “Computer modelling in biology”).

Conclusions

Modern heavy metals content in soils at the Kryvyi Rih Ore-Mining and Metallurgical District is determined by the total natural and anthropogenic sedimentation of these elements, which are formed due to their global and local flows.

In the soils of Kryvbas the natural metals' sedimentation had the following values: from 0,010 to 543,100 mg · m²/year by global flows and from 0,43 to 960 mg · m²/year by local flows. The biomass of herbaceous vegetation determined more than 99% of the HM natural flows to the soils of these areas.

In the soil of Kryvyi Rih District the anthropogenic metals' sedimentation had the following values: from 0,200 to 180,000 mg · m²/year by global flow and from 0,0050 to 80,000 mg · m²/year by local flow. Aerial emissions from ore-mining and metallurgical plants have caused anthropogenic local flows of metals to this district's soils.

Anthropogenic sedimentation dominated in the structure of iron and lead flows to Kryvyi Rih District soil. Its share ranges from 60% to 95%. Natural local sedimentation dominated in the structure of nickel and cadmium fluxes. The share of these metals ranged from 55% to 95%. Alternate dominance of natural and anthropogenic flows was revealed in the structure of manganese, zinc and copper flows in the soils of these areas.

The model of heavy metals flow to soils at Kryvyi Rih Ore-mining & Metallurgical District made by us is very relevant and can be used in biological education. In further research, it is necessary to verify our model of heavy metal flows in the soil of these areas. It will also be important to make and verify the educational technologies that will use this model.

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The origin of misconceptions in inorganic chemistry and their correction by computer modelling

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Abstract. The paper goal was to analyse the typical mistakes in the learning of the university course of inorganic chemistry, determine the origin of misconceptions and estimate the effectiveness of the use of computer simulations to correct false chemical concepts. Ten problems that are the most typical for students were revealed. One of the leading causes of their occurrence is the failure of many students to form mental relationships between different levels of representation of chemical knowledge - microscopic, macroscopic and symbolic. Other reasons include an insufficient understanding of the material, the incompleteness of the knowledge of the microscopic basis of processes, and inability to work with different models, including misunderstanding of their purpose and constraints. NetLogo programming environment was used for students' self-administering tests to study gas laws. Scope for the usage of NetLogo models was estimated in correcting of incorrectly formed conceptions of the chemical knowledge. Independent work with NetLogo models facilitates the formation of stable relationships between multiple levels of representation of chemical information. It improves an understanding of the studied topic fundamentally, and this holds for all students practically independently of their grounding level in chemistry. The introduction of computer simulation into the practice of teaching chemical subjects shows promise. Still, it requires the solution of several scientific, methodological, logistical and organisational issues.

1. Introduction

Incorrect chemical concepts are observed fairly often among university students ([16], [28], [30]). Such a conclusion is based on the experience of teaching basic chemical disciplines at institutes of higher education and also follows from the analysis of the nature of students' wrong answers in examination papers. Two facts evidence the formation of misconceptions [11]. First, a large proportion of incorrect answers (for example, >50%) is observed among all responses obtained. Second, one misthought dominates among wrong answers (>60%), while other possible mistakes occur rarely.

The origin of chemical misconceptions should be analysed in dynamics when the level of assimilation of chemical knowledge at universities is compared with the results of students at secondary schools ([24], [35]). For example, the averaged data of monitoring of 24 secondary schools with 461 school students were described in [3]. A very significant difference was observed in the levels of assimilation of various topics of the school chemistry course. For instance, the proportion of correct answers to questions, which require an understanding of the nature of the periodic law and related regularities and rules, exceeded 80%. Determination of the type of chemical bonds or calculations of solubility and pH occurred with a 70% success.



At the same time, 14% of respondents did not even begin to perform tasks related to the writing of oxidation-reduction reactions. The number of correct answers to this topic did not exceed 25%. It is essential to note that responses to such questions require analytical and synthetic skills. Solving computational problems require skills of systematisation and algorithmisation. Up to 35% of respondents did not begin implementation of such tasks. The share of correct answers was less than 10%. In the course of study of chemical element properties, school students found difficulty in composing reaction equations by chemical transformation schemes. The share of correct answers did not exceed 2-3%; many students demonstrated an inability to compare, analyse, systematise and estimate the chemical properties of all classes of substances. Such a situation is typical not only for Ukraine. It is caused by a formal algorithmic approach which was introduced into an educational process to solving similar problems by teachers of chemistry ([7], [29]). Such an approach does not allow graduates to see various aspects of chemical phenomena at the macro- and microlevels. Still, it directs them to the use of symbolic designations.

All examples mentioned above point to the need to use educational technologies which help students to form the right chemical notations or correct misconceptions. As shown in many research ([10], [15], [28]), some chemical mistakes are persistent and severe to be corrected. Their presence among students is one of the critical problems in the teaching of chemical disciplines. Understanding the nature of errors will help to develop methods for their elimination.

The application of some learning resources based on the information and communication technologies (ICTs) shows promise in the formation of proper chemical concepts ([5], [8], [9], [12], [21], [22], [23]). Nevertheless, the use of ICT does not automatically improve the quality of knowledge. Students with different learning styles differently perceive some electronic learning resources (e-resources) for the teaching of chemistry ([9], [10], [14]). The effectiveness of the application of ICT requires compliance with the dominant styles of learning.

In several works, students of different fields of study were shown to have different preferences in learning styles ([10], [11]). In particular, students of the natural field of study, including chemistry, demonstrate active and sensitive styles in information processing, prefer visual representations of instructional materials. Also, they adhere to a sequential style in learning, favouring in convergent thinking and analysis. Learning preferences are relatively stable because they represent a cognitive, psychological and emotional behaviour of a person and identify the ways of a person's interaction with the learning environment [10].

Therefore, identifying the learning styles for individual students and predominant profiles for student groups is an essential component of developing the best pedagogical approaches and ensuring high-quality teaching. Therefore, the formation of an optimal set of e-resources is a necessary stage of their practical application. To this end, it is required to develop appropriate pedagogical techniques and technologies which take into account the psychological aspect of the perception of ICT. The use of ICT in the educational process requires specific knowledge in the field of computer science from both teachers and students. Given the rapid development of information technology, such knowledge becomes crucial in the construction of psychological and pedagogical methods of teaching.

As is shown in previous research [9], computer modelling is now recognised as a method that is well received by most students, regardless of their learning preferences. Various researchers have proven the question of the effectiveness of computer modelling in the training of future chemists in the study of special disciplines. However, the software packages Mathcad, Gaussian, and other tools of quantum chemical modelling are both objects of study in special disciplines and learning tools. Accordingly, the approach to their application is very different from the traditional teaching of basic chemical disciplines. Students learn software tools and immediately use them to solve chemical problems.

In contrast, in the study of basic chemical disciplines, namely inorganic, analytical, physical and organic chemistry, simulation software packages are used either periodically or not at all. One of the main reasons is the lack of time that is not allocated by the curriculum for mastering the software product. Therefore, teachers are limited to showing demonstrations on the screen and conduct

laboratory and practical classes in the traditional way. At the same time, the foundations of understanding chemical processes at the macro-, micro- and symbolic levels are laid in the study of these disciplines. Unless the links between these levels of understanding of chemical concepts are formed, the conceptual foundations of chemical knowledge will not be formed at the cognitive level in the future.

The first step in the development of methodological support of teaching chemical disciplines by ICT consists of the identification of concepts or topics that cause the most severe difficulties for students. Mistakes of a mass character help to identify the contradictions arising from the controversial nature of the studied material and/or contradictory students' perception. Such factors as a superficial, formal or one-sided understanding of some topics, vague ideas and terms, etc., can form the basis of chemical misconceptions.

Students often come from secondary schools with incorrectly formed chemical concepts. Still, the curricula of Ukrainian universities do not schedule a time to correct such mistakes [10]. At the beginning of the teaching, lecturers must conduct entrance control of students' knowledge. Then, they are trying to focus attention on most problematical issues. Still, they do this through the study of a new program or during instructional sessions. Students are encouraged to work without assistance using learner's guides and textbooks. Such an approach requires self-organisation and self-management skills. Such skills are often undeveloped for first-year students. Thus, it is essential to implement learning technologies that would envisage the stimulation and control of independent learning activities for young students.

The paper goal is to analyse the typical mistakes in the study of the university course of inorganic chemistry, determine their origin and test the effectiveness of computer simulations in correcting chemical misconceptions.

The NetLogo programming environment has been chosen as the one that best meets the principles of effective chemistry teaching using ICT. It provides several important features:

- 1) visualise the links between the microscopic level of data representation, the phenomena of the material world and symbolic forms of description, as well as to study situations that develop over time;
- 2) NetLogo has interface elements that allow students to adapt the work according to their characteristics, and allows teachers to manage the total cognitive load of students.

The previously formulated theoretical principles [9] and all the NetLogo possibilities mentioned above were used in the process of the training organisation.

2. Methodology

The experiment was conducted at the Faculty of Chemistry of Dnipro National University (Ukraine), and it continued for two academic years. All first-year students majoring in "Chemistry" for two years of admission participated in either the first or second phase of the experiment. In the first year of the experiment, the number of first-year students was 45 people, who were formally divided between two academic groups. In the second year of admission, 42 freshmen made up two academic groups. The purpose of the first phase of the experiment was to identify incorrectly formulated concepts of chemical knowledge. The purpose of the second phase was to correct incorrectly formed concepts by applying computer modelling in teaching. During both years of the experiment, one teacher provided course instruction, homework, and exams. Thus, the experiment was conducted under conditions of the same teaching style; the question of the influence of teaching style on learning outcomes was not investigated.

In the first year, 45 first-year students completed the basic course of inorganic chemistry. The course consisted of 16 topics and delivered in the first semester of the school year. On completion, the examination (initial test of the two-years experiment) was conducted. The examination paper was aimed at the assessment of student knowledge for each of the 16 topics. It also focused on the determination of typical chemical misconceptions and the origin of their formation.

The test papers corresponded to the subject and the complexity of the delivered material. Approximately 70% of all tasks consisted of tests of a closed type with the choice of one of four/five answer variants. Open-type tests covered about 7% of the tasks; they implied free responses to theoretical questions. 12% of the tasks included calculating problems. Another 12% were devoted to the equations of reduction-oxidation processes and hydrolysis reactions which should be completed, indicating interaction products and ascribing reaction coefficients. One point was assigned for a correct answer and 0 points to wrong answers. The proportion of students who completed each task was calculated and then averaged for each topic.

The nature of incorrect responses, namely the distribution of false answers among possible options, was analysed to identify the typical misconceptions of the students. A misconception was supposed to arise when two conditions are fulfilled. First, a task is characterised by a large number ($\geq 50\%$) of incorrect answers, and second, one incorrect variant dominates ($\geq 60\%$) over all other wrong answers.

One year later, the next phase of the experiment was performed with the participation of 42 first-year students of the next admission. It was focused on the correction of chemical misconceptions by computer simulation followed by the estimation of the effectiveness of the method used.

This phase consisted of three stages. At the first stage, an incoming writing test with 20 tasks was conducted at the beginning of the study of the topic "Gas Laws". The average score for each student at all second phase exams was calculated by a two-point system similar to that used a year ago. The results of the incoming test allowed a lecturer to determine the level of knowledge of each student and identify the most difficult tasks. The tasks were designed to promote mental transitions. As is known, the chemical material can be usually presented on different representation levels. They are microscopic (micro), macroscopic (macro) and symbolic (mathematical or math) levels. Test questions and answers assumed different options of mental transitions. The analysis of the results allowed one to reveal weak unformed links and determine which transformations are the most difficult to perform.

At the second stage of the experiment, students started to learn the topic "Gas Laws". At first, they listened to an overview lecture. They then were offered to use the programmable modelling environment NetLogo [27]. The authors of NetLogo created some models related to various sections of chemistry. They united them in the course entitled "Connected Chemistry". Dozens of the developed models are available for free use on the project website [4]. Loss of links between microscopic and macroscopic representation levels is often observed in the course of gas laws study [20]. This finding serves as an argument in support of the selection of the gas laws topic.

The second phase of the experiment was designed to fit it into the existing discipline curriculum. This approach significantly limited the time reserved for various forms of classes, as well as the number of computer models that were used in the learning process. In case of a successful introduction of computer modelling in teaching basic chemical disciplines, correction of the curriculum will be necessary for future development.

The students were offered to complete their homework modelling tasks independently in the NetLogo environment. Each task was based on the use of eight ready-made free models related to the topic "Gas Laws". Since a high level of load characterises the curriculum of inorganic chemistry course, only the first three of the eight models were reviewed by a lecturer during an 80 min practical class. Each student worked on a separate computer with installed NetLogo, and the lecturer used the projector. Manuals were developed for all models to support independent students' work methodologically.

Four hours of independent work were planned to fulfil all tasks within the next two weeks. The time gap between listening to the overview lecture, training in a classroom and getting a homework task ranged from one to two days for different groups. Such an approach was used because it did not require the reorganisation of the educational process.

Upon completion of the work, students handed in their papers with calculations, charts and answers. The results of homework were scored on a point scale with a maximum of 24 points for the entirely correct solution of all tasks for eight models. These results were used to analyse possible correlations between the quality of independent work and progress in the study of gas laws.

Then they underwent final testing with 28 questions on the topic “Gas Laws.” Twenty issues were virtually identical to those in the incoming test. Additional eight problems were included to assess more accurately the problem areas identified by the incoming control. The results of the final examination using a two-point system were compared with the input testing. Progress in learning was evaluated using the answers to the 20 questions contained in both tests.

The critical question for assessing the importance of the work is to compare the results of the input and final testing at the second phase of the experiment. The experiment can be considered successful if a statistically significant difference is detected between these results in favour of the final test. The SPSS statistical package was applied, and the t-criterion method for pair samples was used for the comparative analysis of the results of the input and final control.

3. Results and discussion

3.1. The effectiveness of material learning

Table 1 contains titles of topics and the numbers of examination tasks and questions. The results of input testing are also illustrated: The average percentage of correct answers and the quantity of the most complex tasks with the maximal amount (>60%) of mistakes are given for each topic. The average proportions of correct answers ranged from 31% to 79% for various issues that prove the conformity of the tests with the requirements for the complexity index.

Table 1. Topics of inorganic chemistry course.

Topic	Number of exam tasks (questions)	Correct answers, %	Number of tasks with >60% mistakes
1. Basic concepts and laws of chemistry	3(63)	64.9	1
2. Equivalent mass	2(30)	70.4	0
3. Classification of inorganic compounds	6(42)	79.0	0
4. Atomic structure	4(55)	56.2	1
5. Periodic law	3(64)	51.5	0
6. Chemical bonds	3(50)	44.7	1
7. Thermodynamics	3(16)	44.6	1
8. Kinetics	5(15)	64.6	1
9. Equilibrium	4(34)	52.5	1
10. Solutions	3(43)	31.4	2
11. Electrolytic dissociation	3(22)	31.2	2
12. Electrolytes	2(19)	51.7	0
13. Solubility product constant	3(41)	53.3	1
14. Hydrolysis	1(52)	34.6	1
15. Reduction-oxidation reactions	3(96)	37.2	2
16. Structure and properties of compounds	6(33)	33.7	5

The level of solvability exceeds 50% only for 9 of 16 topics. Two topics, namely, “Classification of inorganic compounds” (topic 3 in figure 1 and table 1) and “Equivalent mass” (question 2) can be considered as assimilated on a high level. The average solvability for them is 79% and 70% respectively and is almost independent of task type. All other topics contain at least one or more tasks which are difficult for students, even if the average solvability for them is high enough. For example, the percentage of correct answers exceeds 60% for topics 1, 8 and 13 in figure 1. However, the level of solvability of challenging tasks in these topics varies within 0-35% (figure 1).

3.2. Typical mistakes in the most complex tasks

Based on the results of the input testing, standard mistakes were identified and briefly described for the most complicated topics (average correct answers <50%) and individual tasks with the lowest solvability metrics (table 2).

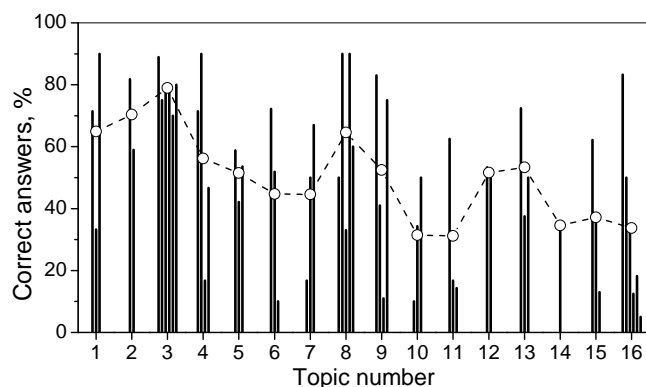


Figure 1. Percentage of correct answers by topics. Separate columns illustrate the results of the performance of individual tasks. The dashed curve represents the average results for each topic.

Table 2. Typical mistakes in the most complicated topics.

No	Task content	Description of typical mistakes/difficulties
1.	Formulation of laws	Loss of essential components in the wording of concepts leads to misconceptions
4.	Isotopes; Ionic state	Confusing the concepts (neutrons, protons, electrons, and mass numbers); Lack of understanding of atomic radius change when electron joining; Problems with symbolic notations of ion electronic configuration
5.	The periodicity of element properties	Confusing the concepts (electronegativity, ionisation energy, electron affinity) and directions of property changes
6.	Bond type – substance correspondence; MO and VB theory	Misunderstanding of the polarity concept and failure to distinguish covalent, polar and nonpolar bonds; Inability to apply the molecular orbital method and complete orbital diagrams
7.	Calculation of ΔH and ΔS	~50% of errors in calculations by the corollary from Hess’s law
8.	Reaction rate and Vant-Hoff equation	Incomprehension of pressure-concentration relations in gases and errors in mathematical calculations
9.	Pressure and temperature effect; Equilibrium constant	Misunderstanding of the concept of activation energy because of a lack of understanding of temperature effects at a microscopic level; Failures in calculating the equilibrium constant and predicting the impact of pressure on equilibrium
10.	Calculation of concentrations	Failure in estimates of the concentrations of solutions and transitions between different units; Lack of understanding of the colligative properties
11.	Dissolution of acid in the water, dissociation constant, pH	Failures in the calculations of pH for acid and alkaline media, dissociation constant, and accounting for changes in reaction conditions
12.	Strong and weak electrolytes	Problems with the classification of compounds which properties were not taught in class
13.	Solubility and sediment formation	Incomprehension of pressure and temperature effects and problems with mathematical calculations
14.	Finish the hydrolysis reaction; pH, hydrolysis constant	Misunderstanding of electrolyte nature leads to failures in the identification of strong/weak electrolytes, and electrolysis stages and products; Many errors in mathematical calculations
15.	Determine the redox reaction type; finish the reaction and identify reaction products	Failures in the identification of reaction types and determination of products by standard electrode potentials
16.	Oxyacids of Cl and I, H_2O_2 , O_3 , acids and peroxyacids of S; S, Se, Te base compounds	Incorrect characterisation of the strength of acids and redox properties; Unsatisfactory explanation of the properties of H_2SO_4 , H_2SeO_4 , H_2TeO_4

3.3. The origin of misconceptions

The experimental results obtained denote inadequate students’ knowledge of the material. It consists in the incompleteness of understanding of the microscopic basis of processes, and inability to work with

different models, including misunderstanding of their objectives and constraints. The following items within the inorganic chemistry course were identified as the most challenging issues for students.

1. Students are not well aware of the structure of atoms at the microlevel and cannot characterise the properties of an element following the structure of its atom. They do not entirely understand processes when the electrons are lost/connected, and cannot often represent the electronic configuration of an excited atom. Thus, it is difficult for students to make transitions between concepts at the micro and symbolic levels.

2. Many mistakes are made in characterising the change in the energy properties of atoms that indicates an inadequate understanding of the concepts of ionisation energy and electron affinity.

3. They have insufficient practical skills in establishing the type of chemical bonds in real substances. They cannot often compare the geometry of molecules.

4. Plotting electron arrangement by the molecular orbital method is difficult.

5. Students merely memorise the macroscopic influence of changes of pressure, temperature and volume on the processes in chemical systems. Still, they do not understand the microscopic nature of these changes.

6. Additional difficulties arise from inexperience in mathematical calculations.

7. Students are challenging to imagine the colligative properties and the nature of the formation of solutions. Half of them do not understand what the solubility is and how the pressure affects this value.

8. Students do not understand the microscopic essence of the processes of dissociation and solvation. The misunderstanding causes problems with writing the reactions of hydrolysis. They cannot distinguish between strong and weak electrolytes, especially for unknown substances. They are mistaken when calculating pH, pOH, and dissociation constants in solutions. The problems mentioned above are caused by insufficient understanding of chemical concepts and unformed structures of chemical knowledge.

9. Inadequate skills are found for calculating the concentrations of solutions and transitions between different units. It is difficult for students to calculate the equivalent concentration of a substance with due regard for the reaction in which it participates.

10. The ability to predict reaction products using the values of standard electrode potentials is unformed.

The above-listed problems are very typical and often caused by the inability of many students to link multiple levels of chemical knowledge representation mentally ([6], [26], [31], [34]). For example, they often use and merely memorise mathematical equations only, but do not understand the nature of phenomena at either atomic or macroscopic levels. In the first case, the problem lies in the unformed links between the microscopic and symbolic levels of knowledge. It is illustrated by the problematic issues 1, 4, 9 and 10 from the list shown above (table 2). In the second case, the unformed connection is between the macroscopic and symbolic levels (issues 6 and 8). Also, in many cases (items 2, 3, 5 and 7), students are not able to understand the relationship between different macroscopic effects, which are based on the same microscopic processes. In other words, they cannot make a transition from macro to micro-level or in the opposite direction.

3.4. Correction of wrong chemical concepts using computer simulation

Answering the questions of the entrance tests, the students experienced astonishment, misunderstanding and cognitive discomfort. Almost all respondents could not link the behaviour of gas particles in a closed volume with the influence of pressure and temperature. There was a lack of knowledge of the microscopic nature of the process. Unformed links between the macroscopic and microscopic representations of a considered phenomenon negatively affect subsequent students' understanding of the influence of changes in parameters (pressure, temperature and volume) on the course of various processes ([1], [13], [25], [31]).

Problem situations, which are desirable to resolve further by ICT tools, were specified with the use of the developed methodology and the data obtained at the first stage of the experiment. The questions

in homework asked students to change specific parameters of a NetLogo computer model and record the results in the form of graphs on the screen. Students plotted dependencies, changed the number of particles, temperature and volume, and independently deduced mathematical equations. Having obtained their equations, then they used them for forecasting. From the dependencies derived empirically, they deduce the equation of ideal gas state already in the form accepted by science. Some tasks included the independent creation of new models. NetLogo allows students to draw a container of any shape, set valves, visualise the direction of particle movement with arrows showing their speed in colour, etc.

Various aspects of the effectiveness of the application of NetLogo models were discussed in some papers ([17], [18], [19], [32]). The use of the NetLogo environment visualises the links between the macro- and microlevels of representations. It also connects real-world phenomena and symbolic forms of their description and simulates model situations that develop in time. Using NetLogo models, students can observe the macroscopic events of the real world, and also try to predict their changes resulting from the interaction of many microscopic objects. Integration of different levels of chemical knowledge contributes to their better understanding ([2], [33]). Perhaps, it is the key advantage of such models.

The NetLogo environment has interface elements that enable students to adapt their work according to the characteristics of their learning style. As a result, lecturers can organise step-by-step work. For example, one can accelerate/slow down the show or repeat it several times to manage the cognitive load of students. It is also possible to make changes to the model parameters and observe what changes occur. All these options clearly illustrate the relationships between different levels of representations and help to make transitions between them etc.

3.5. The effectiveness of computer simulation

Particular test tasks were designed for studying the effectiveness of using computer simulation to correct the typical problems encountered by students. In total, N=31 persons participated in both input (A1) and final (A2) testing. These students were divided into three groups according to the results of NetLogo modelling. In groups 1, 2 and 3, students correctly performed <50%, 50-75% and ≥75% of NetLogo tasks respectively. One may expect that the homework assignment rating generally correlates with the overall student rating; that is, usually, the best students demonstrate better homework results. The results of A2 and A1 testing by these groups are shown in table 3. The difference A2-A1 is significant if $p < 0.05$.

Table 3. Difference between the average points scored in A2 and A1 testing for three students' groups which demonstrated different levels of homework performance.

Group	Test	N	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed) p
1. (<50%)	A1	7	0.3743	0.08344	0.03154			
	A2	7	0.5514	0.05581	0.02109			
	A2-A1		0.17714	0.10750	0.04063	-4.360	6	0.005
2. (50-75%)	A1	10	0.4120	0.14093	0.04457			
	A2	10	0.5890	0.11060	0.03497			
	A2-A1		0.17700	0.14758	0.04667	-3.793	9	0.004
3. (≥75%)	A1	14	0.5621	0.11383	0.03042			
	A2	14	0.6864	0.09361	0.02502			
	A2-A1		0.12429	0.12513	0.03344	-3.716	13	0.003

The results can be summarised as follows.

1) For all groups, the difference between the results of A2 and A1 tests is positive, i.e. the received score has increased, and statistically significant ($p < 0.05$). If only the best students could overcome the mark of 0.5 in the input test, the mean scores of all three groups exceeded 0.55 in the final examination.

2) The average mark expectedly increases in going from group 1 to group 3, both in A1 and A2 testing.

3) The increment of points is practically identical for groups 1 and 2 and is only slightly lower for group 3. In other words, the use of computer simulation significantly improves the results of testing, and the value of the effect does not practically depend on the initial level of students' knowledge.

The design of the tests compels students to make mental transitions between multiple levels of representations of the chemical material. For example, the skills of finding the correspondence between the real-world phenomena and microscopic processes behind them are necessary to solve tasks which include macroscopic and microscopic representations. Another job involves macro-math and math-macro representations when one needs the ability to describe the events of the real world at a symbolic level. Finally, the most complicated problems include transitions between all three representation levels, such as math-macro-micro or micro-macro-math.

Different test questions/answers included different transition options; the analysis of the results allowed one to determine which transitions and links are the most difficult. The results of such a study are shown in coordinates the increment of points scored in A2 compared to A1 tests vs the scored points in A1 (figure 2a) or A2 (figure 2b) tests. The results of a majority of tasks form a reasonably compact general group on the graph marked with shading. The average points obtained for different tasks vary between 0.2 and 0.9 and 0.5 and 1 in the initial and final test, respectively.

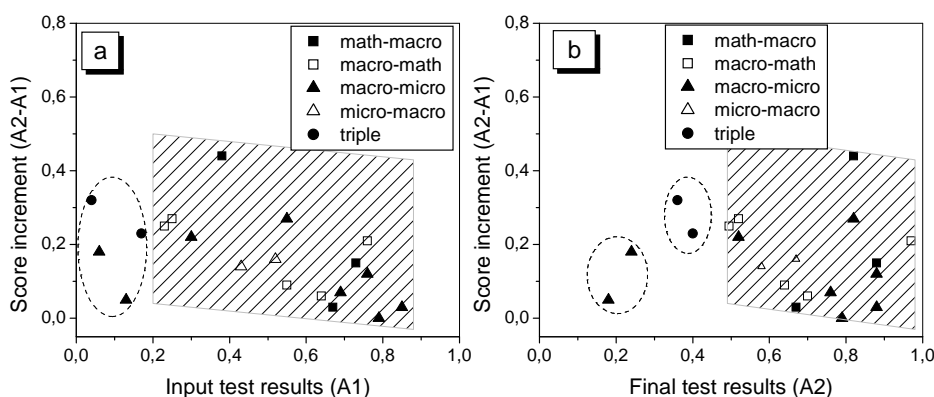


Figure 2. Results of individual task performance in the input (a) and final (b) tests: the score increments (A2-A1) vs the scored points.

The most significant difficulty in the input tests was expectedly caused by the tasks with the most complex triple transitions (figure 2a). Students scored only 0.04-0.17 points, 3-10 times less than the average 0.48 points for the input testing. Two tasks with binary micro-macro transitions shown in table 4 also dropped out of the general group (shaded area) in the initial examination (figure 2a). They differ by lower rates of correct solutions (<15%).

Table 4. Most complicated tasks with binary transitions by the results of final testing

No	Task	Options of answers
8	Basketball ball pumped with air. Assume that the size of the ball does not change, and the temperature remains constant. How does the average number of collisions of particles with the walls of the inflated ball change?	An average number of collisions: (1)Increases (2)Decreases (3)Does not change
19	<div style="display: flex; align-items: center;"> <div style="margin-right: 10px;"> </div> <div> <p>There is a hermetic cylinder with a piston (Fig. A). This piston is pressed in Fig. B. The air is not added and does not come out of the cylinder. The question concerns the states A and B relative to the air inside the cylinder.</p> </div> </div>	Average particle velocity is: (1)Same in A and B (2)Higher in A (3) Higher in B

Training with NetLogo modelling contributed to the improvement of knowledge. The results of the final test shifted to the right along the OX axis for most of the tasks (figure 2b). The most considerable progress (on average 71% of correct answers in the final test) was achieved for macro-math and math-macro binary transitions. The tasks with macro-micro and micro-macro bridges demonstrated somewhat worse but, in general, sufficient progress (63% of correct answers). Some tasks with macro-micro transitions, illustrated in table 4, turned out to be difficult-to-correct that influenced the average result for binary tasks of this type. In other words, the proposed training option turned out less effective for macro-micro and micro-macro transitions than for binary transitions with symbolic representations.

The scored increment, namely the difference between the results of the final and initial tests, can be considered as a measure of the efficiency of NetLogo modelling. Figure 3 illustrates the average increments in points for tasks with different types of transitions. The most significant increase (~ 0.27 compared to the average value of 0.16) was found for lessons with the most complex triple transitions. Therefore, the use of NetLogo modelling allows one to improve efficiently the understanding of issues requiring the formation of the most complex links between multiple levels of chemical knowledge representation. However, since the triple tasks were solved very poorly in the input test (figure 2a), the proportion of correct answers remained quite limited ($<40\%$) in the final examination.

The approach used ensured a transition from the global, undifferentiated images of chemical reality to the operations with its elements, properties and relationships more and more divided into parts. Such experience leads to an increase in the ability of students to link mentally different levels of material representation, improving their professional training.

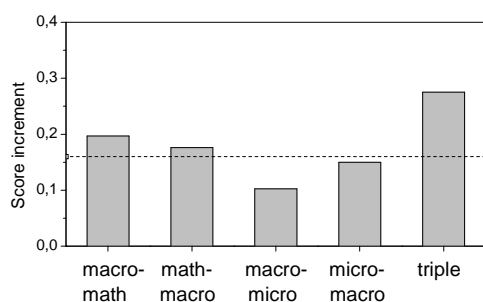


Figure 3. Score increments in the final test compared to the initial examinations for tasks of different types. The dotted line illustrates the increase averaged over all tasks

However, the question arises as to how to combine the use of computer simulation and traditional teaching of inorganic chemistry? Traditionally, ICT tools are used occasionally to teach some selected topics of inorganic chemistry. For example, multimedia presentations are top-rated in delivering lectures or practical classes. Multimedia support is easy to integrate into a traditional curriculum. Such technology requires only the availability of projection equipment and lecturer's computer. It does not require any organisational changes in the work of students in conventional chemical laboratories. A certain level of readiness for all participants of the educational process is necessary for the use of computer simulation methods in inorganic chemistry teaching. From the lecturer's side, it needs the solution of some scientific, methodological, logistical and organisational issues.

4. Conclusions

Unformed conceptual structures of chemical knowledge and inability to make transitions between multiple levels of representation of chemical information are the most critical problems of learning inorganic chemistry. Students often cannot explain the causes of the phenomenon at the molecular level; they just memorise information but do not understand it deeply. As a result, they cannot solve tasks that require conceptual reasoning and cannot operate with chemical knowledge at different levels. Independent work of students with models in the NetLogo environment facilitates the formation of stable links between different levels of representation of chemical information.

At the input testing, students showed practically equivalent results in solving problems with binary transitions. The use of computer simulations during the training process better strengthens the links between macro and math levels, while the impact on the macro-micro transitions was the weakest compared to other variants. Complex triple transitions are the most difficult tasks for understanding. Still, the use of computer simulation demonstrates the best progress in correcting misconceptions caused by complex triplicate representations.

The reported study does not solve all the problems that arise during the teaching of a cycle of chemical disciplines. The introduction of computer simulation into the practice of teaching chemical subjects requires the solution of several methodological, logistical and organisational issues. If simulation software packages with similar NetLogo features are available, the experience of using them can be extended to the whole course of inorganic chemistry. In particular, the integration of the contents of the courses “Introduction to the speciality” and “Inorganic chemistry” may be desirable for the formation of first-year students’ readiness to use computer simulation methods. The following topics show promise for further research:

- the introduction of appropriate changes to the curriculum, and
- the development of the content modules, forms of training and control, which involve the use of computer simulation in the block of fundamental training of chemistry students.

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Specifics of using image visualization within education of the upcoming chemistry teachers with augmented reality technology

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Abstract. It is beneficial to study chemical disciplines, applying the Augmented Reality for the upcoming chemistry teachers, as far as the visualisation of the demonstration material in the 3D helps students understand various processes and phenomena, the structure of chemical compounds and the mechanisms of their correlation in a better way. The object of the project is the development of program and printed tools, designed to visualize the education process within chemistry disciplines according to the augmented reality technology. The authors have developed applications, designed for visualisation of the study material with AR. When a mobile phone is pointed on a marker, the image “comes to life”, its three-dimensional model appears; it can be manipulated in some way (inversion, enlargement, viewing from different sides) to understand its structure, operating principle etc. better. Applying augmented reality objects gives the teacher an opportunity to explain big amount of theory quickly and effectively, and the students – to memorise it effectively, develops creativity and boosts motivation for study. Applying AR while training the upcoming chemistry teachers gives the ability to prepare them for applying this technology during the education process in the general secondary education establishments.

1. Introduction

At the present times, the educational process is being actively informatized. Nowadays, the development level of computer technologies demands utilization of new approaches to the educational process in higher educational establishments, new methods, forms of educational data management in order to activate the perceptual performance of students. Computerized systems are powerful information integrators within all the branches of knowledge, including the educational processes. Utilization of informational and communication technologies (ICT) within teaching chemistry gives an opportunity to intensify the education process, speed up the knowledge and experience transfer, as well as increase the quality of teaching and education [20], [23], [26].

It is common knowledge that chemistry is a science, requiring an illustration of the theory. A well-selected demonstration data can provide a better understanding of various processes and phenomena, the structure of chemicals and mechanisms of their interference. In this way, visualization of scientific material makes its perception and digestion easier [7]. Unfortunately, usual 2D images of the traditional handbooks, textbooks and monographs do not give the complete understanding of the mechanisms of chemical reaction paths, special structure of molecules, the nature of physical and chemical reactions etc. That is why, for an effective study of chemical disciplines and for training the



upcoming chemistry teachers, in the modern era the relevant aim is using numerous demonstrations in the teaching process, which are impossible without special chemistry programs, simulator apps and augmented reality apps [15], [24], [25], [27], [28], [29], [30], [37], [40], [45].

The object of the research is the development of program and printed tools, designed to visualize the education process within chemistry disciplines according to the augmented reality technology.

2. Discussion and results

Studying molecular structures of the chemical compounds is the crucial aim within teaching theory in chemistry, because the explanations of physical and chemical characteristics of the compounds, as well as methods of production are based on it. A 2D image of a molecule does not give the complete picture about its special configuration, the nature of connection between the atoms, interatomic distances and valence angles. For this reason, for a better imagination of the molecular structure, especially within the organic chemistry, 3D images are relevant to be used [15], [27], [28], [30], [37], [40], [45].

Using 3D-images of molecules while explaining theory boosts clearness, gives better understanding of chemical compound's structure, geometry of a molecule, as well as mechanisms of its interferences and prediction of chemical reaction products. Therefore, it expedites a better systemizing and digestion of chemistry knowledges.

Effective up-to-date technology of visualizing the education data is augmented reality (AR), which provides the maximal visualization of the object, in other words, converting a 2D image into 3D, as well as "make it live" [4], [18], [19]. The relevance of the introduction of AR technology and mobile learning in the educational process is highlighted in the works [2], [3], [9], [10], [11], [13], [16], [17], [21], [22], [31], [32], [34], [35], [36], [38], [39], [41], [42], [47], [48]. Utilization of such an ICT tool while studying new material brings an opportunity to increase the dimensional view of the students, "to see" and understand the heard material better, which contributes its better digestion and forms some practical skills [4], [20]. This method has advantages above using computer programs, because it provides the opportunity to visualize images in the educational textbooks with a mobile phone, wherever the student is located without a demand of being near a computer or laptop. This method became particularly effective during the distance education under the circumstances of the quarantine 2020, in the time of the world coronavirus COVID-19 pandemic, when the human endeavour and particularly the study process, were switched into the remote form in the most countries of the world [1], [5], [33], [43], [44], [46]. Visualisation of the study material with AR is effective when students' learning the disciplines "Organic chemistry", "Non-organic chemistry", "Radiation chemistry", "Crystal chemistry", etc.

The authors have developed applications, designed for visualisation of the study material with AR. Based on the Vuforia platform, augmented reality markers were created to use the AR technology [4]; 3D objects were modeled in 3DMax program, the augmented reality objects were realized in the Unity 3D, multi-platform tool for development of 2D and 3D mobile apps [6], [8], [12].

When a mobile phone is pointed on a marker, the image "comes to life", its 3D model appears; it can be manipulated in some way (inversion, enlargement, viewing from different sides) to understand its structure, operating principle etc. The explanation of study material, in this case, is being processed with mobile devices and image markers by the participants of study. The uploaded applications give the opportunity to visualize the study material and make it easier to memorize. As for the teacher, they have the ability to reduce the theory explanation timing and to benefit in discussing controversial questions, solving creative tasks etc.

In this way while being explained about structure of an atom in case of 3D visualization of atomic model, the student receives a picture, shown on figure 1, on his smartphone, which provides a better understanding of mechanisms of chemical bounds development and chemical reactions path.

Figure 2 show example of 3D images, generated from the specially developed 2D marker images for organic chemistry. The authors have developed a mobile application called LiCo.Organic which generates 3D images of organic compounds with AR [14]. This application is beneficial for upcoming

chemistry teachers, as far as it helps them learn theoretical basics of organic chemistry and prepares for the school work with kids during the chemistry lessons. LiCo.Organic has the following abilities, generating 3D-images of molecules, display homologous series of carbohydrates, investigation of the space structure of isomers.

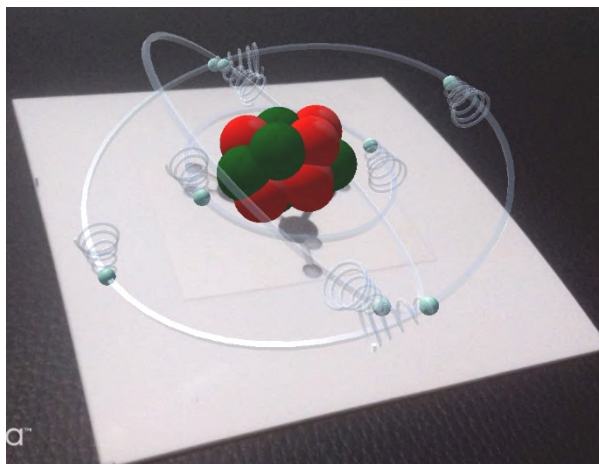


Figure 1. 3D-image of an atom model, generated with AR method [20].

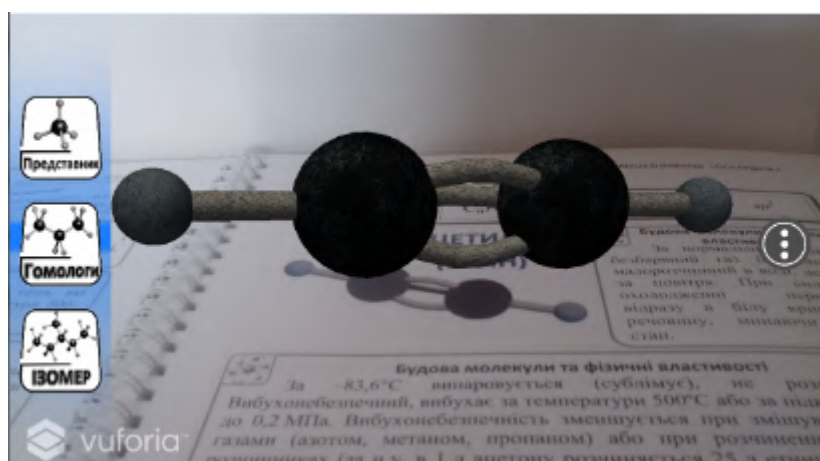


Figure 2. 3D-image of ethyne, generated with the mobile app LiCo.Organic.

When a homologous series of a selected class of organic compounds is displayed, spatial molecules of the first 10 samples and the main quantitative characteristic can be seen: distances between the atoms and the valence angle (figure 3). The generated 3D image of the homologous species is animated, the structure of its samples (alkanes, alkenes, alkynes etc.) is displayed step-by-step, along with demonstration of the extension of the carbon chain. The presentation of the selected classes' of organic compounds isomers is also animated (figure 4).

Figure 5 is showing examples of 3D images, generated from 2D image markers, which are used for studying crystal chemistry.

Within the study of the “Radiochemistry and radioecology” by the upcoming chemistry teachers, students can explore the nuclear decay, nuclear fission, the chain reaction, structure of the nuclear weapon, operating principle of a nuclear powerplant and other subjects, when a crucial element of explaining the study material is not only a well-selected illustration of a concept, but also a

demonstration of the very process (nuclear fission, operation mechanism of a nuclear warhead, operation of a nuclear powerplant).

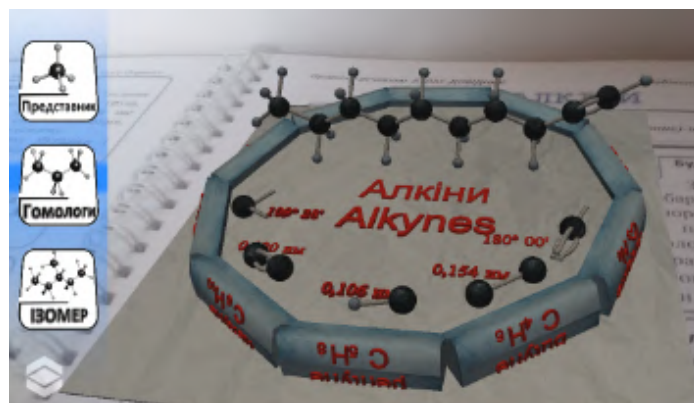


Figure 3. Homologous series of alkynes, generated with the mobile app.

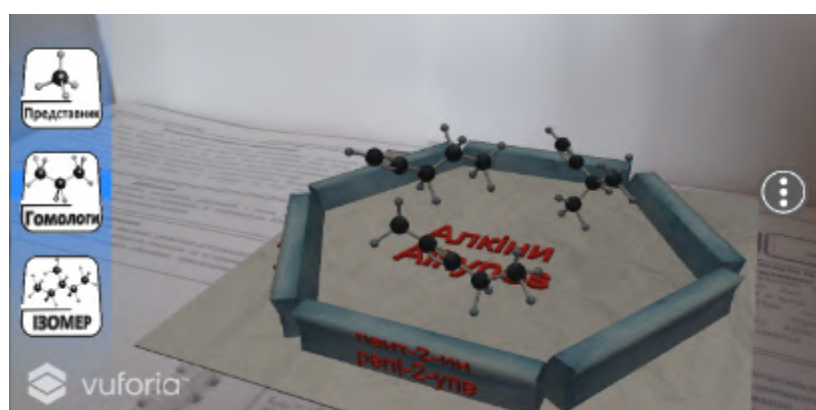
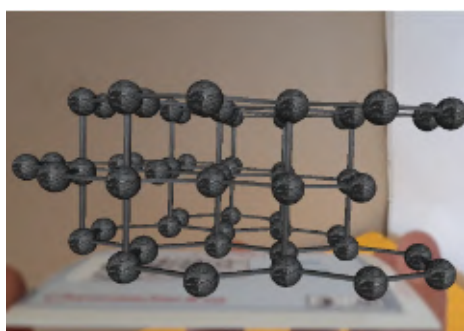
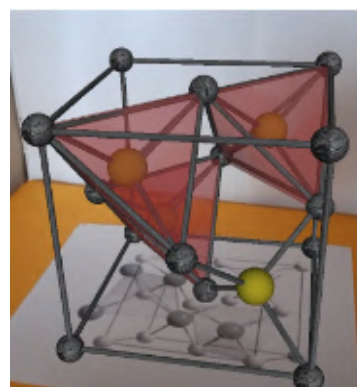


Figure 4. Isomers, generated with the mobile app.



a



b

Figure. 5. 3D-images of the crystal grating of graphite (a) and ZnS (b).

Applying AR technology, for example, the students can see a picture of nuclear weapon (figure 6) with caption of its parts, which “comes to life”, when pointing a cell-phone on it; a 3D model appears

on the screen and the model can be manipulated in some way for better understanding of its structure and operating principle.

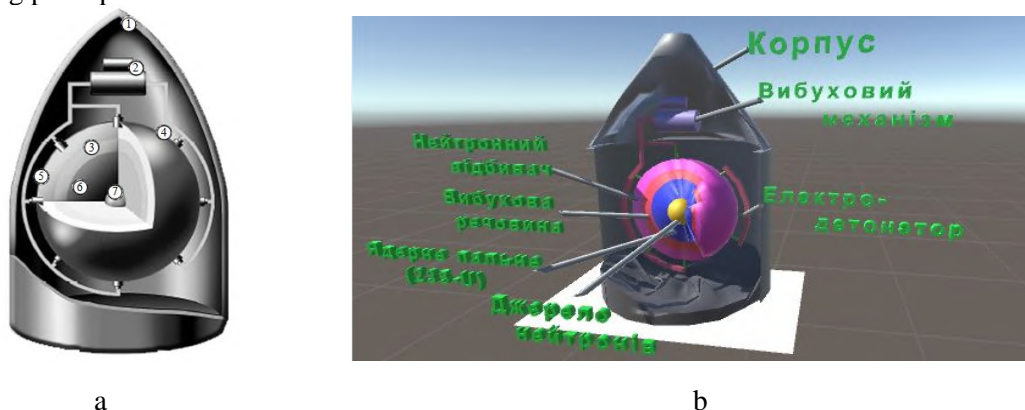


Figure 6. 2D image of a nuclear warhead (a) and three-dimensional model of the nuclear weapon (b), generated with the mobile app (1 – body frame; 2 – detonating mechanism; 3 – detonating substance; 4 – electric detonator; 5 – neutron reflector; 6 – nuclear fuel (^{235}U); 7 – neutron generator; 8 – compression of nuclear fuels by the explosion, aimed inside).

Analogically, with relevant markers α - and β -fissions can easily be visualized not only with a static 3D-image, but also with animation effect (figure 7).

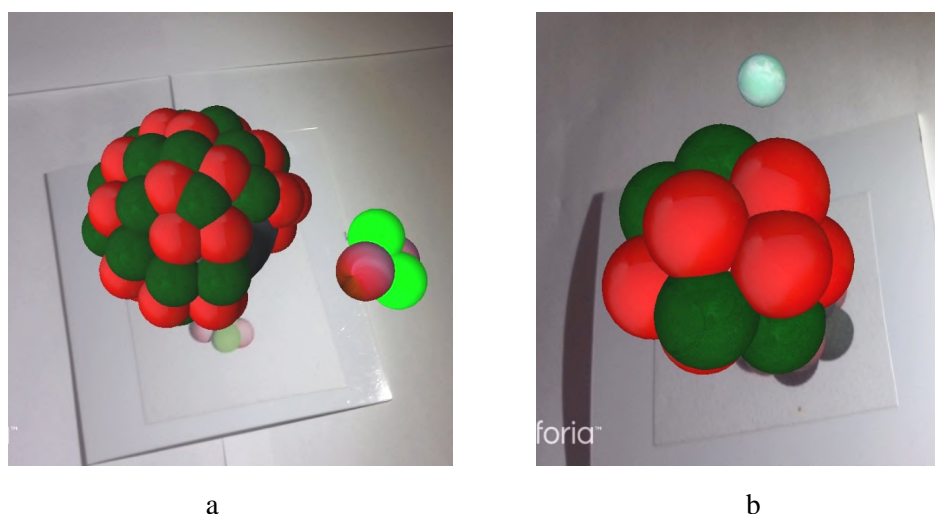


Figure 7. 3D-images of α - fission scheme (a), β -fission scheme (b), generated with AR method.

3. Conclusions

The development of global mobility stimulates the research of new strategies for the study process in general education establishments, as well as creating theoretic materials in chemistry with Augmented Reality. These give the possibility to upgrade the clarity of theoretical data, to make it as close to reality, as possible, develop pupils' creative imagination and build particular skills and techniques, effective while performing a chemical experiment.

It is also reasonable for the upcoming chemical teachers to study chemical subjects with Augmented Reality, because memorizing a huge amount of chemical theory is significantly easier with its good-quality visualization. The 3D visualization of the illustrative data helps students, on one hand, understand various chemical phenomena and processes, as well as the structure of chemical

compounds and mechanisms of their correlation, and on the other hand, to master AR technology in order to use it in the future educational work. The upcoming teachers think that applying Augmented Reality objects gives the opportunity to diversify the education process, make it more interesting, and boost pupils' motivation for study. The main advantage of using the developed mobile applications is the access for study whenever you can, and wherever you are, which is vitally trending during remote education within the national quarantine.

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Contradictions in the traditional methods of electrodynamics teaching as a determinant of its update

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Contradictions in the traditional methods of electrodynamics teaching as a determinant of its update

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Abstract. The article deals with the theoretical analysis of the traditional approaches to electrodynamics teaching. The authors pay attention to the contradictions arising in the process of combined application of Biot Savart and Coulomb's laws. The thesis of some limitation of the traditional presentation of the course of electrodynamics is substantiated. In this connection the necessity of updating methodology of electrodynamics teaching is determined. As an innovative approach to solving this problem, it is proposed to analyze and address the existing contradictions of electrodynamics teaching using a specially developed (copyright) methodology - the methodology of the development of students' critical thinking (MDCT). Using specific examples, the content of each of the stages of the proposed methodology, which can be used in the study of electrodynamics in secondary and higher school, is characterized.

1. Introduction and relevance of the problem

Modern socio-economic realities, rapid development of science and technology put forward a number of new requirements for future teachers training, because in accordance with the well-known pedagogical axiom, only the teacher, who is a professional, a creative person, capable of critical understanding the world around him, can bring up a creative, critically thinking student [13]. First of all, it concerns the students of physics departments – future physics teachers, whose pupils should become the driving force of scientific and technological progress in our country.

However, reference to teaching practice, modern manuals on theoretical physics [4], [8], [11], [17], general and school physics courses (for a review and analysis see [5], [6], [9], [10], [15], [18]) shows that in the methods of teaching electrodynamics during interpretation of certain laws there are contradictions and questions for discussion, which prevent the formation of students' holistic picture of adequate ideas about the system of electrodynamics fundamental laws.

The presence of these contradictions logically leads to the thought that it is necessary to update the methods of teaching electrodynamics. It was determined by us as the starting point for: a) finding ways to resolve them; b) the development of such a methodology for teaching electrodynamics, which, using the content of contradictions and methods for resolving them, would contribute to the development of future physics teachers' critical thinking.



In this regard, *the purpose of the article* is to identify the contradictions and problematic issues of electrodynamics as a science and academic discipline, the modern methodology of its teaching, and the rationale for solving these problems using the methodology for developing students' critical thinking.

2. Research methods

Taking into consideration the limited volume of scientific article we shall concentrate more in detail on the analysis of the content of contradictions associated with Biot Savart Law [5], [6], leaving more thorough investigation of the causes of other contradictions and questions for discussion, taking place in the theory and methodology of electrodynamics teaching as the prospect of further research.

First of all let's note the ambiguity in the treatment of the status of Biot Savart Law and also pay attention to a number of contradictions associated with the interpretation and application of this law:

$$d\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{i \cdot [d\vec{l}, \vec{r}]}{r^3} \tag{1}$$

Despite understanding the fact that the law (1) in principle is unavailable to direct experimental verification, in the vast majority of modern textbooks Biot Savart Law is interpreted as an experimental law. But the analysis of the essence of this law and historical sources testifies about the incorrectness of such approach for the study and interpretation of the ratio of (1) [5], [6].

Secondly, our study has shown that in some cases the application of the law (1) leads to the results that are contrary to the main postulates of the relativistic electrodynamics [6].

Thus from (1) and the superposition principle we can conclude that the expression for magnetic field (MF) induction, which is created by a moving charged particle (CP) is [6], [18]:

$$\vec{B}_1 = \frac{\mu_0 q}{4\pi r^3} \cdot [\vec{v}, \vec{r}] = \mu_0 \epsilon_0 \left[\vec{v}, \frac{q\vec{r}}{4\pi \epsilon_0 r^3} \right] = \mu_0 \epsilon_0 [\vec{v}, \vec{E}], \tag{2}$$

where $\vec{E} = \frac{q\vec{r}}{4\pi \epsilon_0 r^3}$ is the strength of the electric field created by (in the non-relativistic approximation) a mobile CP at the corresponding point of the field; q – the magnitude of a moving charge; \vec{r} – the radius vector drawn from the charge to a given point of the field; \vec{v} – the velocity of charges in a conductor with current (drift velocity of conduction electrons); μ_0, ϵ_0 – magnetic and electric constants.

We'll show that the use of the expression (2) for the induction of the magnetic field of a moving charged particle $\vec{B} = \epsilon_0 \mu_0 [\vec{v}, \vec{E}]$, (which can be seen as a consequence of the law (1)) and $\vec{E} = \frac{q\vec{r}}{4\pi \epsilon_0 r^3}$ for the analysis of the same electrodynamic problem leads to the conclusions that contradict the principle of relativity.

3. Results

Indeed, let's consider a thought experiment, shown schematically in figure 1.

According to the traditional interpretation of the phenomenon of electromagnetic induction, in the loop L , due to time changes in the magnetic field at each point of a flat surface bounded by the loop L (and therefore the change of the magnetic flux in time), there will be EMF of induction. But this conclusion contradicts the principle of relativity: with the transition to the reference frame associated with CP, the loop L will be moving in a centrally symmetric Coulomb field.

Such field is a potential one, so there are no physical reasons that could generate voltage in the loop L . Hence, the use of the law (1) and its equivalent – the expression for MF induction, which is generated by a separate mobile CP $\vec{B}_1 = \epsilon_0 \mu_0 [\vec{v}, \vec{E}] = \frac{\mu_0 q \cdot [\vec{v}, \vec{r}]}{4\pi r^3}$ – in such problems gives the result that contradicts physical reality.

Similarly, in the problem shown in figure 2 the use of the classical Biot Savart Law leads to the result that is contrary to the principle of relativity.

According to Biot Savart Law (1) and the traditional interpretation of the phenomenon of EMI (see the problems, shown in figure 3 and figure 4) we should expect a certain EMF of induction in the loop L_1 .

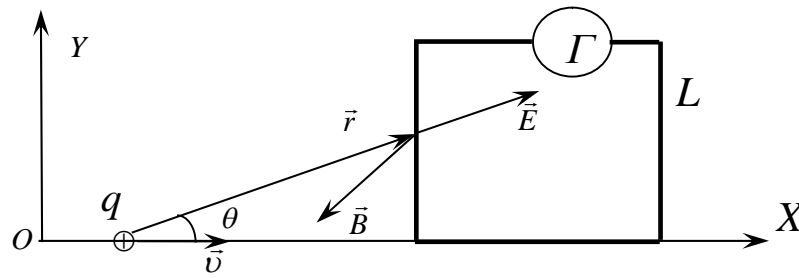


Figure 1. The scheme of a thought experiment to determine the EMF of induction in the loop L . CP is moving with constant speed \vec{v} in the plane of the loop.

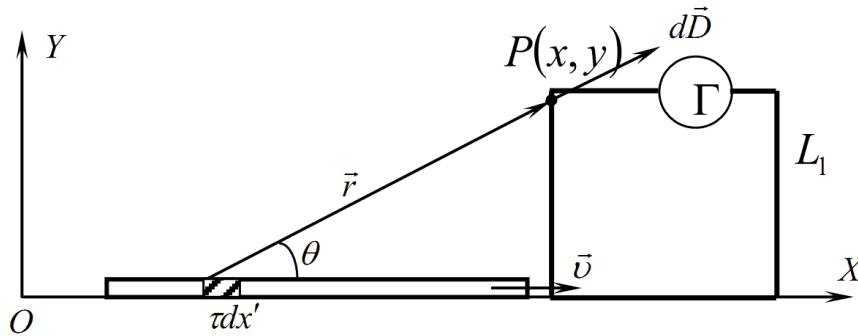


Figure 2. In the loop L_1 there is no EMF with the motion of the charged filament with the speed \vec{v} .

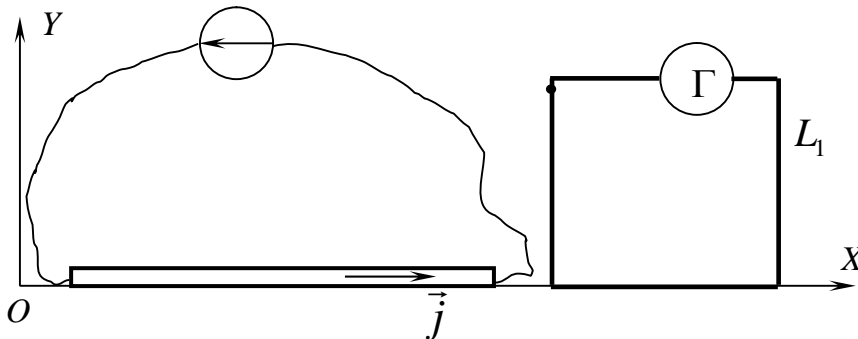


Figure 3. In the wire in the loop L_1 , which is in the vicinity of an infinitely long conductor with direct current there is no EMF.

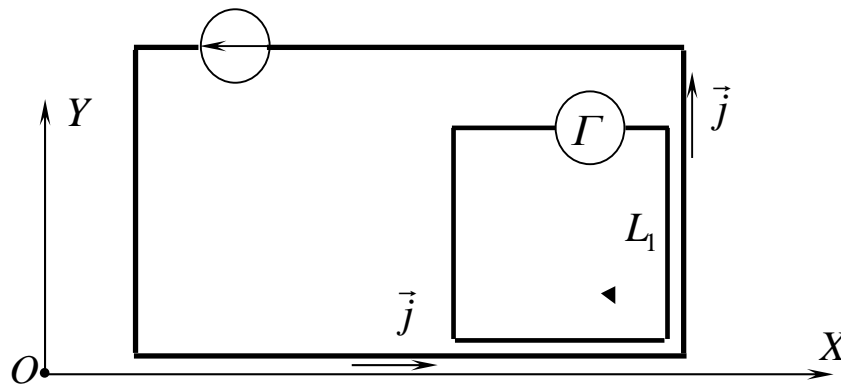


Figure 4. In the wire loop L_1 , which is located next to the DC circuit, EMF is absent.

This conclusion follows from the following considerations.

Each of the conduction electrons, moving with the drift velocity in the conductors of the electric circuit creates alternating magnetic field at each point of the flat surface bounded by the loop L_1 . In its turn this alternating magnetic field creates a vortex electric field ($rot\vec{E} \neq 0$) at each point of the surface bounded by the loop.

Integral effect should manifest itself in the emergence of induced current in the loop L_1 . But experiments show that the voltage in the circuit does not emerge.

So, Biot Savart Law and the formula $\vec{E} = \frac{q\vec{r}}{4\pi\epsilon_0 r^3}$ (which is obviously a consequence of Coulomb's law) are not compatible for simultaneous use in the analysis of the same electrodynamic problem because they lead to principally false conclusions and contradictions [5].

Thus, the traditional method of studying electrodynamics, based, in particular, on the classical Biot Savart Law too cannot explain the absence of voltage in the loop L_1 in figures 1, 2, 3, 4. At the same time in standard textbooks and scientific and methodological publications these two formulas are used together, which is, from our point of view, the physical error [6].

4. Discussion

Our theoretical developments and practical experience [6] give us the opportunity to provide a new approach to the study of electrodynamics, allowing the use of the analysis of inconsistencies for developing students' critical thinking. This approach is embodied in the methodology of the development of students' critical thinking of (MDCT), which was tested in our practice when studying electrodynamics by physics students of the pedagogical university and deepening knowledge by teachers-practitioners in the process of independent work during training in the teacher-training courses at Kherson Academy of Continuing Education and at Kryvyi Rih State Pedagogical University. It is assumed that, in accordance with the principle of binary, teachers' mastery of the methodology of the development of critical thinking will be used by them in the educational process of a comprehensive school. In the most general form, the methodology of the development of critical thinking consists of five main stages, a brief summary of which is proposed below.

The first stage is "Challenge". The functions of the "Challenge" are: identifying the problem situation, understanding the importance of the information offered for study, encouraging schoolchildren (students) to study it using historical material, demonstrating interesting experiments, etc. In our example, drawing student's attention to a number of contradictions connected with the interpretation and application of Biot Savart Law (1) can serve as the "Challenge"

At the same time, the teacher should listen to all hypotheses with respect and attention, focusing on the value of ideas expressed by students.

The second stage – "Understanding" – involves independent classroom work of students on the material being studied, discussion, dispute of problematic issues, a comprehensive analysis of the revealed in these material contradictions. At this stage, the teacher can not be the only source of information, but first of all, he must offer methods of thoughtful familiarization with different sources of information, the formation of their own conclusions. During this period, it is necessary to recommend students to generalize their own thoughts, prepare for their argumentation with the possibility of using the texts of the originals. At the same time, it is advisable for the teacher to adhere to the rule: "The thought of everyone is a precious scientific value".

The result of this step in our example may be a conclusion obtained, in particular, using figure 3 and figure 4, that Biot Savart Law and the formula $\vec{E} = \frac{q\vec{r}}{4\pi\epsilon_0 r^3}$ as a consequence of Coulomb's law are incompatible with each other for simultaneous use in the analysis of the same electrodynamic problem, as it leads to false conclusions and contradictions [5]. At the same time, in many manuals and in scientific and methodological publications, these two formulas are used together, which can be a physical error. The identification of such errors and contradictions contributes to the formation of students' needs for a thoughtful approach to the analysis of the content of school and university

textbooks, which is important for the formation of a critically constructive thinking style of a modern teacher.

The third stage – “Generalization” – is focused on collective analysis, systematization and generalization of knowledge gained. Taking into consideration the content of the topic, which is studied, students can make, for example, such inferences. From the undertaken analysis with reference to ([6], p. 158), we have at least 7 points of view regarding the status of Biot Savart Law. It should also be pointed out that many authors of the manuals and articles on this subject noted the inconsistency and inconsequence of these points of view and the corresponding methods for studying the magnetic field of constant and quasi-stationary currents. At the same time, they felt their own discomfort and some confusion when describing and explaining the basics of magnetostatics (as evidenced, in particular, by inconsistent and contradictory arguments to substantiate Biot Savart Law in such many ways).

And yet, Biot Savart Law is considered to be fundamental in the most of educational publications [3], [8], [14]. The main argument that reinforces this research position is that the results of calculations based on it are confirmed by experiments. But proceeding from the principle of fundamentality, the following problem arises: why should a relation that is not established by direct experiment, and which is a consequence of other principles, be extolled to the rank of fundamental and independent!? In our opinion, questions of such level of problematicity are the basis for the development of critical thinking of the teacher’s personality, and therefore make up the concept of the proposed MDCT. In the development of the discussion topic, the following questions can be offered to students as tasks for independent work and creative understanding [16]:

a) Should Biot Savart Law be granted the status of fundamental and independent one?

b) Some researchers consider the Biot Savart Law as a consequence of Maxwell's equations ([6], p. 164; [7]). Reason the pros and cons of such a position.

The fourth step in the development of critical thinking should be the evaluative and resultant one – “Didactic reflection” stage. At this stage, students should analyze not only the results obtained, but also the process of cognitive activity. It is important that, under the guidance of a teacher, they conclude that: “Critical thinking is not a search for flaws in the conclusions of others, but primarily an objective assessment of the achievements gained, their negative and positive sides” [1].

The final (most important) stage of the proposed methodology is the organization of extracurricular independent work of students, focused on the further development of critical thinking skills.

For example, we give indicative questions for discussion and the content of the conversation with students in order to form motivation to continue working on a problem that began in the classroom.

– Is it possible to get the Biot Savart Law as a result of other initial provisions and principles (for example, based on independent and fundamental provisions: the principle of relativity and Coulomb's law)?

– How to resolve the contradictions indicated and presented in figures 1, 2, 3, 4?

Regarding the last question, it should be remembered that electrodynamics is a relativistic theory. Therefore, the analysis of electrodynamic phenomena (tasks, processes) must be carried out exclusively and sequentially using the methods of the theory of relativity.

Based on the principle of relativity and Coulomb's law it can be shown [6] that with uniform and rectilinear motion of a charged particle with an arbitrary velocity $v < c$, the electric field and the magnetic field induction of a moving charged particle are determined according to the formulas:

$$\vec{E}(\vec{r}, t) = \frac{q\vec{r}(1-v^2/c^2)}{4\pi\epsilon_0[(x-vt)^2+(y^2+z^2)(1-\frac{v^2}{c^2})]^{3/2}} = \frac{q\vec{r}(1-v^2/c^2)}{4\pi\epsilon_0r^3(1-\frac{v^2}{c^2}\sin^2\theta)^{3/2}} \quad (3)$$

$$\vec{B}(\vec{r}, t) = \frac{1}{c^2} [\vec{v}, \vec{E}(\vec{r}, t)], \quad (4)$$

where is q – value of a moving charge; \vec{r} – radius-vector drawn from the instantaneous position of the charge to a given point in the field, $\vec{r} = (x - vt)\vec{i} + y\vec{j} + z\vec{k}$; x, y, z – field point coordinates; \vec{v} – charge

speed; μ_0, ε_0 – magnetic and electrical constants; c – speed of light in vacuum, θ – angle between \vec{r} and charge velocity \vec{v} .

Then the vortex electric field $\vec{E}(\vec{r}, t)$ at any point in space at any moment of time is compensated by a vortex induction electric field $-\frac{\partial B(\vec{r}, t)}{\partial t}$: $\text{rot}\vec{E}(\vec{r}, t) = -\frac{\partial B(\vec{r}, t)}{\partial t}$. And so the EMF in the circuit L_1 in figures 1, 2, 3, 4 in any inertial reference frame is always zero.

From the foregoing, two important consequences follow.

1. Faraday's Law $\text{rot}\vec{E}(\vec{r}, t) = -\frac{\partial B(\vec{r}, t)}{\partial t}$ can be justified on the basis of the Coulomb's law and the principle of relativity.

2. Assuming that \vec{v} is the velocity of motion of charge carriers in the current element (drift velocity of conduction electrons in a conductor with current), in accordance with the principle of superposition, we obtain the Bio-Savart law in relativistic form:

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I[d\vec{l}, \vec{r}](1-\beta^2)}{r^3(1-\beta^2 \cdot \sin^2 \theta)^{3/2}} = \frac{\mu_0}{4\pi} \frac{I[d\vec{l}, \vec{r}](1-\beta^2)}{[(x-vt)^2 + (y^2+z^2)(1-\beta^2)]^{3/2}}, \quad (5)$$

where is $I d\vec{l}$ – current element; $\beta = \frac{v}{c}$; θ – angle between \vec{r} and current element $I d\vec{l}$.

Obviously, with $\beta = \frac{v}{c} \ll 1$, law (5) becomes the usual (classical) Biot-Savard law (1).

5. Conclusions and prospects of further researches

We understand that our reasoning can be perceived ambiguously. But the fact is that there are contradictions in physics and the methodology of its teaching, which have been shown by us using concrete examples in this article. It is desirable that these contradictions will become the subject of scientific and methodological discussion. We propose the use of these contradictions both to deepen the students' knowledge and to develop their critical thinking [2], [6], [12]. The results of approbation in the system of higher and postgraduate education of the methodology for the development of critical thinking [17], which makes it possible to solve these problems in unity, are quite promising. Therefore, we consider promising to use the above-described MDCT on a wider scale (in particular, when studying other branches of physics, and possibly other natural-mathematical disciplines).

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Computational method for studying the thermal conductivity of molecular crystals in the course of condensed matter physics

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Computational method for studying the thermal conductivity of molecular crystals in the course of condensed matter physics

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Abstract. This paper presents a computational method for studying the thermal conductivity of molecular crystals that can be used in the educational course of condensed matter physics. This method is based on the Debye model of thermal conductivity in the approximation of the corresponding relaxation times and allows studying the heat transfer processes features in simple molecular crystals at temperatures close to or above Debye temperature. The thermal conductivity is analysed in the framework of modified Debye model in which heat is transferred by low-frequency phonons and above the phonon mobility edge by “diffusive” modes migrating randomly from site to site. The mobility edge ω_0 is found from the condition that the phonon mean-free path cannot become smaller than half the phonon wavelength. The contributions of phonon-phonon, one-, and two-phonon scattering to the total thermal resistance of molecular crystals are calculated under the assumption that the different scattering mechanisms contribute additively. The presented computational method will be useful in pedagogical activities for teaching students of physical faculties.

1. Introduction

The current state of physical materials science is characterized by the search, creation, and comprehensive study of the new materials properties. Studies on condensed matter physics are the basis for the creation of new materials and structures with specified physical and mechanical properties. A promising direction of such research is molecular crystals in the properties of which the crystalline state features are most clearly manifested [13]. Thermophysical studies of molecular crystals carried out in the field of condensed matter physics have opened the way to their various practical applications. Molecular crystals can be used as refrigerants, which allow increasing the cold reserves in the cryostat. With space technologies development, the need arose for cooling equipment operating in zero gravity conditions, with that molecular crystals successfully cope. There is also considerable interest to molecular crystals in astrophysics since the giant planets consist mainly of crystallized gases. Molecular crystals are found in the atmospheres of many planets and comets nuclei, which allows by analyzing their emission and reflection spectra to solve the problem of studying the composition and properties of distant celestial bodies.

It should be noted that an important aspect of quality education is the constant introduction of the latest scientific advances in condensed matter physics into the educational process [28], which ensures



its innovation and compliance with the current stage of society development. In this paper we present an effective computational method that is used in research on the thermal conductivity of molecular crystals and can be used to teach students in the study of the course of condensed matter physics. One of the urgent and at the same time the most difficult problems in the condensed matter physics is the problem of studying the processes of energy transfer [36]. The transfer processes in dielectric crystals associated with such a kinetic phenomenon as thermal conductivity are of interest to researchers. Data on thermal conductivity allow us to obtain important information about the dynamics of the crystalline lattice. There are a number of mechanisms that determine the thermal conductivity, and a number of processes that limit the effectiveness of each of the mechanisms. The development of industrial technologies has contributed to the creation of high-precision methods for the study of thermal conductivity, which made it possible to obtain more complete information about the nature of the interaction in crystals. However, accurate, quantitative prediction of the amount of thermal conductivity due to the complexity of describing specific heat transfer mechanisms for real crystals is possible only in some cases [15].

Molecular crystals possess a number of peculiarities, which can significantly influence the dynamics of the crystalline lattice. The thermal and mechanical properties of simple molecular crystals are determined by both translational motion and orientational dynamics of molecules at sites of the crystalline lattice [29], [40]. With increasing temperature, the rotational motion can in principle pass through the following stages: growth of the libration amplitudes, appearance of jump-like reorientations of molecules, increase of the frequency of reorientations, hindered rotation of the molecules and, finally, nearly free rotation of the molecules [20]. The peculiarities of translation-rotation coupling depend on molecular and crystal symmetry, and are determined by the relationship between central and non-central intermolecular interaction forces. At temperatures close to or above the Debye temperature ($T \geq \Theta_D$), the general regularities of heat transfer in molecular crystals can be formulated as follows. A strong translational-orientational interactions contribute significantly to the thermal resistance $W = 1/\Lambda$ [12], [20]. This, in turn, leads to large deviations of the isochoric thermal conductivity from the $\Lambda \propto 1/T$ law owing to its approach to a certain lower limit Λ_{\min} . The concept of the lower limit of thermal conductivity is based on the following: the mean free paths of the oscillatory modes participating in heat transfer are essentially limited but it cannot become smaller than half the phonon wavelength $\lambda/2$, and the site-to-site heat transport proceeds as a diffusive process [26]. In this case the lower limit of the lattice thermal conductivity Λ_{\min} can be written as [7]:

$$\Lambda_{\min} = \left(\frac{\pi}{6}\right)^{1/3} k_B n^{2/3} \sum_i v_i \left\{ \left(\frac{T}{\Theta_i}\right)^{2\Theta_i/T} \int_0^{\Theta_i/T} \frac{x^3 e^x}{(e^x - 1)^2} dx \right\}. \quad (1)$$

The summation is over three (one longitudinal and two transverse) sound modes with the sound velocities v_i , Θ_i is the Debye cutoff frequency for each polarization in Kelvins: ($\Theta_i = v_i (\hbar/k_B) (6\pi^2 n)^{1/3}$), n is the number of molecules per unit volume, and k_B is Boltzmann's constant.

In molecular crystals with a relatively weak non-center interaction, the changeover from libration to weakly hindered rotation is observed with increasing temperature. In this case, the translational-orientational component of the thermal resistance is reduced and the isochoric thermal conductivity can increase with an increase in the temperature. A similar behavior has been observed in orientationally disordered phases of molecular crystals and in some special cases of the development of orientational mobility without subsequent phase transition [24], [25], [38], [39].

This article addresses the question of the application of the computational method by students for the practical study of the peculiarities of heat transfer processes in molecular crystals with different types of translation-rotation coupling.

2. Computational method

2.1. Modification of the Debye thermal conductivity model

The first stage of computational method is devoted to modification of the Debye thermal conductivity model to take into account the heat transfer by low-frequency phonons and “diffuse” modes. This calculation was performed on the basis of the Debye’s expression for thermal conductivity [15] using the approach of Roufosse and Klemens [43] who used the idea of a lower limit for the phonon mean-free path:

$$\Lambda = \frac{k_B}{2\pi^2\nu^2} \int_0^{\omega_D} l(\omega)\omega^2 d\omega \quad (2)$$

where ν is the polarization-averaged sound velocity, ω_D is the Debye frequency ($\omega_D = (6\pi^2)^{1/3} \nu / a$), $l(\omega)$ is the phonon mean-free path, and a is the lattice constant. At $T \geq \Theta_D$ the phonon-mean free path is restricted mainly by the U -processes and can be written as:

$$l_u(\omega) = \nu / AT\omega^2, \quad (3)$$

$$A = (18\pi^3 / \sqrt{2}) (k_B \gamma^2 / ma^2 \omega_D^3) \quad (4)$$

where the Grüneisen parameter $\gamma = -(\partial \ln \Theta_D / \partial \ln V)_T$, $l_u(\omega)$ is the phonon mean free path determined by U -processes, m is the average atomic (molecular) weight.

According to the model of the minimum thermal conductivity the mean free path $l(\omega)$ of vibrational modes is described by equation (3) for frequencies smaller than ω_0 otherwise it is a constant of the order of inter atomic distance [43]. In this case $l(\omega)$ can be written as:

$$l(\omega) = \begin{cases} \nu / A\omega^2 T, & 0 \leq \omega \leq \omega_0, \\ \alpha \pi \nu / \omega = \alpha \lambda / 2, & \omega_0 < \omega \leq \omega_D \end{cases} \quad (5)$$

where α is the numerical coefficient of the order of unity. The frequency ω_0 can be found by substituting of $l(\omega)$ in equation (5) at $\omega = \omega_0$:

$$\frac{\nu}{AT\omega_0^2} = \frac{\alpha \pi \nu}{\omega_0}. \quad (6)$$

It is

$$\omega_0 = 1 / \alpha \pi AT. \quad (7)$$

The condition (6) is the well-known Ioffe-Regel criterion which implies localization. We can therefore assume that the excitations whose frequencies are above the phonon mobility edge ω_0 are “localized” or “diffusive”. Since completely localized modes do not contribute to the thermal conductivity, we supposed that the localization is weak and the excitations can hop from site to site diffusively, as was suggested by Cahill and Pohl [7]. If the mean free path of all modes exceeds $\lambda/2$ the thermal conductivity is determined solely by the processes of phonon scattering. At $\omega_0 \leq \omega_D$ the integral of thermal conductivity (2) is subdivided into two parts describing the contributions to the heat transfer from the low-frequency phonons Λ_{ph} and high-frequency “diffusive” modes Λ_{dif} :

$$\Lambda = \Lambda_{ph} + \Lambda_{dif}. \quad (8)$$

2.2. Accounting for translation-rotation coupling

The second stage of computational method is devoted to accounting translation-rotation interaction in the Debye model of thermal conductivity. The extra phonon scattering at librions leads to nothing but renormalization of the coefficient A as compared to pure phonon-phonon scattering [29]. In orientationally disordered phases of molecular crystals there is no long-range order, which suggests that the distinct pure libration modes cannot propagate in the crystal. Nevertheless, the correlation effects are still strong immediately after the phase transition and the short-range orientational order persists. In this region there is strong phonon scattering at the short-range orientational order fluctuations and it becomes weaker on a further temperature rise (the free molecule rotation does not lead to phonon scattering) [20]. Therefore, we assumed that the heat transfer in molecular crystals at $T \geq \Theta_D$ is determined by phonon-phonon and phonon-rotational interactions, and that the phonon-rotation relaxation time is described by one- and two-phonon scattering processes [27], [48]. Using the equations for one- and two-phonon relaxation times [27], the phonon mean free path of one- and two-phonon scattering can be expressed as [38]:

$$l_I(\omega) = \rho v^5 / B^2 \Lambda_{\text{rot}} T \omega^2, \quad (9)$$

$$l_{II}(\omega) = \pi \rho^2 v^8 / C^2 k_B C_{\text{rot}} T^2 \omega^4 \quad (10)$$

where $l_I(\omega)$ and $l_{II}(\omega)$ are the phonon mean free paths for one and two-phonon scattering, respectively, B and C are the constants of non-central intermolecular interactions, Λ_{rot} is the thermal conductivity of the orientational subsystem, C_{rot} is the rotational heat capacity per unit volume. In the first approximation $B=C^2$ [27].

The coefficient B can be found from the pressure dependence of orientational ordering temperature:

$$B = -(1/\chi_T) (\partial(\ln T_f) / \partial P) \quad (11)$$

where χ_T is the isothermal compressibility, T_f is temperature of the orientational phase transition, P is the pressure. The thermal conductivity Λ_{rot} can be found from the well-known gas-kinetic expression:

$$\Lambda_{\text{rot}} = \frac{1}{3} C_{\text{rot}} a^2 \tau^{-1} \quad (12)$$

where τ is the characteristic time of orientational excitation transfer from one lattice site to another. This time can be estimated from relation $\tau \approx \hbar / \Delta E$ [6], where the non-central part ΔE of the intermolecular interaction was calculated on the basis of the expression given in [48] relating it to the temperature of transition into the orientationally ordered phase of corresponding molecular crystals.

Then, $l(\omega)$, the combined phonon mean-free path, can be written as:

$$l_{\Sigma}(\omega) = \sum_i (l_i(\omega)^{-1})^{-1}. \quad (13)$$

By substituting (3, 9, 10) in (13), the combined phonon mean-free path can be expressed as [38]:

$$l_{\Sigma}(\omega) = \left(\frac{AT\omega^2}{v} + \frac{B^2 \Lambda_{\text{rot}} T \omega^2}{\rho v^5} + \frac{C^2 k_B C_{\text{rot}} T^2 \omega^4}{\pi \rho^2 v^8} \right)^{-1}. \quad (14)$$

Expression (14) is not applicable if $l(\omega)$ becomes of order or smaller than half the phonon wavelength $\lambda/2 = \pi v / \omega$. A similar situation was considered previously for the case of U -processes alone [26]. Let us assume that in the general case:

$$l(\omega) = \begin{cases} l_{\Sigma}(\omega), & 0 \leq \omega \leq \omega_0, \\ \alpha\pi\nu/\omega = \alpha\lambda/2, & \omega_0 < \omega \leq \omega_D \end{cases} \quad (15)$$

where α is the numerical coefficient of the order of unity. The frequency ω_0 can be found from the condition:

$$\left(\frac{AT\omega_0^2}{\nu} + \frac{B^2\Lambda_{\text{rot}}T\omega_0^2}{\rho\nu^5} + \frac{C^2k_B C_{\text{rot}}T^2\omega_0^4}{\pi\rho^2\nu^8} \right)^{-1} = \frac{\alpha\pi\nu}{\omega_0}. \quad (16)$$

It equals

$$\omega_0 = -u / \left(-\eta + \sqrt{u^3 + \eta^2} \right)^{1/3} + \left(-\eta + \sqrt{u^3 + \eta^2} \right)^{1/3} \quad (17)$$

where the parameters u and η are:

$$u = \frac{\pi\rho^2\nu^7}{3C^2k_B C_{\text{rot}}T} \left(A + \frac{B^2\Lambda_{\text{rot}}}{\rho\nu^4} \right), \quad \eta = -\frac{\rho^2\nu^7}{2\alpha C^2k_B C_{\text{rot}}T^2}. \quad (18)$$

The integral of thermal conductivity splits into two parts describing the contributions to the thermal conductivity from the low-frequency phonon and the high-frequency “diffusive” modes. In the high-temperature limit ($T \geq \Theta_D$) these contributions are:

$$\Lambda_{\text{ph}} = \frac{k_B}{2\pi^2\nu^2} \int_0^{\omega_0} \frac{\omega d\omega}{\frac{C^2k_B C_{\text{rot}}T^2\omega^3}{\pi\rho^2\nu^8} + \frac{AT\omega}{\nu} + \frac{B^2\Lambda_{\text{rot}}T\omega}{\rho\nu^5}}, \quad (19)$$

$$\Lambda_{\text{dif}} = \frac{\alpha k_B}{4\pi\nu} (\omega_D^2 - \omega_0^2). \quad (20)$$

In the case of orientationally ordered phases equation (19) gives the well-known dependence $\Lambda \propto 1/T$ at $\omega_0 > \omega_D$

$$\Lambda_{\text{ph}} = \frac{k_B\omega_0}{2\pi^2\nu AT}. \quad (21)$$

The validity of such description is supported by molecular dynamics simulations using the Green-Kubo method. Recently, the thermal transport in the Lennard-Jones argon face centered cubic crystal was described by two time constants related to the decay of the heat current autocorrelation function [31], [32], [33]. The first time scale is associated with short wavelength acoustic phonons that have mean-free paths equal to one half of their wavelength. The second time scale is longer, and corresponds to acoustic phonons with mean-free paths longer than one half of their wavelength.

2.3. Phonon scattering

To answer questions as to basic peculiarities of phonon-phonon and phonon-rotational scattering of simple molecular crystals in the framework of third stage of this method we have undertaken to separate the phonon-phonon and phonon-rotational contributions to the total thermal resistance. A number of molecular crystals have several solid phases, which substantially differ in the character of orientational ordering. If the non-central forces are strong and the temperature is low, there is a long-range orientational order in the location of molecular axes. The molecules perform small vibrations around the selected axes (librations), so that the motion of the neighbouring molecules is correlated and the collective orientation excitations (librons) propagate in the crystal. In the first approximation, the translation-orientation interaction in molecular crystals leads to an additional contribution to the

thermal resistance $W=1/\Lambda$ [29]. If the noncentral forces are relatively weak, and the temperature is high enough, the molecules can have a considerable orientational freedom. In this case a number of orientations are accessible to the molecule, which can pass from one orientation to another. In individual cases the limit of such reorientational motion can be a continuous rotation. The additional phonon scattering (compared to the phonon-phonon one) may originate in molecular crystals due to the collective rotational motion of molecules. As a rule, the unfreezing of molecular rotation is accompanied by an increase of the isochoric thermal conductivity due to the weakening of phonon-rotational scattering [20], [39]. We assume that the contributions of different scattering mechanisms to the thermal resistance are additive [38]:

$$\sum_i W_i = W_{pp} + W_{pr1} + W_{pr2} \quad (22)$$

where W_{pp} is the phonon-phonon thermal resistance, W_{pr1} and W_{pr2} are thermal resistances determined by one and two-phonon mechanisms of phonon-rotational scattering, respectively. Using (2) and (3, 9, 10) we have:

$$W_{pp} = 2\pi^2 \nu AT / k_B \int_0^{\omega_0} d\omega, \quad (23)$$

$$W_{pr1} = 2\pi^2 B^2 \Lambda_{rot} T / k_B \nu^3 \rho \int_0^{\omega_0} d\omega, \quad (24)$$

$$W_{pr2} = 2\pi C^2 T^2 C_{rot} / \left(\nu^6 \rho^2 \int_0^{\omega_0} \frac{d\omega}{\omega^2} \right). \quad (25)$$

3. The objects

Solid SF₆, CCl₄ and C₆H₆ crystals with different type of molecular rotational motion were chosen as an example to study of heat transfer processes features in the high-temperature phases of molecular crystals. The existence region of high-temperature β-phase of solid SF₆ is extraordinarily large: the crystallization of SF₆ occurs at 222.4 K, and the phase transition lowering the symmetry of the translational and orientational subsystems of the crystal does not occur until 94.3 K [16]. Sulphur hexafluoride is often classed as a substance that has a plastic crystalline phase. Indeed, the relative molar entropy of melting $\Delta S_f/R$ of SF₆ is 2.61 [47], which is close to Timmerman's criterion. Here R is the universal gas constant. However, the nature of orientational disorder in the high-temperature phase of SF₆ is somewhat different from that of plastic phases in other molecular crystals, where the symmetries of the molecule and its surroundings do not coincide. The SF₆ molecule has the octahedral symmetry. At 222.4 K sulphur hexafluoride crystallizes into *bcc* lattice of $I_m 3_m (O_h^9)$ symmetry with two molecules per unit cell. As a result, the molecule and its surroundings have the same symmetry. On further cooling to 94.3 K, a polymorphous transition occurs, which suppresses the symmetry of the translational and orientational subsystem to the monoclinic one, of space group $C2/m (C^3_{2h})$. The interaction between the nearest neighbors in the *bcc* phase is favorable for molecular ordering caused by the S-F bonds along the {100} direction and the interaction with the next nearest neighbors is dominated by repulsion between the F atoms. According to x-ray and neutron diffraction data [10], [11], [16], a strict order is observed in β-SF₆ just above the phase transition point. The structural dynamical factor \mathfrak{R} characterizing the degree of the orientational order is close to unity in the interval 95-130K. This feature distinguishes SF₆ from other plastic crystals, such as methane, carbon tetrachloride, adamantane and so on, where the long-range orientational order becomes disturbed immediately after the phase transition. Orientational disordering in SF₆ starts to intensify only above 140 K. As follows from the analysis of the terms of the Debye-Waller factor derived from neutron-

diffractometric data for the β -phase of SF₆, the F atoms have large effective librational amplitudes. As temperature rises, the librational amplitudes increase to 20° and higher, but the F localization is still appreciable near the {100} direction. This implies that the orientational structure of SF₆ does not become completely disordered even at rather high temperatures. The disordering itself is dynamic by nature. The increasing amplitudes of librations are not the only factor responsible for the increasing orientational disordering with dynamic reorientations, which become more intensive due to frustrations of the intermolecular interactions [10], [11], [16], [17].

Carbon tetrachloride has an interesting feature: on cooling to 250.3 K liquid CCl₄ crystallizes into a face-centred cubic (fcc) form (I_a) with four molecules per unit cell, which at further temperature decrease by some degrees transforms into the rhombohedral phase (I_b) with 21 molecules per unit cell [37], [44]. Below 225.5 K the rhombohedral phase transforms into a monoclinic one of space symmetry group $C2/c - (C_{2h}^6)$ with $Z=32$. On heating, the low-temperature phase (II) always changes to the rhombohedral form. Because of low entropy of melting $\Delta S_f/R=1.21$, the phase (I_b) of CCl₄ may be classified as “plastic” [46]. The three forms of solid CCl₄ are closely related. The centres of mass of the molecules are only slightly shifted relative to their positions in the cubic and rhombohedral phases. Besides, the molecular orientations in the phase (II) correlate closely with the directions of the highest-density distributions function in the phase (I). According to experimental data, the character of the molecular motion in the plastic phase of CCl₄ is closely similar to that in the liquid state. For example, for CCl₄ no discontinuities are observed in the curve of spin-spin relaxation time T_2 of ³⁵Cl on plastic phase melting [34] and in the curve of reorientational correlation time obtained from Raman line broadening [4], [9]. Zuk, Kiefte, and Clouter estimated the elastic constants of CCl₄ in the phase (I) by the Brillouin scattering method [49]. They discovered an anomalously high (as compared to solid inert gases) ratio of sound velocities in the <110> and <111> directions and interpreted this as an indication of a strong translation-orientation interaction.

Solid benzene under the pressure of its own saturated vapor has only one crystallographic modification: it has the orthorhombic spatial symmetry $P_{bca} (D_{2h}^{15})$ with four molecules per unit cell [2], [8]. Benzene melts at 278.5 K and the melting-caused change in the entropy is $\Delta S_f/R=4.22$ [47], which is much higher than Timmermans criterion for orientationally disordered phases. Here R is universal gas constant. The high-temperature magnitude of the Debye temperature of C₆H₆ is 120 K [18]. In the interval 90-120 K the second NMR moment of C₆H₆ drops considerably as a result of the molecule reorientations in the plane of the ring around the sixfold axis [1]. The activation energy of reorientational motion estimated from the spin-lattice relaxation time is 0.88 kJ/mole. The frequency of molecular reorientations at 85 K is 10⁴ s⁻¹. On a further rise of the temperature it increases considerably, reaching 10¹¹ s⁻¹ near melting temperature. The basic frequency of the benzene molecule oscillations about the sixfold axis at 273 K is 1.05 · 10¹² s⁻¹ [40].

4. Results and discussion

To compare computational results obtained in the framework of above mentioned method with experimental results it is necessary to use the reliable experimental data on thermal conductivity of molecular crystals. Up to now, the thermal conductivity of solid SF₆ has been studied for several isochores in the narrow temperature interval near the melting point [22] and in the whole region of the existence of β -phase under isobaric conditions [39]. The thermal conductivity of solid CCl₄ had been measured at constant pressure in the temperature range 80-250 K [41] and on several isochores above 200 K [21]. At present, the thermal conductivity of solid C₆H₆ has been experimentally studied in the temperature range from 80 K to the melting temperature [23]. The isobaric thermal conductivity of solid C₆H₆ was also measured under the pressure above 100 MPa [42]. The experimental data of the isochoric thermal conductivity of solid SF₆ ($V_{\text{mol}}=58.25 \text{ cm}^3/\text{mole}$), CCl₄ ($V_{\text{mol}}=86.48 \text{ cm}^3/\text{mole}$) and C₆H₆ ($V_{\text{mol}}=70.50 \text{ cm}^3/\text{mole}$) [21], [23], [39] are presented in figure 1 as black squares. The computer simulation of the thermal conductivity of solid SF₆, CCl₄ and C₆H₆ using equations (16)-(20) was performed by the parameter fitting method [35], varying the coefficients A, B, C, and α .

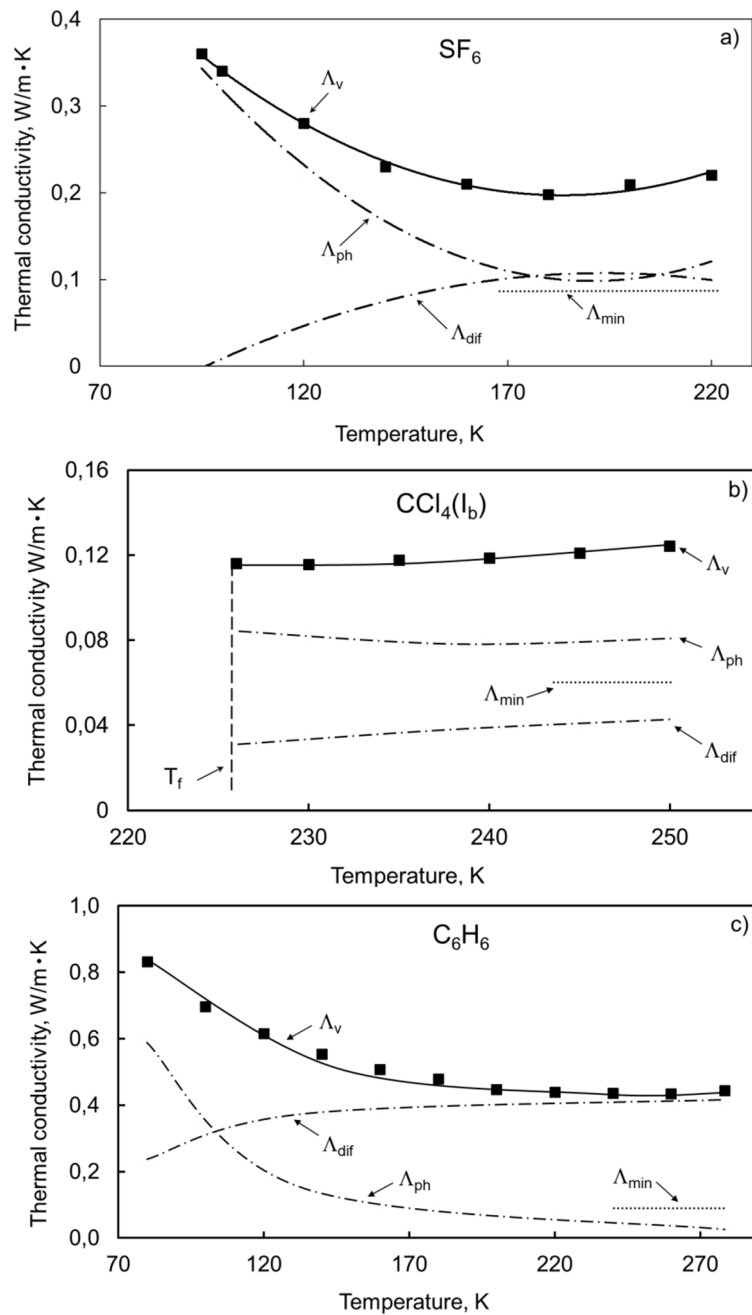


Figure 1. Isochoric thermal conductivity Λ_v of solid β -SF₆, CCl₄ (I_b), and C₆H₆. The solid line is the fitting curve for isochoric thermal conductivity. Λ_{ph} and Λ_{dif} are contributions of phonons and “diffusive” modes to heat transfer, respectively. The lower limits of the thermal conductivity Λ_{min} calculated according to equation (1). T_f is the phase transition temperature.

The necessary for simulation data on sound velocity and density in solid β -SF₆, CCl₄ (I_b) and C₆H₆ were taken from [14], [38], [39]. To determine rotational components of the heat capacity of solid β -SF₆, CCl₄ (I_b) and C₆H₆, we used the method described in [16] and data cited in [3], [5], [16], [18], [30], [38], [39], [45]. The computer simulation results for isochoric thermal conductivity Λ_v of solid SF₆, CCl₄ and C₆H₆ are shown in figure 1. As shown in figure 1, the simulation results for isochoric thermal conductivity of solid SF₆, CCl₄ and C₆H₆ (solid line) are in good agreements with experimental data and the maximum differences do not exceed 5%. The same figure shows the

contributions (dot-and-dash lines) to the heat transfer from the low-frequency phonons Λ_{ph} and the high-frequency “diffusive” modes Λ_{dif} (calculated by equations (19), (20)). The dotted lines in figure 1 illustrate the lower limit of the thermal conductivity Λ_{min} (1) calculated for the isochoric case, according to Cahill and Pohl [7] in the framework of the Einstein model for the diffusive transfer of heat directly from site to site on a time scale of one-half of the period of oscillation. The parameters of the Debye model for thermal conductivity used in the simulation (a , v , γ), and the fitted values A , B , C , and α are listed in table 1.

Table 1. Parameters of the Debye model of thermal conductivity obtained by the fitting, and other quantities which were used for computer simulation.

Substance	V_{mol} , cm ³ /mole	a , 10 ⁻⁸ cm	v , m/s	γ	α	A , 10 ⁻¹⁷ s/K	B	C
β -SF ₆	58.25	4.6	994	2.01	2.0	9.65	7.0	2.62
CCl ₄ (I _b)	86.48	5.3	1118	2.62	1.5	13.9	6.1	2.46
C ₆ H ₆	70.50	4.9	2275	3.30	4.4	7.60	6.8	2.59

From figure 1, it can be noted that the experimental thermal conductivity Λ_{exp} (black squares) at premelting temperatures approaches to its lower limit. As the temperature increases, the isochoric thermal conductivity in β -phase of solid SF₆ and in phase I_b of solid CCl₄ also increases. At the same time, the isochoric thermal conductivity of solid C₆H₆ decreases with increasing temperature. It can also be seen from figure 1 that in OD phases of β -SF₆ and CCl₄(I_b) heat is transferred by both phonons and “diffusive” modes, whereas in C₆H₆ above 150 K heat is basically transferred by “diffusive” modes. In β -phase of solid β -SF₆ heat transfer by phonons Λ_{ph} decreases with temperature, passes through a minimum and then starts to grow. The observed effect can be attributed to a weakening of phonons scattering by collective rotational excitations of molecules as the correlations of their rotation becomes weaker. These findings are in good agreement with results of different structural study of solid SF₆ [11], [16], [17] according to which in solid SF₆ the nature of orientational disorder in the high-temperature β -phase of solid SF₆ is somewhat different from that of plastic phases in other molecular crystals, where the symmetries of the molecule and its surroundings do not coincide. As indicated in [16], in the β -phase of solid SF₆ observed a rather strict orientational order immediately after the phase transition at 93.4 K and intense growth of the orientational disordering processes starts only at temperature above 140 K that correlated well with simulation results for Λ_{ph} presented in figure 1a. The Brillouin scattering results [19] also attest to a weaker translational-rotational coupling in the β -phase of solid SF₆.

In phase I_b of crystalline CCl₄, the contributions of Λ_{dif} increases and that of the Λ_{ph} weakly decreases (figure 1b) this also can be attributed to the weakening of phonon scattering by rotational excitation of molecules. This again is in good agreement with results of structural study of solid CCl₄ cited in [4], [9], [34], [46]. Unlike β -phase of solid SF₆ in crystalline CCl₄(I_b), the orientational disordering processes starts immediately after the phase transition to phase I_b (225.5 K). According to results of experimental research [4], [9], [34], the character of the molecular rotational motion in the plastic phase of CCl₄ is closely similar to that in the liquid state i.e. nearly free rotation. Therefore, the temperature dependence of the Λ_{ph} in phase I_b of solid CCl₄ practically does not change with temperature at isochoric condition.

Theoretical models of heat transfer in solid dielectrics have predicted the thermal conductivity behaviour $\Lambda \propto 1/T$ at temperatures $T \geq \Theta_D$ [15]. The behaviour of temperature dependence of isochoric thermal conductivity Λ_v of solid C₆H₆ is inconsistent with the theoretical prediction. Above 180 K, Λ_v is practically constant and even starts to grow slightly at premelting temperatures. With temperature rises (figure 1c), the part of heat transferred by the “diffusive” modes Λ_{dif} increases, and in a range of 110 K it becomes equal to the heat transferred by the low-frequency phonons Λ_{ph} . It is seen that our simulation results for thermal conductivity of solid C₆H₆ in good agreement with

experimental data (black squares) cited in [23] if the different density of the samples is taken into account.

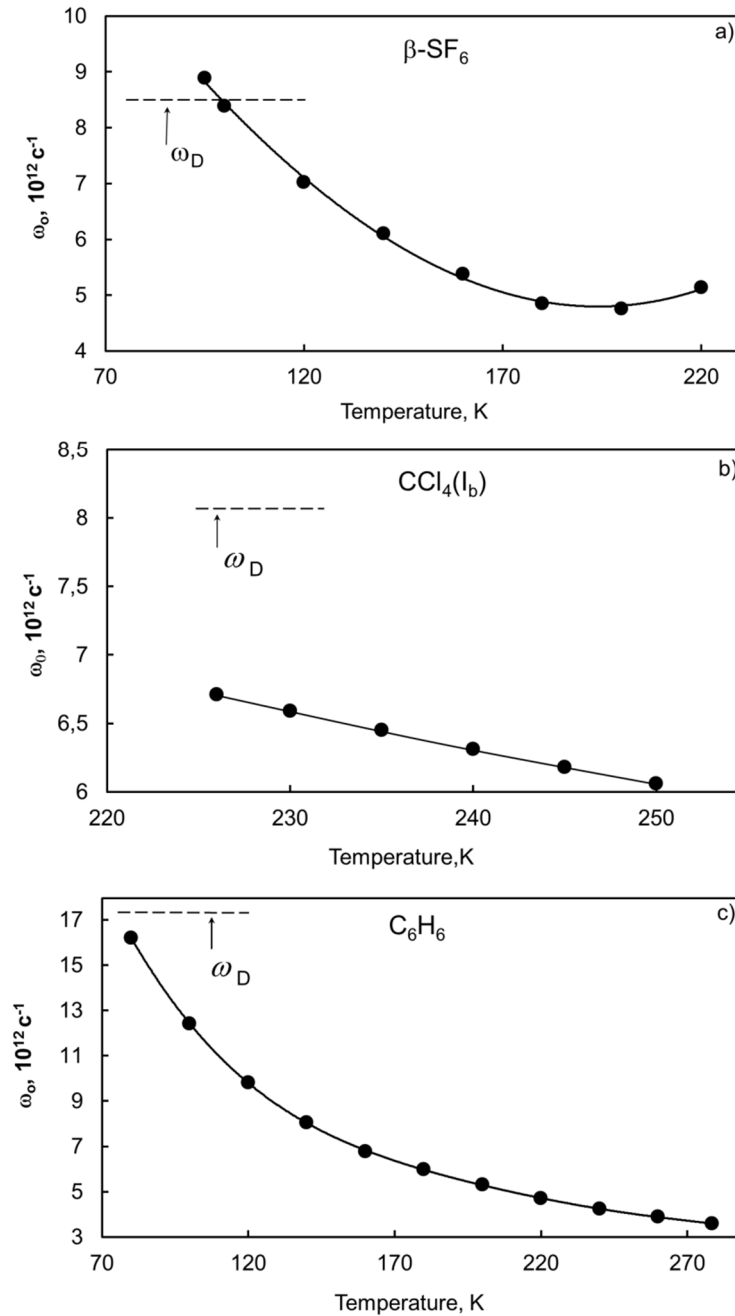


Figure 2. Temperature dependence of the phonon mobility edge ω_0 for solid SF_6 , CCl_4 and C_6H_6 . ω_D is the Debye frequency.

The phonon mobility edge ω_0 for solid SF_6 , CCl_4 and C_6H_6 calculated by equations (17) and (18) are presented in figure 2. Phonon mobility edge temperature dependence in β -phase of solid SF_6 decreases with increasing temperature then passes through a minimum, and starts to increase. This increase can be related to decreasing of the phonon scattering, which occurs as the rotational correlations between the neighbouring molecules become weaker. In solid CCl_4 and C_6H_6 , as the

temperature rises the phonon mobility edge ω_0 decreases. This occurs because the nature of molecular rotational motion in these crystals practically does not change with temperature.

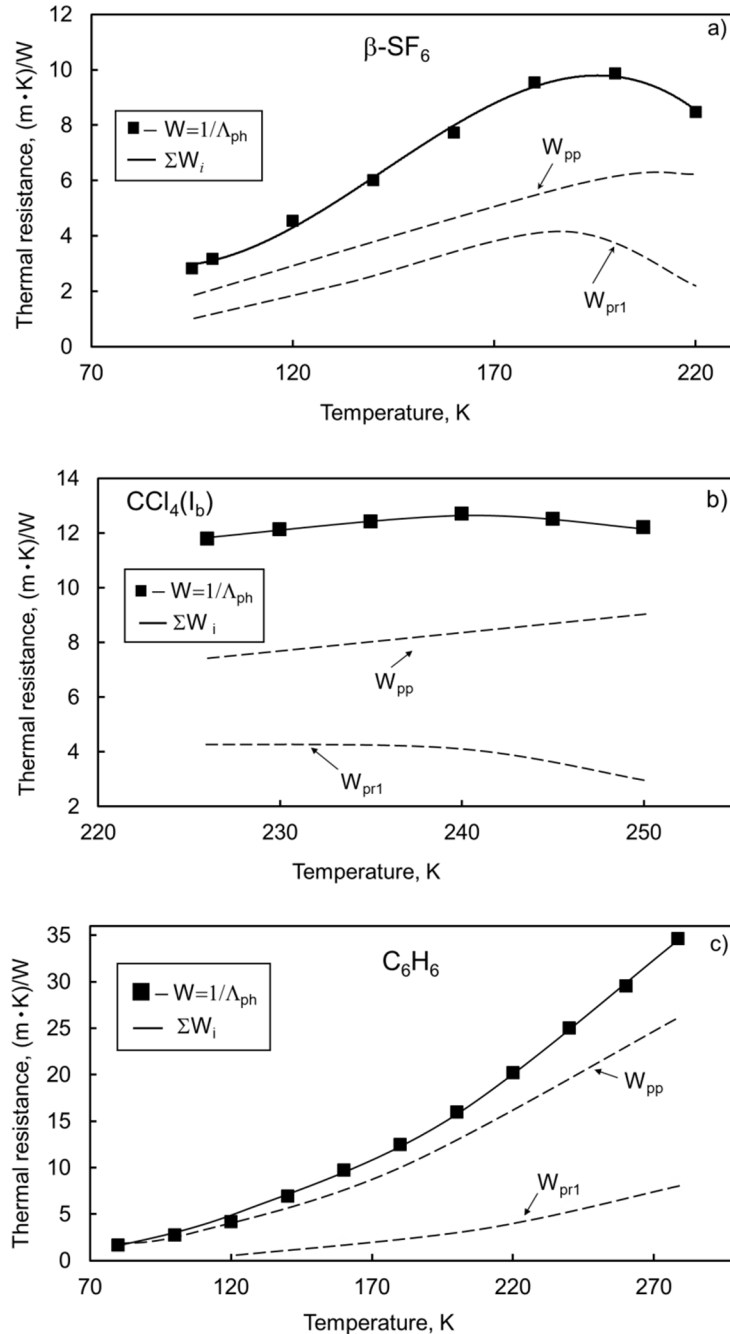


Figure 3. Contributions of the phonon–phonon scattering W_{pp} , and one-phonon W_{pr1} scattering by collective rotational excitation to the total thermal resistance W of solid β -SF₆, CCl₄ (I_b), and C₆H₆.

To study peculiarity of heat transfer processes in solid SF₆, CCl₄ and C₆H₆ we used above described computational method to separate the phonon-phonon and phonon-rotational contributions to the total thermal resistance. Figure 3 shows the obtained results for thermal resistance. The total thermal resistance was determined as $W = 1/\Lambda_{ph}$. The solid curve is the sum of the thermal resistances,

calculated by equations (23)-(25). The solid line shows the sum of thermal resistances W_{pp} , W_{pr1} , and W_{pr2} . Square symbols indicate total thermal resistance $W=1/\Lambda_{ph}$. The two-phonon component W_{pr2} of the total thermal resistance are practically zero in all cases (not exceeds $4 \cdot 10^{-5} \text{m} \cdot \text{K}/\text{W}$). The contributions of phonon–phonon scattering W_{pp} and one-phonon scattering by rotational excitations of molecules W_{pr1} are presented in figure 3 as dashed lines. For investigated molecular crystals the phonon–phonon component W_{pp} of the total thermal resistance increases with temperature. The behaviour of temperature dependences of the phonon-rotational thermal resistance W_{pr1} are differs. The observed variations in temperature dependences of the phonon-rotational thermal resistance W_{pr1} of solid SF_6 , CCl_4 and C_6H_6 can be explained by the different type of rotational motion of molecules in these crystals.

5. Conclusion

The results obtained by applying the computational method clearly demonstrate the features of heat transfer processes in molecular crystals with different types of translation-orientation interaction. The experimental temperature dependence of isochoric thermal conductivity for simple molecular crystals can be adequately described by Debye approximation in the frame of the model where heat is transferred by phonons and “diffusive” modes on the assumption that the mean free path of phonons cannot be smaller than half the wavelength. Unlike the classical Debye model of thermal conductivity described method makes it possible to take into account not only the heat transfer by low-frequency phonons and “diffusive” modes but also the influence of translation-rotation coupling on the heat transfer processes. The presented computation method based on the modified Debye model of thermal conductivity can be used in the educational process within the teaching the discipline “Condensed matter physics”, in particular, in the framework of a lecture on the topic “Thermal properties of dielectrics”. In this method, students studying different molecular crystals can track how the structure of the molecules, the types of interaction, the structure of the translation and orientation subsystems and their dynamics affect the thermal conductivity of molecular crystals.

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Organization of astronomy hometasks with the use of informational and communicative technologies for cognitive activity increase

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Abstract. The method of astronomy homework organization in order to increase students' cognitive activity is described in the article, as well as the possibility of individualisation and differentiation of homework is shown. Modern methods offer a lot of techniques and innovative forms of teaching methods in order to improve students' knowledge. These innovations are aimed at applying activity-based and person-centered approaches to learning that will help to intensify students' training activities therefore it will be engaging and productive. Examples of independent practical tasks of different types and use of information and communication technologies are given. The article gives examples of such kinds of work on astronomy classes as: preparation of a textbook, preparation of supporting notes, practical tasks, solution of astronomical problems and creative tasks.

1. Introduction

The work of astronomy teachers should be aimed at the development of each student's personality, mastering basic astronomical concepts, the use of information and communication technologies in the educational activity. Nowadays the issue of necessity and importance of homework is often discussed [6], [30], [34], [35], [37], [42]. Homework is an integral part of disciplines study, it has an educational value and should contribute to the consolidation of the acquired knowledge and skills improvement. The necessity of students' homework is determined not only by solving of purely didactic tasks (knowledge consolidation, skills improvement, etc.), but by the tasks of formation of independent work skills and students' preparation for self-education [14], [18], [39], [40]. One of the important tasks of a school is to teach the child to learn (preparation for lifelong learning), so the statement does not have basis that homework is unnecessary as essentials of the material must be studied during the lesson. The necessity of homework is also determined that knowledge, skills and abilities are absorbed not immediately but after a periodic repetition.

Besides educational significance a homework has also an educational value forming a sense of responsibility for the task involved, producing neatness, diligence and other socially valuable qualities. Students' homework is essentially different from the classroom one as, first of all, it is held without teachers' direct guidance, although on their recommendations. Students determine time of task accomplishment by themselves, choose the most appropriate rhythm and work pace.

Visibly, it is impossible to master a school programme in astronomy as well as in other subjects on the proper level. High school students are conscientious about studying interesting and necessary disciplines, in their opinion. Astronomy refers to the so-called "unimportant subjects", because it is



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studied only in 11th class (or in 10th and 11th classes within physics), it is often conducted in the last lessons and most importantly, because there is no STA or testing in astronomy. Accordingly, students either do not do their homework in astronomy or do it partially and irregularly (from 25 surveyed 11 respondents do homework sometimes, 12 respondents do it very rarely and only 2 respondents do it always). Little attention is devoted to homework and independent work in astronomy in the methodological literature. The teacher has a difficult task – to make the study of astronomy to be interesting for students [2], [16]. And to solve this problem it is necessary to answer the following questions:

1. How to make the tasks effectively help students to learn basic knowledge and skills in astronomy?
2. What is necessary to do in order to increase the motivation of traditional astronomy tasks accomplishment?

The aim of this work: to consider different approaches to homework organization that will enhance students' cognitive activity, namely: to use individual approach more, to use information technologies and cloud environments services both for homework accomplishment and its checking.

2. Homework organisation

Homework should teach children how to organize their time, to choose the place and method of learning, to build their own work pace, to search, to select, to analyse and to use information as a result – to be able to apply acquired knowledge and skills. So, homework is students' independent work that can be performed both at school and at home.

2.1. Differentiation of homework

In some cases, homework must be the same in content for all students, however, these tasks also can be differentiated. If one child has learnt better the material during the lesson, then it is enough for him to refresh knowledge during next lesson, however, some students will need to repeat the material at home more seriously. So while organizing homework in astronomy a teacher should contemplate tasks for students with high and low levels of academic achievements and a teacher should actively use students' various hobbies and interests such as using computer technology, design, drawing, etc.

As the experience shows, decreased interest to homework is also caused by the use of the same type of tasks for a long period of time. Homework should contain an element of novelty and provide new options for their accomplishment. In some cases, it is advisable to give students individual tasks that help to eliminate gaps in the knowledge of weak students and support the interest of more motivated students.

Individual and differentiated homework can help to realize the development of each student's individuality and to take into account their abilities. In order to study the role of individualized homework in the formation of strong knowledge in the work by Syrotiuk [36] a survey of teachers and students was conducted and it was found that the learning material is absorbed better when individual homework is accomplished, preferring to accomplish creative work, but 4-15% of students receive such tasks.

2.2. Development of cognitive interest

During teaching a teacher should influence on all areas of students' motivation [43]: from the formation of the need for new information, new ways of action and activity in general to the formation of dependence on the results (product) of educational and cognitive work. The main high school student's motivations in the training process are self-affirmation, self-development and cognitive interest.

The presence of a student's cognitive interest prompts him to set his own learning goals, except those that a teacher sets. It means that cognitive interest provides search, creative character of educational activity in any form. Homework should help to increase cognitive activity, only then a student starts to study effectively when he is an important active component of the educational process, as we know, it is impossible to teach, it is possible to learn. Reproductive tasks (to read textbook or synopsis) do not have such efficiency but it is impossible without them to absorb the studied material better. When

preparing homework based on the textbook a teacher should take into account that some students are able only for semi-mechanical reading of the material, they cannot divide it into separate knowledge parts and do not make out self-control on the knowledge mastering, that is why in addition to the task to read the material self-control tasks should be provided. Such tasks are compulsory for all students, that is why everybody of them must be checked, accordingly, it is preferable that answers to the questions for the stating a level of material absorption should be in the form of notes or a text. In this case a teacher can easily and quickly check them in the classroom. As an example, a teacher can use the collection of independent work in astronomy [17].

The use of electronic resources and cloud environments services will diversify and modernize the educational process [4], [8], [12], [13], [15], [19], [22], [24], [27], [28], [33], [38], [41], [44], [45]. Implementation of information and communication technologies in order to check the level of learning will simplify teacher's work and will reduce time for this kind of work. For example, ordinary electronic testing allows a teacher to control students' learning level and promotes students' self-control. Although there are warnings that test results do not allow to estimate students' real knowledge and skills. There are many electronic resources which are available for test preparation: <https://quizizz.com/join/>, Moodle [1], [26], [31] or Google Classroom [3].

2.3. Types and forms of tasks

The study of astronomy must be accompanied by practical and astronomical tasks. Most part of these tasks is usually done during the lessons but in order to increase interest to discipline learning some additional practical works or homeworks can be offered. We increased the number of practical astronomy tasks and students immediately began to demonstrate better understanding of the studied material. In addition, teachers noted more fair homework. Mostly, it is to make an observation (for example, during a week or two to mark the rising and setting of the Sun or the Moon), another task may be to use Internet resources, computer or mobile applications with a purpose to study and explore this or that phenomenon [25]. Most observatories provide data on solar activity; there are solar system simulator programmes that allow you to "go" on a virtual journey to different planets or even around the universe, to study the phases of the Moon with appropriate applications. To get acquainted with the stellar sky, we offered students tasks using mobile applications, such as Sky Map, Star Walk, Sky View, or computer programme Stellarium [22], [23], [32]. When students use a computer or mobile applications, they need to know not only the name of the application but also to have clear instructions for their use. As well as those tasks have to give new knowledge in astronomy, the students will be able to analyze the results and their own conclusions. Here is an example of such a task. The students have to use the mobile application Phase of the Moon to compile a table: date, time of Moon's rise and set, phase, and the constellation in which the Moon is located. Then they analyze the conditions, place and time of observation The Moon, the motion of the Moon during the month on a stellar map. Students do actively such tasks, analyze the results and make their own conclusions.

Solving astronomical problems is one of the most popular type of homework among surveyed students, but it is not the favorite one. The number of tasks in the astronomy school course is small, so it is impossible to abandon them, on the contrary, it is necessary to increase their amount in order to understand practical and mathematical components of astronomy. It is also possible to diversify this type of work by presenting tasks and solutions in an electronic form, however, it is necessary to take into account students' abilities, and for some students it may be sufficient to check the results of solving problems by including these tasks in tests.

A teacher has to use various methods, techniques and tools in order to activate the external actions and internal processes of students' development, thereby encouraging them to become independent in learning. The main methods of development of cognitive interest are known in psychology: stimulating by interesting content, making situations for creative search on the basis of revealed contradictions, creating a game plot around educational material, presenting educational material in the form of achievement results in the corresponding science [16], [29].

In order a student to become an active participant of the educational process, an important type is

interesting tasks for logical thinking development, creative tasks (creation of comics, puzzles, writing composition, drawings, forming education and visual books, developing animations, etc.). All these forms of work can be easily used in astronomy classes, but students must have skills and ability of work with different applications [5]. Nowadays there are many opportunities, for most of them it is even not necessary to install specific applications, it is possible to use the Internet resources and to perform tasks online. For comics creation the resource: <https://www.storyboardthat.com/> can be used and for riddles making: <http://rebus1.com/ua/> can be used.



For example, when students study the structure of solar system, they can prepare a comic book about traveling to planets, during their work they have to tell about distances to planets, describe the peculiarities of physical conditions on various planets. Similar tasks can be also offered while studying the structure of the Universe for students to present legends about the stellar sky. For better memorization new terms or names it is advisable to offer students to prepare puzzles or rebuses in advance and to solve them together in the classroom. Such tasks are interesting for students, and the implementation of such tasks has led to an increase the number and quality of the completed homework.

2.4. Long-term homework

Long-term tasks (month or half a year) may be important and interesting. Such tasks can be used for: making training and visual textbooks; preparing reports and their defending it in the classroom; holding an exhibition; making observations. Work of this type can be both individual and group. This kind of tasks will contribute to student's longer involvement in the learning process and it will increase his responsibility. Differentiated group homework solve another important task, they can and must reveal the preference of collective activity (one of four important competencies such as creativity, critical thinking, communication and cooperation) to students. For example, nowadays project-based learning and preparing projects in the form of presentations and reports are a widespread: in the astronomy lesson the first group of students will present interesting information about scientist's life and activity, the second group will tell about this scientist's scientific contribution to the development of astronomy, the third one will offer information about the technical means used by this scientist, and the fourth group will inform about the significance of this work for the further development of science and technology. Alternatively, one group reports about an astronomical phenomenon, the second one explains how this phenomenon can be observed, the third one reports about research results, and the fourth group informs about research prospects. Summarizing the contemplated task, a teacher can emphasize the effectiveness of a group work and evaluate the contribution of each student. Students' groups should be heterogeneous i.e., they should include "strong" and "weak", active and less active students. Individual homework allows to experience a sense of success also by those students who have low and average levels of educational achievements in most subjects. Such tasks give these students an opportunity to prove themselves, their strengths, thus to create a positive attitude towards schooling (the principle of successful learning).

Individual tasks must not be given from time to time. Their thoughtful system will enable unsure students to strengthen themselves in their abilities, as well as it will enable sure students to develop their interests, to increase enthusiasm and to teach them both to learn independently.

From didactic goals homeworks can be divided into three types:

- it has a beforehand studying (preparing for the adoption of new material, learning a new topic);
- continuing the work that was begun in class (aimed at consolidating knowledge, developing skills);
- consolidation the material that has been studied in class (requiring application of knowledge in practice).

Depending on the didactic purpose and type homework may be compulsory for all students or individual task "for those who want", in any case they are differentiated because each of them works according to their abilities and competence.

There is also a model of learning which is named Flipped Class [9]. The Flipped Class training model

is a kind of blended learning [3] whereby students learn the new material at home. Instead, in the class children discuss learned material with their teacher, also they perform tasks to check their level of learning and understanding of the studied, they do exercises, conduct laboratory and practical research etc. In this form of homework students may work in online environment, read a textbook, watch educational videos or information resources in order to study new learning material. A teacher becomes an assistant-consultant and coordinator from the main translator of knowledge. Consequently, it promotes close collaboration with students in the classroom. Students' role also changes and they are no longer just observers. Students themselves are responsible for the obtained knowledge, direct an educational process, look for practical application of the received information.

As a result of using homework for preparing to study new material the following issues are solved:

- Increasing students' realization of a need to do homework.
- Saving time for learning new material at the lessons.
- Students acquire the skills to systematize the learned and to deepen their knowledge through systematization.
- Creating a success situation and opportunities for students' intellectual and personal growth in the realization of homework.

Differentiated homework should be used to consolidate a material in order to develop students' individual abilities and to use it for the benefit of the whole class. Individual homework can be used for educational purposes as well as for development of each student's abilities.

One of the possible options for keeping the level of preparation, initiative, assimilation of content and volume of educational material is writing support notes for peculiar topics, sections, paragraphs. Supporting notes should serve not only as a solid means of memorizing learned material based on visual images and associative relationships but also they should contribute to the development of thinking as well as general and special abilities. Such a task can be: preparing for the study of new material, then in the lesson a teacher will check the level of understanding of this material and therefore it can possible to devote more time to the practical application of the acquired knowledge. Supporting synopsis is often used to consolidate new material and to continue work begun in the lesson.

In order to compile supporting notes a student must have a sufficiently high level of skills to work with educational literature. Therefore, at first, it is necessary to identify the skills level of independent work with a textbook and additional literature. For this aim a teacher can propose students to draw up a plan and synopsis of a paragraph from the textbook or a part of it and then to analyze the work from these positions:

- ability to highlight the main;
- ability to divide material into semantic parts;
- ability to summarize the read, using visual images, signs.

To simplify the compilation of the supporting syllabus students can use prepared forms in which they fill the appropriate columns. Printed notebooks or electronic notes can be used. When drafting the use of prepared forms a teacher controls an amount of material learned: terms, laws and definitions that students need to know [21]. For example:

1. Fill in the table in figure 1

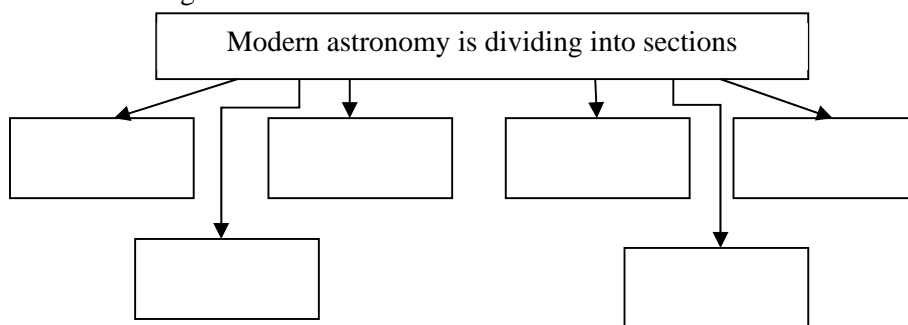


Figure 1. Table with task for students.

2. Fill in the scheme in figure 2.

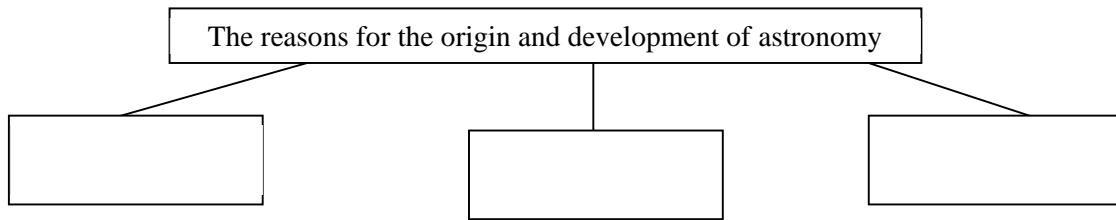






Figure 2. Scheme with task for students.

3. Identify the images of the first astronomers and write their achievements in astronomy from table 1.

Table 1. Astronomer and achievement.

Astronomer		Achievement
	<p>Claudius Ptolemy</p>	
	<p>Nicholas Copernicus</p>	
	<p>Johann Kepler</p>	
	<p>Galileo Galilei</p>	

4. Sign the planets of the Solar system. Arrange in order of distance from the Sun in figure 3.

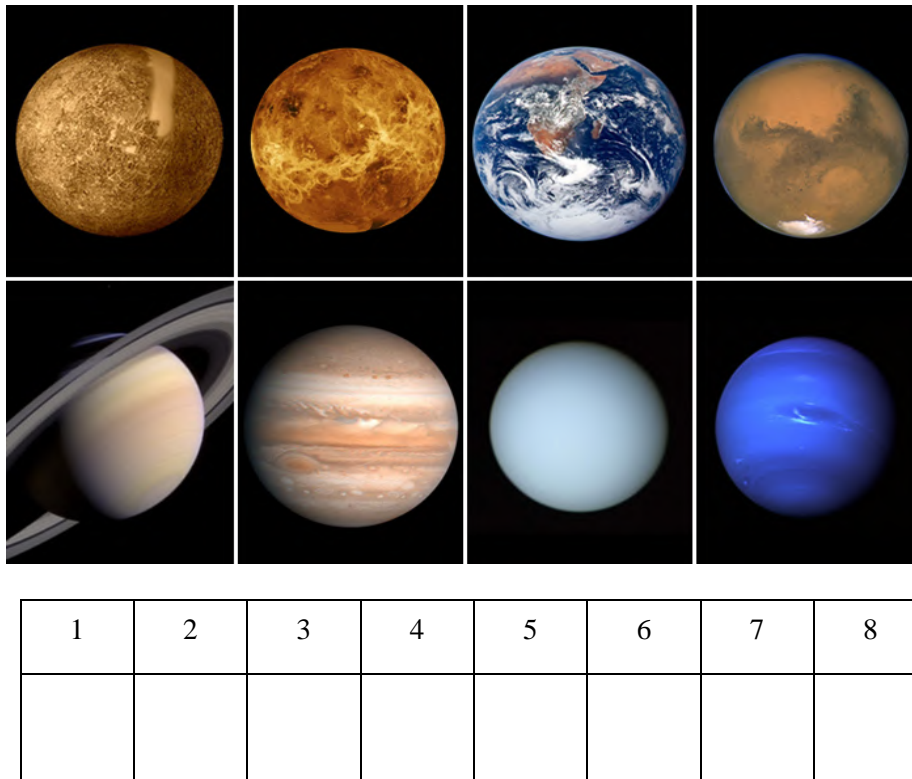


Figure 3. Planets of Solar system.

2.5. Homework estimation

Taking into account the number of hours to study astronomy at school the most often final mark consists of the scores for 2-3 tests and one or two essays / reports / presentations / projects. This approach appeals to students because it does not require additional effort, but does not motivate or enhance their cognitive activity. Implementing different types and kinds of tasks for students it is appropriate to use such form of assessment as students’ portfolio. It is a way of recording, accumulating and evaluating student’s individual achievements over a study period. Different types and kinds of tasks imply a different approach to assessment. A portfolio can contain both current marks and marks for completed and submitted creative, project and research works. The effectiveness of assessment depends to a great extent on its comments by a teacher, because the humanization of education “requires” that during learning it should be free from pressure on students, psychological discomfort caused by biased assessment. The evaluation of portfolio’s materials is carried out in accordance with the tasks for which they are directed, with the use of quantitative and qualitative evaluations.

Forming a portfolio helps:

- to discover child’s individual capabilities;
- to monitor the dynamics of the student’s educational achievements over a period of time;
- to determine the effectiveness of the tasks and their relevance to the child’s abilities;
- to monitor the development of socialization and the formation of a student’s personality.

However, it is important to control the number of tasks that a student performs in order to encourage a student to learn during the whole period, not just to do interesting tasks. For this purpose, such tasks are planned at the beginning of astronomy study and immediately for the whole year.

Olena V. Gozbenko proposes to develop a homework grid plan and to present it to students in order to motivate their activities [10] (table 2).

Table 2. Homework estimation.

No. of a lesson	Standard homework (compulsory for all)	Additional homework	Reports, presentations (view or form)	Projects

3. Discussion

In addition to the standard tasks of developing cognitive activity, there are also interesting individual tasks that can be offered to all students, but not obligatory for everyone.

The examples of such non-standard homework related to the student’s self-development technology are the following:

1. To create an advertisement about a law, a section, a concept, etc. (such as promoting astronomy as a science).
2. To make test assignments on the topic for other students.
3. To prepare a crossword or rebus for the topic.
4. To write a story, a poem, a narrative poem (for example it may be about traveling to the Orion Nebula or the Andromeda Galaxy).
5. To make your own observations (it may be moving of the Sun, the Moon or planets without using a telescope).
6. To make a comic book or animation of the topic.
7. To make a device (sundial or homemade telescope) or a model (layout of a constellation or the Solar system) [20].
8. To analyze the possibilities of computer or mobile applications and their correspondence to a theory (Universe Sandbox 2, Celestia, RedShift).
9. To prepare (to make with the help of applications) a puzzle of terms or illustrations for the material studied.
10. To find interesting facts from the world of science, technology, about scientists’ life etc.

The purpose of homework as a form of organizing students’ cognitive activity is to expand students’ knowledge, to teach them to regular independent educational work, to develop skills of self-control, to foster independence, activity, a sense of obligation and responsibility. It is closely linked with the lesson. This connection means that the cognitive activity at lesson requires additional work: practice in applying rules, solving tasks, finding answers to questions in the textbook, etc. While doing their homework students prepare to perceive new material in the next lesson.

One of the ways to reduce students’ workload, which may be recommended for astronomy teachers, is to enhance student’s independent cognitive activity taking into account their natural abilities and aptitude for learning. Depending on the content of training the forms of homework are the following:

- learning material by a textbook.
- performing oral exercises, doing written tasks.
- doing practical and laboratory work.
- project activity (group, pair, individual).
- preparing reports.
- conducting astronomical observations.

The problem with homework for many students is the inability to organize their working hours which leads to hurry in the work and surface learning of the material. One more reason for the failure of doing written tasks is that they are performed without first learning the relevant theoretical material.

Summarizing, it can be concluded that homework optimization consists of the following factors:

- Clear goal setting for homework.
- Variety of homework forms, the sequence and the feasibility of their use.
- Use of modern digital technologies.
- Differentiation of homework due to the level of difficulty.
- Timely, diverse, open control of homework.

- An optimum amount and timing of homework.
- Clear and competent teacher's instructions for homework.
- Linking homework to learning new material.
- Creating a success situation and opportunities for intellectual and personal growth for students in the process of doing homework.

This approach to students' tasks, which begins with a teacher's explanation at the lesson, continues independently by students and ends at the next lesson with their checking, helps to solve basic astronomy teaching tasks at school as following:

1. To provide students with the basics of knowledge and skills in order to understand properly processes and phenomena occurring in the Universe, as well as its structure and evolution.
2. To form the ability to apply knowledge to explain astronomical phenomena, to understand their interconnections in space and time.
3. To show the role of astronomy in the culture and the formation of the natural-scientific picture of the world, the development of scientific and technological progress.
4. To acquaint students with the basic methods of astronomy, to form appropriate cognitive and practical skills.
5. To form the idea of the Universe as a coherent system in a state of self-development and self-organization, and the idea of possibility of the emergence and existence of life in the Universe.
6. To form the ability to perform astronomical observations (visually or using simple astronomical tools), simple calculations and also to solve astronomical and astrophysical problems.

4. Conclusions

The described approach to the organization of homework in astronomy was suggested to school teachers in the city. They used different types and forms of tasks, used computer technologies, practiced long-term tasks (preparation of messages, speeches, drawings, animations, etc.) and "non-standard tasks". Then we interviewed the students and studied teachers' opinions. The questions were as follows: did the students do their homework better, did their interest in studying astronomy increase, and did this approach take into account the individuality of each student? All of them testified that a result of this has increased interest in the process of studying astronomy, the student has become an active participant in the educational process, it also has reduced the problem of doing homework. It is important to practice the individuality of such tasks that will increase students' self-esteem and desire to learn. Homework will promote the development of students' cognitive activity only when the student becomes an active participant of the educational process. Finally, it is concluded that homework (or independent work) is required to be provided in case it is properly organized.

Separately, it can be added that such homework organization is also suitable for the organization of education for children with special needs [11]. What matters is the visualization, the ability to use computer technology and the submission of tasks in logically completed portions.

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The application of geographic information systems in schools around the world: a retrospective analysis

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Abstract. The article is devoted to the problem of incorporation geographic information systems (GIS) in world school practice. The authors single out the stages of GIS application in school geographical education based on the retrospective analysis of the scientific literature. The first stage (late 70 s – early 90s of the 20th century) is the beginning of the first educational GIS programs and partnership agreements between schools and universities. The second stage (mid-90s of the 20th century – the beginning of the 21st century) comprises the distribution of GIS-educational programs in European and Australian schools with the involvement of leading developers of GIS-packages (ESRI, Intergraph, MapInfo Corp., etc.). The third stage (2005–2012) marks the spread of the GIS school education in Eastern Europe, Asia, Africa and Latin America; on the fourth stage (from 2012 to the present) geographic information systems emerge in school curricula in most countries. The characteristics of the GIS-technologies development stages are given considering the GIS didactic possibilities for the study of school geography, as well as highlighting their advantages and disadvantages.

1. Introduction

1.1. Scientific relevance of the research

The humanity has made a gigantic step from industrial to information era by the end of the second millennium. Nowadays the decisive factors in the development of society are intelligence and information access compared to material and labor resources of the previous epochs. Presently the information of spatiotemporal nature is mainly used for solution of practical tasks [26], [27], [34]. Accordingly, an objective necessity arises to bring in geographic information systems that provide full-fledged and operative analysis of spatiotemporal data [22], [25], [33].

Geographic information systems (GIS) in a broad sense mean a model of the real world, and in a narrow sense – modern computer technology for mapping and analysis of natural and anthropogenic objects, phenomena, processes and events occurring on our planet [38].

William J. Cook, Warren Cohen et al considers GIS to be one of 25 most important events that caused the most substantial impact on people's life in 20th century [12]. In modern geographic science, GIS-technologies play exactly the role that in the era of the Great Geographical Discoveries vehicles played [7].



Today GIS become not only an integral part of professional work place in various fields of science and economy but surround people in day-to-day life. Thus, the younger generation urgently need to master this type of geographic information technology. Besides, the GIS introduction in school education allows to create an exciting and potentially favorable learning environment. Therefore, we believe that GIS education should take its worthy place as a method of world exploration.

1.2. Article objective

The effective use of GIS in school geographical education is impossible without knowing the history of their development, the use of advanced pedagogical experience and a balanced analysis of the problems that happened and still occur during their implementation. The purpose of the proposed publication is to give a retrospective analysis of the use of GIS in global school practice.

2. Results and discussion

We consider it primarily important to identify the main stages of GIS technologies development in school geographical education for the achievement of the article goal.

The first stage of GIS-technologies development in school geographical education occurs in the late 70's – early 90's of the twentieth century, and is associated with the emergence of the first training GIS programs in the United States and Canada. The introduction of GIS in geographical education dates back to the end of 1970s at the university level and since then the interest in them grows like an avalanche. Thus, the number of geographic GIS curricula offered by American and Canadian universities in 1984, according to David Richard Green, was approximately 10 [20]. By the end of 1990, their number exceeded 2,000, and the disciplines incorporating GIS included History, Information Technology, Biology, Mathematics and other sciences.

Such active use of GIS in universities ultimately provided a powerful impact on the secondary education system. The interest in this field at the school level grew dramatically after numerous studies proving that GIS is an efficient educational instrument. They are made by Ronald F. Abler [1], Richard H. Audet and Joshua Paris [2], Thomas R. Baker and Sarah Witham Bednarz [3], Nick Bearman, Nick Jones, Isabel André, Herculano Alberto Cachinho and Michael DeMers [5], Sarah Witham Bednarz and Joop van der Schee [6], Josep Blat, Angel V. Delgado, Maurice Ruiz and Joana Maria Seguí [9], James Cadoux-Hudson and Ian Heywood [11], William J. Cook, Warren Cohen et al [12], David DiBiase [16], Karen K. Kemp, Michael F. Goodchild and Rustin F. Dodson [23], Joseph J. Kerski [24], Carol McGuinness [32], Jonathan Raper and Nick Green [35], Jan Ketil Rød, Wenche Larsen and Einar Nilsen [36], Tim Sutton, Otto Dassau and Marcelle Sutton [39], Robert F. Tinker [40], Patrick Wiegand [42]. Accordingly, GIS merged in school curricula in many countries, among which we note the United States and Canada, and among European countries – Great Britain, Denmark, Germany, France, Finland, Sweden and the Netherlands. The United States and Canada take the lead in this area as they were the first to use GIS in high school in the 1990s. Virtually, they laid the foundation for the development of school geo-informatics not only in the United States, but also stimulated its development around the world.

National Geographic Society of America (NGSA) was one of the first to be involved in the work of introducing GIS in school education process. NGSA began to hold introductory seminars with school teachers throughout the country in 1986, where teachers received basic skills in working with new educational resources.

The National Center for Geographic Information Analysis (NCGIA) carried out the planned and purposeful development of GIS education in US schools. Established in 1989, the Center is a consortium of three universities (University of California, Santa-Barbara; Maine State University and Buffalo University of New York State), which was funded mainly by the National Science Foundation. Its mission was to conduct outreach activities aimed at the development of GIS technologies, among both professionals and a wide range of the persons concerned. The early stages of this work were reflected in the Yearbook of the Association of Geographical Information 1992–1993 [11].

Secondary Education Project (SEP) developed by NCGIA, aimed at solving the following problems:

- to favor dialogue between a teacher and students;
- to collect, develop and analyze GIS teaching materials;
- to inform of current and future GIS schools' activities;
- to deliver information;
- to encourage development of the relevant GIS teaching materials for schools.

One of the first activities was the development of a weekly GIS seminar for secondary school teachers, which later became a series of "GIS in schools" seminars aimed at:

- introduction to GIS;
- studying work GIS applications;
- practical work with GIS software;
- discussion the role of GIS at schools;
- analysis of available teaching materials.

The researchers from the Institute for Environmental Systems Research (ESRI), established by Jack Dangermond in 1969, facilitated a special development of geo-information school education. ESRI established a school and library department in 1992 in order to gradually use GIS in schools in the United States and the United Kingdom. The mission of the department is to form a GIS-supported spatially educated society. Since 1993, ESRI has been publishing the ArcSchool Reader newsletter. In addition to geo-informational news, this information bulletin supplies the instructions for using GIS ArcView, one of the main products of the institute, in various disciplines of the educational process: from pre-school to high school. Generally, the educational activity of ESRI staff in almost all countries have contributed to the involvement of a wide range of educators in the GIS community. The ArcView program has become the most widespread in the field of education.

Due to the widespread of the Internet, ESRI initiated interactive education of teachers and students at various levels and majors related to the GIS-education.

Robert F. Tinker demonstrated the practical application of GIS possibilities for secondary education system in his article in 1992 [40]. The author described personal experience of using digital maps in the study of various environmental issues by four-six grade students in the framework of the KidNet project. Tinker demonstrated the educational importance of GIS application to the analysis of attributive data of the environment monitoring, obtained during surface and satellite observations. The students involved in the project saw in a live and spontaneous way what opportunities are revealed in the spatial analysis with the involvement of GIS. The author paid special attention to the motivation factor that stimulated the students' interest for acquiring new, previously unknown and unused technologies.

The emergence of new scientific directions is inevitably accompanied by a surge of professional meetings, conferences and congresses on the subject. Geographic information systems in education are no exception. Thus, in January 1994, the US National Geographic Society hosted the first annual conference on the educational potential of GIS. The conference, announced as EdGIS, was a great success and became an annual event. EdGIS still makes a significant contribution to solving the problems of GIS implementation in school education: methodology, curriculum, psychology, etc.

The effectiveness of EdGIS contributed to the emergence of new conferences at various levels: the first international conference on GIS education (GISED'98), GIS education: the European perspective (EUGISES'98) and a number of others.

The IDRISI geographic information package from Clark Labs Corporation (USA) is considered successful. Since 1995, more than 250 copies of the program have found their way into primary and secondary schools around the world. To provide informational support for the implementation and use of their product, Clark Labs staff regularly conducts workshops for teachers in the United States, Canada, and other countries.

GIS education, as mentioned above, originated in universities. For example, back in the 1970s, the pioneers in this field were the Computer Graphics Laboratory at Harvard University (USA) and the Department of Experimental Cartography at the Royal College of Art (UK). In these institutions new computer algorithms and programs designed for spatial information processing were developed

experimentally by trial and error method. Due to this, advanced students and teachers gained the first experience of integrating GIS technologies into the educational process, which began to spread actively among other universities in the world.

Thus, in 1995, a joint project of hundreds of American universities “Environmental and Spatial Technologies” (EAST) was launched. The project uses strategies and technologies of problem-based learning to stimulate the intellectual development of students based on GIS.

Since then, GIS technologies began to evolve so rapidly that educational opportunities simply have not kept pace with them. GIS software products began to provide profits and buy out quickly. Many educational courses have been developed, the content of which does not involve the study of basic concepts of GIS, but were mainly aimed at studying the use of certain GIS. In the mid-1990s, it became clear that there was a shortage of specialists capable of conveying basic geo-information knowledge to future teachers. This contributed to the development of the NCGIA GIS Training Course by the US National Science Foundation. This project was based on the premise that the developed teaching materials would be widely disseminated among GIS teachers. The core of the course, about 1000 pages, was translated into many languages and purchased by many educational institutions around the world (more than 70 countries purchased about 1300 copies of the analyzed training course in 5 years). According to an international survey, more than 450 universities in the United States, Europe, and Australia provided GIS education by the 1990s [28].

Consequently, partnership agreements between schools and higher education institutions made a significant contribution to solving the problems of primary GIS education. For example, the GIS Laboratory of Washington College developed a curriculum for studying geographic information systems by students of all ages. This program allowed students to gain basic GIS skills. The recommended form of the educational process is distance learning (online) and weekly courses in summer camps.

Researchers of the University of Texas, in collaboration with the National Science Foundation (NSF) and Covington High School (Texas, USA), developed a curriculum including the comprehensive use of GIS in the Geography for students of six-eight grades. The authors insist that the age level and educational process stages in high school allow to combine optimally the standard curriculum with geospatial technologies. Thus, in the sixth grade school curriculum, students acquire new environmental knowledge. The use of GIS at this level helps collect and organize information flows effectively. At this stage, students develop basic skills and abilities to work with GIS software (figure 1).

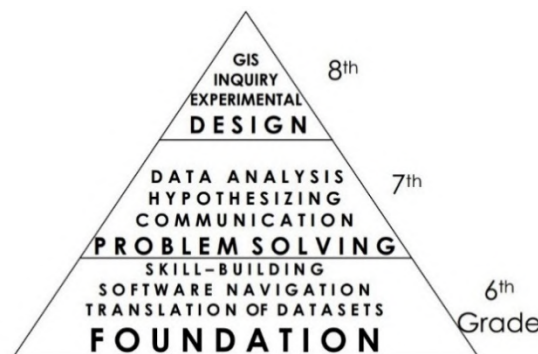


Figure 1. Structural diagram of GIS teaching program at Covington Secondary School, Texas, USA [31].

In the seventh grade the role of GIS analytical functions increases in view of the growing students’ self-awareness. Students learn to perform basic spatial analysis at this level, which ultimately contributes to their ability to produce hypotheses to solve practical problems.

In the eighth grade, students are ready to solve intellectual problems by doing research projects and experiments. They study to use GIS for construction predictive models that have significant practical value.

The second stage of GIS technologies development in geographical school education falls on the middle of the 1990s – the beginning of the 21st century. This stage is characterized by the spread of GIS curriculums in schools of the most developed countries in Europe and Australia.

In Europe, geographic information educational systems were first used in schools in the United Kingdom. For example, teachers at Bishop’s Stortford College under the leadership of Peter O’Connor developed a multi-level program for the use of GIS in schools as part of the Geographical Association project in the early 1990s. The program is based on the GIS package of ESRI ArcView (version 9.1) and covers three conceptual levels around which GIS-educational activities were organized:

- 1 level. Spatial data presentation.
- 2 level. Spatial data processing and analyzing.
- 3 level. Spatial data input and editing.

At the first level, GIS is used as a tool that allows teachers to demonstrate GIS capabilities in the processing of various spatial information to students aged from 9 to 13 (see table 1).

Table 1. Examples of activity types and levels of student academic achievements at the first level of GIS study.

Level of GIS theory knowledge	GIS software knowledge requirements	Studying examples
None	Skills to start GIS app;	9 years: Demographic indicators; quality of life measures; indicators of regional development; crime development models in the UK.
	Skills to use basic GIS-pack navigation functions (for instance, scaling and panning);	10 years: Use of global energy; energy resources in the UK, 11 years: Global warming; sea level; distribution of earthquakes and volcanoes on planet Earth.
	Skills to work with data layers	12 years: Social and economic structures of the city of Cambridge. 13 years: Industries nesting; patterns of world derivation distribution

This approach does not require students to know the theory of GIS unless they have some basic software skills. For example, a teacher demonstrates for 9-year-olds the layers of cartographic studies of crime patterns in England and Wales (figure 2). So, students get an idea of the different nature of crime in rural areas compared to urban ones.

The nature of the processed spatial information becomes more complicated with the age of students. The purpose of the first stage is considered fulfilled if students have learned to obtain information that is not available when analyzing statistical tables and graphs.

At the second level, students need a deeper understanding of GIS theory, the principles of cartographic and statistical analysis (see table 2).

Teachers plan and organize work in such a way that provides a gradual increase in students GIS knowledge. It is important that at this level students already acquire a certain level of GIS theory. The higher this level is; the more complex analytical tasks they are able to solve.

Consequently, students gain greater academic independence and can take full advantage of the program's wide range of analytical capabilities. GIS at the second level allows students not only to determine where certain processes (phenomena) occur, but, more importantly, to answer why they take place there. Figure 3 shows an example of a cartographic analysis of the distribution of infant mortality in Europe and Africa, performed using GIS by 13-year-old students. They identified not only patterns in the spatial disproportion of this indicator, but also established the factors that determine it.

Teaching students to input and edit spatial data into GIS at the third stage is, perhaps, one of the most important skill formed within the program framework (see table 3).

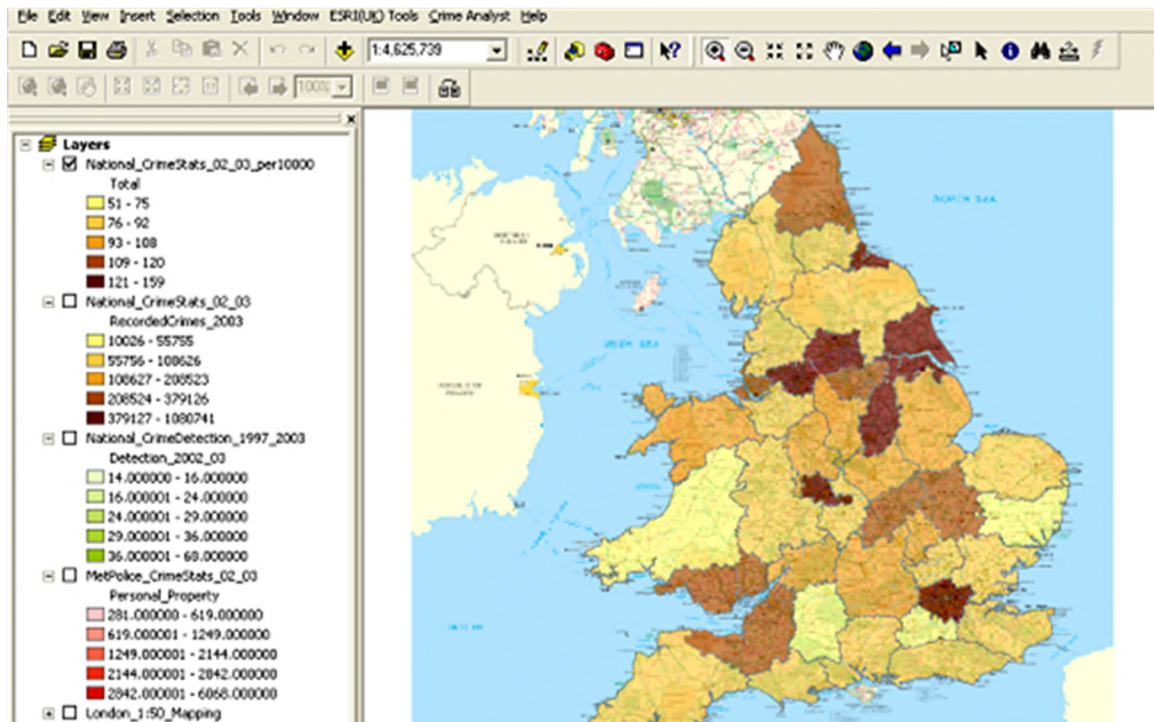


Figure 2. The example of the map demonstrating the patterns of crime distribution in England and Wales [8].

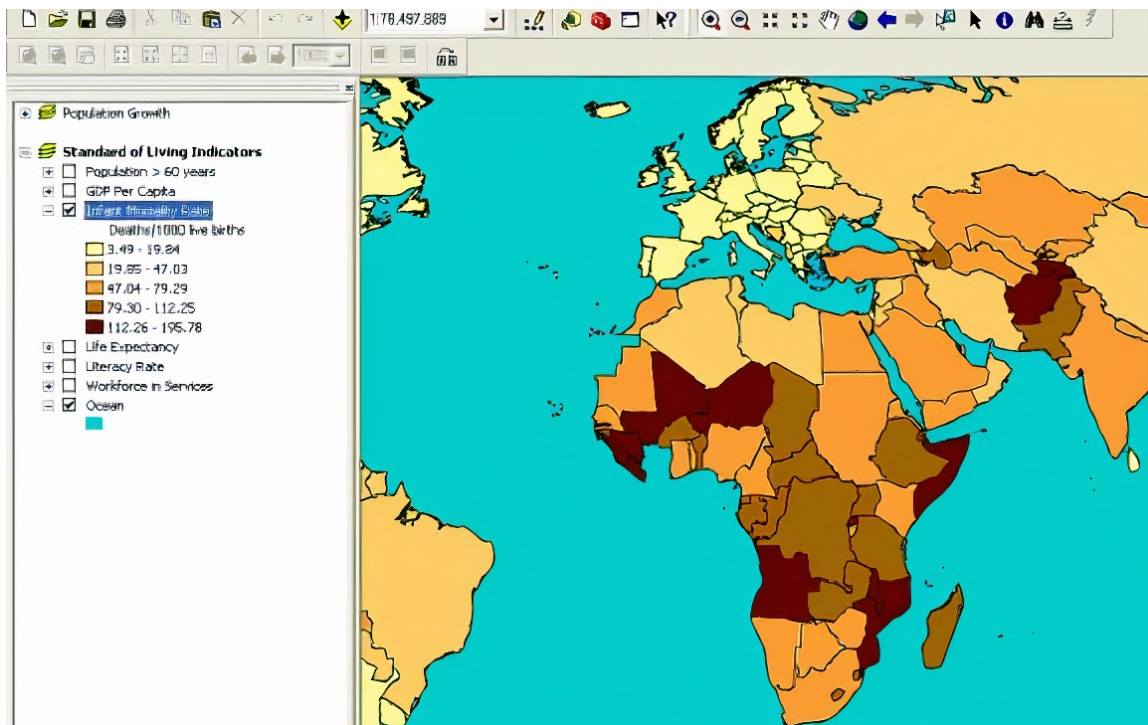


Figure 3. The example of the map demonstrating infant mortality indicator distribution pattern in Europe and Africa [8].

Table 2. Examples of activity types and levels of student academic achievements at the second level of GIS study.

Level of processing and data analysis skills	Level of GIS theory knowledge	GIS software knowledge requirements	Studying examples
Basic	Qualitative and quantitative methods of maps classification; map symbolization and using of a size, a form, color shade, color and texture brightness. Two-dimensional data display methods. Map planning and designing. Object length, perimeter and square measuring.	Students are to develop understanding of classification range, symbolization and display designing methods available in the software and how to access them. Students should practice using GIS input data in forms of maps, images, graphs, tables and reports.	9 years: Spatial representation of historic and future of Bishop’s Stortford development. 12 years: Spatial representation and global tectonic activity symbolization
Intermediate	Data and queries selection. Base logic principles. Data aggregation methods. Statistics methods. 3D-cartography and visualization making.	Students should be familiar with statistics and data processing capabilities in GIS packages	10 years: Identifying areas of high and low levels of economic development on a global scale. 13 years: Mapping of seismic activity zones in the USA
Advanced	Reclassification. Buffering and zoning. Overlay operations. Spatial interpolation. Surface analysis.		13 years: GIS analytic functions are most often used together with experienced users within GIS-projects of A1 level.

These skills are specially significance if students plan to apply GIS in further education or profession. Practically, at this stage student learn various methods of cartographic and attributive data input, their vectorization and identification.

Table 3. Examples of activity types and levels of students’ learning achievements at the third level of GIS study.

General knowledge and GIS theory level	Teaching examples
Data input into electronic tables.	11 years. GIS-project: representation of Bishop’s Stortford municipal structure
Table data Import in GIS-pack.	
Making dotted, linear and areal cartographic layers.	13 years. Students’ work in GIS-projects of A-2 level.
Editing dotted, linear and areal cartographic layers.	
Bonding attributive data with dotted, linear and polygonal cartographic layers.	
Understanding the role of cartographic projections and coordinates systems in GIS.	

Figure 4 shows an example of the map made by students within A2 project, aimed to make a forecast the results of the 2004 elections within Haolow County, as a representation of spatial disproportion in the level of population deprivation. While working, students went through all stages of GIS, starting

with the collection and input of primary information and ending with the compilation and analysis of cartographic materials, thus demonstrating the skills formed at all three conceptual levels of the program.

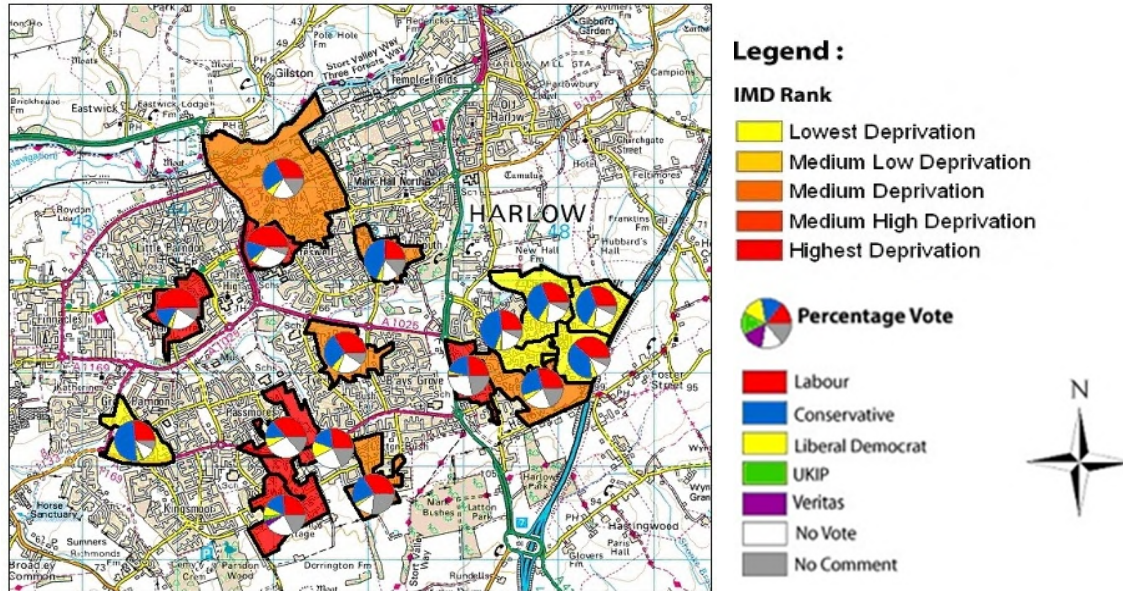


Figure 4. The map of 2004 election results forecast within the Harlow County, USA (Green, 2000).

In 1999, ESRI Schools and Libraries, together with highly qualified teachers and methodologists, developed the High School GIS Study Program, which is now widely used in thousands of schools around the world. The program is based on the use of GIS ArcView. In order to expand the GIS community, ESRI is creating its own virtual campus to study GIS technology [19]. The campus currently has 200,000 registered users from 185 countries.

That same year, ESRI, together with the World Resources Institute (IWR), published an ArcView GIS extension called DataScape, which allowed students to use an IWR database covering more than 450 socioeconomic indicators from more than 160 countries.

GIS became especially popular among students who performed thematic tasks of special scientific and practical significance. An example is the study of students in Minnesota (USA) who gained important information about the migration of endangered wolf species via GPS collars and GIS used. In Chelsea (Massachusetts, USA), students used GIS to identify storage areas for environmentally hazardous materials in the region. These materials were used by the State Emergency Management Agency [1]. In a summer camp research program in Ohio, students used GIS to study watersheds and to model the development of ecological processes. Young researchers also received information about the ecology of streams and soil erosion as part of their work.

Despite extensive research conducted by individual educational and commercial organizations from 1990 to 2000, we note that at the beginning of the 21st century GIS were disregarded in the school education system globally. For example, in the United States, the country with the most active development of geographic information technology, less than 50% of schools used GIS in 2003. When we assess the level of GIS use in European secondary schools at the end of the 20th century, we found out that it was about the same in the UK as in the US and Canada, and did not exceed 20% in France, Sweden and Finland. In other European countries, these figures are even lower: in Russia, Ukraine, Turkey and most others, GIS was absent in school curricula at all and was used only in individual educational institutions thanks to enthusiastic teachers.

Active and comprehensive implementation of GIS in the world schools began at the beginning of the 21st century. The analyses of the current use of GIS in world schools reveals that the historical leadership of the United States in the development of GIS education mirrors in the use of GIS in secondary schools.

Undoubtedly, the main factor is the ESRI policy of GIS education priority in schools, colleges and universities. For example, in the United States, the ESRI Yearbook for Teachers and a special GIS handbook are published, and training seminars are held. Websites are created to store information related to the implementation of GIS in the curricula of different countries: the ArgGIS Online for Schools site [39] offering software, digital maps, lesson plans, ESRI products instructions, etc. According to education surveys, 47% of GIS study groups use ESRI products. Today, the vast amount of U.S. geography teachers uses spatial information analysis programs as an established educational tool.

Other countries, even the most developed ones such as France, Germany and the United Kingdom, lag far behind in this regard. Thus, only since 2007, according to educational qualification programs, GIS has become mandatory for high school students in the UK. The Geography curriculum requires students to master spatial thinking skills, use maps, electronic visual images, the modern technologies, including GIS, to obtain and analyze information.

The German education system comprises several programs of Federal Lands with different educational content and terms of training. Despite attempts to integrate these programs into a single system, there are still some differences. Still GIS is introduced in most schools in Germany, although at different times and with different approaches. Diercke GIS software based on ArcView 3.2 was developed especially for educational purposes. The package comes with a large collection of maps and ready-to-use data (figure 5).

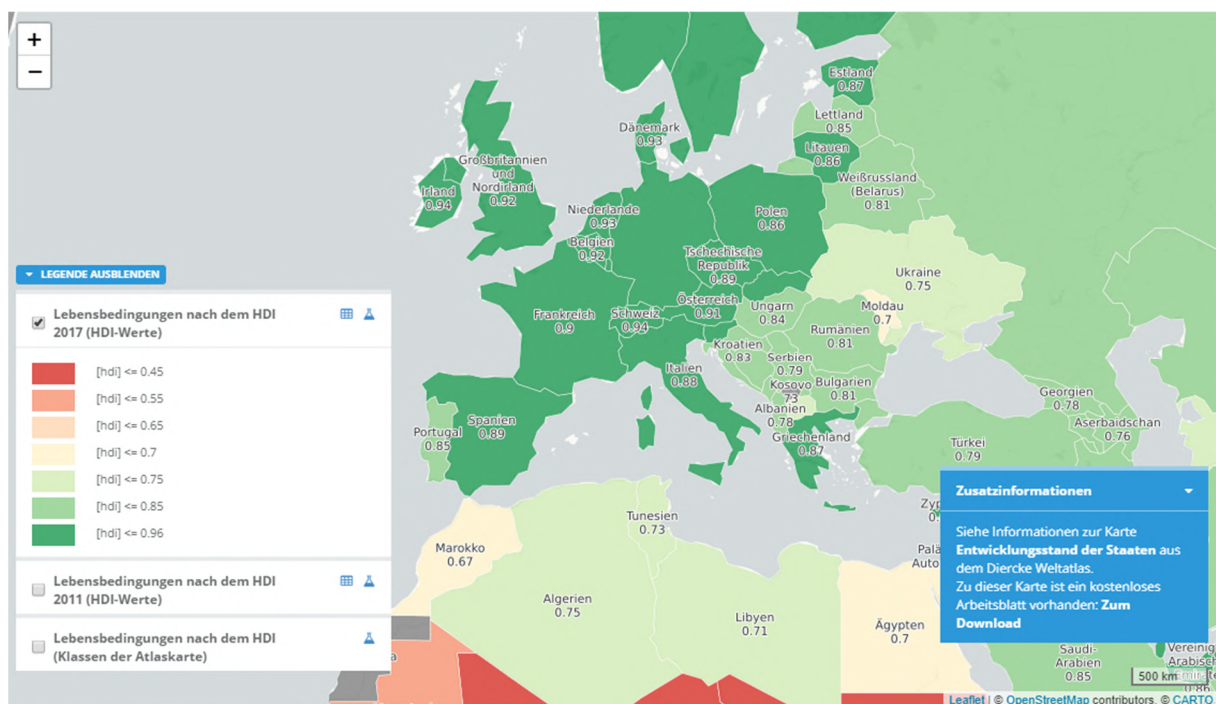


Figure 5. The example of the map made with Diercke GIS [41].

The third stage of GIS technologies development in school geographical education is related to the spread of school GIS education in Eastern Europe, Asia, Africa and Latin America during 2005–2012.

French educational system does not see GIS as a priority. In 1990, the Ministry of Education attempted to introduce a program to study GIS and remote sensing at the national level, but this program did not last long. To change the situation with GIS education, ESRI developed software in French. The Ministry of Education together with the National Institute of Geography (NIG) created the EDUGEO website on the French geoportals to open access to geographic information resources for teachers and students [14].

Presently we observe a cardinal change in GIS education in European Union. In 2014 ESRI signed an agreement with representatives of the EU education system which brought about innovative solutions in European Union education within three years, particularly, the application of geographic information systems in teaching. The ArcGIS Online platform as a base provides lesson plans and other methodological and organizational materials. The other example of this approach is the Schoolnet Future Classroom Lab project launched in 2011, and is specifically designed for online learning via which students and teachers get the ArcGIS online platform access. Such online educational services fit perfectly into modern realities and make an affordable learning service that makes study easier for both students and teachers.

Turkey, India and China take the leading position in GIS-education among Asian countries. Although GIS education in Turkey was developed much later than in USA, Canada, Great Britain, etc., today geo-information technologies are actively implemented at all educational levels. Thus, the national geography programs in Turkey, introduced by the Ministry of National Education in 2005, recommended the introduction of new technologies, including GIS technologies in geographical classes. Since then, the country has published methodological materials for secondary schools, held various conferences and educational programs for teachers of geography.

The GIS study in India was introduced into the high school curriculum in 2000, as part of the National School Curriculum in 2000. It led to the creation of appropriate curricula and publication of teacher's textbooks, the development of teacher training, and the purchase of software and technical equipment.

China widely involves GIS in higher education. In 2004, GIS was studied at 120 universities and colleges, and today this figure raised up to 150 universities. Despite China's school education reform and the introduction of a new progressive school curriculum in 2004–2005, GIS was not widely implemented in it. Meantime in Taiwan new educational program GIS education is marked as one of the priority areas after the transition to 12-year education in the period 2006–2009.

We want to pay special attention to the introduction of GIS in the educational process of African schools. The main problem of the black continent schools is extremely poor technical equipment. The lack of computers, one of the main components of GIS, is the biggest deterrents to the development of geographic information technology in African schools. Hence, it is of great interest the experience of researchers from the Faculty of Geography, Geo-informatics and Meteorology at the University of Pretoria (South Africa), who under the auspices of ESRI developed a paper-based GIS Education Package for South African schools with small information resources [10]. The teaching material complex includes a topographic map at a scale of 1 : 50000, ortho-photos at a scale of 1 : 10000, tracing paper, proofreader, colored chalk, glue, notebooks for students and a guide for teachers. The textbook's list of contents amounts seven practical lessons:

Lesson 1 Theme: Introduction into GIS.

Lesson 2 Theme: Determinations of GIS, GIS components and GIS application.

Lesson 3 Theme: Raster and vector data application in GIS.

Lesson 4 Theme: GIS data input.

Lesson 5 Theme: Dots, lines and polygons digitizing in GIS.

Lesson 6 Theme: Digitizing and Buffering.

Lesson 7 Theme: Geographic data analyses.

The fourth stage of GIS technologies development in school geographical education is characterized by the spread of GIS in school curriculums in most countries (from 2012 to the present).

Russia takes one of the leading places among the East European countries in GIS secondary education. Aleksandr M. Berlyant [37], Aleksei I. Krylov [30] and Vladimir S. Tikunov [17] researches laid a foundation for GIS realization at higher education in Russia. However, the lack of the necessary methodology, staff and facilities substantially restrains the primary GIS-education in the country.

Russia currently works on developments to create a school GIS, which aims to solve new and traditional geographical tasks in geography lessons. The school GIS "Living Geography" is very popular in Russian schools. It is an educational and methodical complex that contains a software shell with tools for working with geospatial data, sets of digital geographical and historical-geographical maps, a set of

space images and guidelines for teachers. It enables a student under the guidance of a teacher to determine their location or geographical coordinates of objects on the ground, build a digital map of an area, draw a route on a digital map or plan, etc.

In Ukraine, there is the need to introduce students to the basics of geographic information systems. The GIS Association of Ukraine was established in 1996. Experts of the association took the first steps in the direction of training personnel with GIS-outlook and capable of spreading geospatial analysis technology. They held scientific and methodical seminars, published scientific articles and monographs. Nevertheless, for objective and subjective reasons geographic information systems did not find a worthy application in school education.

Considerable changes took place in this sphere only in recent years. This is primarily due to the profiling of the school in accordance with the Concept of General Secondary Education, approved by the Resolution of the Board of the Ministry of Education and Science of Ukraine and the Presidium of the Academy of Educational Sciences of Ukraine in 2001. This created much better conditions for differentiated learning, taking into account the individual characteristics of students' development. As a result, Ukrainian researchers have developed a number of elective course programs for specialized classes.

Liudmyla M. Datsenko and Vitalii I. Ostroukh together with the editorial board of the State Research and Production Enterprise "Kartographia" developed the program of the optional course "Fundamentals of Geographic Information Systems and Technologies". The program is designed to study the basics of geographic information systems and technologies in 10–12 grades of senior school of all profiles of natural-mathematical, technological directions. The purpose of the course "Fundamentals of Geographic Information Systems and Technologies" is to provide students with a theoretical geo-information knowledge base, skills to use effectively modern geographic information systems and technologies. It is supposed to provide them with basic principles of geographic information representation and visualization in geo-information systems and skills in modern geographic information software [13].

Liudmyla M. Datsenko published a textbook "Fundamentals of Geographic Information Systems and Technologies" in 2013 to implement practically the analyzed program. The material of the textbook helps students to get a theoretical knowledge base on the basics of geo-informatics, skills and abilities to use effectively modern geo-information systems and technologies [15].

Olha P. Kravchuk proposed one more variant of the optional course "Geographic information systems". The course extends and elaborates "Geography" and "Informatics" general education subjects, deepens senior students' ideas about GIS, and how to apply GIS in scientific research. The course content provides variety for the profile schools and encourages professional orientation. The program trains students to perform practical tasks both in the classroom and independently after classes [29].

The contribution of the staff of the Institute of Advanced Technologies under the leadership of Oleksandr V. Barladin to school GIS education must be also credited. Thus, they developed the educational IPT-UCHGIS, which has a wide range of functional capabilities to support the educational process, including solving many practical problems, geo-information support of educational practices, expeditions and excursions. We would like to mention the administrative names module of search, a drawing module for the marking-off various polygonal, linear or dotted objects, relief visualization, a profile plotting, etc. (figure. 6). It makes possible to scale, edit the properties of objects (colors, thicknesses, names), and print the created maps.

The Concept of the new Ukrainian school announces the importance of ICT and digital competence formation: "ICT and digital competencies envisage confidence and critical appraisal in the use of Information and Communication Technology (ICT) to produce, research, process and exchange information at the workplace, in the public domain and in personal communication. Information and media competence, the fundamentals of programming, algorithmic thinking, working with databases, and skills in Internet security and cyber security. Understanding of the ethics in information processing (copyright, intellectual property, etc.)" [21].

Consequently, radical changes occur in GIS-education of the secondary school. Thus, the regulations that define the strategy for the development of geographical school education state that GIS is a

perspective area for the development of computer technology to be used in curricula. In geography lessons, students need to understand that geographic information systems associate a cartographic object that has a shape and location with descriptive and attributive information that belongs to those objects and characterizes their properties. As a result, the new Geography curriculum of the secondary schools (grades 6–9), the course “Ukraine in the world: nature, population” (grade 8), incorporates the study of GIS technologies of cartographic Internet sources, geo-information and modern navigation systems in geography lessons. The study of electronic maps and globes, cartographic Internet sources, navigation maps, geographic information systems, remote sensing of the Earth and areas of their practical application is included in the course “Geographical space of the Earth” (11 grade standard level and profile level). Yet, the issue of form, technical means, programs and methods to fulfill the requirements of the curriculum for a teacher remains open.

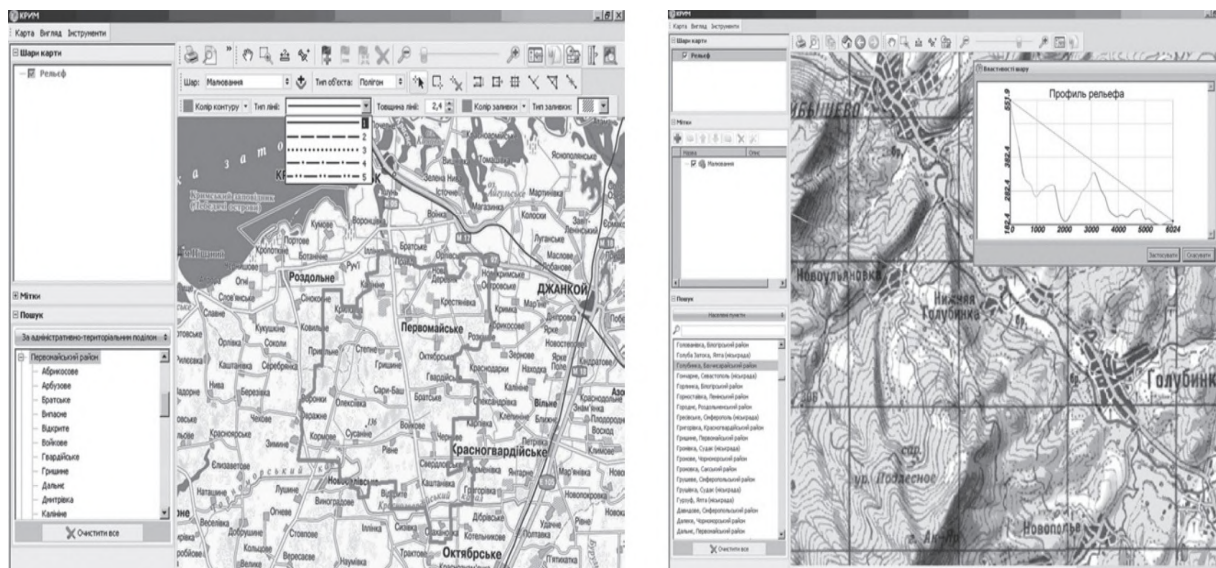


Figure 6. Searching by administrative units, relief visualization and making a hypsometric profile in IPT-UCHGIS school-and-student program [4].

3. Conclusions

A retrospective analysis of using GIS in global school practice allows to make the following conclusions.

1. The analysis of the sources on the research problem reveals the main stages of development of GIS technologies in world schools:

- the first stage (late 1970 – early 1990's) marked the development of the technology as well as the emergence of the first GIS training programs in the leading universities of the United States and Canada, which led to partnership agreements between schools and universities the of these countries;
- the second stage (mid-1990s – beginning of the 21st century) is the dissemination of GIS-educational programs in schools of the most developed countries of Europe (France, Germany, Great Britain, etc.) and Australia, as well as active participation of leading GIS developers packages (ESRI, Intergraph, MapInfo Corp., etc.) in GIS education at all levels;
- the third stage (2005–2012) is related to the spread of the GIS school education in Eastern Europe, Asia, Africa and Latin America;
- the fourth stage (from 2012 to the present) represents the appearance of geographic information systems in school curricula of most countries.

2. The active dissemination of GIS technologies in education demonstrates the methodological problems of GIS education: reasonable and competent use of world experience in the methodology of

implementing GIS in the school educational process, but taking into account the specifics of the educational process of their country, is the key to obtaining a decent pedagogical result.

3. The lack of specialized educational GIS programs in most countries, adapted to the school program, forces schools to use professional GIS in the framework of special educational programs carried out by large GIS companies, but a modern teacher is not always able to understand these complex software packages.

4. Judging from world experience, the successful development of school GIS education is observed only in those countries where there is a system of interactive teacher education through professional courses, meetings, conferences, congresses, etc.

5. We see further development of research in the development of educational and methodological support for the introduction of GIS in the school educational process, determining the didactic foundations of teaching the basics of GIS, taking into account the retrospective analysis.

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Analysis of natural and technogenic factors on the seismicity of Kryvyi Rih

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Abstract. Information is provided on the number of earthquakes in Kryvyi Rih and their parameters for the period 2007–2018. The types of seismic phenomena, the criteria for their identification are considered. The most probable natural and technogenic factors of the epicenters of local earthquakes are established by analyzing their location and sequence in time from the point of view of the tectonic features of the territory and the nature of the technogenic interference in its structure. The necessity of creating a local seismological network in Kryvyi Rih is substantiated. With a view to predict hazardous seismic phenomena, there is a need to continue hydrogeodynamic monitoring of ground water, to introduce seismic gravity monitoring and to conduct microseismic monitoring at mining enterprises. The results of systematic monitoring shall serve as the basis for seismic microzoning of the city. It is emphasized that popularization and dissemination of knowledge about the seismicity of mining regions among the population shall play an important role in the implementation of this task. The research materials can be used in the master's degree programme within the framework of higher education system and in advanced training of specialists in the mining industry.

1. Introduction

For almost 140 years, the Kryvyi Rih structure has undergone an active anthropogenic impact – mining of ferruginous quartzites and rich iron ores by open and underground methods, accompanied by significant changes in the geological environment. Historically, both the residential quarters and the entire infrastructure of the city of Kryvyi Rih are in close proximity to the mining zones. The combination of the critical volume and duration of the mining in quarries and mines of Kryvyi Rih, with global seismotectonic activity, can increase the measure of seismic hazard for the city.

The world seismic activity for the period from 2010 to 2018, considering the number of earthquakes with a magnitude of 2.5–3.5, has grown almost by a factor of three. A significant part of the emerging elastic energy of earthquakes realized in recent mobile zones of the earth's crust, is transmitted to geological structures of relatively calm platforms in which dangerous local earthquakes can occur [7]. In general, the seismic hazard of Ukraine's territory is determined by the location of the south-eastern regions of the country near the powerful seismically active Mediterranean (Alpine-Himalayan) belt of the planet. About 10 % of Ukraine's territory is in the Vrancea zone. This is a seismically active zone

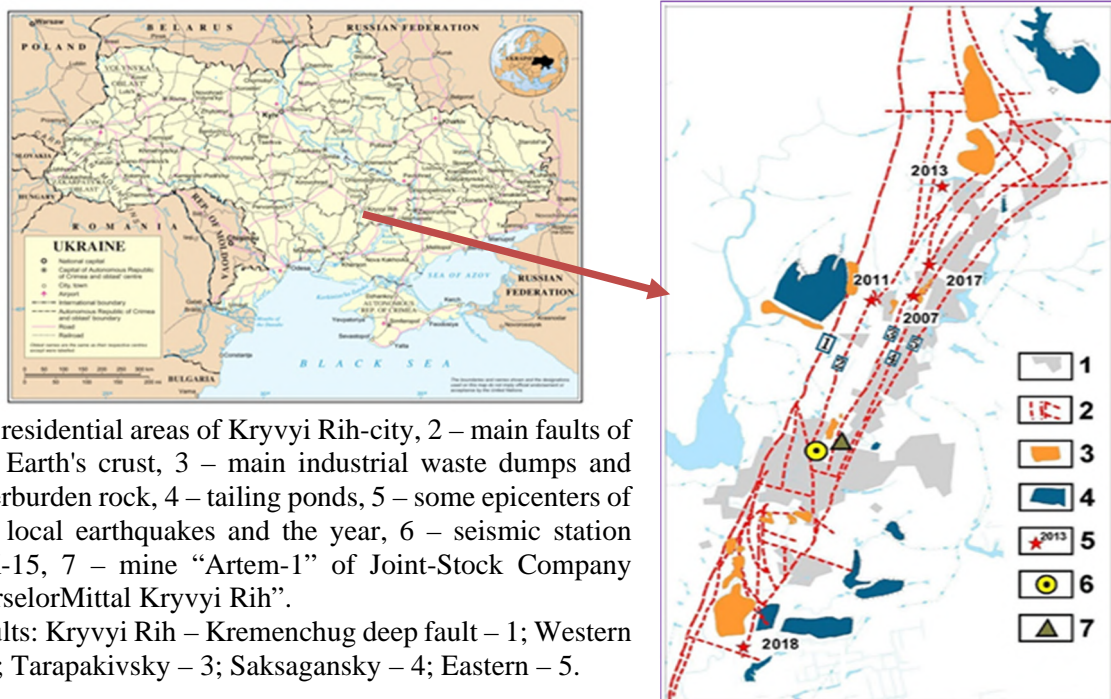


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at the junction of the Southern and Eastern Carpathians in Romania. Southwest Ukraine is directly influenced by it. Earthquakes from 6 to 9 points on a 12-point macroseismic scale (MSK-64) can occur here. Therefore, a significant territory in both southwestern and southern parts of Ukraine is classified as seismically dangerous.

Geologically Kryvyi Rih basin is located in the central part of the Ukrainian shield on the border of two megablocks of different ages – Ingulsky and Serednepydrniprovsky, separated by the Ingulets – Kryvorizhsky sature zone. The Kryvyi Rih structure is located in the eastern part of this zone and, according to the latest data, is represented by two large synclinal folds (Main and Saksagansky), which are substantially deformed by discontinuous faults that are part of the Kryvyi Rih – Kremenchuk deep fault system (Western, Tarapakivsky, Eastern, Saksagansky) (figure 1).

The territory of Kryvyi Rih basin, as well as the Ukrainian shield as a whole, has traditionally been considered to be aseismic. The territory of the Kryvyi Rih district as well as the territory of Ukraine belongs to the zone where earthquakes with an intensity of up to 5 points on the MSK-64 scale can occur once every 500 years; once in 1000 years – 6 points and once in 5000 years – 7 points. Taking into account local engineering and geological conditions and the influence of technogenic factors, the intensity of seismic impacts can vary by 1–2 points [16]. With an increase in the degree of interference in the geological environment, the establishment of real seismicity of the territory becomes more and more relevant even for seismically weakly active regions. Since the establishment of the National Center for Seismological Data on the basis of the Institute of Geophysics by S. I. Subbotin name of the National Academy of Sciences of Ukraine, this Center has the opportunity to collect and analyze data on seismic events occurring in the Krivyi Rih region as recorded by various seismic stations of both the Ukrainian and international seismological networks. Table 1 shows the parameters of earthquakes that have been recorded in the Krivyi Rih area in recent years (since 2007), although similar phenomena have occurred in Kryvyi Rih basin before (09/12/2000; 01/27/2006, etc.) [16]. At the end of 2012, the UK15 seismic station was installed in Krivyi Rih (figure 1).



1 – residential areas of Kryvyi Rih-city, 2 – main faults of the Earth's crust, 3 – main industrial waste dumps and overburden rock, 4 – tailing ponds, 5 – some epicenters of the local earthquakes and the year, 6 – seismic station UK-15, 7 – mine “Artem-1” of Joint-Stock Company “ArselorMittal Kryvyi Rih”.
 Faults: Kryvyi Rih – Kremenchug deep fault – 1; Western – 2; Tarapakivsky – 3; Saksagansky – 4; Eastern – 5.

Figure 1. Local technogenic mining load on the territory of Kryvyi Rih [19], [3] with the authors additions (<https://www.earthdoc.org/content/figure/10.3997/2214-4609.201902490.F1>).

Table 1. The list of seismic events of various origin within the Krivyi Rih region for the period from 2007–2018.

No	Date	Latitude φ	Longitude λ	Magnitude M	Depth H, km
1	25-12-2007 04:09:31	47.79	33.38	3.3	-
2	13-06-2010 03:58:17	48.02	32.35	4.3	0.447-0.527
3	18-09-2010 04:00:35	47.84	33.30	3.3	0.447-0.527
4	14.01-2011 05:03:12	48.10	33.40	3.5	1.200-1.300
5	26-06-2011 04:04:30	48.02	32.99	2.5	0.447-0.527
6	22-10-2011 04:06:45	48.89	33.24	3.1	1.200-1.270
7	31-03-2012 04:00:42	48.20	32.50	3.0	1.200-1.270
8	17-06-2012 04:03:16	47.70	33.57	3.0	1.270-1.300
9	28-11-2012 20:47:43	48.10	33.50	3.1	-
10	23-06-2013 21:16:33	48.04	33.42	4.6	2.000
11	29-07-2017 03:31:00	48.03	33.46	4.3	3.000-3.500
12	19-02-2018 00:35:03	47.86	33.45	2.8	17.000

For the period from 2007 to 2018 inclusive, in the city of Kryvyi Rih and near it there were 12 earthquakes. For the territory located within the generally aseismic Ukrainian crystalline shield, this number of hazardous seismic phenomena is anomalous, therefore it is extremely important to identify the causes and origin of these phenomena, to anticipate the effects of seismic impacts on the city's population and infrastructure.

2. Literature review

Recently, the seismicity of the Kryvyi Rih basin has been repeatedly covered in various scientific publications.

Volodymyr M. Shmandii, Viktor I. Bredun and O. V. Kharlamova [17] investigated an earthquake near Kryvyi Rih on December 25, 2007, and looked into the mechanism and formation of the seismic component of environmental hazard emphasizing the limitations on the practical study of specific earthquakes. Soon, Olexander M. Sklyar et al. [18], Bella G. Pustovitenko et al. [12], [13], Valentina V. Kutas et al. [8] investigated further the parameters and origin of this earthquake. Petro G. Pihulevskyi [11], [16], [19] summarized information about the seismic activity of the Kryvyi Rih – Kremenchug and Orekhovo – Pavlograd suture zones.

Yuri A. Andrushchenko, Valentina V. Kutas, Olexander V. Kendzera and others [1], [5] considered the difference between weak earthquakes which had occurred on the East European platform in 2005–2010 from industrial explosions, as well as the difference between man-made and tectonic earthquakes, in particular, the earthquakes of 2007, 2010, 2011 were discussed. The necessity of identifying seismic events and determining their origin is noted.

Olexander V. Kendzera [7], Sergii V. Scherbina, Petro G. Pihulevskyi, Iryna V. Gurova and Olha O. Kalinichenko [16], Oleg K. Tiapkin, Olexander V. Kendzera and Petro G. Pihulevskyi [19], Dmytro V. Malitsky, Sergii T. Verbytskyi, Lyudmila A. Shumlyanska, Volodymyr A. Il'yenko [14] and others studied the origin of individual earthquakes from 2011 to 2017.

An analysis of the geodynamic features of the natural – and technogenic seismicity of Kryvyi Rih basin on the interpretation of monitoring data on the hydrogeodynamic parameters of groundwater is given in the works by Petro G. Pihulevskyi, Volodymyr K. Svistun, Sergii V. Scherbina [11].

The need to create a subregional seismological and geophysical network of system monitoring to control the activation of non-tectonic processes (including natural and technogenic seismicity) in the territory of the Kryvyi Rih agglomeration, and the main steps to implement this task were discussed in the review article by Olexander V. Kendzera [7].

Lyudmila V. Feskova [5] examined the need for geodynamic monitoring, and methods of seismic protection, in order to increase the seismic resistance of the construction of industrial facilities relative to the safe operation of the Kryvyi Rih geotechnical system.

The aim of the study is to identify the influence of natural – and technogenic factors on the seismicity of Kryvyi Rih by analyzing the location of the epicenters of local earthquakes and their sequence in time in terms of the tectonic features of the territory and the nature of the technogenic interference in its structure which will minimize the impact of powerful explosions in mines and quarries on the city's infrastructure.

3. Results and discussion

Most researchers of the Kryvyi Rih earthquakes [7], [16], [19] share the view that these seismic phenomena are technogenic, directly related to technogenic impact, namely: explosive works in quarries and mines, naturally technogenic ones – associated with landslide processes in zones of shifts from iron ore mining or in other technogenic underground cavities, and tectonic, caused by the discharge of tectonic stress arising in the geological environment [16]. As a rule, the causes of such stress in the bowels are analyzed approximately, due to the complexity and insufficient knowledge of the geodynamic environmental conditions. The main attention is paid to the development of criteria and the identification of these types of seismic phenomena.

Another important criterion is the energy characteristics of earthquakes, which is closely related to the determination of the magnitude. In practice weak seismic events with $M_b = 3.5-4.5$, surface-waves of any magnitude are extremely rare. This is partly due to the fact that there are regional features in the attenuation of the surface-wave energy and specific ranges of frequencies for a Rayleigh wave, and partly due to a generally uncertain allocating a specific time interval for measuring amplitude. However, this magnitude is involved in the law of attenuation of macroseismic intensity. Therefore, in the unified catalogs involved in seismic zoning, all other energy and magnitude definitions are converted to macroseismic intensity. All recalculation formulas have inaccuracies and depend on the representativeness of the samples on which they are built. Therefore, obtaining instrumental magnitudes from a surface wave is extremely important.

Among the proposed methods for weak earthquakes, it turned out to be attractive to calculate the broadband surface-wave magnitude $M_s (V_{max})$ [5], where the assessment of surface-wave magnitude is carried out when measuring the amplitudes of a Rayleigh wave in 9 frequency intervals with periods from 8 to 25 seconds, instead of the usually used 17-23 second period. This method allowed increasing the number of M_s observations for small earthquakes at regional distances. The results obtained led to the development of a time-domain method for measuring surface waves [15] with minimal digital processing using a Butterworth zero-phase filter. This technique shows the stability of the result, both at regional and teleseismic distances. Under the conditions of a continental crust, the formula for calculating $M_s (V_{max})$ in an extended range of periods has the form 1:

$$M_{s(b)} = \log_{(a_b)} + \frac{1}{2} \log(\sin(\Delta)) + 0,0031 \left(\frac{20}{T}\right)^{1,8} \cdot \Delta - 0,661 \log\left(\frac{20}{T}\right) - \log(f_c) - 0,43, \quad (1)$$

where a_b – the amplitude in nanometers at the maximum of the Rayleigh wave, Δ – the epicentral distance in degrees, T – the period at the maximum of the Rayleigh wave, f_c – the angular frequency that is used to find the frequency band f or the filters is calculated by the formula 2:

$$f = \frac{G_{min}}{T\sqrt{\Delta}} \tag{2}$$

For continental paths and Rayleigh wave periods between 8 and 25 s, the value of $G_{min} = 0.6$ (based on dispersion effects). An algorithm was compiled at the GS RAS, in which the recommendations of the authors of M_s (V_{max}) were taken into account [5], [15].

Man-made earthquakes, like powerful explosions, are characterized by low energy, confined epicenters to the zones of mining, occurring simultaneously with the explosive operations. Any man-made explosions are clearly established by recordings on seismograms where there are no S waves and surface waves LQ (Love waves) (Figure 2).

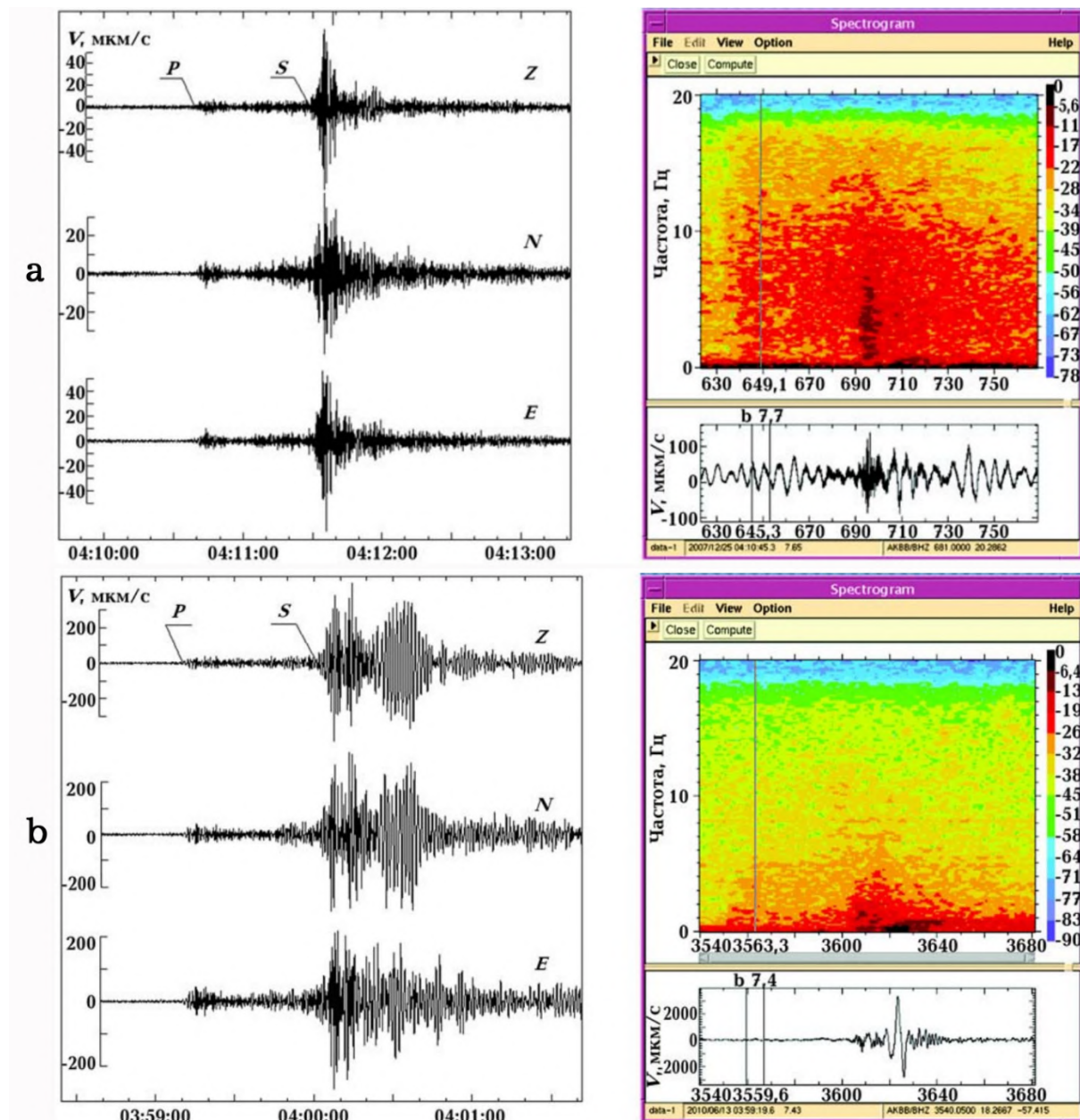


Figure 2. The records and spectrograms (screen shots) of the local Kryvbas seismic events (seismic station “Malin” PS-35, distance from Kryvyi Rih-city – 430 km, 0.5-2.0 Hz): a – the earthquake 25/12/2007, 4:09:31 UTC, $M_b = 3.3$; b – explosion in mine 22/10/2011, 03:58:45 UTC, $M_b = 3.1$ (depth – 1200–1300 m, 60 tons of explosives).

Natural technogenic earthquakes occur under the influence of natural factors, which are quantitatively and qualitatively altered by technogenesis processes. The natural process of collapse occurs within the cavities of artificially created mining operations. These processes are not controlled by humans and occur as a result of a voltage discharge that has accumulated as a result of disturbance of the natural equilibrium by technogenesis. The energy of such earthquakes can be both low and significantly exceed the energy of any explosions in mines, their places and times do not coincide either. But their direct relationship with the places of treatment works can be traced. The depths of these earthquakes do not go beyond the depths of the development of rich iron ores. The seismograms do not have a clear structure of wave entry and there are no S waves.

Tectonic earthquakes have all the signs of natural tectonic processes and they are therefore the most potentially dangerous. Their energy can fluctuate significantly and often exceed the energy of earthquakes of the second group. The depths are most often, much more than the depths of mining. The seismograms always show a clear structure of wave arrival. For Love surface waves LQ , which is not typical when recording explosions, the ratio of the wave amplitude P to the wave amplitude S is less than 1 [19].

Despite the fact that the causes of these earthquakes are of natural origin, it is possible that the proximity of the mining industry with a disrupted technogenesis, unstable zone of the Kryvyi Rih – Kremenchuk deep fault helps increase the intensity of natural tectonic deformations to a critical level at which the total stresses can exceed the rock strength and cause their destruction. An external manifestation of the influence of technogenesis on the seismicity of Kryvyi Rih basin is an increase in the number of seismic events (table 1). According to 2004 seismic zoning, tectonic earthquakes with an intensity of up to 5 points should only take place on the average once every 500 years within Kryvyi Rih basin. In reality, they happened more often in a shorter period of time. The origin of at least three earthquakes from this table, which was investigated in detail, are determined as tectonic. For two of them, their landslide origin has been proved and for two of them caused by explosives, with an explosive mass of up to 60 tons (figure 2). The rest of the earthquakes are in one way or another connected with the sites of the workings and at the same time they are caused by a significant release of energy, comparable to a small nuclear explosion if one perform a comparative analysis of their energy magnitudes. The energy of Kryvyi Rih earthquakes is often significantly more than the energy of any explosions in mines, their places and times do not coincide either. That is, this is a manifestation of the anomalous seismicity of a complex geological structure on the surface of which the city of Kryvyi Rih is located.

Determination of the parameters of Kryvyi Rih earthquakes with minimal errors is possible if there are records of at least three nearby seismic stations. Kryvyi Rih earthquakes, the parameters of which are listed in the table, were recorded by seismic stations around the world and in Ukrainian seismological networks. However, due to the lack of stations located directly in Kryvyi Rih, in the center and in the east of Ukraine, the accuracy of determining earthquake parameters is insufficient. Errors in determining coordinates are thus up to 0.03 degrees. This was the reason for the disagreement in the interpretation of the origin and the mechanisms of earthquakes.

The situation improved somewhat after the installation of a seismic station in Kryvyi Rih in late 2012. This made it possible to increase the accuracy of determining the parameters of earthquakes using records of the Crimean seismic network, and to establish the landslide nature of the earthquake on November 28, 2012 [16].

It is well known that the accuracy of determining the mechanism and origin of earthquake organization depends on the accuracy of determining the parameters of the earthquake. To get an unambiguous solution, one nearby station is not enough. With the expansion of the seismic network in central Ukraine, the start of seismic stations in the Dnipro, Zaporizhia, Kremenchuk, Poltava, it became possible to accurately determine the parameters of the earthquake 07/29/2017 (from records of 8 stations) and, accordingly, unambiguously establish the nature of the earthquake as a tectonic related to displacement blocks along the fault [19].

A more reliable determination of the parameters of earthquakes and, accordingly, their identification allows a more accurate analysis of both natural and technogenic factors of these phenomena, taking into account local conditions for their localization. For example, for the seismic events of June 23, 2013 and July 29, 2017, the establishment of close coordinates of the epicenters located in the central part of Kryvyi Rih between the sludge dumps of the Central Iron Ore Enrichment Works (CGOK) and the zones of shift from mining of rich iron ores (figure 1). The first earthquake was identified as a landslide (natural-technogenic). Its magnitude – 4.6 was high, as for such phenomena and may indicate the displacement of a significant amount of rocks, although this was not reflected in the relief of the earth's surface. The next earthquake occurred after 4 years and had all the signs of a tectonic process. It was accompanied by acoustic phenomena, not typical for Kryvyi Rih earthquakes. It may indicate the activation of fault structures in the complex zone of the Kryvyi Rih – Kremenchuk deep fault. Despite the precise localization of these seismic events, it is possible to conclude that the first of these earthquakes, which had a natural-technogenic character, accelerated or started the release of their own reserves of elastic energy, which accumulated in the Precambrian crystalline rock mass.

The technogenic factor that contributed to the disruption of natural balance in this region leading to the implementation of this chain of events, is the localization to the west of the Kryvyi Rih – Kremenchuk deep fault zone (which has a north-western fall) of the slime storage of the CGOK bordered by dumps, which holds much more than 300 million m³ liquid waste enrichment. Filtration of water from the slag storage facility is carried out both to the west towards the Karachunivka reservoir and to the southeast – into fault zones and a zone of shear from mining of rich iron ores and, accordingly, towards a depression funnel created by mine drainage. Numerous underground cavities are located within the depression funnel, which create a redistribution of masses and disturbances of the natural balance. The role of these technogenic factors in the seismic activation of fault structures must be studied in the future.

Despite the fact that in the determination of the coordinates of earthquakes for that period, there was some uncertainty due to the lack of nearby seismic stations (error 0.2–0.30° in latitude 0.15–0.4° in longitude), a similar causal relationship can be traced in the seismic events of 2010 and 2011. First, a powerful landslide (natural-technogenic) earthquake occurred on June 13, 2010, which manifested itself on the earth's surface by the formation of a huge dip in the shear zone and partially beyond it and was triggered by an underground massive explosion at a neighboring mine. A year later an earthquake occurred on January 14, 2011 in the same area, which had signs of a natural tectonic process. It was also preceded by an underground explosion at the mine and the moment of neotectonic activation by the water level in the observation well, where on January 7, 2011. A decrease in groundwater level of 7–8 cm was recorded. This was due to the disclosure of a network of small faults and cracks [16]. In turn, this earthquake provoked the release of a funnel in the shear zone of the CGOK on January 18, 2011.

Thus, the assumption that technogenesis has qualitatively and quantitatively changed the nature of natural processes and is quite acceptable. The tectonic earthquakes that occur in the Kryvyi Rih region should also be attributed to natural-technogenic, since their factors were changed by technogenesis, as suggested [17]. The authors classified such earthquakes in the category of discharge ones, suggesting that the discharge of technogenic stresses occurs along zones of active neotectonic faults, and collapses in underground cavities. This is not their main cause, but only provoking and reinforcing factors [4], [9].

The classification of technogenic seismicity [5], available in geodynamics, to a certain extent more clearly reflects these patterns. According to this classification, seismic vibrations that occur immediately at the time of anthropogenic impact, are defined as primary seismicity.

All seismic phenomena that occur in a mountain massif for various reasons after or during anthropogenic impact are commonly called reduced seismicity. In turn, induced seismicity is divided into two categories: induced (excited) seismicity and trigger (initiated) seismicity.

The source of primary seismicity is technogenic factors, in particular such as demolition work in mines, quarries, and the like. It manifests itself in the form of a certain time interval of seismic waves,

the duration of which is determined by the conditions of the explosive process, and the amplitude of the oscillations is determined by the energy of the explosion and the distance from where it takes place.

Any forms of technogenic seismicity that is formed after primary seismicity, are reduced seismicity. Induced seismicity is the result of various human influences on the earth's crust taking place dynamically, slowly growing, static or periodically. The main characteristic feature of induced seismicity is that the source of its manifestation is both its own reserves of elastic energy in the medium and the energy transferred to the medium during exposure.

Induced seismicity usually manifests itself in the form of relatively weak shocks during technogenic impacts both in tectonically active rock masses and in rocks with a low level of stress state. Due to the influence of stored energy in the medium, a certain level of stress state triggers the activation of the deformation processes. Hypocenters of induced seismicity are usually located within the influence area of a technogenic source. The oscillation energy during induced seismicity is usually not large and is limited by magnitudes $< 3.0-3.5$.

Trigger seismicity arises due to the release of its own energy reserves in the geological environment under the influence of external technogenic sources. The energy of vibrations generated in this case will be determined by the level of tectonic stresses and the size of the region with this level of stresses. The energy of trigger seismicity can exceed the energy of anthropogenic impact. Trigger seismicity can sometimes occur during industrial impacts in non-seismic or weakly seismic regions. Man-made impact only triggers and accelerates the process of releasing own reserves of elastic energy in the array. Thus, the manifestations of tectonic seismicity indicate that the technogenic changes in the geological environment in Kryvyi Rih have reached a certain critical point, and if landslide earthquakes are localized in the fault zones and their energy depends on the size of these zones, then the energy of tectonic triggers earthquakes. It is thus difficult to predict and to what extent they constitute a significantly greater seismic hazard.

The almost 140-year-old mining of iron ore in Kryvyi Rih has created enough conditions for disturbing the balance of the geological environment and the appearance of tectonic stresses in the bowels of Kryvyi Rih basin, the discharge of which causes earthquakes [5].

Among the technogenic factors that upset the balance of the geological environment are the following:

- redistribution of masses in the bowels of the Earth and on its surface significantly changes the distribution of local fields of tectonic stresses (the creation of huge quarries, dumps, sludges, underground cavities, shear zones);
- changes in hydrogeological conditions (the creation of a depression funnel of ground waters as a result of water reduction in iron ore mining sites, causes a large gradient in the velocities of these waters in the surrounding massifs and, as a result, changes in the stress state and rock properties that affect the nature of groundwater movement);
- constant exposure to working mechanisms and periodic explosions in mines and quarries, which affects the physical properties of rocks;
- continuous growth of depths and scale of mining operations [10].

An example of the fact that earthquakes do not always occur in underground mining of iron ore, as well as in other areas transformed by technogenesis, is an earthquake that occurred 2018-02-19 00.35.03. The parameters of this earthquake were determined from the records of three stations located in Kiev (Kiev IRIC) (USGS) and Zaporizhia (PDUO and ZAES) (Local seismic network). The stations are distant, that is, some errors in determining the parameters are likely. The coordinates of the epicenter 47.86 950; 33.45 300, indicate that it was in the industrial zone in the south of Kryvyi Rih and was felt by residents mainly in the southern part of the city. The magnitude of the earthquake is 2.8, and the depth is 17 km. If we take into account the nature of the recording on the seismogram, the obtained depth of the hypocenter, it may be concluded that the earthquake was tectonic. The location of the epicenter in the south of Kryvyi Rih basin indicates that stress in the geological environment can also occur outside the Kryvyi Rih – Kremenchuk deep fault zone in areas transformed by technogenesis. The largest quarries are concentrated in the south of Kryvyi Rih basin (PGZK, Novokryvorizhsky GOK)

where systematic explosions occur, quarries are surrounded by dumps, as well as sludge dumps from which filtration occurs and groundwater penetrates into the fault zones through cracks. It is likely that the earthquake was the result of a discharge of stress in the neotectonic fault zone.

Thus, one cannot deny the influence of technogenesis on the anomalous seismicity of Kryvyi Rih basin and also associate it with one kind of anthropogenic impact. Natural balance is disturbed by a complex situation of triggering technogenic factors.

Given the power and scale of the modern technogenic impact on the geological environment, its instantaneousness compared to geological time, the violation of natural equilibrium and the activation of seismogenic processes can be expected not only in Kryvyi Rih basin, but also in other mining regions of Ukraine. It is therefore necessary to create and expand the existing seismological networks in the future [19].

For the territory of the East European platform, the potential maximum magnitudes of earthquakes are possible ($M_b = 5 - 5.5 - 6.6$), determined from data on the bending of the earth's crust, the intensity of modern tectonic deformations, heat flux, the depth of the Precambrian basement and the Moho border [6]. Now, the energy of the Kryvyi Rih earthquakes did not exceed these values – max $M_b = 4.3-4.6$. But if earthquakes with potentially maximum magnitudes, take place in Kryvyi Rih basin, it can have significant negative consequences.

For example, the area of intense shaking of the 2017.07.29 earthquake was within the urban area. In order to determine the intensity (strength) of the earthquake, a survey of the residents of Kryvyi Rih was conducted (figure 3).

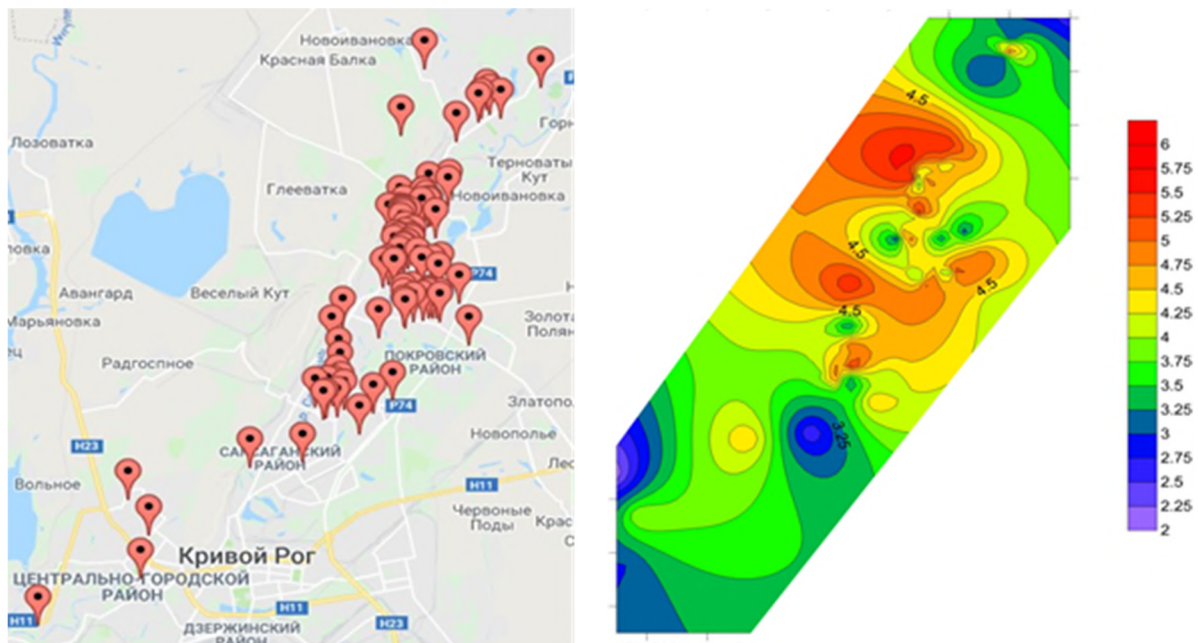


Figure 3. Map of the survey of city residents (1), map of the earthquake isoseismists of 07/29/17 based on the results of the survey (2).

With the number of polls 96, it was determined: the maximum value of the score 5.5; the minimum is 2.5; the average value is 4.2. The magnitude of the earthquake is 4.3, and the maximum divinity, as we see more and it is not determined at the epicenter itself. The distribution of pestilence on several floors of multi-story buildings was also examined and it was found that there is a tendency to increase the magnitude on each floor by 0.1 points on average [16], [19]. Thus, in the event of the occurrence of earthquakes in Kryvyi Rih basin with the highest possible magnitudes, at small depths of hypocenters, the magnitude can increase to critical values of 7–7.5 and even 8 on the upper floors of high-rise

buildings, and this will be accompanied by the destruction of these floors and possibly some brick houses [2].

4. Conclusions

Considering the unique nature of the Kryvyi Rih iron-ore basin – its location in the Kryvyi Rih – Kremenchug deep fault, the significant duration and the scale of man-caused interference with its subsoil, it is necessary to continue comprehensive studies of present-day geodynamic processes occurring in the geological environment in order to provide detailed assessment of the effect of particular man-caused and natural factors on abnormal seismicity of the territory. The introduction of systematic seismic monitoring shall play a leading role in the said research. For this, as has been repeatedly noted, it is necessary to:

- create a local seismic network from at least 3 seismic stations and seismic data processing service;
- continue to study the geodynamic conditions of the territory of Kryvyi Rih basin by monitoring the hydrogeodynamic parameters of groundwater and by introducing seismic gravity monitoring as promising methods for predicting local earthquakes.
- to implement online general microseismic monitoring on the premises of all mining enterprises.
- compile a map of active neotectonic disturbances based on a generalization of geological, geophysical, seismic and geodynamic studies of the Kryvyi Rih region.

The next step should be microseismic zoning of the city based on the results of systematic monitoring and studies of active fault zones the use of scientifically based stabilizing measures and increase the seismic resistance of buildings and structures. Funding for these studies is needed, both at the state and local levels.

The conscious response of the population to any seismic events, irrespective of their magnitude, shall play an important role in microseismic zoning. This applies to the assessment of seismic impact on objects, houses, human consequences, objective recording of this impact and active participation in the survey. Raising the awareness among city residents is possible by means of popularizing knowledge about the seismicity of Kryvyi Rih basin among the population making an emphasis on the most active part of employees at mining enterprises, as well as on the students.

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The turmite-based cryptographic algorithm

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The turmite-based cryptographic algorithm

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Abstract. The novel turmite-based cryptography algorithm has been designed and implemented. The turmites ability to generate pseudo-random number series makes them promising for cryptographic applications. At the same time, most turmites-related researches concentrate on their mathematical properties and generally don't consider possible applications. Lack of effective implementations of turmites-based cryptographic algorithms makes this research topical. The properties of the proposed algorithm have been examined. The frequency analysis resistance and avalanche criterion have been estimated. The results demonstrate that turmites-based algorithms may be used in cryptography and this application deserves attention and further examination.

1. Introduction

The number of computer crimes grows constantly. A lot of people use Internet-banking, e-mail, social networks, and electronic passports, which hold personal information. Smartphones and computers keep synchronized with cloud storage documents, often owned by a third party, so users security depends on the third party integrity. Recent years events show that personal information leaks may cause material and moral damage for owners. Hence nowadays, information protection issues go far beyond the military and corporate scope. Virtually everyone, consciously or unconsciously, deals with data and personal information, which may be abused and compromised. Therefore, cryptography is presently one of the leading scopes of Computer Science.

Until now, cryptography has been employed to ensure the confidentiality of messages (that is, encryption) via message transformation from a clear into an encoded form and vice versa. Thus, it will be impossible for a third party to read the message without secret knowledge (namely, the key required to decrypt the message). In the first two decades of the 21 century, the scope of cryptography has expanded and now includes not only the secret message transmission, but the sender identification and recipient authentication, digital signatures, interactive verification, secure communication techniques, etc.

A turmite is a Turing machine that has infinite two-dimensional cells array, current state, and orientation in space. Turmites may be divided into those with relative and absolute orientation. Relative turmites have their internal orientation. Program instructions change their orientation relatively: “left”, “forward”, “right”, and “turn around”. An example of such a turmite is Langton’s Ant [9].

Let’s consider the rules of the Ant movement. We have endless plane with black and white square cells and the Ant situated in some cell. At each step it can move in any one of the four neighboring cells. The Ant moves according to the following rules:

- at a black square turn 90° counter-clockwise, change the cell color to white, then move forward one square;



- at a white square turn 90° clockwise, change the cell color to black, then move forward one square.

These simple rules cause quite complicated behavior: after a certain period of quite random moves, the Ant always begins to build a pattern of 104 steps, which is repeated infinitely, regardless of the initial coloring of the field [3].

The quality of the encryption algorithm depends mainly on its strength, i.e. cryptanalysis resistance. If a successful attack requires unattainable computational resources, unattainable number of overheard messages or unattainable time, then such an algorithm is considered to be strong. In most cases, it is impossible to prove mathematically the algorithm strength, while it's often possible to prove the cryptographic algorithm vulnerability.

2. Results and discussion

2.1. The algorithm designs

Despite the fact that Langton's Ant have been a research subject for a long time [1], [2], [6], [7], [9], it is rarely considered to be used in cryptography. However, some researches imply that it generates usable pseudorandom number sequences [4], [8].

While studying the possibility of Langton's Ant cryptography application, we have found the only implementation [10], but it has a number of shortcomings. This implementation takes into account just digital images encryption and tends to modify primarily less significant bits (LSB). It may cause the serious cryptographic strength reduction. Furthermore, while multiple Ants act simultaneously, one of them can annihilate another.

Evidently, the cryptographic Langton's Ant application has not been adequately studied). Turmites have great potential in cryptography, and need further study. Taking into account the aforesaid, the following requirements for our algorithm have been introduced:

- the algorithm should be capable of encrypting across-the-board data;
- the algorithm should change all bits with the same probability, not only LSB;
- the data should be encrypted by several turmites;
- each turmite should have its area and not block the actions of others.

Our implementation of the algorithm has the following scheme:

- split the file with input data into blocks of the same size;
- translate each block into a bit matrix that will be used as a turmite's field (bit values "0" and "1" represent two cell colors of the original Langton's algorithm);
- select randomly the starting positions of the turmites;
- further, according to the rules of the Langton's ant movement, perform the bitwise encryption of data.

We implemented the periodic boundary conditions, so after jumping over block's edge, turmite appears at the opposite side. It ensures the Ant's unfettered run on the plane.

The algorithm of creating the keys deserves particular attention since it depends on several parameters and its size increases in proportion to the file size growth. The encryption key to one turmite consists of the starting position, the starting orientation, and the number of steps. The decryption key contains the final position, the final orientation, and the number of performed steps. The encryption key is partially defined by user, while the decryption key is calculated by algorithm.

Figure 1 shows the algorithm for the decryption key.

2.2. Experimental results

The examination of the algorithm's properties allowed us to determine the optimal encryption parameters. The first thing we investigated was the number of Ant's steps, since it is known that after a certain period of rather random motion Langton's Ant always begins to build a recurrent pattern of 104 steps that repeats indefinitely, regardless of the initial field state [3].

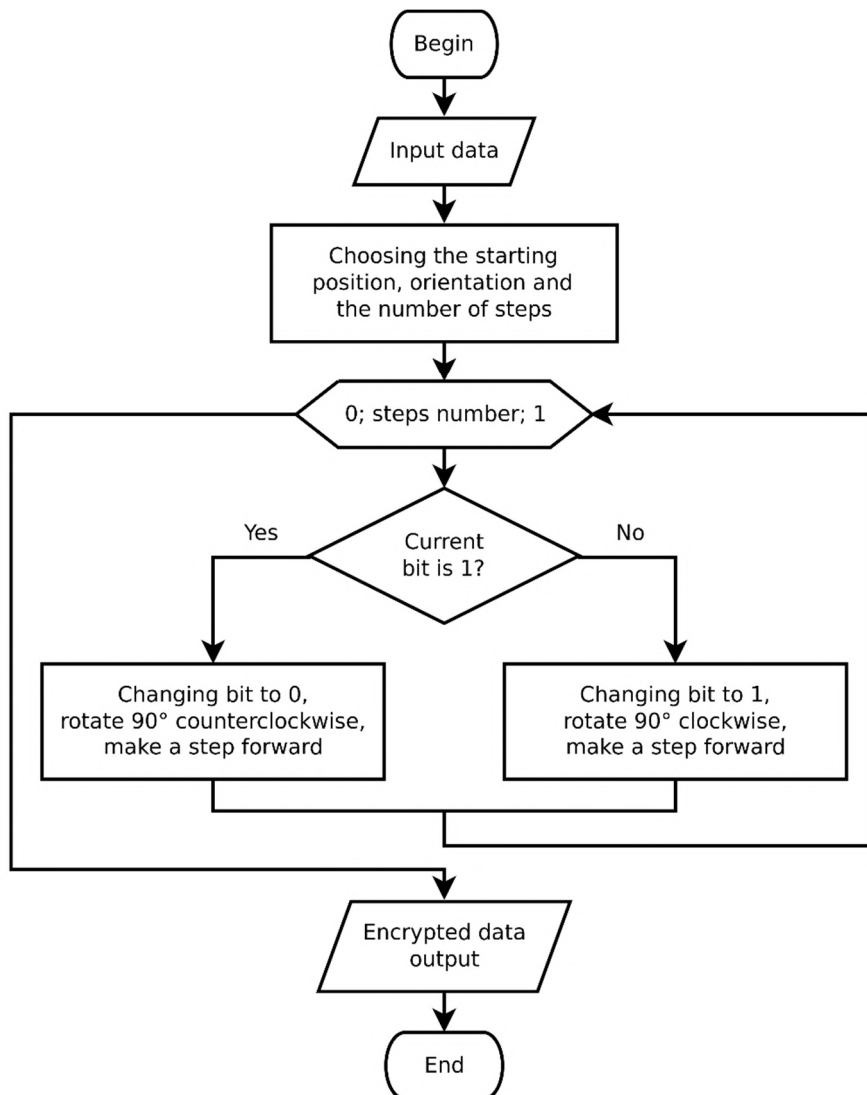


Figure 1. The flowchart of the algorithm.

To test this phenomenon, the bit change matrix has been introduced. We took blocks of different sizes and checked how many steps in each block should be done to encrypt about 80% of the data. For more accurate results, the test has been applied to multiple files of different types.

Figure 2 shows the dependence of steps number on block size.

It can be seen that steps number increases with block size growth. And this increasing is more intensive for blocks larger than 100 bits. Therefore, for encryption it is preferable to use blocks of size fewer than 100 bits.

Now let's test how the number of modified bits varies depending on the quantity of steps. We introduce some coefficient n , which shows the ratio of the encrypted bits number to the number of steps. It will help estimate the optimal block size, since the more n is, the more efficiently algorithm works.

The table 1 below shows the dependence of the modified bits number on the number of steps for different block sizes.

In order to see whether the Ant moves all over the block or its movement localized at some area, it have been built the matrix of modified bits that shows which bits were visited by Ant.

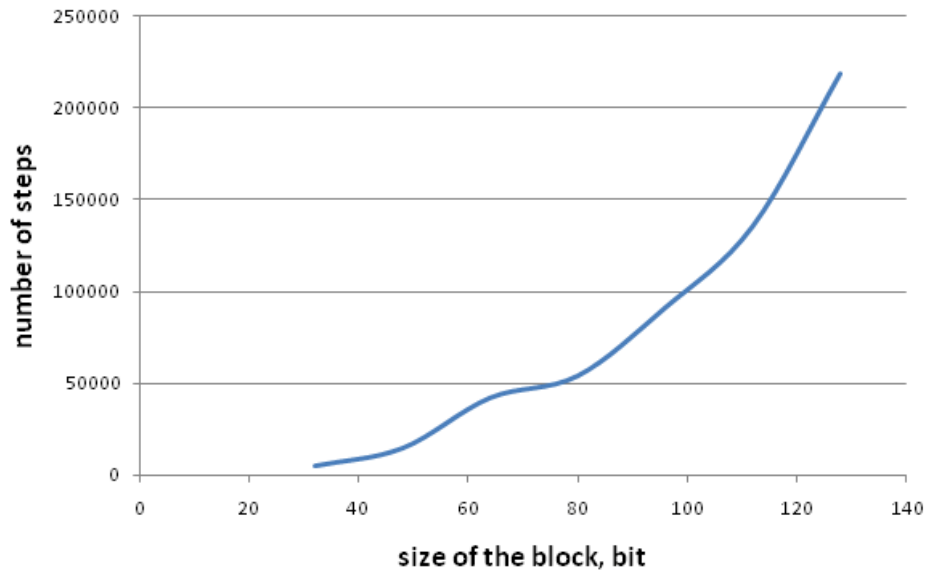


Figure 2. The dependence of the number of steps on the size of the block.

Table 1. The dependence of the modified bits number on the number of steps for different block sizes.

Block size	The number of modified bits	The number of steps	n
32×32	819	5104	0.16
48×48	1843	14774	0.12
64×64	3276	42128	0.08
80×80	5120	54072	0.09
96×96	7372	91155	0.08
112×112	10035	135439	0.07
128×128	13107	218522	0.06

Figures 3–4 show three matrices of modified bits for different types of data (from left to right: text, graphics, and sound). Black color marks the areas visited by Ant, and white cells indicate unvisited areas.

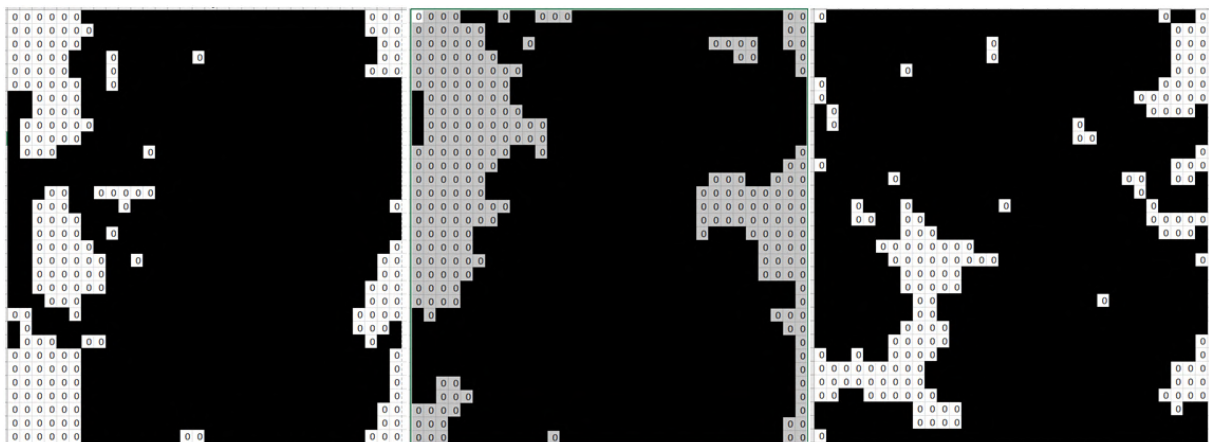


Figure 3. The matrices of modified bits distribution for block size 32×32 .

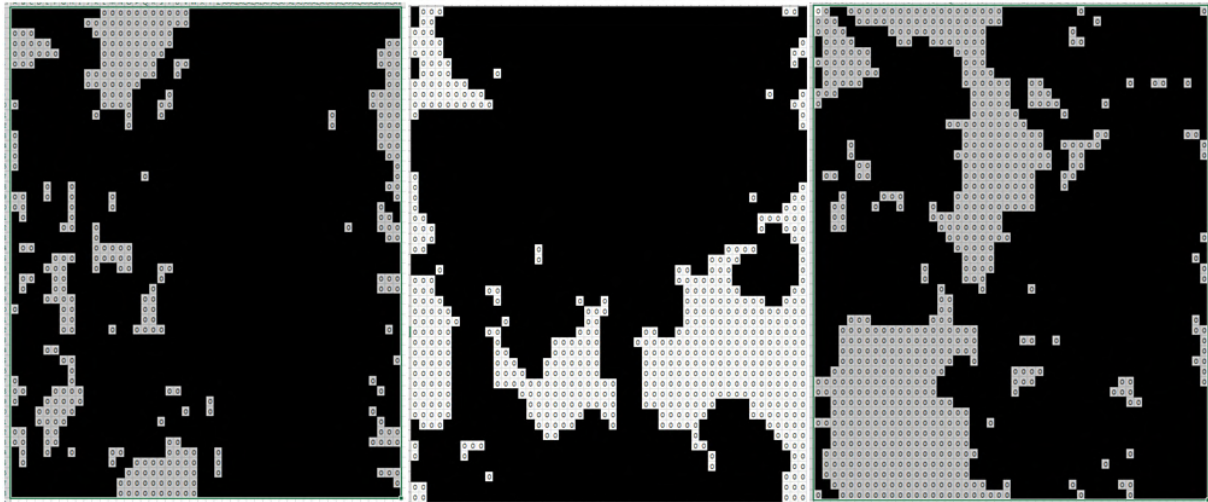


Figure 4. The matrices of modified bits distribution for block size 48×48 .

As it is seen, that the Ant moves all over the block rather than concentrating in one area.

Therefore, we may conclude that the step number and the block size are dependent on each other. The smaller the block, the fewer step number we need to cover it. The most effective appears to be the 32×32 block because it has the largest value of n parameter, namely 0.16. Hence, for further research we used the 32×32 block and 5104 steps.

To examine the quality of encryption, we considered the encrypted data byte distributions. It is known that the letter frequency in languages corresponds to the normal distribution, and it often becomes the vulnerable place in cryptographic algorithms. So, for security issues, it is necessary that the character distribution in the output file corresponds to the uniform distribution. To check the byte distribution, we used the Pearson's chi-squared test.

As a result, the Pierson's criterion equals 1.05 for encrypted text files, 3.46 for graphic files, and 1.03 for sound files. It is much less than the critical value, which is more than 15. Therefore, we can accept the hypothesis that the distributions are uniform.

We also calculated the correlation coefficient to ensure that there is no dependence between input and output data. The correlation coefficient is -0.03 for text files, 0.67 for image files, and 0.1 for audiofiles. Hence, we can infer that there is correlation between input and output data stored in graphic files.

To resolve this issue, we increased twofold the step number and calculated the Pearson's criterion and correlation coefficients again. As a result, we obtained the following values of Pearson's criterion: 0.98 for text files, 1.47 for images, and 1.07 for audio. It is much less than the critical value, which is more than 15. Therefore, the distributions can be considered uniform. The new values of correlation coefficient were -0.03 for text files, 0.01 for images, and -0.06 for audio. The obtained results allow us to imply that there is no correlation between input and output data, and the output data corresponds to the uniform distribution. Therefore, the algorithm should be resistant to frequency analysis.

Afterwards, we have tested if the algorithm satisfies the avalanche criterion [5]. It does if all output bits change with a probability of 50%, provided a single input bit is changed. Figure 5 shows the bit difference matrix for two encrypted files that had just one different bit before encryption. In this matrix, "1" (black cell) means that the bit is different in two files after encryption, and "0" means that the bit is the same in both files.

From figure 5 we can see that two similar files after encryption have 92 equal bits, which is 18% of file size. To satisfy the avalanche criterion, we had to slightly modify the algorithm. To make the Ant's movement random, we decided to choose its initial position and direction randomly instead of determining by user's key. In that way, we implemented the cryptographic salt.

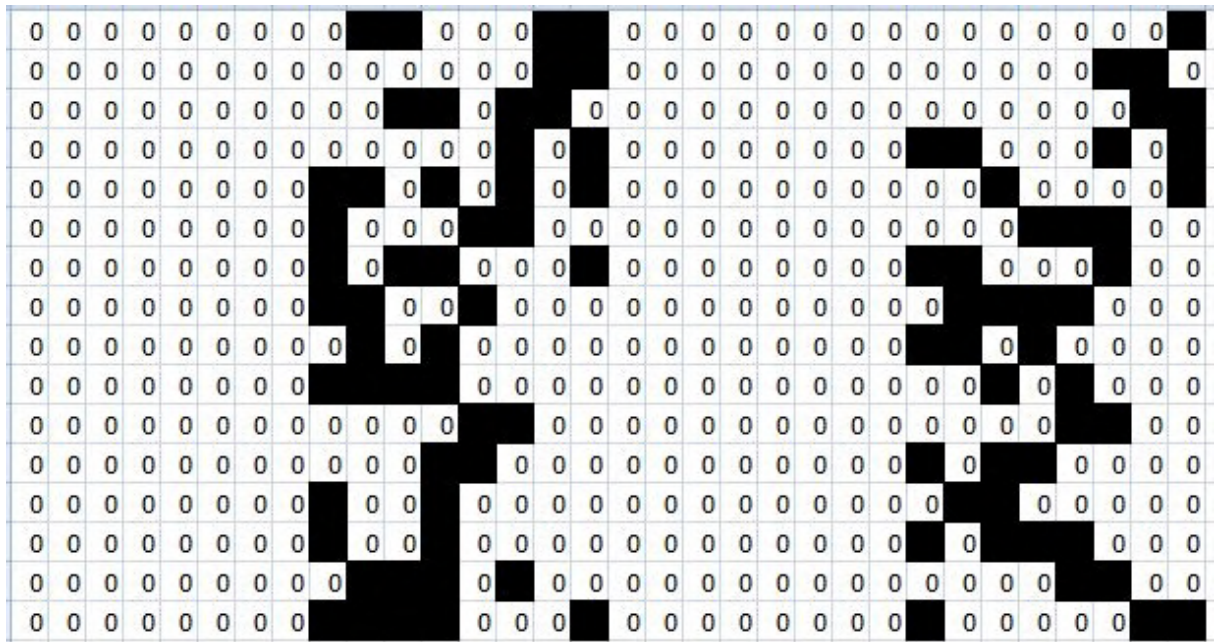


Figure 5. The bit difference matrix.

The new bit difference matrix is shown in figure 6.

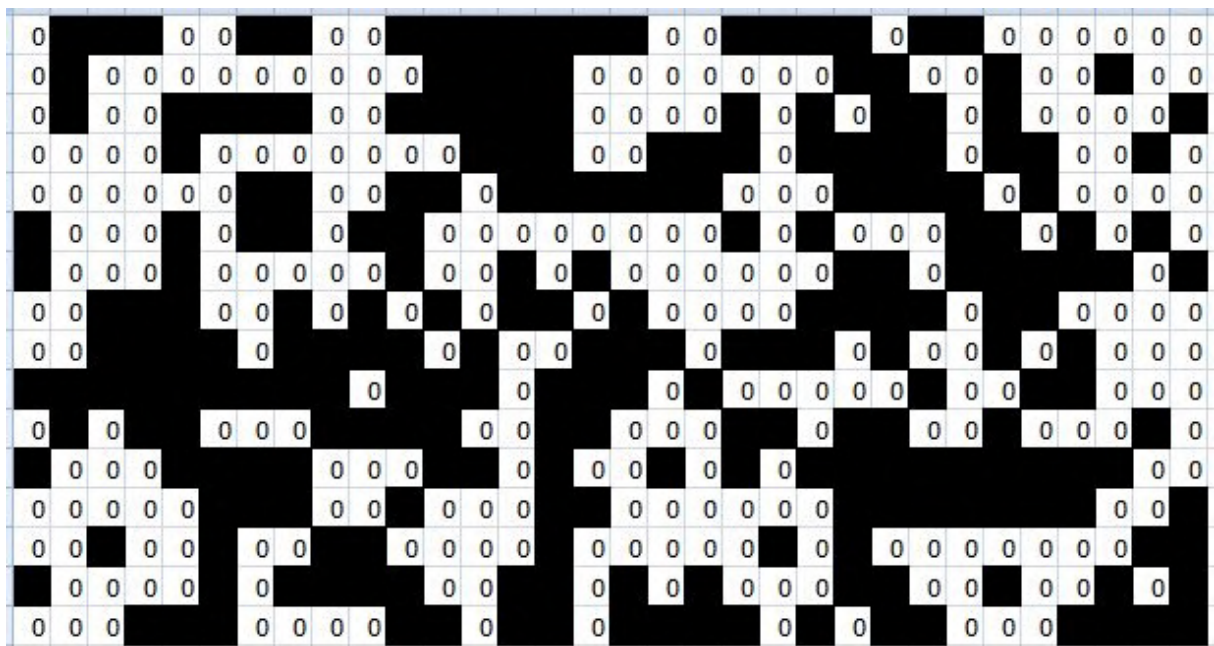


Figure 6. The bit difference matrix after cryptographic salt implementation.

From figure 6 we can see that two similar files after encryption have 239 equal bits, which is 47% of file size. It means that the algorithm meets the avalanche criterion.

3. Conclusions

The analysis of the current cryptographic turmite application shows that the issue remains topical. The attempts to implement the algorithms reveal a number of shortcomings that call into question their

practical usability. Taking it into account, we introduced the functional requirements to our algorithm. The Qt library has been chosen for software implementation because of its cross-platform features and sufficient performance due to optimization capabilities of the C++ compiler.

The analysis of algorithm's properties allowed us to optimize its parameters, such as block size and steps number. The algorithm resistance to the frequency analysis and the avalanche criterion satisfaction have been tested, as well. In the future, the algorithm may be improved by implementing Turmites with different movement rules.

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The dynamics simulation of knowledge potentials of agents including the feedback

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The dynamics simulation of knowledge potentials of agents including the feedback

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Abstract. The conceptual and mathematical models of the agents' knowledge potential redistribution considering their constituent components are constructed in the paper. A nonlinear model describing the dynamics of agents' knowledge potentials is developed taking into account the feedback effects (agent – student) on the source of knowledge (teacher / lecturer). In particular, the procedure of constructing a multicomponent two-dimensional array of discrete values of the knowledge potential constituent components for generating procedures to enhance (improve) the professional competences of knowledge sources, is generalized and specified.

1. Introduction

In a changing and closely interconnected world, everyone needs a wide range of skills and competences that need to be developed throughout their lives [18]. Therefore, one of the contemporary visions is to analyze and study the formation of a person-oriented educational trajectory that is a personal educational (training) program of a person, which provides with the acquisition of professional competences that correspond to their abilities, interests, motivation, psychodynamic and emotional characteristics, age and level of knowledge potential (for example, in the form of hard skills and soft skills, etc.) [15].

Thus, the construction and analysis of mathematical and information models of the formation of teachable and measurable abilities (hard skills) that can solve complex problems, is a necessary and urgent task.

2. Brief literature review

An analysis of studies [6], [13], [14] have showed that a lot of scientists focused to develop models that reflect the interaction processes between the objects of the educational sector and the labor market and the modernization of educational programs. Nowadays, these results cannot be used in practice in all cases.

Despite the rapid research development of knowledge dissemination modeling, it is known a little about how knowledge potential is created and transmitted. Since the processes of knowledge dissemination between individuals (agents) are characterized by complication, dynamics, adaptation, and nonlinearity, they are heavy for empirical research. It means that computational (computer) modeling can be a useful tool to study the dynamics of knowledge transfer between agents ([1], [11]).



An agent-modeling approach to study the knowledge dissemination was used by Morone and Taylor, Xuan, Hirshman, Giacchi and others. These researches mainly concerned the influence of network (agent group) properties on knowledge dissemination within that network (organization). In particular, Morone and Taylor, using a cellular vending machine model, studied how knowledge is transferred through a network where agents interact through direct communication. Their scientific works represents the effect of network structure on the learning process ([10], [16], [19]).

Xuanet and others have explored the impact of the knowledge relation structure on knowledge transfer in this network. They have shown that the diversity of knowledge facilitates their dissemination.

A lot of scientists used agent-based modeling formed on the mechanism of homophily to study the effects of the social connection level. They have positioned the society where agents interact with their counterparts ([2], [9]). Their works propose that simulation of the emergence of multilevel social relations using a homophilic model is possible, and the simulation results are up to the models observed in real human networks.

In the model proposed in scientific work [10], agents (nodes) transmit knowledge based on two criteria, namely knowledge distance and confidence. They display that in a more distributed network configuration, the dynamics of knowledge discussion and confidence level are much greater than the centralized structure [19].

Generally, in the studied knowledge dissemination models, knowledge is represented in several ways as a stock (each agent has a primary knowledge level, which is an integer selected randomly from a given range), as a tree where a little potential knowledge corresponds to each node or as a set of facts that characterizes the agent’s knowledge matrix [7].

As result, the purpose of this work is to analyze and develop a mathematical model of the redistribution of potential of knowledge processes in the derivation of the agent’s professional competence system.

3. The problem formulation

The numerical characteristic that helps fix a some level of agent’s knowledge, gathered during training, life experience, etc., has been suggested in our previous works ([3], [4], [5]) to call as knowledge potential ϕ .

It has been constructed the so-called diffusion-liked models of information processes of knowledge potential redistribution in the educational social and communication environment of the city and focuses on the description (simulation) of processes of knowledge potential redistribution in the system formation of professional competences. The competence usually means a functional combination of intellection, ways of cogitative, views, evaluates, skills, capacity, and other private properties of that determines a person’s capability to successfully pursue professional and further educational activities [5].

It is estimated that a particular competence is described by a definite of components of knowledge potential and their constituents.

Using $\phi_{q,l,k,m,\varepsilon}$, it is denoted the value of q constituent of l knowledge potential component of k agent at m time ($l = \overline{1, l^*}, q = \overline{1, q^*}, k = \overline{1, k^*}$).

For example, figure 1 presents some characteristics of competence formation based on the constituents and components of the knowledge potential.

In general, as in [5], the set of all possible components of the knowledge potential constituents at a given time situation can be characterized by a matrix (two-dimensional array (with the size $l \times q$)):

$$\begin{pmatrix} \phi_{1,1,k,m,\varepsilon} & \phi_{2,1,k,m,\varepsilon} & \dots & \phi_{q^*,1,k,m,\varepsilon} \\ \phi_{1,2,k,m,\varepsilon} & \phi_{2,2,k,m,\varepsilon} & \dots & \phi_{q^*,2,k,m,\varepsilon} \\ \dots & \dots & \dots & \dots \\ \phi_{1,l^*,k,m,\varepsilon} & \phi_{2,l^*,k,m,\varepsilon} & \dots & \phi_{q^*,l^*,k,m,\varepsilon} \end{pmatrix}$$

where ε is any small variable that will characterize further disturbing effects on the learning process. The complex of potential subsets of such an array will be joined with the set of competences gained by agents during educational.

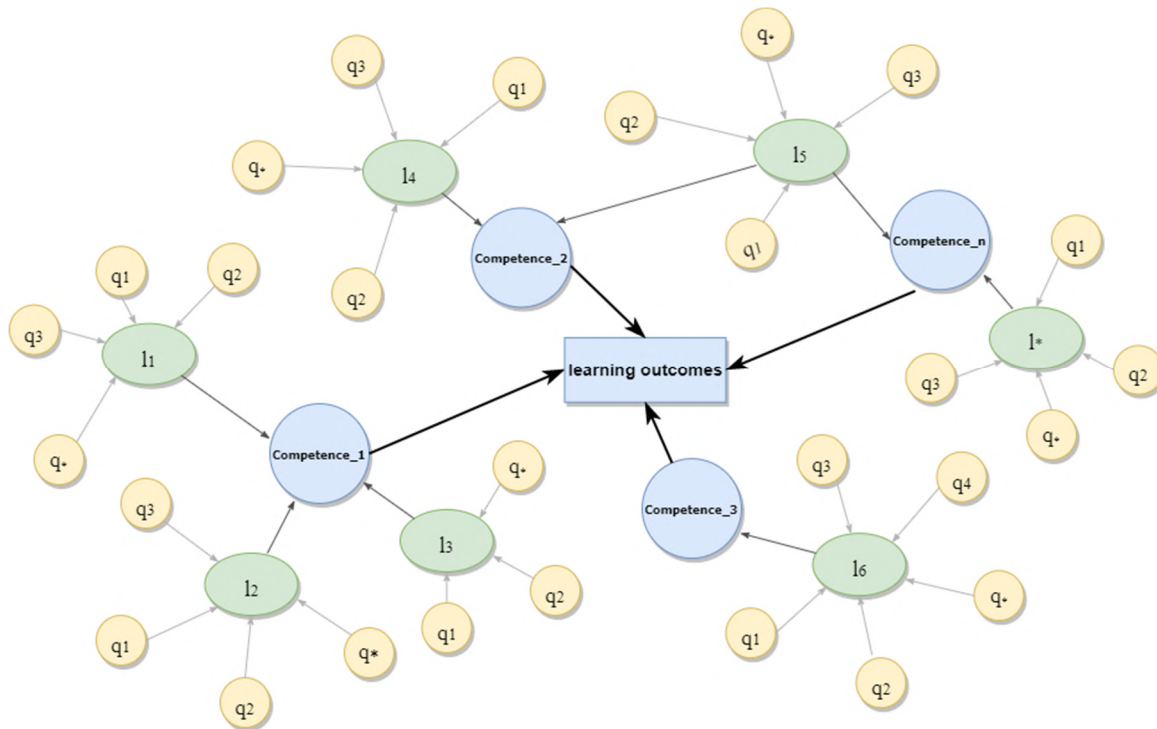


Figure 1. Components of competencies.

It is shown some examples of such subsets on figure 2.

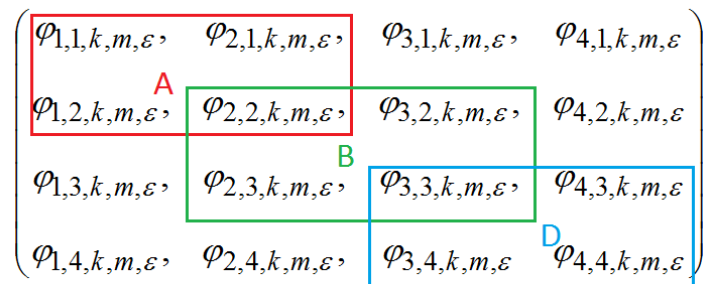


Figure 2. Schematic image of competence.

It is set out to form such subsets to satisfy certain optimal conditions for training costs and program outcomes, with regard to the needs dictated by stakeholder conditions.

4. Mathematical model of the reverse influence process

The acquisition of professional competences and the implementation of program learning outcomes are the result of three forms of interaction ([12], [17], [8]):

- Agent / Knowledge Source (teacher / lecturer);*
- Agent / Agent;*
- Agent / Educational Content*

In this paper, it is described not only the interaction between agents (learners), knowledge sources and learning content, but also the feedback between teachers and agents, as well as the educational content used to enhance the level of knowledge potential (figure 3).

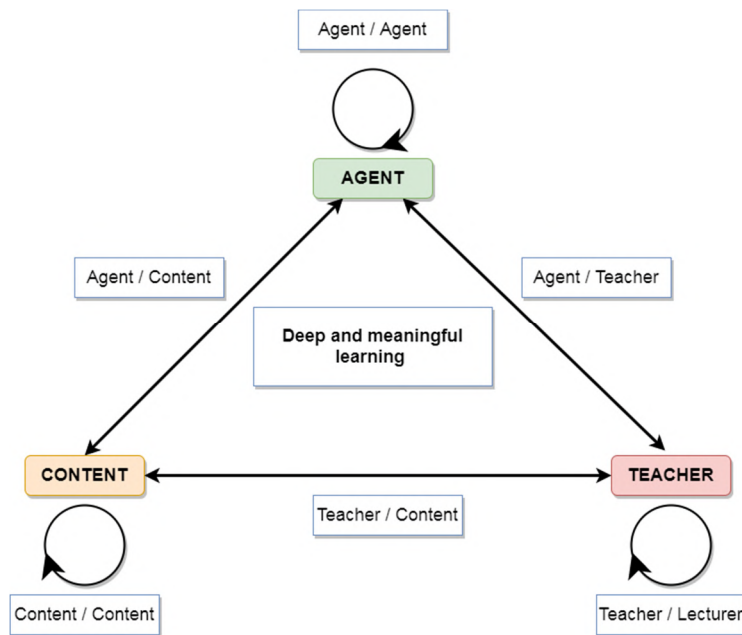


Figure 3. Forms of interaction between agents, teachers and educational content.

As mentioned in [4], the process of knowledge potential redistribution (including the acquired knowledge) at the next time stage without considering the knowledge redistribution between agents is represented as:

$$\phi_{q,l,k,m+1,\varepsilon} = \phi_{q,l,k,m,\varepsilon} + \sum_{\tilde{m}=1}^{m+1} (f_{q,l,*,\tilde{m}} + \varepsilon\alpha_{q,l,k,\tilde{m}}f_{q,l,k,\tilde{m}}^*(\phi_{q,l,\tilde{k},\tilde{m}}; \tilde{k} = \overline{1,k^*}, \tilde{m} = \overline{1,m+1})) \quad (1)$$

where $f_{q,l,*,\tilde{m}}$ is the main part of the characteristic of the knowledge source (teacher), and $\varepsilon\alpha_{q,l,k,\tilde{m}}f_{q,l,k,\tilde{m}}^*$ is the corresponding correction (disturbing influence) on the traditional nature of the knowledge presenting by the teacher / lecturer, depending on the final needs (requirements) of the agents ($f = f_* + \varepsilon\alpha f^*$ is the general characteristic of the knowledge source).

It can also be directly formed redistributions in time of the constituents of knowledge potential components, for example, as follows:

$$\begin{aligned} \phi_{q,l,k,1,\varepsilon} &= \phi_{q,l,k,0,\varepsilon} + f_{q,l,k,1,\varepsilon} = \phi_{q,l,k,0,\varepsilon} + f_{q,l,* ,1} + \varepsilon\alpha_{q,l,k,1}f_{q,l,k,1}^* \\ \phi_{q,l,k,\tilde{m},\varepsilon} &= \phi_{q,l,k,0,\varepsilon} + \sum_{\tilde{m}=1}^{m+1} f_{q,l,* ,\tilde{m}} + \varepsilon\alpha_{q,l,k,\tilde{m}}f_{q,l,k,\tilde{m}}^*, \\ \phi_{q,l,k,m+1,\varepsilon} &= \phi_{q,l,k,0,\varepsilon} + \sum_{\tilde{m}=1}^{m+1} f_{q,l,* ,m+1} + \varepsilon\alpha_{q,l,k,m+1}f_{q,l,k,m+1}^* \end{aligned} \quad (2)$$

If the requirements for teacher's / lecturer's advanced training, can only be characterized by a set of final knowledge (program outputs) of pupils / students, then the corresponding dependence can be represented as:

$$f_{q,l,k,\tilde{m}}^* = f_{q,l,k,\tilde{m}}^*(\phi_{q,l,k,\tilde{m}}; k = \overline{1,k^*}, \tilde{m} = \overline{1,m+1}) = \sum_{k=1}^{k^*} \beta_{q,l,k,m+1}\phi_{q,l,k,m+1} \quad (3)$$

where $\beta_{q,l,k,m+1}$ are some weight coefficients.

If all the other constituents and components at different time moments are used, then the formula can be generalized as follows:

$$f_{k,m+1}^* = \sum_{q=1}^{q^*} \sum_{l=1}^{l^*} \sum_{k=1}^{k^*} f_{q,l,k,m+1}^* \quad (4)$$

Taking into account the final components of competence, the parameters $\alpha_{q,l,k,\tilde{m}}$, $\beta_{q,l,k,\tilde{m}}$ will be selected optimally depending on the form of agents' requests (regarding the professional qualification of knowledge sources) to the goals and program results of the training, which characterize the required professional competences, as well as the optimal costs. In the simplest case, the following conditions can be formed in the form of inequalities:

$$\underline{\phi}_{q,l,k,m+1} < \phi_{q,l,k,m+1,\varepsilon} < \overline{\phi}_{q,l,k,m+1} \quad (5)$$

where $\underline{\phi}_{q,l,k,m+1}$, $\overline{\phi}_{q,l,k,m+1}$ are certain thresholds of components and their constituents of knowledge potential, which should satisfy the program results of training of the corresponding specialty. In this case, each of the elements A, B, C, etc. (sets of elementary competences and their constituents) will be characterized by the initial and final indices of the corresponding matrices, for example:

$$A = A_1 = A_{(1,1)(2,2)}, B = A_2 = A_{(2,2)(3,3)}, D = A_3 = A_{(5,6)(5,6)} \dots$$

In general:

$$A^i = A^i_{(k_1, j_1)(k_2, j_2)}.$$

Then the inequalities of type (5) can be applied only to the elements of the corresponding subsets A_i . For example, the appropriate restrictions for $B = A_2$ can be presented in the form:

$$\underline{\psi}_{2,2} < \alpha_{2,2,k,m} \phi_{2,2,k,m,\varepsilon} + \alpha_{3,2,k,m} \phi_{3,2,k,m,\varepsilon} < \overline{\psi}_{2,2}$$

$$\underline{\psi}_{2,3} < \alpha_{2,3,k,m} \phi_{2,3,k,m,\varepsilon} + \alpha_{3,3,k,m} \phi_{3,3,k,m,\varepsilon} < \overline{\psi}_{2,3}$$

As a result of solving the optimization problem of certain functionals (for example, cost optimization), under the conditions as in (5), it is found the parameters and according to formulas (1-4) the characteristics of the corresponding “disturbances” of educational programs are considered, for example, needs, dictated by stakeholder conditions.

5. Conclusion

The characterization of the agents’ knowledge potential, taking into account the units of its components and the interactions in the learning process, provided an opportunity to specify these models (consideration of dependencies between the parameters characterizing interpersonal relationships), and, consequently, modeling of more real situational states that has considerable practical value.

In particular, a mathematical model was developed to describe the dynamics of the components and their constituents of the agents’ knowledge potentials, taking into account the feedback (agent – student) on the knowledge source (teacher / lecturer) and the achievement of program results, in particular regarding to the needs dictated by employers.

To identify the relevant parameters (according to their further use in the creation of individual training trajectories of a person), it might be used the procedure of their step-by-step fixations (block iterations), similar to our previous works.

The prospect of further research is the introduction of objective functions (as functions whose arguments are subsets of the proposed two-dimensional array), the solution of various kinds of nonlinear optimization and control problems.

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Comparisons of performance between quantum-enhanced and classical machine learning algorithms on the IBM Quantum Experience

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Abstract. Machine learning is now widely used almost everywhere, primarily for forecasting. In the broadest sense, the machine learning objective may be summarized as an approximation problem, and the issues solved by various training methods can be reduced to finding the optimal value of an unknown function or restoring a function. At the moment, we have only experimental samples of quantum computers based on classical-quantum logic, when quantum gates are used instead of ordinary logic gates, and probabilistic quantum bits are used instead of deterministic bits. Namely, the probabilistic nature problems that provide for the determination of a certain optimal state from a large set of possible ones on which quantum computers can achieve “quantum supremacy” – an extraordinary (by many orders of magnitude) reduction in the time required to solve the task. The main idea of the work is to identify the possibility of achieving, if not quantum supremacy, then at least a quantum advantage when solving machine learning problems on a quantum computer.

1. Introduction

Traditionally, quantum computing is defined as a type of nonclassical computing that operates on the quantum state of subatomic particles, which represent information as elements denoted as quantum bits (qubits). A qubit can represent all possible values simultaneously (superposition) until read. Qubits can be linked with other qubits, a property known as entanglement. Quantum algorithms manipulate linked qubits in their undetermined (entangled) state, a process that can address problems with vast combinatorial complexity [7], reaching “quantum supremacy”.

Identifying potential applications for quantum computing, Kasey Panetta points out that they “will be narrow and focused, as general-purpose quantum computing will most likely never be economical” [13]. In his opinion, quantum computing could enable breakthroughs by machine learning, finance, healthcare, creation of new materials, artificial intelligence (which requires 100s – 1000s qubits), chemistry and biochemistry (100-200 qubits). In particular, for finance, quantum computing could enable faster, more complex Monte Carlo simulations (for example, trading, trajectory optimization, market instability, price optimization and hedging strategies) and machine learning methods, which in



the general case are reduced to problems of finding the extremum of a multidimensional function along the nonlinear response surface.

Currently, computing devices capable of performing quantum computing (quantum computers) are available for consumers of computing services using the QCaaS (quantum computing as a service) model. As of June 2020, the maximum number of qubits available for simultaneous use does not exceed 60, which is significantly less than the number required to achieve “quantum supremacy”. This raises the problem of investigating the possibilities of quantum programming for machine learning tasks implementation, namely, the use of machine learning algorithms, implemented by the quantum programming language, to analyze traditional data and compare the performance of quantum and von-neumanns implementations at the present stage of their development.

The aim of the research is to carry out a comparative analysis of the implementation of quantum-enhanced machine learning algorithms in the quantum programming language.

To achieve the goal of the study, the following tasks were set:

1. Analyze Quantum Software Engineering tools in order to select a tool that is appropriate for the implementation of machine learning tasks.
2. Consider quantum-enhanced machine learning algorithms.
3. Conduct a comparative analysis of the efficiency of quantum-enhanced and classical machine learning algorithms.

2. Fundamentals of Quantum Software Engineering

2.1. Basic research concepts

Quantum computer is a computing device using quantum-mechanical phenomena (superposition, entanglement, etc.) for data transmission and processing.

Quantum programming is a software development process for quantum computer.

«Classical» applications of quantum computers (by Richard Feynman) – modeling complex [many-particle physical] systems: Zalka and Wiesner’s algorithm.

«New» applications of quantum computers are tasks that require enumerating a large number of options: Grover’s algorithm (general task), Shor’s algorithm (factorization), Abrams and Lloyd’s algorithm (identification of periodic properties), etc.

Quantum machine learning is an application of machine learning algorithms for quantum data analysis.

Quantum-enhanced machine learning is the use of machine learning algorithms implemented in the quantum programming language for the analysis of traditional data.

Software Engineering is a systematic application of engineering approaches to the design, implementation, testing and documenting of software.

2.2. Concept of Quantum Software Engineering

The first systems presentation of the Quantum Software Engineering concept was made by John Clark and Susan Stepney in 2002 [4]. Researchers believe that quantum computing cannot be effectively implemented in the traditional computer Von Neumann architecture, the mathematical model of which is the Turing machine. The authors [3] refer to the main challenges that Quantum Software Engineering will face in 2020:

- the question of what a quantum programming language should be – an extension of traditional languages, a logical programming language in a low-level programming language or a language that implements a new paradigm;
- the need to develop compilers for quantum programming languages;
- the need to develop new quantum algorithms and define the classes of traditional algorithms that can be quantised;
- feasibility of developing quantum computer simulators for use on traditional computer systems;

- despite the fact that quantum execution is in principle unobservable, debugging and testing techniques are necessary for quantum programming languages;
- quantum algorithms require visualization for their understanding, design, and implementation.

The criteria and success indicators of Quantum Software Engineering proposed by John Clark and Susan Stepney are summarized in table 1.

Table 1. The criteria and success indicators of Quantum Software Engineering (according to [4]).

Criteria	Indicators
It arises from scientific curiosity about the foundation, the nature or the limits of a scientific discipline	Quantum computation has broadened the fundamental limits of computer science and software engineering
The ability to create new engineering solutions	The physical infrastructure is constantly evolving, each solution is new
Technological continuity	The existence of high level languages and development techniques that can be used by computer scientists and software engineers with only the same style of training they receive today (so, no need to teach the fundamentals of quantum mechanics to all)
Research community support	Support for all interested in new computing paradigms and new levels of computing power
International character of research	This is a new fundamental area of software engineering
It is generally comprehensible, and captures the imagination of the general public, as well as the esteem of scientists in other disciplines	It is not generally understood, but is known for its worldwide interpretation
The problem has a long-standing statement, but has not yet been resolved	Formulated by Richard Feynman in the late 1970s.
It promises to go beyond what is initially possible, and requires development of understanding, techniques and tools unknown at the start of the project	Problems exist on every level, from developing a whole new conceptual paradigm, to building intellectual and simulation tools
It calls for planned co-operation among identified research teams and communities	Research is needed in a number of areas (languages, algorithms, tools, simulation, visualisation, etc.)
It encourages and benefits from competition among individuals and teams, with clear criteria on who is winning, or who has won	There need not be a single “winner”, diversity of solutions should be encouraged, as in classical software engineering, to be applicable to a range of application domains
It decomposes into identified intermediate research goals, whose achievement brings scientific or economic benefit, even if the project as a whole fails	There are several components of the problem that can be explored in parallel
It will lead to radical paradigm shift	Quantum computing is a radical paradigm shift

In 2020, Quantum Software Engineering includes such components [19]:

- Paradigms for developing quantum software
- Quantum software design
- Quantum software testing
- Quantum software verification
- Quantum software coding practices
- Quantum software reuse
- Quantum software experimentations
- Quantum software execution
- Industrial applications
- Empirical evaluations

In February 2020, at QANSWER 2020: 1st International Workshop on the QuANtum SoftWare Engineering & pROgramming, the Talavera Manifesto for Quantum Software Engineering and Programming [12] was adopted, containing a set of principles and commitments:

Quantum Software Engineering

- *is agnostic regarding quantum programming languages and technologies;*
- *embraces the coexistence of classical and quantum computing,* and advocates the use of reengineering techniques to integrate new quantum algorithms with the existing classical information systems. Reverse engineering techniques are also needed to parse and abstract quantum program information that is to be integrated into classical programs;
- *supports the management of quantum software development projects,* delivering quantum software that fulfils the initial business goal and requirements, while at the same time ensuring that quality, time, and cost constraints are being properly observed; methodologies for developing quantum programs must be created or adapted from the existing ones; effort estimation methods for quantum software development need to be provided as well;
- *considers the evolution of quantum software:* quantum software should be maintained and evolved from inception to removal, and quantum software evolution must be handled throughout the whole quantum software lifecycle;
- *aims at delivering quantum programs with desirable zero defects:* It is in charge of defining and applying testing and debugging techniques to quantum programs in such a way that most defects can be detected and solved before the program is released;
- *assures the quality of quantum software:* quality management for both process and product are essential if quantum software with expected quality levels is to be produced; since we cannot improve what we cannot measure, new metrics for quantum programs and quantum processes have to be developed;
- *promotes quantum software reuse,* helping development teams to share, index, and find quantum software that can be reused: this requires study of design and architectural patterns for quantum programs, facilitate technical communication, and work on creating libraries of reference examples and application demonstrations;
- *addresses security and privacy by design:* quantum information systems must be secure and guarantee the privacy of data and of users from the initial phases of quantum software development, i.e., by design;
- *covers the governance and management of software:* managers should be aware of the particular processes, organizational structures, principles, policies and frameworks, information, culture, ethics and behaviour, people, skills and competences, as well as the services, infrastructure and applications that are associated with quantum software and that are (or should be) provided by organizations.

The authors of the manifesto separately appeal to educators with a request to integrate quantum software engineering in curricula within the existing software engineering degrees and/or courses in this or other disciplines, and clearly specify which competences and skills are required for future quantum software engineers [15].

2.3. Quantum Software Engineering tools

The execution of quantum programs on personal computer equipment is difficult to access due to its lack of prevalence, so for more than a quarter-century, quantum simulators – software tools that simulate quantum circuits – have been the main means of their execution. The first mention of QCaaS (Quantum Computing as a Service) occurs only in 2015 in the article [20] by Mijanur Rahaman and Md. Masudul Islam.

The world's largest QCaaS providers:

- D-Wave Systems Inc. (Canada) – SDK Ocean [6] (Python, C++);
- International Business Machines Corporation (USA) – SDK ProjectQ [22] (Python), Qiskit [17] (Python);
- Cambridge Quantum Computing Limited (Great Britain) – SDK $t|ket\rangle$ [2] (Python);
- QC Ware, Corp. (USA) – SDK Forge (Python);
- StationQ - Microsoft (USA) – SDK LIQUi> [11] (F#), Microsoft Quantum Development Kit [10] (F#);
- Rigetti Computing (USA) – SDK Forest [21] (Python).

Thus, the main programming language for cloud access to quantum computing is Python. Another criterion for choosing a QCaaS vendor is computing power, measured in qubits. This indicator is the largest in D-Wave Advantage – 5000 (in clusters of 8) qubits based on quantum annealing, which narrows the scope of its application to solving optimization problems, which boil down to finding the ground state for a set of spins. For universal quantum computers on quantum circuits, the number of qubits is significantly lower and today (June 2020) is the highest in IBM Q 53 (53 qubits) and Google Bristlecone (72 qubits). Unfortunately, Google's Quantum Computing Playground [19] is a browser-based quantum simulator, and there is no open cloud access to Google's Bristlecone. For cloud access to IBM Q, you can use both their library – Qiskit, and a third-party – ProjectQ. Considering that the highest level of specialization is provided by its own SDK, Qiskit was chosen for further work.

3. Quantum-enhanced machine learning

3.1. Quantum models of machine learning

Srinivasan Arunachalam and Ronald de Wolf y [1] offer three main quantum learning models:

1. *Quantum exact learning* based on membership queries to find the most accurate unknown function (quantum approximation problem). The efficiency of quantum algorithms in relation to classical ones in this case depends on how the learning efficiency is measured. If the measure of efficiency is the training time, then there are such classes of functions for which quantum algorithms are much faster than classical ones, assuming that the queries implementation in a quantum superposition is possible.

2. *Quantum Probably Approximately Correct (PAC) learning* to find an unknown function over a set of samples (quantum supervised learning). The difference between quantum PAC learning and classical learning is that the dataset can be in a state of quantum superposition.

3. *Quantum agnostic learning* to search for the $(n + 1)$ -th bit, which is a continuation of a sequence with n bits (quantum prediction task).

The authors point to three types of complexity that arise when applying quantum learning models [1]:

a) query complexity of quantum exact learning: the number of quantum membership queries needed to exactly learn a target concept can be polynomially smaller than the number of classical membership queries, but not much smaller than that;

b) sample complexity: for the distribution-independent models of PAC and agnostic learning, quantum examples give no significant advantage over classical random examples: for every concept class, the classical and quantum sample complexities are the same up to constant factors. In contrast, for some fixed distributions (e.g., uniform) quantum examples can be much better than classical examples;

c) time complexity: there exist concept classes that can be learned superpolynomially faster by quantum computers than by classical computers, for instance based on Shor's or Simon's algorithm.

In the case of applying quantum machine learning models to the analysis of traditional data, we are talking about quantum-enhanced machine learning. Frank Phillipson [11] defines three main benefits of quantum machine learning:

- improving runtime (for example with a quantum hybrid Helmholtz machine);
- learning capacity improvements (for example with a quantum Hopfield neural network);
- learning efficiency improvements: less training information or simpler models needed to produce the same results or more complex relations can be learned from the same data.

Various methods can be applied to increase the efficiency of training, one of which is variational quantum circuits – VQC [14].

Evidence of the intensity of quantum-enhanced machine learning development is the fact that the systematic review of the problem in 2016, carried out by Peter Wittek in [23], today (June 2020) is already considered as a classic, and that is indicated by the co-author in a new review [5].

Vedran Dunjko and Peter Wittek also highlight such perspective directions in the development of quantum machine learning in general:

- a) supervised and unsupervised learning: continuous-variable quantum neural networks, quantum convolutional neural networks, quantum algorithms for feedforward neural networks, Bayesian deep learning, sublinear quantum algorithms for training linear and kernel-based classifiers;
- b) reinforcement learning: quantum algorithms for solving dynamic programming problems (including hidden quantum Markov models), quantum gradient estimation.

The authors conclude that “the entire field of “genuinely quantum” machine learning (where the data itself is quantum) is still finding its right place and full recognition. Perhaps as quantum technologies mature, and problems of quantum learning become genuinely practical, the field will crystallize and grow. ... In summary, QML [quantum machine learning] is diverse, growing, inclusive, and it is rich in open questions. ... Capturing all the QML trends, which will in the end be central is, for the time being, an impossible task – and, in a way, this is the key message of this note” [5].

3.2. An overview of quantum-enhanced machine learning tools in Qiskit

Qiskit provides the ability to develop quantum software both at the quantum circuits level using OpenQASM [16] and at a high level of abstraction using Python in a Jupyter notebook. The main components of the library are:

- quantum circuits modeling tools (Terra);
- implementation of standard quantum algorithms (Aqua – Algorithms for QUantum Applications), in particular, for solving optimization tasks;
- cloud quantum computing tools (Aer);
- tools for simulating quantum noise (Ignis).

Aqua includes modules for research in finance (qiskit.finance), machine learning (qiskit.ml), optimization (qiskit.optimization) and chemistry (qiskit.chemistry) [16].

The machine learning module contains standard datasets and ways to access custom. Various optimization algorithms can be used to process them:

ADMMOptimizer – an implementation of the ADMM-based heuristic (ADMM – alternating direction method of multipliers);

CobylaOptimizer – the SciPy COBYLA optimizer (COBYLA – Constrained Optimization BY Linear Approximation);

CplexOptimizer – the CPLEX optimizer for linear, integer and quadratic programming tasks;

GroverOptimizer – uses Grover Adaptive Search (GAS) to find the minimum of a QUBO function (QUBO – quadratic unconstrained binary optimization);

MinimumEigenOptimizer – minimum eigen solvers;

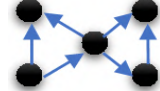
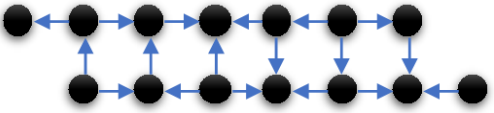
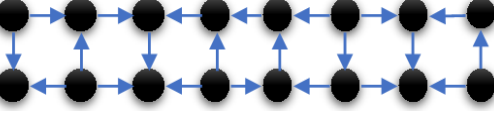

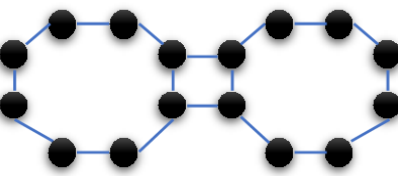

RecursiveMinimumEigenOptimizer – a meta-algorithm that applies a recursive optimization.

The `qiskit.aqua.components.optimizers` module offers a set of algorithms for local (Analytic quantum gradient descent optimizer, constrained optimization by linear approximation optimizer, Nelder-Mead optimizer, Nakanishi-Fujii-Todo algorithm, Powell optimizer, truncated Newton optimizer, etc.) and global optimizations (controlled random search with local mutation optimizer, evolutionary optimizer, etc.). It is advisable to use quantum support vector machine (QSVM) and variational quantum classifier (VQC) algorithms to solve classification tasks.

4. Experimental verification of the efficiency of quantum-enhanced machine learning algorithms

When implementing quantum computing on real architectures, in addition to the classical decoherence problem, which significantly limits the running time of quantum algorithms (70-150 μ s for a 20-qubit IBM Q System One with a maximum number of simultaneously entangled qubits equal to 6), it is also necessary to take into account error reading the results. The authors [9] provide the following values for quantum computers accessible via QCaaS (table 2).

Table 2. Characteristics of common quantum computers (according to [12]).

Machine	Qubits	2Q gates	Coherence time (us)	1Q error, %	2Q error, %	Read output, %	Qubit topology
IBM Q5 Tenerife	5	6	40	0,2	4,76	6,21	
IBM Q14 Melbourne	14	18	30	1,19	7,95	9,09	
IBM Q16 Rüsçhlikon	16	22	40	0,22	7,14	4,15	
Rigetti Agave	4	3	15	3,68	10,8	16,37	
Rigetti Aspen1	16	18	20	3,43	8.92	5,56	
Rigetti Aspen3	16	18	20	3,79	5,37	6,65	
UMD Trapped Ion	5	10	1,5·10 ⁶	0,2	1,00	0,6	

Thus, at the current state of quantum technologies development, it is necessary to use such data sets, the processing steps of which by quantum-enhanced machine learning algorithms correspond to the requirements of the chosen platform – IBM Q.

Machine learning was performed on the wine and breast_cancer datasets using the Qiskit (quantum-enhanced machine learning) and sklearn (classical machine learning) libraries. Testing was performed on a local two-qubit quantum simulator with 8 GB of RAM and servers ibmqx2 (2 qubits),

ibmq_16_melbourne (16 qubits), ibmq_vigo, ibmq_london and ibmq_burlington (all 5 qubits). The machine learning procedure was repeated 6 times for each dataset. The results are presented in table 3.

Table 3. Experimental verification of the efficiency of machine learning on quantum and traditional architectures.

Server	Time of quantum-enhanced machine learning (s)		Time of classical machine learning (s)	
	wine	breast_cancer	wine	breast_cancer
ibmqx2	24.8	18		
	24.7	18.1		
	24.5	17.9		
	24.6	18.1		
	24.8	18.1		
	24.7	17.8		
ibmq_16_melbourne	25	18.9		
	25.2	18.7		
	25.2	10.2		
	25.1	10.2		
	25.2	18		
	24.8	18.9		
ibmq_vigo	28.3	20.4	0.021	0.027
	28.3	20.4	0.021	0.027
	28.1	20.4	0.026	0.026
	28	20.7	0.026	0.027
	26.9	20.4	0.026	0.027
	28.3	20.7	0.026	0.026
ibmq_london	26.1	19.4		
	26.2	19.3		
	26.5	19.6		
	26.5	19.5		
	26.3	19.4		
	26.2	19.7		
ibmq_burlington	27.3	20.4		
	27.1	20.4		
	26.7	20.3		
	27.1	20.5		
	27	20.3		
	27.1	20.1		
local quantum simulator	111	22.2	0.190	0.021
	105.1	23.3	0.020	0.023
	102.8	32.7	0.028	0.021
	103.5	31.7	0.021	0.021
	111.2	22.4	0.020	0.026
	99.9	22.1	0.022	0.021

When using sklearn on IBM Q Experience, there was no way to determine on which server the execution was occurring – multiple repetitions of tests at different times of the day did not lead to a significant change in the results.

The code for all types of tests is presented in appendices A, B, C.

Analysis of Table 3 allows us to conclude that at the current stage of quantum technologies development traditionally machine learning provides greater performance than quantum-enhanced. At the same time, quantum-enhanced machine learning algorithms turned out to be inversely sensitive to the complexity of the dataset: training on a more complex dataset breast_cancer (30 inputs, 2 outputs, 569 elements) was performed at a higher speed than training on a less complex data set wine

(13 inputs parameters, 3 outputs, 178 elements), while a direct relationship was observed for classical machine learning, confirmed by [2] and other sources. The results of the analysis give an opportunity to make the assumption that it is advisable to apply quantum-enhanced machine learning to datasets with a large input dimension, the assumed value for which is the probability of choosing one of two sets of classes – such classes are effectively worked out by single-qubit systems.

5. Conclusions

1. The core of Quantum Software Engineering is quantum programming – the process of developing programs for a quantum computer: a computing device that uses the phenomena of quantum mechanics to process data. Due to the low level of availability of such devices, it is advisable to access them under QCaaS model (quantum computing as a service). The conducted review of Quantum Software Engineering tools provided an opportunity to single out their main classes (quantum simulators, libraries, visualizers and cloud quantum services) and recommend using IBM Q as a hardware platform for quantum computing, Qiskit as a library of quantum algorithms, Python as a programming language and IBM Quantum Experience as QCaaS Provider.

2. The use of machine learning algorithms for the analysis of quantum data can be described by three quantum machine learning models (quantum exact learning, quantum Probably Approximately Correct learning and quantum agnostic learning), in the application of which there are three types of difficulties associated with the query complexity of quantum exact learning, quantum the intricacy of datasets and the sensitivity of quantum algorithms to them. A prospective direction in the machine learning development is the use of quantum learning models for analyzing traditional data, the implementation of which in Qiskit Aqua 0.7.3 is still a limited solution to classification tasks.

3. The results of an experiment using a variational quantum classifier on two datasets showed that at the current stage of quantum technologies development, classical machine learning provides greater performance than quantum-enhanced machine learning. At the same time, the use of quantum-enhanced machine learning algorithms for the binary classification tasks, even with a high dimension of the input data, gives a significant (several times) acceleration compared to the ternary classification tasks, while when using classical machine learning, the execution time increased depending on the volume dataset and their dimensions. The analysis of the experimental results provides an opportunity to make an assumption that quantum-enhanced machine learning is advisable to apply to datasets with a large input dimension, the assumed value for which is the probability of choosing one of two sets of classes – such classes are efficiently processed by one-qubit systems.

Prospects for further research are in a systematic study of the capabilities of Quantum Software Engineering and its applications to solving forecasting problems.

Appendix A. Code for quantum-enhanced machine learning on the wine dataset (ibmq_burlington server, 5 qubits)

```
# Importing standard Qiskit libraries and configuring account
from qiskit import QuantumCircuit, execute, Aer, IBMQ
from qiskit.compiler import transpile, assemble
from qiskit.tools.jupyter import *
from qiskit.visualization import *
from qiskit import BasicAer
from qiskit.aqua import QuantumInstance, aqua_globals
from qiskit.aqua.algorithms import VQC
from qiskit.aqua.components.optimizers import COBYLA
from qiskit.aqua.components.feature_maps import RawFeatureVector
from qiskit.ml.datasets import wine
from qiskit.circuit.library import TwoLocal
import time

# Loading your IBM Q account(s)
provider = IBMQ.load_account()
```

```

from qiskit import BasicAer
from qiskit.aqua import QuantumInstance, aqua_globals
from qiskit.aqua.algorithms import VQC
from qiskit.aqua.components.optimizers import COBYLA
from qiskit.aqua.components.feature_maps import RawFeatureVector
from qiskit.ml.datasets import wine
from qiskit.circuit.library import TwoLocal
import time

seed = 1376
aqua_globals.random_seed = seed

# Use Wine data set for training and test data
feature_dim = 4 # dimension of each data point
_, training_input, test_input, _ = wine(training_size=12,
                                         test_size=4, n=feature_dim)

instance = QuantumInstance(provider.get_backend('ibmq_burlington'),
                           shots=1024, seed_simulator=seed, seed_transpiler=seed,
                           skip_qobj_validation=True)
feature_map = RawFeatureVector(feature_dimension=feature_dim)
start_time = time.time()
vqc = VQC(COBYLA(maxiter=100),
          feature_map,
          TwoLocal(feature_map.num_qubits, ['ry', 'rz'], 'cz', reps=3),
          training_input, test_input)
result = vqc.run(instance)

print('Testing accuracy: {:.2f}'.format(result['testing_accuracy']))
print(result)

print("--- %s seconds ---" % (time.time() - start_time))

```

Appendix B. Code for quantum-enhanced machine learning on breast_cancer dataset (local quantum emulator, 5 qubits)

```

from qiskit import BasicAer
from qiskit.aqua import QuantumInstance, aqua_globals
from qiskit.aqua.algorithms import VQC
from qiskit.aqua.components.optimizers import COBYLA
from qiskit.aqua.components.feature_maps import RawFeatureVector
from qiskit.ml.datasets import breast_cancer
from qiskit.circuit.library import TwoLocal
import time
import random

seed = 1376
aqua_globals.random_seed = seed

# Use Wine data set for training and test data
feature_dim = 2 # dimension of each data point
X_train = []
Y_train = []
_, training_input, test_input, _ = breast_cancer(training_size=12,
                                                  test_size=4, n=feature_dim)
instance = QuantumInstance(BasicAer.get_backend('statevector_simulator'),
                           shots=1024, seed_simulator=seed, seed_transpiler=seed)

```

```

feature_map = RawFeatureVector(feature_dimension=feature_dim)
start_time = time.time()
vqc = VQC(COBYLA(maxiter=100),
          feature_map,
          TwoLocal(feature_map.num_qubits, ['ry', 'rz'], 'cz', reps=3),
          training_input, test_input)
result = vqc.run(instance)

print('Testing accuracy: {:.2f}'.format(result['testing_accuracy']))
print(result)

print("--- %s seconds ---" % (time.time() - start_time))

```

Appendix C. Classical machine learning code on breast_cancer dataset

```

import numpy as np
from sklearn.datasets import load_wine
from sklearn.svm import SVC
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.datasets import load_iris, load_breast_cancer
from sklearn.model_selection import train_test_split
from sklearn.svm import LinearSVC, SVC
from sklearn.metrics import classification_report
from sklearn.model_selection import GridSearchCV
import time
import pandas as pd

# Load data
x,y = load_breast_cancer(return_X_y=True)

data = load_wine()
df = pd.DataFrame(data['data'], columns=data['feature_names'])
df['Target'] = data['target']
X = df.drop('Target', axis=1)
y = df['Target']
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25,
random_state=1376)

start_time = time.time()
svc = SVC(kernel="linear", C=0.025)
svc.n_iter_ = 100
svc.fit(X_train, y_train)
test_predictions = svc.predict(X_test)
train_predictions = svc.predict(X_train)
print("Train:")
print(classification_report(y_train, train_predictions))
print("Test:")
print(classification_report(y_test, test_predictions))
print("--- %s seconds ---" % (time.time() - start_time))

```

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Information technology for mobile perimeter security systems creation

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Abstract. The main aim of this research is the creation of information technology for mobile (of rapid deployment) security systems of the area perimeter. This system appears to be a complex of models and methods, information, software, and hardware mean that have interacted with users during decision-making and control of implementation for management solutions. The proposed information technology aimed at improving the protection level for security departments by automating the process of danger detection for perimeters and decision-making for alarm. The structural model of the system, the model of the system's components interaction, and the model of identifying the subjects of emergency threats have been proposed. A method for identifying unauthorized access to the perimeter of the secure facilities, using the production model of knowledge representation, was created. It is a set of linguistic expressions (such as "IF-THEN") and the knowledge matrix. The method of ranking for objects, which are threats of unauthorized access to the perimeter for secure facilities, has been proposed. The practical value of work consists of the possibility of the use of this information technology by perimeter's security systems of various objects. Proposed models are complete and suitable for hardware and software implementation.

1. Introduction

The development of information technologies forms a new digital suspension and a new blockage of its safety. Computers of science have completely disappeared from our life. It's important to live your life without technology this year. However, the insane progress in automation, intellectualization, and sophisticated processes in operation is deprived of one of the rounds of informatization of the suspension. The development of science and technology through the introduction of new direct advances in the field of cybersecurity and engineering systems of physical security. Today's food for cyber defense is a common problem of suspension. It is hard to get rid of the latest information technologies without the proper acquisition of resources, technology, the transmission of money.

Analysis of criminal situation shows an increasing number of thefts, vandalism, attempts of unauthorized access to the territory of the secure facilities. The issue of protection of the perimeter for static secure facilities has been already solved. But the problem of protection for mobile (moving) secure facilities is still very complicated.



Therefore, this study is devoted to solving the problem of increasing the level of protection of objects from unauthorized access, which is extremely relevant for military and commercial enterprises. These studies will be interesting in the field of weapons, logistics, Internet of things. The object of the research is the processes of building mobile (quickly deployed) sensor systems for protecting the perimeter of the territory.

2. Theoretical background

The research works [1], [3], [4], [6], [7], [10], [12], [13] are the most notable among the others concerning methodology and methods of creating modern perimeter security and information security systems. Mobile perimeter security systems are built using sensor networks and wireless data transmission systems [9], [11]. The relevance of the problem is emphasized in articles [5] and [9]. However, there is no methodology for the creation of mobile security systems.

The experience of conducting an anti-terrorist operation in the east of our country, the participation of Ukrainian Armed Forces units in peacekeeping operations and armed conflicts, analysis of activities of extremist organizations against military objects showed that early detection of the intruder (on approaches to the secure facilities) can save lives and the health of staff, can provide the proper protection of ammunition and military equipment. Automation of the process of detecting the intruder on approaches to secure facilities is an urgent problem. It determines the effectiveness of the training of troops (forces).

The equipment of radio-electronic equipment of protection of long-range approaches to positions of checkpoints, mechanized units, areas of concentration, and location of military equipment, warehouses will allow guards, patrols, guard posts securely protect military objects [5], [11]. An analysis of recent research [2], [5], [11], [15] found that the Armed Forces of Ukraine paid low attention to the improvement of defense systems of approaches to military objects, including temporarily located objects, in comparison with similar systems of the armed forces of the most developed countries of the world.

Notice that in NATO (the first of all in the US Mature Force) such systems have been created since the 1970s. So, in 1972, there was an initiative to implement radio-electronic technologies and the BISS (Base and Installations Security System) system for all kinds of Armed forces. That initiative included the creation means to protect all buildings and rooms that store all types of weapons. As well as there was a separate program to create an autonomous and remote-controlled alarm system for battlefields [5], [11], [15]. Since the 1980s, the Soviet Union has been creating radio-electronic equipment to protect approaches to secure facilities. But in 1985 that initiative had been stopped. Since 1985, the TASS (Tactical Autonomous Security) system implementation program has been started [5], [11], [15]. For the construction of mobile perimeter security systems US Armed Forces most widely used portable radar systems radar AN / PPS-5 and -15 different modifications. Such systems were temporary parking of aircraft, military equipment, vehicles, as well as individual buildings and other small objects. For the construction of mobile perimeter security systems US Armed Forces most widely used portable radar systems radar AN / PPS-5 and -15 different modifications. Such systems were temporary parking of aircraft, military equipment, vehicles, as well as individual buildings and other small objects. For the proper organization of protection of temporarily located objects, it is necessary to use a combination of active (burglar-alarm security systems) and passive (intelligence-alarm systems) technical means of security. Burglar alarm systems are aimed at detecting the intruder due to its interaction with a specially formed electromagnetic field.

The use of such systems requires an increased power supply for the formation of the electromagnetic field and can be detected by special monitoring systems due to the lack of radio masking. The advantage of such systems is the ability to control large areas at near and far approaches and automatic alert notification. Intelligence-alarm systems – identify the intruder by changing the existing physical field (magnetic, vibration, thermal). These systems are characterized by radio and visual masking. But the decision to identify the event (intruder/obstacle) is made by the operator located near the main or portable control panel. Data transmission is performed using ultra-short wave (VHF) radio channels

(700-900 MHz). Multiple portable controls and indicators are recommended to increase the tactical flexibility of terrain deployment and redundancy (destruction). The system health check is carried out by direct radio call and periodic self-monitoring. Typically, sensors are point-to-point with a sectorial or circular detection area within a radius of 300 m. Usually, sensors are masked on the background of objects that surround them. The detection is based on known physical principles such as using radar, television (TV), infrared (IR), thermal imaging (TPV), photoelectric, laser, magnetic, electromagnetic, seismic, vibration detection principles. Also electronic and optic devices are widely used. Different combinations of those devices are used for radar detection and surveillance [2], [15]. Detection range, the accuracy of detection, interference protection of forward and reverse channels, retrieval time, range and speed of transmission, mass and size indicators, cost, reliability, efficiency, hiding, cryptography protection against unauthorized access in the radio channel, power consumption are main technical characteristics of the equipment [2], [15]. The sources of false alarms in the technical means for security can be animals, strong wind combined with close vegetation, lightning in thunderstorms, etc. All means except infrared can be used for all types of weather, but there are restrictions on their use, such as in high snow, grass, shrubs, trees, mountain passes, and settlements. The main task of technical means for security is fast and reliable alarm security of areas, boundaries, arsenals of weapons, etc. The boundaries of which are covered should be closed. But that is very difficult to organize fully closed perimeter for areas with the various landscapes, with forests and gullies. Therefore, usually that requirement is provided partly.

Therefore, in such areas, it is additionally necessary to use a mobile radar station and radar reconnaissance system ground targets, in hiding places near forest paths, and in ravines, mountain passes should be laid remotely controlled electronic (optical) detection means. Such radio-electronic systems of technical means of protection will allow us to detect, count, classify and determine the direction of movement of manpower and self-propelled equipment, to transfer data to the portable control panel and an indication of on a radio channel. Transmission of information (detection signals) from such technical means of protection to the portable control panel and indication (10 ... 20 km away) should be carried out on noise-protected ultra-short waves radio channels. The electronic equipment of technical means of protection should be powered by various power sources, mainly from autonomous power supply: batteries, accumulators, and solar batteries. Such batteries must recharge the batteries, provide batteries with 30 ... 50 W of power, which is sufficient for the operation of technical equipment. At the same time, the power supply from the external power supply and electrical equipment of cars should be provided.

The joint use of technical means of rapid response protection and means of detecting a mobile radar station allows solving several tasks: to carry out inconspicuous temporary alarm scanning (blocking) of the perimeter of the object, to detect violators crossing the border; to conduct covert engineering and technical reconnaissance in the uncontrolled territory (including during hostilities) in places of probable movement of armed people, transport, military equipment, signaling their appearance, number, and direction of movement. Technical means of protection, which are designed to protect temporarily located objects, can also be used in the systems of protection of stationary objects and large premises (hangars, warehouses). It is also advisable to use electronic means of protection when performing tasks on state border protection by units of the State Border Guard Service, services of the Ministry of Emergencies in summer in hard-to-reach areas of most probable forest fires, monitoring poachers on rivers and lakes (especially at night).

To protect the military facilities of the Armed Forces of Ukraine, it is necessary to develop and use unified, block-modular security systems with advanced security functions that solve the problems of intelligence, detection, signaling, and classification of violations (violators). They should be integrated security systems with extensive capabilities (remote control, field positioning, GSM, satellite, digital data transmission, etc.). Additional use of computer capabilities on a portable control panel and indication will allow a three-dimensional display of the area from a given location of the observer or a virtual flight of the area with the environment, which is applied taking into account signals (information)

automatically transmitting security devices. This allows the main portable control panel and displays to make decisions on adequate response to the situation.

The purpose of this article is to develop information technology for the construction of mobile security systems around the perimeter of the security units and extracting units from unauthorized access, detecting the violator and generating an alarm signal for the unit.

3. Results

Let's create the information system model of ranking for objects, which are threats of unauthorized access to the perimeter for the protected area. As a result of previous research [8], was proposed a model information system of ranking for objects, which are threats of unauthorized access to the perimeter for secure facilities, which displays the component modules of the system: contactless radio frequency identification subsystem (RFID) (Module 1), intelligent video surveillance subsystem (Module 2), DSS of detecting and prevent unauthorized access to the perimeter of protected area (Module 3); subsystem of detection the movement along the protected perimeter (Module 4) [8]. Also in [8] describes the purpose of each module.

The interaction model of information system components is shown in figure 1.

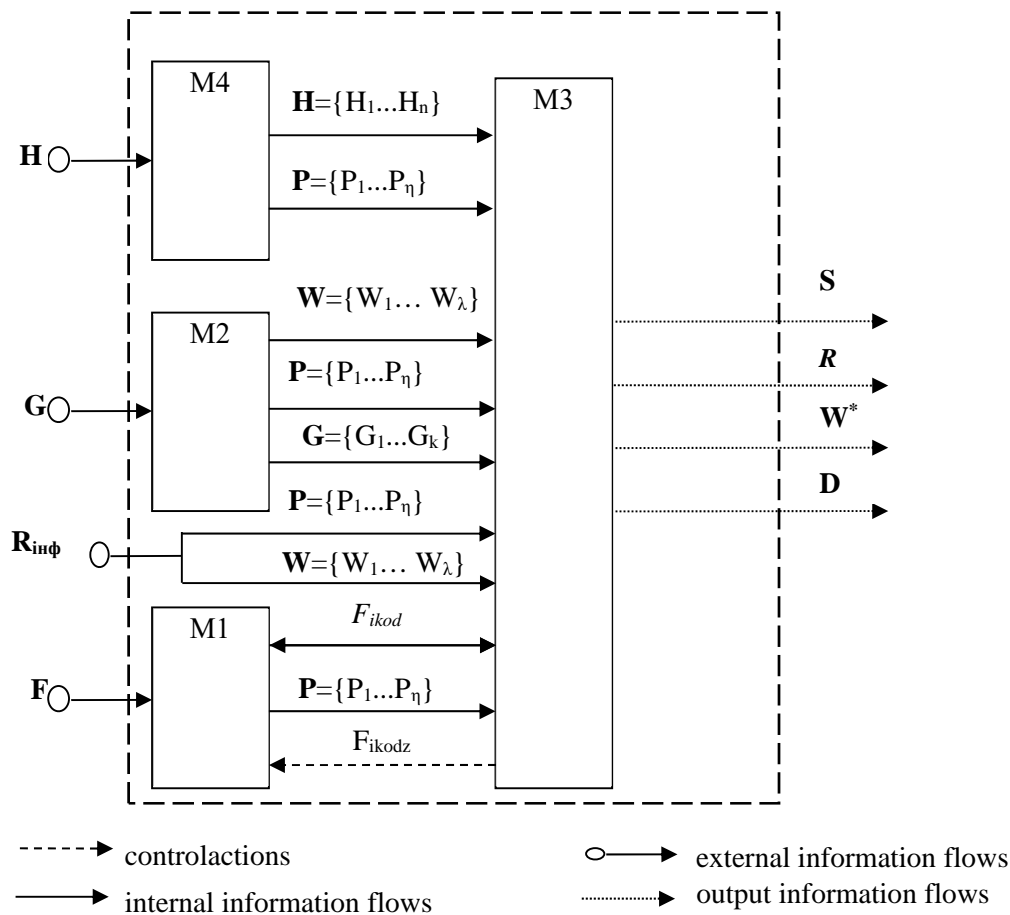


Figure 1. The interaction model of information system components.

Input system data are $\mathbf{F} = \{F_1, \dots, F_i\}$ – a set of signals RFID-signs that are received by RFID-scanners; $\mathbf{G} = \{G_1, \dots, G_k\}$ – video data flow coming from cameras; $\mathbf{R}_{inf} = \{R_{inf1}, \dots, R_{inf\rho}\}$ – information flow coming from protected area resources of the military base; $\mathbf{H} = \{H_1, \dots, H_y\}$ – a set of

signals received by motion detectors.

Information flows using for system interaction consists of F_{icod} – digital code (ID) received from RFID-sign of i -employee, $i = \overline{1 \dots n}$; $G_{v1} = \{G_{v1}, \dots, G_{vn}\}$ – a set of digitized frames in a form of images in BMP format coming from cameras; $P = \{P_1, \dots, P_n\}$ – detected dangerous subjects; $W = \{W_1, \dots, W_\lambda\}$ – a set of parameters that are controlled and analyzed to determine the danger class.

The control influences are F_{icodz} – ID of worker i . Input system parameter is informative vector $W^* = \{W_i\}$, $i = \overline{1 \dots \lambda}$, that is transmitted by channels as an electronic message from day duty to the security unit and in a case of necessity to the external law enforcement agency; informative vector $D = \{D_l\}$, $l = \overline{1 \dots \varepsilon}$, is generated automatically by the system and is addressed to the person on duty and is transmitted in a case of necessity to the external law enforcement agency; R – the decision of DSS as to dangerous subjects classification; S – the decision of DSS as to the detection of unauthorized access inside the protected area.

To construct the information system model of ranking for objects, which are threats of unauthorized access to the perimeter for a protected area, it is needed to develop some other models, such as the model for identifying subjects of threats at the protected area, the model of the process of the level threats determination, and block for management decision-making.

Let us create the model for identifying subjects of threats at the protected area. Ones of the dangerous subjects (P) can be mentally ill persons (P_1), spies (P_2), regional terrorist organizations (P_3), international terrorist organizations (P_4), lone extremists or a group of extremists (P_5), and sabotage and reconnaissance groups (P_6). It is possible to represent them as open dangerous subjects' classification (a set of subjects' classification) that may be supplemented or adapted. The model for identifying subjects of threats at the protected area is shown in figure 2. Therefore, we obtain open classification groups:

$N = \cup_j N_j$ – a set of staff under danger attack as a result of unauthorized access;

$X = \cup_a X_a$ – a set of hitting objects.

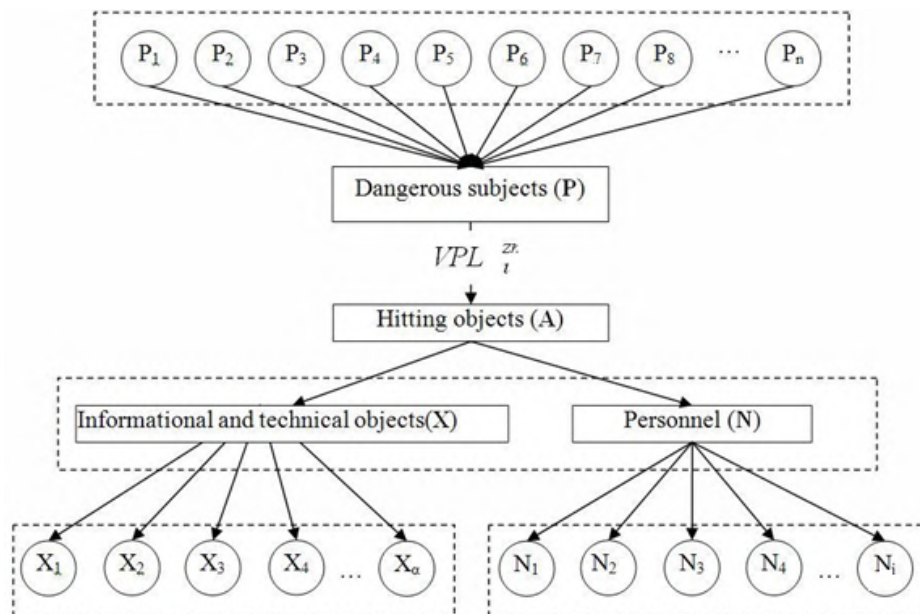


Figure 2. The model for identifying subjects of threats at the protected area.

Therefore, we have the open classification grouping of hitting objects in the form of a union of sets of potential goals of unauthorized access, (1):

$$A = N \cup X = (N \setminus X) \vee (X \setminus N) \vee (X \wedge N) \tag{1}$$

Thus, we determined the threat sources in the form of a set of dangerous subjects (**P**) that may attack VPL^{zn} the position of the subdivision on duty to destroy or to invade informational and technical objects (**X**) or/and personnel (**N**).

During the analysis of the functioning of the subdivision on duty the objects with the maximum impact zone were discovered: radio-electronic means (X_1^p), reconnaissance information (X_2^p), subdivision's equipment (X_3^p), signal center (X_4^p), subdivision's weapon (X_5^p), and food supply (X_6^p).

Staff in potential danger include: chief of the position (N_1^l), worker on duty (N_2^l), post operator (N_3^l), signalman (N_4^l), doctor (N_5^l), sentry (N_6^l).

As a result of investigations, a set of threats of unauthorized access **S** was formed. Unauthorized access S_θ is determined by the set of hitting objects **A** according to the formula (2):

$$S_\theta = \{A_\sigma | \sigma = \overline{0, (X_a + N_j)}\} \tag{2}$$

Unauthorized access determined at the hitting object S_θ may be expressed by the set of dangerous subjects **P**, the formula (3):

$$S_\theta^p = \{P_n | n = \overline{0, m_{sz}}\}, \tag{3}$$

where m_{sz} – the number of dangerous subjects.

Unauthorized access determined at the hitting object and by the set of dangerous subjects S_θ^p is obtained by the set of impacts occurred by subjects, the formula (4):

$$S_\theta^{pv} = \{VPL_i^{zn} | i = \overline{0, k}\}, \tag{4}$$

where m_{sz} – the number of possible impacts.

The set of possible acts at the hitting object is determined by the set of possible impacts and the set of dangerous subjects and is found using the expression, the formula (5):

$$T = (P \wedge VPL^{zn}) \tag{5}$$

Unauthorized access determined at the hitting object and by the set of dangerous subjects and the set of possible impacts is obtained by, the formula (6):

$$S_\theta^{pvs} = \{H_y, F_i, G_k | \theta = \overline{1, \mu}, y = \overline{1, \psi}, i = \overline{1, n}, k = \overline{1, \delta}\}, \tag{6}$$

where n, δ, ψ – amount of means to detect each class; μ – the number of system solutions.

Therefore, an informative vector of unauthorized access can be represented in the form of, the formula (7):

$$I_{\mu_i}^{pvs} = \{T_v, VPL_i^{zn}, P_n, A_\sigma | v = \overline{0, \xi}, i = \overline{0, c}, \sigma = \overline{0, (X_a + N_j)}, n = \overline{0, m_{sz}}\}. \tag{7}$$

Thus, S_θ^{pvs} is determined as an integral value $W_i', i = \overline{0, \mu}$, the formula (8):

$$S_\theta^{pvs} = f(H_y, F_i, G_k) \tag{8}$$

According to the formula (8) S_θ^{pvs} , the presence of unauthorized access is determined and decision about the alarm is made. To classify the rank of the violator, who committed unauthorized access to the perimeter of the object, we use a set R, which is a subset of Q and has the same parameters. The method of detection of unauthorized access threat to the protected area is constructed with the help of a productive model of knowledge representation. It is a complex of linguistic expressions "if-then". Let us consider that the scales of all expert rules equal 1.

As at the beginning formalized experts' knowledge is not enough, so it is supposed that the knowledge matrix may compete with the appearance of new knowledge about the possibility to detect unauthorized access, experimental data. It is performed by the creation of new rules that make the method of detection of unauthorized access closer to the real conditions. Thus, adaptation and settings of the knowledge matrix are supposed.

So, the threat detection of unauthorized access to the subdivision on duty may be shown as, the formula (9):

$$S_{\theta}^{pvs} = f_{\theta}(H_y, G_k, F_i), \theta = \overline{1, \mu}, y = \overline{0, \psi}, k = \overline{0, \delta}, i = \overline{0, n} \tag{9}$$

where H_y – a set of discrete signals coming from motion detectors; F_i – a set of discrete signals of RFID signs; G_k – a flow of data coming from cameras; $f_{\theta}(H_y, G_k, F_i)$ – logical expressions that determine the level of threat for unauthorized access on the safety principle $S_{\theta}^{pvs}, \theta = \overline{1, \mu}$.

The range of changes of the motion detector's characteristics of the state $H_y \in [H_y, \overline{H_y}], y = \overline{1, \psi}$, RFID signs $F_i \in [F_i, \overline{F_i}], i = \overline{1, n}$, the flow of video data $G_k \in [G_k, \overline{G_k}], k = \overline{1, \delta}$ an output value of the result of situation classification (identification) is known. Here $[H_y, \overline{H_y}], [F_i, \overline{F_i}], [G_k, \overline{G_k}]$ are the respectively lower and upper value of motion detector's characteristics of the state, signals from RFID signs, and flow of video data that get values 0 or 1.

Then the solution S_{θ}^{pvs*} is placed as conformity to fixed states of H_y, F_i, G_k determined by fixed vectors of input parameters. Considering the abovementioned factors, we obtain authorized access in the form of knowledge matrix (table 1).

1. The table dimension equals $(\lambda+1) \times N$, where $(\lambda+1)$ – number of columns, which value equals the number of classification groups for indexes of the protected perimeter; N – the number of rows.
2. First λ columns of the matrix correspond to input variables H_y, F_i , and G_k , but $(\lambda+1)^{th}$ column corresponds to the value S_{θ}^{pvs} of the output variable $\mathbf{S}, \theta = \overline{1, \mu}$.
3. Each row of the matrix is a combination of input variable values that refers to one of the possible values of output variable \mathbf{S} . Besides, first k_{θ_1} rows correspond to the output variable value S_1 , but others k_{θ_2} correspond to the S_2 .
4. Input variables are binary. An element of the matrix α_{μ}° that is placed at the intersection of row and column corresponds to the linguistic assessment of the input data parameter and takes place in the determination of the possible value of output variable that detects unauthorized access.

Table 1. Knowledge matrix used to classify the threat of the appearance of unauthorized access.

Number of input value combination	Input variables			Output variable S_{θ}^{pvs}
	Motion detector's signals (H_y)	RFID-sign signals (F_i)	Changes of video data Stateflow (G_k)	
1	0	1	0	S_1
2	0	1	1	
3	1	1	0	
4	1	1	1	
5	0	0	0	
6	0	0	1	S_2
7	1	0	0	
8	1	0	1	

Categorization of unauthorized access detection $\mathbf{S} = \cup_{\theta} S_{\theta}^{pvs}, \theta = \overline{1, 5}$ consists of classification units: $S_1 = S_1^{pvs}$ – the alarm is not generated; $S_2 = S_2^{pvs}$ – the alarm is generated.

The input knowledge matrix determines the system of logical expressions "IF-THEN, ELSE" that connect values of input variables with one of the possible solutions. In this case, the system determines the presence of unauthorized access to the area of the subdivision on duty $S_{\theta}^{pvs}, \theta = \overline{1, \mu}$, the formula:

IF (F=0) AND [((H=0) AND ((G=0) OR (G=1))) OR (H=1) AND ((G=0) OR (G=1))], THEN S=S2, ELSE, S=S1

If the location of the subdivision on duty is a constant place for a long time and there is a possibility to extend the protected perimeter by distribution the motion detectors, RFID signs, and cameras as far as possible (thereby to increase the time for operator's decision and realization of appropriate measures) the possibility to realize violator classification appears.

4. Discussions

The research yielded the following results:

1. The structures of the information system for ranking objects, which are threats of unauthorized access to the perimeter for the protected area, have been proposed. This system consists of a contactless radio frequency identification subsystem (RFID), intelligent video surveillance subsystem, DSS of detecting and prevents unauthorized access to the perimeter of the protected area, a subsystem of detection the movement along the protected perimeter. The integration and implementation of these subsystems allow automating the process of violator's detection and the process of decision-making for alarm generation.

2. The first time the model of components interaction for information systems of ranking objects, which are threats of unauthorized access to the perimeter for the protected area has been proposed. This model determines informational flows and realizes the interaction of system components. Also, it was determined as a form of transmitted vectors.

3. The model for identifying subjects of threats for unauthorized access to the protected area has been improved. It determines classification groups of dangerous subjects, staff, and informational-technical objects. This model was the base to form a classification set of potential hitting objects. Therefore, threat sources were determined in the form of dangerous subjects set that may attack the location of the subdivision on duty to destroy or to invade staff and/or informational-technical objects.

4. The method of detecting unauthorized access to the perimeter for a protected area has been proposed. It is constructed with the help of a productive model of knowledge representation, which is a set of linguistic expressions "IF-THEN". Given expressions are in the form of operations of indistinct logic and knowledge matrix, thus, there is the opportunity to automate the determination of threats. The method of classification of dangerous subjects for unauthorized access to the protected area has been realized.

5. Conclusions

A set of proposed models, methods, information, and software-hardware means that are interrelated and interacted with users during preparation, adoption, and control of management decisions, creates information technology for mobile perimeter security systems and increases the security level of guard subdivision and subdivision on duty. This technology makes be automated processes of violator detection and decision-making for alarm generation. The practical value of this article consists of the possibility to use given information technology in security systems for different objects. Proposed models are finished and able to software and hardware realization.

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Single-rotor integrating gyroscopic gravimeter

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Abstract. The paper describes the gravity acceleration sensor (GAS) design, the technical characteristics of which provide an increase in the static transfer constant of the GAS, the ability to determine the current static transfer constant of the GAS, reducing the level of noise effects in the output signal of GAS. The acceleration vector components from the side of a moving vehicle add a noise to the gravity vector components. These investigations give an answer how to obtain of GAS’s desired metrological features by the developing of new GAS based on pendulous integrating gyroscopic accelerometer. The presented material can be seen as an example of how to explore a gyro system mechanics and how to develop new gyro systems structure. The presented methods and the sequences of expressions can be used in master’s and bachelor’s disciplines in the field of applied mechanics, instrument development and automatic control.

1. Introduction

Gravity acceleration sensors (GAS) are today the most promising in terms of large-scale study of gravity acceleration anomalies [10], [13]. GAS is considered as a sensitive element of the aviation gravimetric system (AGS). The involving of automation technologies into the system of device functioning, making the computer processing of information signals of the device possible, is relevant. The problem is to design GAS for AGS with the aim of improving measurement accuracy of gravity acceleration anomaly [10]. Accurate knowledge of the Earth gravitation field anomaly is necessary for aviation and space technology, geology geophysics and geodesy.

Therefore, it is necessary to find solutions to improve the accuracy of gravity sensors.

Nowadays such AGS gravimeters are exploited: quartz, string with liquid damping, magnetic, spring, piezoelectric-type [12]. All of them have almost the same accuracy but different source of measurement errors, which depend on their principle of operation.

The disadvantages of quartz, magnetic, spring, string and piezoelectric-type gravimeters are [1]:

- 1) instability of static transfer constant;
- 2) inability to determine the current static transfer constant;
- 3) presence in the output signal obstacles, due to the fact that the accelerometer is mounted on a movable basis;
- 4) there is a compulsory need for a sophisticated hardware procedure that filtering the output GAS signal [2].



2. Literature review

Disadvantages of existing GAS can be overcome by using gyroscopic devices in gravimetry. For these purposes the acceptable gyroscopic devices are: dynamic gyroscope [2] or linear gyro-integrator [1], [4], [5], [9].

Even nowadays, precision gyroscopes are considered the best for use as major sensing elements in inertial navigation and control systems of ballistic rockets. These devices were designed for use in rigid dynamic conditions: 1) axial overload: over 30 g; 2) temperature range: from -60 to $+50^{\circ}\text{C}$; 3) range of air pressure: 700 to 800 mmHg (near the Earth's surface) and 10-6 mmHg (at a height of 200 km) [9], [11].

In the gyroscopic gravimetric systems with a dynamic gyroscope [8] a two-level gyroscope is used as a gyroscopic sensor of gravity acceleration. The center of rotor mass is shifted in the rotation plane of the rotor, creating pendulum. Rotor itself is attached to the suspension axes with the help of elastomeric rotational springs, the work of which principally depends on twisting and they act as dampers.

Initially, rotor is rotating in the perpendicular to the vertical of a place (normal to the ellipsoid rotation). The rotor deviation from the initial position is measured by an angle sensor with the output signal of a gravity acceleration sensor and with the input signal for the torque sensor. The torque sensor creates an additional torque relative to the rotor suspension axis.

Ideally, a static transfer constant of the gyroscopic GAS (GGAS) as a gravimeter depends only on the pendulum and on the transfer constant of the torque sensor. But in practice the stability of a static transfer constant of GGAS is limited due to the strong dependence of the elastomeric bearings on the temperature and vibration parameters at the installation site causing its weariness [6], [11].

The temperature changes also result in electric parameters changes in the electromechanical system of the torque; and, thus, affect the value of its transfer constant. Instability of the torque transfer constant causes additional instability of the static transfer constant of the gyroscope gravity acceleration sensor.

As mentioned above there are the gyroscopic gravimetric systems based on a linear gyro-integrator or PIGA (Pendulous Integrating Gyroscopic Accelerometer) [4], [5], [9].

PIGA is a three-dimensional gyroscope whose center of gravity is shifted relative to the point of suspension. As a result, PIGA is sensitive to transmitted acceleration of the object, because arising at the moment of inertia forces causes the precession of the gyroscope with an angular velocity proportional to the specified moment, i.e., the magnitude of the acceleration of the object. Then the precession angle will be proportional to the linear velocity of the object, which allows finding the velocity of an object by measuring this angle.

PIGA responds to the acceleration of the object that appears, that is, the sum of the absolute acceleration of the object and the gravitational acceleration (acceleration of gravity). As a result, the device output is proportional to the integral of the total acceleration that applied to the object where PIGA is installed.

Both gyro-gravimeters of dynamic and integrating type accept a "useful" moment from the vertical vector component of gravity acceleration, interference moments from the horizontal vector components of gravity acceleration, interference moments from the vertical and horizontal vector components of the movable basis linear acceleration, interference moments from the vertical and horizontal vector components of the angular acceleration of the movable basis and the interference moments from the horizontal vector components of the angular acceleration of the movable basis simultaneously act with the gravimeter relative to the rotor suspension axis.

The moments mentioned above result in the appearance of relevant components in the output signal of gyroscope gravity acceleration sensor – interference moments, but for those, caused by horizontal components of gravity acceleration vector, are explained by the fact that gyroscope gravity acceleration sensor is installed on the movable platform.

In addition, both gravimeters operate by rotating the gyroscopic rotor. This fact mechanically explains the appearance of precession, compensating centrifugal forces, mechanical torques and more. Thus, the rotation of the rotor causes kinetic moment, which fully determines the static transfer constant

for the instruments. When recalculating the output of the gravimeter back to the acceleration value, it is very important to know at all times the current static transfer constant of the gyro-gravimeter. Available data indicate that the described gyro-gravimeters have another drawback – the absence of means for controlling the static transfer constant.

In the integrating gyroscopic gravimeter the property of integrating the applied accelerations allows to reduce the influence of frequency components of obstacles, but to detect the low-frequency component of accelerations – gravity acceleration.

2.1. General problems

The essential disadvantages of the existing gravimeters are:

- Instability of the static transfer constant of GGAS, caused by the changes of rotation spring properties, the changes of gyroscope rotation frequency and the changes of electrical parameters in electromechanical system of the torque;
- Impossibility to define the current static transfer constant of GGAS;
- Presence of interference components in the output signal of GGAS, explained by the GGAS being installed on the movable basis, and interference components from the horizontal vector components of gravity acceleration.

The indicated factors significantly reduce the measuring accuracy of the gyroscope gravity acceleration vertical vector component, performed by such a device from the board of the aircraft.

2.2. Objectives

To suggest GGAS of the new structure with the following criteria:

- It is need to develop GGAS on principles that are in PIGA – integrating properties;
- Increase the stability of the static transfer constant of the GGAS;
- Possibility to measure the current static transfer constant of GGAS;
- Decrease the amount of interferences in the output signal of GGAS leading to a significant increase of accuracy measurement of gravity acceleration vertical vector component from the board of the aircraft.

3. Suggestions and solutions

The targets can be reached by using a new single-rotor integrating GGAS and additional information channels.

On the figure 1 the suggested GGAS is depicted as a part of gravimetric system: GGAS (1); the system of current navigation parameters measurement (velocity, direction and geographic latitude) (2); altimeter (3); board computer (4).

GGAS (1) consists of a gyro-motor (5) attached to the internal gyro-motor suspension axis with spring dampers (7) designed so that the twisting rotation of spring dampers stiffness along the internal gyro-motor suspension longitudinal axis (8) is much less significant than the spring dampers stiffness (7) in bending.

The longitudinal axis (8) of internal gyro-motor suspension axis is shifted relative to the outer plane frame (9) and is found in the perpendicular to the axis plane (10) of the outer frame with the gyro-motor mass center (5) found on the gyro-motor rotor rotation axis that if this axis (11) is perpendicular relative to the outer frame plane (9), then the gyro-motor mass center (5) is placed on outer frame suspension axis installed along the vertical of a place.

The outer frame suspension axis (10) installed along the vertical of a place is carried out, for instance, through the gyroscope gravity acceleration sensor installation (1) at the horizontally-stabilized platform. Moreover, the outer frame axis (10) is being installed along the vertical axis ξ of the horizontally-stabilized platform and axis η , ζ – are the horizontal axis of the platform.

The sensor (12) that measures twisting rotation angle of spring dampers is placed on the internal gyro-motor suspension axis (6) is being connected to the first amplifying element (13) that is connected

to the operating engine (14), stiffly fixed on the outer frame (9), and the operating engine axis (14) is the internal suspension gyro-motor axis (6).

The gyro-motor turning angle sensor (15), installed on the outer frame (9), is connected to the board computer (4) and to the second amplifying element (16) that is connected to the torque sensor (17) being placed on the outer frame suspension axis (10). Connecting the gyro-motor turning angle sensor (15) to the board computer (4) allows controlling the gyro-motor's rotor rotation axis (11) perpendicularity to the outer frame suspension axis (10).

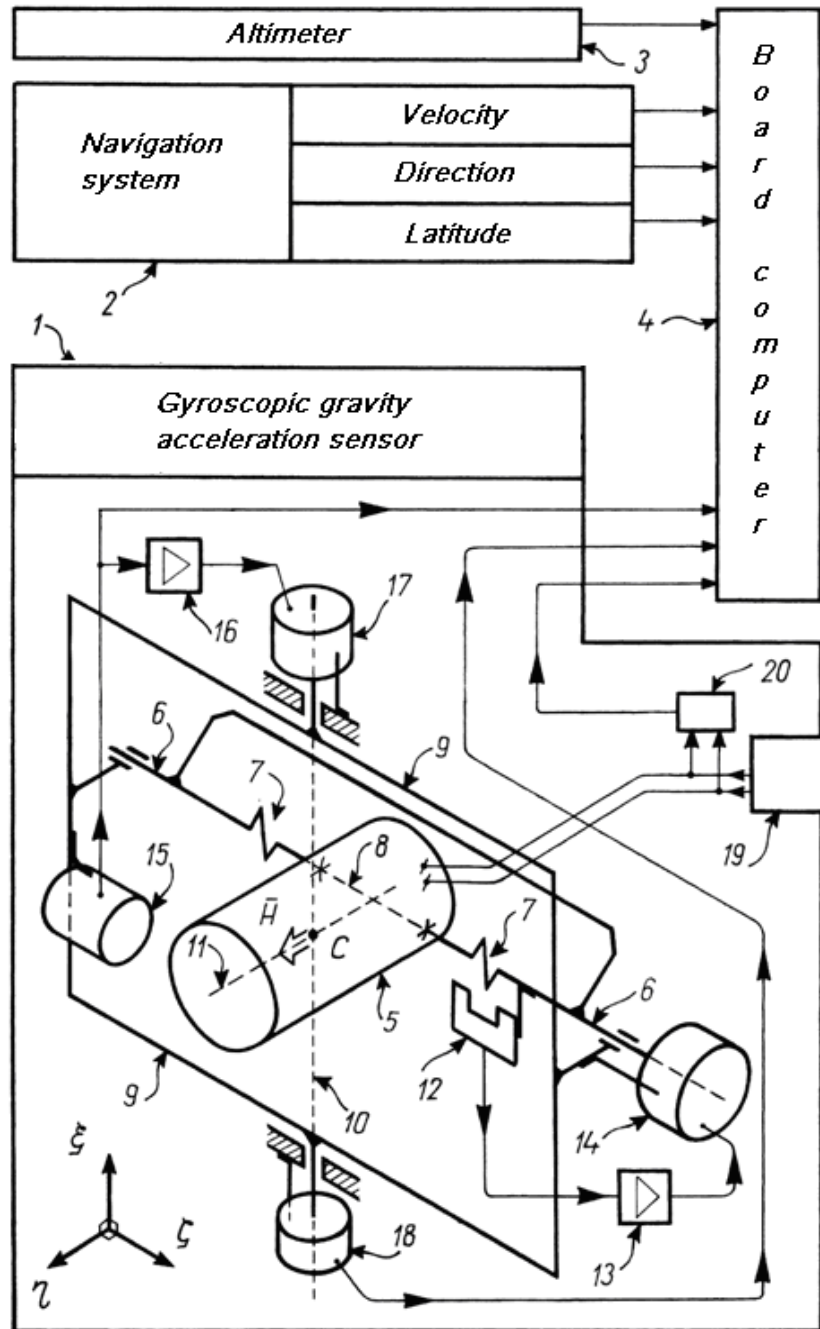


Figure 1. Single-rotor integrating gyroscope gravity acceleration sensor as an element of a gravimetric system.

The outer frame turning angle sensor (18) is placed on the outer frame suspension axis (10) and connected to the board computer (4). The outer frame turning angle sensor (18) output signal is the main output signal of GGAS (1).

The current power supply frequency sensor (20), connected to the board computer (4), and the gyro-motor (5) are both connected to the frequency-stabilized power supply unit (19).

The power supply frequency sensor output (20) is connected to the board computer (4) in order to measure the current frequency of gyro-motor rotor rotation 5 and the board computer (4), based on the measurements, further defines the static transfer constant of GGAS (1).

Gravimeter does perform in the following way:

The gyro-motor's rotor (5) is rotating with the velocity γ around gyro-motor rotor rotation axis (11), creating an angular moment H .

The vertical element g_ξ and horizontal elements g_η, g_ζ of gravity acceleration vector together with the vertical element W_ξ and horizontal elements W_η, W_ζ of the linear acceleration vector of a horizontally-stabilized platform act upon the shifted relative to the longitudinal axis of the gyro-motor internal suspension axis (8) mass center C of the gyro-motor. At the same time a moment $M_{g,w}$ exists relative to the longitudinal axis (8) of the gyro-motor internal suspension axis. If to address to the general principles of the gyroscope systems description [1], [5], the moment $M_{g,w}$ is defined in the following way:

$$M_{g,w} = -m \cdot l \cdot \left[(W_\xi - g_\xi) \cdot \cos \beta + (W_\eta - g_\eta) \cdot \sin \alpha \cdot \sin \beta - (W_\zeta - g_\zeta) \cdot \cos \alpha \cdot \sin \beta \right] \quad (1)$$

where $m \cdot l$ – the gyro-motor (5) pendulum; β – the gyro-motor (5) turning angle around the longitudinal axis (8) of the gyro-motor internal suspension axis; α – the outer frame (9) turning angle around the outer frame suspension axis (10).

With the presence of the vector angle acceleration horizontal elements $\omega_\zeta, \omega_\eta$ of horizontally-stabilized platform, where the GGAS (1) is actually installed, the inertia moment M_{in} appears relative to the longitudinal axis (8) of the first gyro-motor internal suspension axis that is calculated as follows:

$$M_{in} = -B \cdot (\dot{\omega}_\eta \cdot \cos \alpha + \dot{\omega}_\zeta \cdot \sin \alpha) \quad (2)$$

with B being a gyro-motor (5) inertia moment relative to the longitudinal axis (8) of the first gyro-motor internal suspension axis.

The vertical element ω_ξ and the horizontal components $\omega_\zeta, \omega_\eta$ of horizontally-stabilized angular velocity vector, where the GGAS (1) is installed, cause the appearance of compound centrifugal force moment M_k (gyroscopic moment) from the transmission angular velocity of the horizontally-stabilized platform. The moment M_k found relative to the longitudinal axis (8) of gyro-motor internal suspension axis is calculated in the following way:

$$M_k = H \cdot (\omega_\xi \cdot \cos \beta + \omega_\eta \cdot \sin \alpha \cdot \sin \beta - \omega_\zeta \cdot \cos \alpha \cdot \sin \beta) \quad (3)$$

with H being a kinetic moment emerging from the gyro-motor rotor rotation 5.

The moments M_g, W, M_k, M_{in} cause the gyro-motor's (5) rotation around the longitudinal axis (8) of gyro-motor internal suspension axis and that is why:

$$\beta \neq 0 \quad (4)$$

The gyro-motor (5), rotating around the longitudinal axis (8) of gyro-motor internal suspension axis, twist the spring dampers up (7). In this way there appear moments, caused by the spring dampers (7) force, relative to the mentioned axis and are calculated in the following way:

$$M_{spr} = C \cdot \Delta\beta_{spr} \quad (5)$$

$$\Delta\beta_{spr} = \beta - \beta_{mtr} \quad (6)$$

with C being spring dampers (7) stiffness constant of twisting along the longitudinal axis (8) of gyro-motor internal suspension axis; $\Delta\beta_{spr}$ being the angle of spring dampers (7) twisting rotation; β_{mtr} – the rotation angle of the gyro-motor internal suspension axis (6) around the longitudinal axis (8) of gyro-motor internal suspension axis performed by the drive engine (14).

In the presence of the spring dampers twisting rotation angle $\Delta\beta_{spr}$ in the output of the sensor there is the proportional to the angle $\Delta\beta_{spr}$ signal that is transmitted to the first amplifying element (13) with its output being connected to the drive engine (14). The drive engine will rotate the gyro-motor internal

suspension axis (6) around the longitudinal axis (8) of gyro-motor internal suspension axis till the condition is being performed:

$$\Delta\beta_{\text{spr}} \neq 0 \tag{7}$$

Thus, the direction of the gyro-motor internal suspension axis (6) rotation around the longitudinal axis (8) of gyro-motor internal suspension axis is always the one providing the decrease of the current angle $\Delta\beta_{\text{spr}}$ value measured by the sensor (12) of spring dampers twisting rotation angle. In the result, the following condition is possible to be performed: the steady angle value $\Delta\beta_{\text{spr std}}$ is approaching the zero ($\Delta\beta_{\text{spr std}} \rightarrow 0$). It also means:

$$M_{\text{spr std}} \rightarrow 0 \tag{8}$$

Even if $\Delta\beta_{\text{spr std}} \rightarrow 0$ during sensor operation:

$$\beta = \beta_{\text{mtr}} + \Delta\beta_{\text{spr}} \neq 0 \tag{9}$$

here the correction circuit between the longitudinal axis (8) of gyro-motor internal suspension axis and the outer frame suspension axis (10) starts acting.

The gyro-motor turning angle sensor (15), installed on the outer frame (9), measures the β angle and transmits the signal proportional to the β angle to the other amplifying element (16), the output of which is connected to the torque sensor (17).

The torque sensor (17), in relation to the input signal, causes the correction moment M_{corr} :

$$M_{\text{corr}} = -K_k \cdot \beta \tag{10}$$

with K_k being the general transfer constant of the described channel.

The torque sensor (17) applies M_{corr} to the outer frame suspension axis (10). The outer frame (9) affected by M_{corr} acquires α angle velocity that is enough to compensate the total moment relative to the longitudinal axis (8) of gyro-motor internal suspension axis and, as a result, provide the smallness of β angle that $\cos \beta$ meaning is as close as possible to the unit: $\beta \rightarrow 0$.

The β angle smallness signifies the directly proportional smallness of the following moments: M_g , W , M_k , M_{in} depending on $\sin \beta$ value. In this way it becomes possible to insure the minimum dependence of the output signal of GGAS (1) on the interferences components, caused by W_η , W_ζ horizontal components of the linear acceleration vector and ω_η , ω_ζ – horizontal components of the angular velocity vector of the horizontally-stabilized platform on which the GGAS (1) is actually installed; and also caused by the horizontal g_ζ , g_η components of the gravity vector acceleration.

Referring to the general principles of the gyroscope systems dynamic description [3], [7], and taking into consideration $\beta \rightarrow 0$, $M_{\text{spr}} \rightarrow 0$ conditions, $\alpha(t)$ – turning angle of the outer frame (9) in the steady mode:

$$\alpha_{\text{std}}(t) \approx \frac{-1}{H} \int_{t_0}^t (M_{g,W} + M_{\text{in}} + M_k + M_{\text{spr}}) dt = \frac{ml}{H} \int_{t_0}^t (W_\xi - g_\xi) dt - \int_{t_0}^t (\omega_\xi) dt + \frac{B}{H} \int_{t_0}^t (\dot{\omega}_\eta \cos \alpha + \dot{\omega}_\zeta \sin \alpha) dt \tag{11}$$

with t being the time between the starting data sample time moment t_0 and the ending data sample time moment.

In this case, a “useful” signal component is:

$$\alpha_{\text{usf std}}(t) = -\frac{m \cdot l}{H} \int_{t_0}^t (g_\xi) dt \tag{12}$$

Other components are the interference (error) signals:

$$\alpha_{\text{int err std}}(t) = \frac{ml}{H} \int_{t_0}^t (W_\xi) dt - \int_{t_0}^t (\omega_\xi) dt + \frac{B}{H} \int_{t_0}^t (\dot{\omega}_\eta \cos \alpha + \dot{\omega}_\zeta \sin \alpha) dt \tag{13}$$

$\alpha(t)$ signal is detected by the outer frame turning angle sensor (18), installed on the outer frame suspension axis (10) and is the main output signal of the GGAS (1). From the outer frame turning angle sensor (18) output this signal gets into the board computer (4) for its further processing.

To calculate the average value \bar{g}_ξ of the vertical component of the gravity acceleration vector, the board computer chooses the intervals of the already measured signal values $\alpha(t)$ according to the data stability in these intervals of the gyro-motor kinetic moment (5) H and according to the angle β value

data in these intervals. For this the board computer (4) during the whole time while the measurements are taking place, reads the gyro-motor power supply (5) frequency γ' data coming from the output of the current frequency supply (20) data and from the output of the gyro-motor turning angle (15) sensor – the β angle data. The board computer (4), according to the gyro-motor power supply (5) frequency γ' , defines the appropriate gyro-motor rotor rotation frequency value. This can be achieved by simple measuring of gyro-motor's rotor frequency by embedding appropriate sensor.

Based on the received data, the board computer (4) chooses the intervals, for which the indicated below conditions are carried out.

The first is the stability of gyro-motor rotor rotation (5) frequency:

$$\bar{\gamma}_i = \text{const} \pm \Delta\gamma_i \tag{14}$$

with γ_i being the corresponding to i interval of the gyro-motor rotor rotation frequency γ' value (5); $\Delta\gamma_i$ – module of the difference between the gyro-motor rotor rotation frequency γ' value (5) and the average gyro-motor rotor (5) frequency $\bar{\gamma}_i$ value, meanwhile $\Delta\gamma_i$ can be omitted and consider as the one equal to zero.

The second is the angle β smallness condition:

$$\beta_i = 0 \pm \Delta\beta_i \tag{15}$$

with β_i being the corresponding to i interval of the gyro-motor turning angle β value around the longitudinal axis (8) of gyro-motor internal suspension axis; $\Delta\beta_i$ – the module of the angle β_i deviations from zero that can be omitted and considered as the one equal to zero.

For every i -type interval chosen by the board computer (4) performs a calculating operation of the current static transfer constant $R_{st,i}$ of the GGAS (1) taking into account the corresponding to each of the interval $\bar{\gamma}_i$ value:

$$R_{st,i} = \frac{ml}{H_i} = \frac{ml}{J \cdot \bar{\gamma}} \tag{16}$$

with J being the gyro-motor rotor (5) inertia moment relatively to the gyro-motor rotor rotation axis (11).

At the same time while reading the main $\alpha(t)$ signal and the additional $\beta, \bar{\gamma}_i$ signals, the board computer (4) reads the data from the connected to it devices: the current navigation parameters measurement system (2) and the current altitude measurement. According to the received data, the board computer (4) calculates the values for each of the i -type chosen interval:

$$\int_{t_{start\ i}}^{t_{end\ i}} W_{\xi,i} dt, \int_{t_{start\ i}}^{t_{end\ i}} \omega_{\xi,i} dt \tag{17}$$

with t_{start} is the start and t_{end} is the end time moments of the i -type data interval; $W_{\xi,i}, \omega_{\xi,i}$ – are the current i -type interval values according to the vertical component W_{ξ} of the linear acceleration vector and the vertical component ω_{ξ} of the angular velocity vector of the horizontally-stabilized platform.

The board computer (4), having performed the calculations, defines the average value of the vertical vector gravity acceleration $\bar{g}_{\xi,i}$ for each of the i -type chosen interval:

$$\bar{g}_{\xi,i} = \frac{-1}{R_{st\ i} \cdot (t_{end\ i} - t_{start\ i})} \left[(\alpha(t_{end\ i}) - \alpha(t_{start\ i})) - R_{st\ i} \cdot \left(\int_{t_{start\ i}}^{t_{end\ i}} W_{\xi,i} dt \right) + \left(\int_{t_{start\ i}}^{t_{end\ i}} \omega_{\xi,i} dt \right) \right] \tag{18}$$

In general case, the board computer (4) performs an additional reduction of the received vertical component value of the gravity acceleration vector.

4. Conclusions

The suggested implementation of the single-rotor integrating gyroscopic sensor as the GGAS allows improve the stability of the static transfer constant of the indicated sensor. It is possible because in this case the static transfer constant is measured only by the pendulum value, the axial inertia moment and the gyro-motor rotor rotation frequency. As soon as it is possible to stabilize the pendulum, the axial inertia moment and the gyro-motor rotor rotation with the help of low heat growth and to reach the

stability of gyro-motor rotor rotation frequency value using a high-quality precision synchronic gyro-motor together with the power unit of the stabilize frequency, the stable static transfer constant of the GGAS is received.

It is a significant advantage as the stability of this constant is one of the key points defining the output accuracy of the single-rotor integrating gyroscopic gravimeter with the controlled parameters and, therefore, the gravity acceleration vertical component measurement accuracy from the board of the moving vehicle with the help of such equipment.

The system with the current frequency supply sensor, connected to the board computer, takes control of the gyro-motor power supply frequency and the gyro-motor rotor frequency, creates an additional information channel and allows, chose out the intervals with the necessary, for the required accuracy, stability of the gyro-motor frequency. It also defines the current mean value of the static transfer constant of the GGAS with accordance to the gyro-motor rotor rotation frequency value. Then it is possible to calculate the proper value of correction and remove some kind of obstacle from the gravimeter output signal.

High-frequency interference components cause the need to average the output signal of the GGAS, involving the integration procedure. The suggested single-rotor integrating gyroscopic gravity acceleration sensor has a significant advantage in this way, since it is an ideal integrator from the precession theory point of view [7].

The gyro-motor arrangement, as well as the arrangement of the gyro-motor internal suspension axis is that the center of the gyro-motor mass is as close as possible to the outer frame suspension axis, allows get rid of the interference's components in the output signal of the GGAS caused by the centrifugal acceleration affecting the gyro-motor mass center during the outer frame rotation together with gyro-motor around the outer frame suspension axis

Fixing the gyro-motor on the gyro-motor internal suspension axis with spring dampers, mainly working on twisting, initiates that in the operating mode in relation to the longitudinal axis of gyro-motor internal suspension axis, the moments, caused by the dry friction forces are not applied and simultaneously provides the absence of the GGAS threshold.

The correction circuit consisting of the gyro-motor rotation angle sensor, which is connected to the torque sensor installed on the outer frame suspension axis, allowing ensure the minimum deviation angle of the gyro-motor rotor rotation axis, from the perpendicularity to the outer frame plane, and, therefore, from the perpendicularity to the outer frame suspension axis. Thus, the "zero-point" stability and maximum sensitivity of the proposed gyroscopic gravity acceleration sensor are provided being a standard requirement for such devices [7].

All of these increase the accuracy in measurements of the gravity acceleration vertical component from the board of the movable vehicle.

The presented materials are related to general methods and sequences of mathematical description of gyro-systems. All this can be part of fundamental research, as well as an educational aspect for such areas as applied mechanics, instrument development and automatic control. Analysis of existing gyros can be used by bachelors, but masters can explore new forms of gyro structures.

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Software model for studying the features of wireless connections in Flying Ad-Hoc Networks (FANETs)

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Software model for studying the features of wireless connections in Flying Ad-Hoc Networks (FANETs)

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Abstract. Over the last decade, earlier named self-organizing mobile computer networks, MANET (Mobile Ad Hoc Network), including those based on unmanned aerial vehicles (UAV) – FANET (Flying Ad Hoc Network), have become widespread. In FANET, the UAV is connected to the network using wireless technology. Due to the constant dynamics of the nodes of such FANET, in this network, there are sometimes lost connections between the nodes. Modern wireless technologies such as WiFi, ZigBee, AirMAX, and others, have different technical characteristics that significantly affect the ability to build FANET. In the article developed a software model that allows you to study the statistical characteristics of mobile networks. The motion of each object (network node) is described using a quaternion model. The software model is developed in the Python programming language. The obtained software model for the given conditions allows us to estimate the basic statistical characteristics of FANET and to make recommendations to their construction and application.

1. Introduction

In recent years, the capabilities of computer networks have greatly increased. Networks developed rapidly and found applications in many areas of human life and activity. Computer networks have received new properties: mobility and self-organization. So there was Mobile Ad Hoc Network (MANET), in which network nodes can move on a plane. As a result of advances in new technologies, such as sensors, microprocessors, wireless communications, and network technologies, it has also become possible to implement networks using unmanned aerial vehicles (UAV). Such networks are called Flying Ad Hoc Network (FANET). In FANET, network nodes move in three-dimensional space. The use of several UAVs to create a network requires the coordination of their actions for the joint achievement of goals. This level of coordination requires the development of new network models.

2. Background

FANET is a non-droning measure (COM), which is self-organizing, like a UAV unit (figure 1). This measure is characterized by high mobility of the universities, a dynamically variable topology, clutter in the 3D space, interchangeable characteristics of the universities (the need for transmission, battery charge, and battery.). Interconnection between the higher education institution and the higher education institution will be denied by the higher-order through some industrial universities, which can be used for routing functions [10].



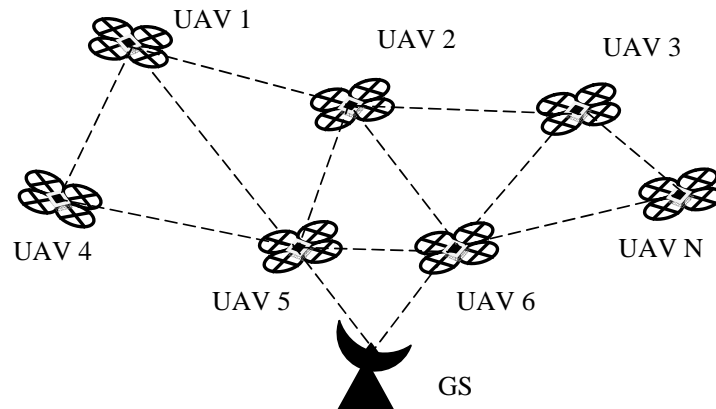


Figure 1. The general scheme of FANET [10].

These features create a large number of additional difficulties in organizing network communication and require solving some problems [7], [8]:

- at the physical level: the study of radio wave propagation models and antenna structure are key development factors [1];
- MAC level: due to high mobility and large differences in distances between nodes, there are often problems with the quality of the communication channel. Changing the value of the packet transmission delay is another problem of the MAC layer in FANET. This is especially critical for real-time applications [11];
- network level: routing is one of the most difficult issues for FANET. Existing solutions may not meet all FANET requirements [10];
- transport level: the success of FANET projects is closely linked to the reliability of the communication architecture, and the creation of a reliable transport mechanism is important, especially in a highly dynamic environment [3], [9], [12].

Due to the constant dynamics of the nodes of such FANET, in this network, there are sometimes lost connections between the nodes.

3. Communication in FANET

Modern wireless technologies such as WiFi, ZigBee, AirMAX, and others, have different technical characteristics that significantly affect the ability to build FANET.

Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access [5].

Zigbee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks.

The main feature of ZigBee technology is that with low power consumption it supports not only simple network topologies (point-to-point, tree, and star), but also self-organizing and self-healing mesh topology with relaying and routing messages.

Unlike IEEE 802.11 protocols, were at a greater distance the subscribers can no longer hear each other, when using AirMax technology there are no errors due to the overlap of packets from multiple subscribers due to the use of TDMA technology. Its essence is as follows: the base station, working with the AirMax protocol, determines the order of operation of the devices connected to it by allocating to each subscriber its time interval (slot) for data transmission. Therefore, the occurrence of collisions is eliminated, and the quality of data reception and transmission is improved.

AirMax technology uses the MIMO antenna configuration to achieve high radio bandwidth.

The advantages of AirMax include the ability to scale the network. So, if when working on WiFi standards, the maximum number of simultaneous connections to the access point should not exceed 20-

25, then AirMax provides simultaneous operation in the radio channel up to 120 devices. All AirMax devices run the AirOS operating system.

Of course, many other technologies can be used to build a FANET. Only those that the authors tested in physical experiments are mentioned here.

4. Mobility models

According to the classical theory of dynamics [2], we will consider the aircraft as a “solid”, which is a set of material points rigidly interconnected. When moving, the distance between the points and the center of mass does not change and the trajectory of the aircraft can be described as the trajectory of the center of mass.

The motion of any type of aircraft can be represented as a set of translational and rotational motion. In this study, we will consider only translational motion.

The position of the UAV can be represented by quaternion equations, which are a system of linear equations that do not degenerate and satisfy a single equation of communication. Representation of orthogonal coordinate transformations in the form of the product of quaternions allows us to perform modeling of arbitrary motion with lower computational costs [4].

The quaternion, in general, can be represented as an ordered system of four real numbers, or as a scalar and vector part [2]:

$$E = \begin{bmatrix} e_0 \\ e_1 \\ e_2 \\ e_3 \end{bmatrix} = e_0 + \begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix} = e_0 + \vec{e}, \quad (1)$$

where \vec{e} is the vector part of the quaternion.

The vector part of the unit quaternion \vec{e} can be represented as:

$$\vec{e} = e_1 i^i + e_2 j^j + e_3 k^k \quad (2)$$

where $i^2 = j^2 = k^2 = -1$.

A single quaternion can describe a single rotation in three-dimensional space around a certain axis. Rotation around the axis at an angle θ specified by a single vector ϑ can be represented as:

Scalar part

$$e_0 = \cos\left(\frac{\theta}{2}\right) \quad (3)$$

Vector part

$$\vec{e} = \vartheta \sin\left(\frac{\theta}{2}\right) \quad (4)$$

We introduce an inertial coordinate system $A(\vec{i}_1, \vec{i}_2, \vec{i}_3)$ (figure 2) and a connected coordinate system $O(\vec{e}_1, \vec{e}_2, \vec{e}_3,)$ in which the origin coincides with the center of mass of the aircraft, the axis \vec{e}_1 is directed along the velocity vector at each point in the simulation time, \vec{e}_3 directed upward perpendicular to \vec{e}_1 , the axis \vec{e}_2 complements the coordinate system to the right.

We introduce an additional basis $O(\vec{i}_1, \vec{i}_2, \vec{i}_3)$, the axes of which are parallel to the axes $A(\vec{i}_1, \vec{i}_2, \vec{i}_3)$, and the center is at a point O . Then the motion of the aircraft is determined by the motion of the point O (the motion of the end of the vector \vec{R}_0 to the point O'), and the kinetic – the rotation of the basis $O(\vec{e}_1, \vec{e}_2, \vec{e}_3,)$ relative to $O(\vec{i}_1, \vec{i}_2, \vec{i}_3)$.

The rotation of the basis can be set by some normalized quaternion of rotation E .

$$\vec{e}_k = E \circ \vec{i}_k \circ \vec{E}, k = 1,2,3. \quad (5)$$

where $E = \lambda_0 + \vec{\lambda}_k$ – some normalized quaternion, \vec{E} – quaternion, inverted to E , such that $E \circ \vec{E} = 1$.

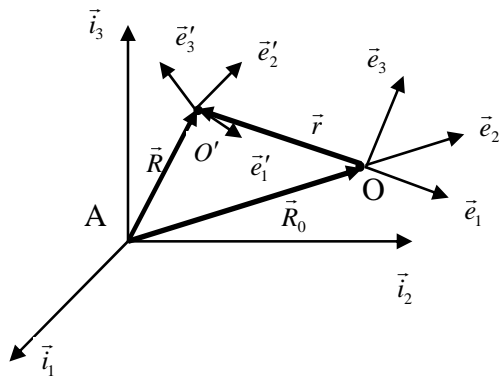


Figure 2. Representation of UAV motion as a transformation of bases

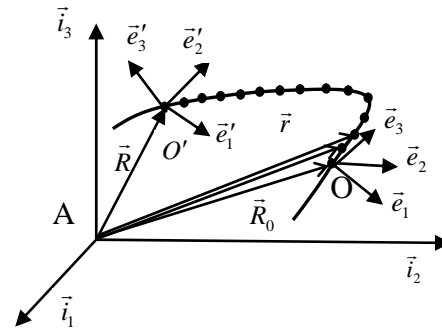


Figure 3. These two figures have been placed side-by-side to save space. Justify the caption.

In this case, the final position of the object can be given by the formula

$$\vec{R}(t) = \vec{R}_0 + E \circ \vec{r}(0) \circ \vec{E} \tag{6}$$

Applying the quaternion representation of rotations, the position of the object in the system $A(\vec{l}_1, \vec{l}_2, \vec{l}_3)$ can be represented as (figure 2):

$$\vec{R} = \vec{R}_0 + E \circ \vec{r}^0 \circ \vec{E} \tag{7}$$

where $\vec{r}^0 = \sum_{k=1}^3 r_k \vec{l}_k$ determines the initial position of the object in the base $O(\vec{l}_1, \vec{l}_2, \vec{l}_3)$.

Given the condition for the normalized quaternion

$$\dot{E} \circ \vec{E} = 1, \dot{E} \circ \vec{E} + E \circ \dot{\vec{E}} = 0 \tag{8}$$

we obtain the UAV velocity vector in the basis $A(\vec{l}_1, \vec{l}_2, \vec{l}_3)$

$$\vec{V} = \dot{\vec{R}}_0 + \dot{\vec{r}} = \vec{V}_O + \dot{E} \circ \vec{r}^0 \circ \vec{E} + E \circ \vec{r}^0 \circ \dot{\vec{E}} = \vec{V}_O + \dot{E} \circ \vec{E} \circ \vec{r} - \vec{r}^0 \circ \dot{E} \circ \vec{E} \tag{9}$$

where \vec{V}_O – the speed of the point O in the system $A(\vec{l}_1, \vec{l}_2, \vec{l}_3)$, \dot{E} – the derivative of the quaternion time, which is calculated as:

$$\dot{E} = \dot{\lambda}_0 + \sum_{k=1}^3 \dot{\lambda}_k \vec{l}_k \tag{10}$$

The angular velocity vector of an object relative to the base $A(\vec{l}_1, \vec{l}_2, \vec{l}_3)$

$$\vec{\omega} = 2(\dot{E} \circ \vec{E}) \tag{11}$$

Therefore, according to the rules of multiplication of quaternion's

$$\vec{V} = \vec{V}_O + \vec{\omega} \times \vec{r} \tag{12}$$

If the object rotates around a fixed axis $\vec{\xi}$ at an angle α , then the quaternion of rotation, velocity, and angular velocity vector can be written as:

$$E = \cos \frac{\alpha}{2} + \vec{\xi} \sin \frac{\alpha}{2}; \quad \dot{E} = \frac{1}{2} \left(-\sin \frac{\alpha}{2} + \vec{\xi} \sin \frac{\alpha}{2} \right) \dot{\alpha}, \quad \left(\dot{\vec{\xi}} = 0 \right); \quad \vec{\omega} = 2\dot{E} \circ \vec{E} = \vec{\xi} \dot{\alpha}. \tag{13}$$

Let us know the trajectory along which the object moves. Divide it into segments corresponding to time intervals dt (fig. 3). We will interpolate the trajectory by quaternions. This interpolation is called spherical linear interpolation (SLERP) [6]. The SLERP results in a unit length quaternion.

Therefore, the resulting trajectory can be described by the product of quaternion's

$$E = E_0 \circ E_1 \circ \dots \circ E_j \circ \dots \circ E_N, j = 1, 2, \dots N. \tag{14}$$

SLERP interpolation is not easy enough and requires a lot of trigonometric operations. However, other forms of representation are no fewer complexes, and representations of rotations are unacceptable for linear interpolation in general. For example, interpolating the components of a matrix can yield a matrix that degenerates an object into a plane.

It should be noted that quaternion multiplication is noncommutative (when changing the order of factors, the result of quaternion multiplication is different).

5. Software model

For the general case, the mathematical model of the FANET network can be represented as:

$$H(t) = f(S, F, Y, X, t) \tag{15}$$

where $H(t)$ – vector of network characteristics at the current time t ($t \geq 0$), $H = \{V, T, N, C, Z\}$. Parameters – primary network data: S – structural, F – functional, Y – network load, X - environment. Characteristics – secondary data: V – power, T – time, N – reliable, C – economic, Z – other.

Changing the structural and functional organization of the FANET network, due to the movement of UAV in space, leads to the improvement of some performance indicators and the deterioration of others, this significantly complicates the choice of the best option, as performance indicators are contradictory. It is impossible to simulate all parameters and characteristics of the network taking into account the movement.

Therefore, when creating a software model, some restrictions and assumptions were introduced:

- UAV performs only uniform rectilinear motion without maneuvers, modeled by formulas (11-14). The height of each UAV during the experiment does not change;
- each UAV has a radio range, the size of which depends on the wireless communication technology being simulated (power, frequency range, etc.). The radio field of view is a layer in 3D space (in 2D space circle) the center of which is UAV. An example of modeling the radio visibility zones of two UAVs in 3-D space (in conventional units of radius) is given in figure 4;
- the connection between UAVs appears when the spheres intersect.

When modeling a large number of UAVs, the visualization of the intersection of spheres is complicated, so a simplified mode of 2-D visualization is provided (figure 5).

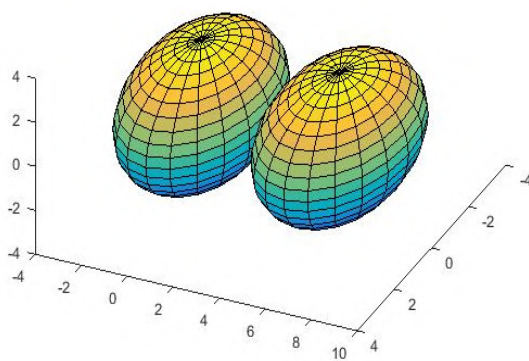


Figure 4. Example of modeling the radio visibility zones of two UAVs in 3-D space.

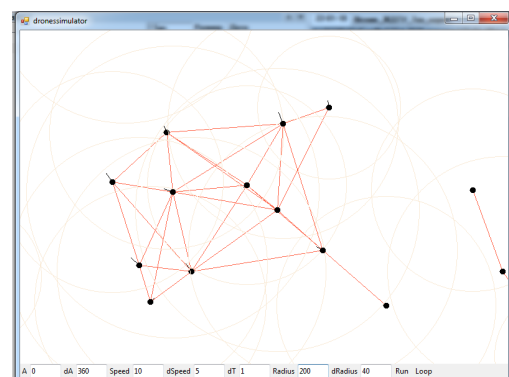


Figure 5. Simplified mode 2- D visualization of communication between UAVs.

The input data of the software model are:

- the number of UAVs to build a FANET;
- for each UAV the speed, direction (trajectory), and altitude of flight, the radius of a zone of radio visibility is set.

The software model allows you to calculate the following characteristics of FANET:

- connectivity or the average number of adjacent nodes in the radio range;
- network survivability or probability of information delivery to any existing node in the network;
- mortality of nodes (disappearance, exit from the zone of visibility of nodes for a certain period, average value).

6. Conclusions

Thus, the developed software model allows us to study the characteristics of connectivity and survivability of FANET for different wireless technologies.

The quaternion model of UAV motion allows us to solve the inverse problem, namely to optimize the trajectory of UAVs to maintain the connectivity and survivability of FANET.

In recent years, several experiments have been conducted to build UAV-based networks, which have confirmed the adequacy of the software model. Ubiquiti Networks equipment was used to build the network: the Ubiquiti Rocket M5 wireless access point and the Ubiquiti NanoStation M5 access point, which use the developed AirMax communication protocol. The appropriate equipment was chosen because of the availability on the market and the presence of some advantages of the AirMax standard over conventional WiFi in conditions where a large number of subscribers are far away from the base station.

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Information system of economic and mathematical modelling of pricing in the residential sector of Ukraine

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Abstract. The article deals with the development of a web application on forecasting the dynamics of prices in the residential sector of Ukraine. The classification of economic forecasting methods according to which they are divided into formalized, extrapolated, intuitive methods of forecasting the financial state is presented. It has been established that forecasting methods should meet the following requirements: a combination of subjective value and objective significance of estimates; clear application of estimates, which does not allow different interpretations regarding the choice of methods; create the ability to accumulate statistical information and use it for forecasting. The model of standard square collocation for the real estate market is presented. A web-based application for forecasting the dynamics of prices in the Ukrainian housing sector was developed and tested.

1. Introduction

Today, there are a large number of statistics covering almost all areas of human activity. This also applies to real estate. On the Internet, you can find web portals for advertising real estate in Ukraine. General statistics, such as the average cost per square meter by a city or a region, are publicly available. Therefore, each user of the global network has the opportunity to view the dynamics of changes in real estate prices, to analyze it, and then to draw conclusions from the analysis.

However, looking only at the figures in the table or graph, it is difficult to say exactly how the price of real estate has changed over some time. There is also a more important, practical point of view, as to how the price will change in the future. A mathematical model of the real estate market should be developed to answer this question. With the adequacy of the model, it is easy to predict changes in real estate.

The average Internet user is more likely to be unable to interpret statistics correctly, and even more so to predict price changes in the future. Therefore, there is a need to develop a specialized web application where an average user who is not an expert in mathematics and economics, will be able to interpret the statistics correctly and understand how the real estate market can develop in the future.

2. Theoretical background

Economic and mathematical modeling has been studied by many scholars, in particular: Vakulenko



examines the conceptual principles of pricing in the real estate market [12], Voronin, Liantse & Mamchin investigates the real estate market in three aspects: problems, trends, forecasting [13], Mezentseva, Dmitrieva, Kuchevsky, Marynich & Stebletska conduct socio-geographical study of Ukrainian housing market [6], Potashev considers forecasting the price situation in the housing market in times of economic crisis [8].

Shapovalova investigates real estate price forecasting in the light of business cycle trends [10], Shaposhnikova analyzes time series of the primary residential real estate market in Kyiv [9].

Babeshko et al considers forecasting collocation model quantitative characteristics of the main financial instruments of the stock market [1] and forecasting of financial and economic indicators for heterogeneous data [2].

However, the economic and mathematical modeling of pricing in Ukrainian housing sector and the problem of developing an informative web application on forecasting price developments in Ukrainian housing sector have not been sufficiently investigated.

Therefore, the aim of the study is to develop an informative web application on forecasting price dynamics in the residential sector of Ukraine.

3. Results

Economic forecasting methods are a set of forecasting methods and techniques that allow, based on the analysis of retrospective data, external and internal factors of influence, as well as their quantitative changes, to make convincing predictions about the future development of the economy or society as a whole. For forecasting, statistical information on the processes of the recent years and expert assessment of trends in macroeconomic indicators is carried out. The objects of forecasting are the economy, its industries, regions, forms of ownership, etc. To choose the forecasting method, the aim and objectives of the forecast and the period for which it is formed should be determined. Moreover, the specifics of the forecasting object, types, completeness and probability of the input information, as well as some other factors should be considered [7].

3.1. Formalized and extrapolated methods of forecasting financial condition

One of the groups of methods of forecasting the financial state of enterprises consists of formalized (quantitative) methods, which include stochastic, deterministic methods and methods of economic and mathematical modeling. A common characteristic of formalized methods is to evaluate the future state of projected objects and to quantify the projected indicators that characterize them, based on a retrospective study of their development [11].

Quantitative forecasting methods are extremely important in managing the enterprise financial resources and forecasting its financial condition. Although the application of these methods also has some limitations. First, any formalized forecasting method does not allow to take into account all the factors influencing the target parameter, but simply simplifies the correlation between the indicators ([8], [13]).

Secondly, for each forecast indicator, several variants of the forecast can be formed, each of which will have a high probability of realization, which does not allow making unambiguous conclusions about the dynamics of phenomena development, based solely on quantitative indicators.

The use of quantitative methods in the construction of forecasts for the short term when it is possible to reach fairly accurate estimates of changes in indicators is the most effective [3].

Formalized forecasting methods are based on stochastic methods, including methods for trend extrapolation, regression, and auto regression. Stochastic methods are based on the probabilistic nature of the relationship between variables, whose formalization accuracy increases with the increase of the input of empirical data [4].

Stochastic methods have many variations and can be adapted to almost any prediction need, making them the most common of the methods studied. The main disadvantage of using these methods is the possibility of obtaining significant errors in forecasting due to the influence of random fluctuations on the change of indicators.

Another method of short-term forecasting of economic phenomena is extrapolation.

The term “extrapolation” has several interpretations. Extrapolation is, in a broad sense, a method of scientific inquiry that consists of extending the conclusions drawn from observations of one part of the phenomenon to another part of it. In the narrow sense, it is a function of defining the function of other values outside the series by a series of data.

Extrapolations are the study of past and present sustainable tendencies of economic development and transfer them to the future.

The purpose of such a forecast is to show what results can be achieved in the future if we move at the same speed or acceleration as in the past [13].

The forecast determines the expected economic development assumptions based on the hypothesis that the main factors and trends of the previous period will be preserved for the forecast period or that the direction of their changes in the considered perspective can be justified and taken into account. A similar hypothesis is made based on the inertia of economic phenomena and processes.

In forecasting, extrapolation is used in the study of time series.

Extrapolation, in general, can be represented as a certain value of a function $y_t^* = f(y_t, l, a_i)$, where y_t – the predicted value of the level of several dynamics; i – bias period; y_i – the bias period taken as the extrapolation basis; l, a_i – parameters of the trend equation.

Depending on the peculiarities of changes in levels in the series of dynamics, extrapolation methods can be simple and complex.

Simple methods of extrapolation are based on the assumption of relative constancy in the future of absolute values of levels, an average level of a series, average absolute growth, average growth rate [2].

Consider the following methods of extrapolation.

Extrapolation based on the mean of the row-level uses the principle that the predicted level is equal to the average of the row levels in the past, $y^* = \bar{y}$.

In this case, the extrapolation gives a prognostic point estimate. The exact coincidence of these estimates with actual data is unlikely. Therefore, the forecast should be in the form of an interval of values. The confidence interval of the forecast for the mean with a small number of observations is according to the formula $y^* = \bar{y} \pm t_\alpha \cdot \sigma \sqrt{1 + \frac{1}{n}}$, where t_α is the tabular value of the Student's t -test with $n - 1$ degrees of freedom; σ is the root-mean-square deviation.

The mean square deviation for the sample, in turn, is: $\sigma = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}}$, where y_i is the initial level of the dynamics; n – the number of levels of several speakers.

The confidence interval obtained takes into account the uncertainty associated with the estimate of the mean, and its use for forecasting increases the degree of reliability of the forecast. However, the disadvantage of this approach is that the confidence interval is not related to the bias period.

Extrapolation by the average absolute increase can be carried out when we consider the general tendency of the development of the phenomenon linear.

To calculate the predictive value of the level, it is necessary to determine the average absolute increase l . Then, knowing the level of the dynamics taken as the basis of extrapolation y_n , write down the extrapolation formula: $y^* = y_n + \bar{\Delta} \cdot l$

Extrapolation of the average growth rate can be carried out when there is reason to believe that the general trend of several dynamics is characterized by a show curve. The predicted level of the series, in this case, is determined by the formula $y^* = y_n \cdot \overline{TP}$, where \overline{TP} – the average growth rate, which is calculated by the formula of the geometric mean.

The confidence interval of the average growth rate forecast can only be determined if the average growth rate is calculated by statistically estimating the exponential curve parameters.

All three considered methods of trend extrapolation are the simplest, but also the closest.

Complex extrapolation methods involve the identification of a major trend, that is, the use of statistical formulas to describe a trend. The methods of this group can be divided into two main types: analytical (growth curves) and adaptive.

The basis of analytical methods of forecasting (growth curves) is based on the principle of obtaining, by the method of least squares, the estimation of the determined component, which characterizes the main trend.

Adaptive forecasting methods are based on the fact that the process of their implementation is to calculate sequential values of the predicted indicator over time, considering the degree of influence of the previous levels. These include the methods of the current and exponential averages, the method of harmonic weights, and the method of auto-regression.

The method of analytical trend equalization (the least squares method) can only be applied if the development of the phenomenon is well described by the constructed model and the conditions that determine the trend of development in the past will not change significantly in the future. When these requirements are met, the forecasting is done by substituting in the trend equation the values of the independent variable J , which corresponds to the magnitude of the bias period [12].

The procedure for developing a forecast for the use of analytical trend equalization undergoes the following steps:

- 1) selection of the curve shape that reflects the trend;
- 2) identifying indicators that quantify trends in change;
- 3) estimation of the probability of predicted calculations.

You can choose the shape of the curve based on the graph, the general appearance of which usually indicates:

- 1) whether the dynamic range of the indicator has a clear trend;
- 2) if the trend is smooth;
- 3) what the nature of the trend is.

When answering these questions, it must be remembered that the external simplicity of the graph is wrong. Any dynamic task is much more complicated than a static one, and every point in the curve is the result of a change in the phenomenon, both in space and in time.

In this regard, to improve the validity and likelihood of alignment to more accurately identify the current trend, it is necessary to carry out a variant calculation for several analytical functions and to determine the best form of communication-based on expert and statistical estimates [8].

In the second step, it is necessary to determine the parameters of the equation of communication. To do that we use the method of least squares. In this case, the equalization function will occupy a position among the actual values of the indicators, in which the total deviation of points from the function will be minimal.

A reliable and reasonable estimation of the obtained results can be given using such statistics as average growth rate, total and residual variance, correlation coefficient, correlation index, the correlation coefficient of the original series and the number of deviations determined by the difference of actual and equivocal data.

To test the hypothesis of the presence or absence of autocorrelation, use tables with critical values of the autocorrelation coefficient at different levels of significance. If the table value of the autocorrelation coefficient is higher than the actual one, then it can be argued that the autocorrelation is missed or eliminated, and therefore formulas can be used to probabilistically estimate the values predicted by these points.

For this reason, it is necessary to develop a multifunctional web application that allows the user to correctly interpret statistics on the dynamics of real estate prices within Ukraine and make forecasts based on fluctuations in prices in the real estate market.

Therefore, to implement this web application, we need to:

- develop website design;
- create a database and populate it with data provided by <http://domik.ua/nedvizhimost/dinamika-cen.html>;
- output statistics in tables and graphs by date and every month;
- realize the ability to save data in json and xml formats;
- enable site visitors to register and authorize:

- to implement a model of standard square collocation for forecasting housing prices in Ukraine;
- enable users to make an adequate forecast of price movements for 1-12 months.

3.2. *Technical specification*

3.2.1. *Goal and aim of creating an informative web application*

The web application should provide statistics on the sale of apartments in Ukraine and make a forecast based on these data.

The main goals of creating an information web application: provide the user with quick access to real estate statistics within Ukraine with a user-friendly interface, the ability to save the received data in the form of files of different formats and to make a forecast on the model of the average square collocation.

In the target audience of the web application, you can select groups such as Guests, Users, and Administrators.

3.2.2. *Requirements for an information web application*

1. Requirements for the structure and operation of the information web application.

The web application should be an information structure accessible on the Internet. Moreover, it should include interconnected sections with clearly separated features.

2. Requirements for storing and updating information.

The web application information management system should view database records and the registered users. The procedure for updating statistics in the database should be carried out automatically and only when the data have not been updated for three days.

3. Demarcation requirements.

The information hosted on the information web application is publicly available.

Web application users are divided into three groups according to their access rights:

1) visitors have access to the public part of the web application only. In addition, they can view statistics as a table, graph, and view and save data in json format;

2) registered users are provided with the access to additional features of the site, namely to view and save statistics in xml markup;

3) administrators have access to the administrative part, can view information about the registered users of the site as well as data on the sample stored in the database.

4. Information web application structure.

The web application consists of the following sections:

- dynamics of changes in real estate prices and its forecasting (main page);
- database entries are available (administrative part);
- information about its registered users (administrative part);

The web application interface provides an intuitive view of the structure of the information contained therein. Navigational elements contribute to better understanding of the content: links to pages should be provided with headings, the conventions should be generally accepted.

The system provides navigation to all available user functions and displays relevant information. A content menu system is used for navigation. The menu is a text block at the top of the page.

When selecting any of the menu items by the user, there is a smooth transition to the block with relevant information (statistical information, pricing, available records in the database, information about registered users).

The filling of the database of the statistical web application should be done automatically (the necessary information is taken from the following pages on the Internet <http://domik.ua/nedvizhimost/dinamika-cen.html>) [5]. Only the site administrator can view the available records in the database.

3.2.3. *Navigation system (map of a web application)*

The relationship between sections of the web application is presented in figure 1.

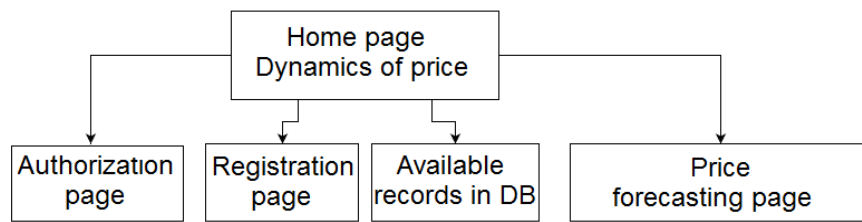


Figure 1. Map of web application.

Content management system (administrative part) views database records and registered users’ data. The content management system has an interface that meets the following requirements:

- uniform design style;
- intuitive assignment of interface elements;
- displays only those features that are available to the user;
- provides the necessary data only to solve the current application problem information.

3.3. The functionality of sections

The following information is displayed on the main page:

- graphical user interface elements for input;
- statistical and forecast data in the form of tables and graphs;
- links to the pages “Authorization”, “Registration”, “Administrative part”, “Price forecasting”.

In the section “Authorization” the form of authorization includes email; password; password recovery links; registration form link.

The “Registration” section is displayed in the registration form, which includes: login; email; password; repeat the password option.

The “Records in the database” section should show all records in the database with a detailed description of each record.

3.3.1. General design requirements

The style of the site is contemporary with a clean, minimalistic design in light blue and orange. The site design uses the concepts of material design. Fonts are tails in order not to strain the user's eyes.

The site header includes the logo centred and the main menu located at the top of the window (to the right of the logo) that contains links to all sections of the first level.

The basement has site information, links to additional resources, developer information, and contact information.

The header and navigation menu of the site are located at the top of the main page. In the area of the main page (figure 2) there is an input selection form, a table and a graph in which statistics are displayed.

3.4. RMS (root-mean-square) model for the real estate market

Using the root-mean-square collocation model, values with different physical, economic or mathematical nature can be observed and predicted ([10], [9]), that is, the dynamics of changes in housing prices in the coming months can be predicted. The collocation prediction model retains the main advantages of classical regression models and can be used not only to construct an optimal prediction of homogeneous data but also to evaluate any characteristics based on heterogeneous source information.

Description of the algorithm of the collocation method.

1. Enter the input data:

- Y – time-series of real estate prices with an interval of a month;
- n – the number of points in the time series;

- m – is a parameter that shows how many months to forecast.
2. Centre the time series Y .
 3. We calculate the auto-covariance function S .
 4. We calculate the approximating function V by the method of significant parameters.
 - A parameter k is an index of the first number in an array S that is less than the value, where σ is the mean square deviation of the sample Y .
 - The parameter j is the index of the first negative number in the array S .
 5. Calculate the auto-covariance matrix.
 6. Calculate the forecast for m months.

The screenshot shows a web interface for data analysis. At the top, there are two main input sections. The first section contains a 'Region' dropdown menu set to 'Kyiv' and a 'Select' dropdown menu also set to 'Region'. The second section contains a 'Parameter' dropdown menu set to 'Middle price', a 'Currency' dropdown menu set to '\$', and an 'Approximation' dropdown menu set to 'Hi'. Below these is a 'receive statistics' button. Underneath, there is a summary row with 'Region' set to 'Kyiv', 'Select' set to 'Region', and 'Parameter' set to 'Middle price'. Below this is another row with 'Currency' set to '\$' and 'Approximation' set to 'no'. There are three buttons: 'Table', 'Graph', and 'Save file'. The 'Table' button is active, displaying a table with the following data:

Date	By region
21.09.19	2600
24.09.19	2484
27.09.19	2523
01.10.19	2567

To the right of the table is a large empty area with a diagonal cross and the text '291 x 211'. At the bottom of the table area are two buttons: 'Json' and 'XML'.

Figure 2. Home page of the site.

The block diagram of the collocation method algorithm is shown in figure 3. The flowchart shows the additional functions used in the calculation:

- mean (arr) is a function that returns the average of an array of arr numbers
- reverse (arr) is a function that returns an array of arr with elements in reverse order;
- slice (arr, start, end) is the function that returns an array that is a cross-section of the arr array, starting from the start position and ending with the end position.

3.5. Web application architecture design

According to the terms of reference, the MVC model and the Laravel PHP framework should be used in the development of a web-based information application for real estate pricing.

The implementation of the MVC model for the development application is presented in figure 4.

Figure 4 shows a simplified MVC principle in Laravel. First, the user enters the URL he needs. The corresponding controller class method is then executed according to the URL.

Moreover, the query methods are explicitly listed here. It means that only “get” and “post” page requests/forecasting trigger the forecasting () method of the ForecastingController class.

Controller classes usually spell out the logic behind the application. It involves working with the database through model classes. Each controller class returns a representation, in which case it returns a blade template compiled into PHP.

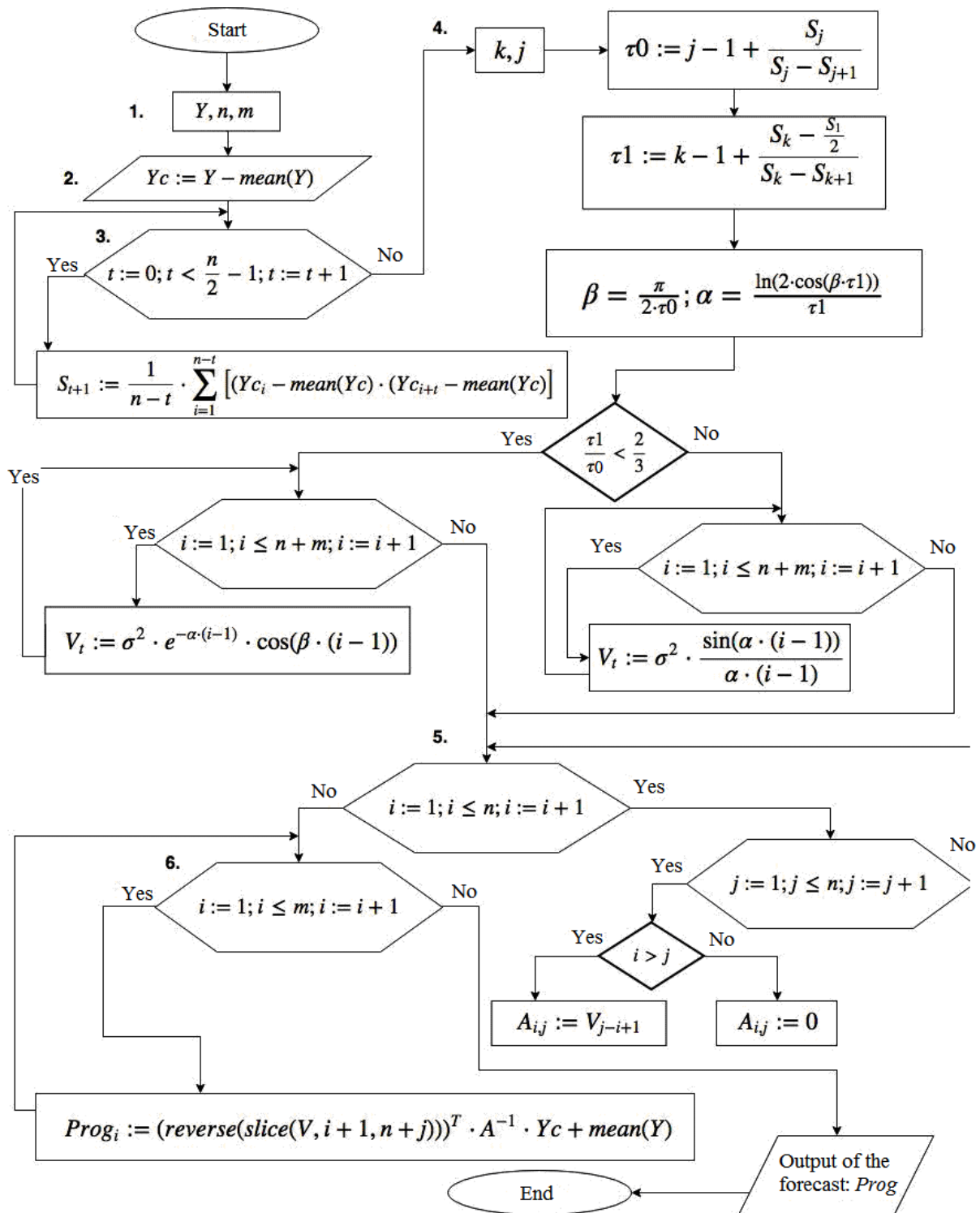


Figure 3. Flowchart of the collocation method algorithm.

ForecastingController is responsible for forecasting statistics and returning the finished forecast page (forecasting results are presented as a table and graph).

StatisticController is responsible for processing statistics and storing them in a database.

StatisticController deals with methods for working with the administrative page of the site.

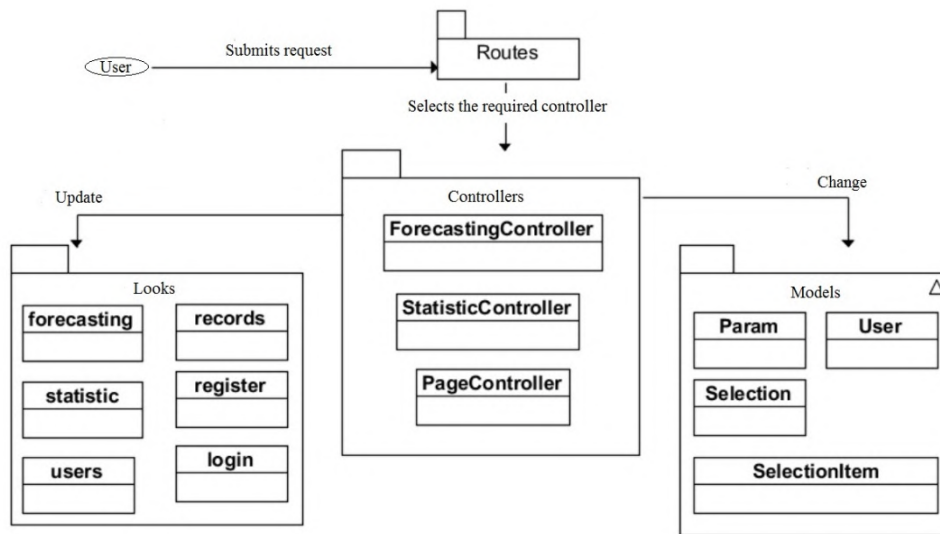


Figure 4. Model MVC web application on Laravel.

User implies a model for handling user data registered on the site.

Param is a class model for working with the Params table, which stores additional parameters for forecasting processing.

Selection is a class model for working with a Selections table that stores statistics in JSON format.

SelectionItems is a model class for working with a SelectionItems table that contains additional information about a sample (for example, a specific area or type of house).

Forecasting view is a blade template that displays the results of the forecast in tables and graphs.

Statistic view is a blade template that displays price statistics in a specific region of Ukraine in the form of tables and graphs.

“Users” view displays information about all registered users in the administrative part of the site.

“Records” view displays detailed information about available statistics samples in the administrative part of the site.

Register view displays the registration form for new users.

Login view displays the authorization form.

3.6. Software testing

One of the available statistical data sets has been selected to test the implementation of the RMS method and the operation of the information web system as a whole [5].

Source statistics set information:

- region: Kyiv;
- sampling: by district (Darnytskyi);
- currency: dollar;
- approximation: moving average (5 points);
- parameter: average price per square meter. m.

The forecasting period is 6 months.

The layout of the main forecasting page is presented in figure 5.

The result of the simulation is to predict the dynamics of changes in real estate prices in the form of a table (figure 6) and a graph (figure 7). In figure 6 Months are highlighted in bold, for which projected values of housing prices per square meter are constructed (from March 2020 to August 2020). The same information is given in figure 7 in the form of a graph (predictive values are plotted in the right half of the graph).

To ensure the adequacy of the built-in collocation model for online predictions of average prices per

square meter in the housing market of Ukraine it is necessary to compare the forecast values for three months with the actual values for this period. Table1 shows the calculated average sales price of 1 sq. km. area of the constructed collocation model and the actual average sales data of 1 sq. m. of residential real estate in Kyiv for the specified period.

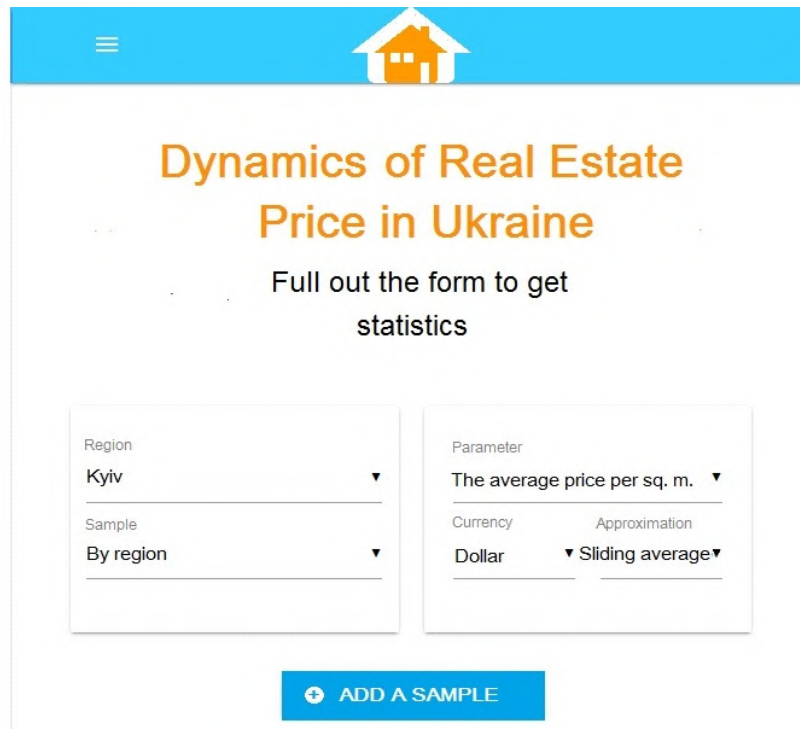


Figure 5. The result of the information web application implementation.

TABLE		GRAPH	SAVE TO FILE
BY DATE		BY MONTHS	
Months	Price - Average by city		
December 2020	1222,62		
November 2020	1213,27		
October 2020	1199,03		
September 2020	1180,23		
August 2020	1157,45		
July 2020	1131,49		
June 2020	1224,25		
May 2020	1226,80		
April 2020	1242,25		
March 2020	1252,25		

Figure 6. Results of the housing prices forecast in Kyiv.

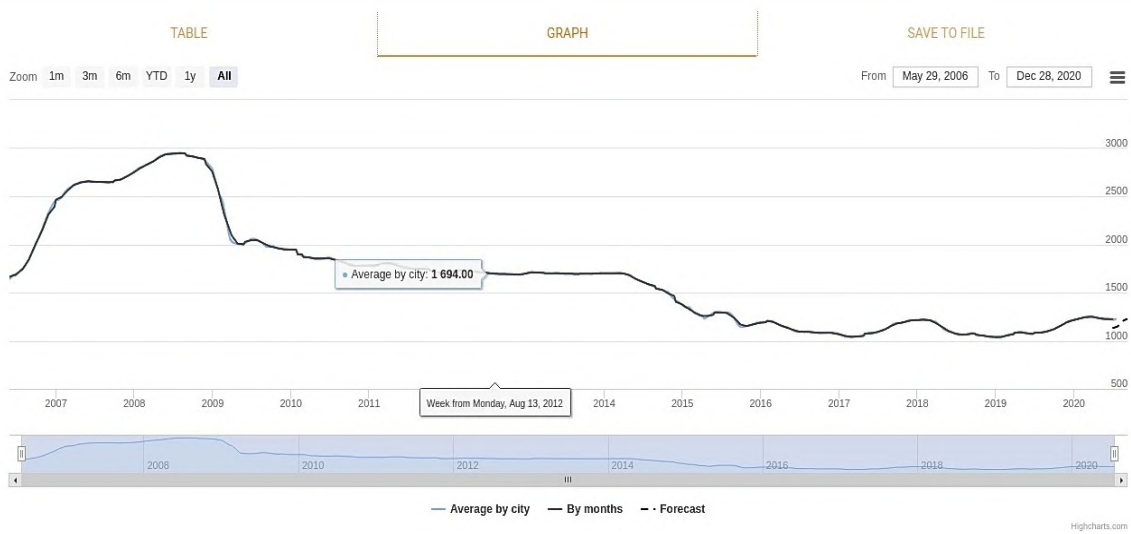


Figure 7. Results of housing price forecasting in Kyiv.

The estimation of the adequacy of the obtained model proves its high accuracy (table 1), namely, the average error of approximation is rather small (up to 10%):

$\hat{A} = \frac{\sum_{t=1}^m |e_t|}{m \cdot Y_t} \cdot 100\% = 2.2\%$, where e_t – the difference between actual and predicted values; Y_t – actual housing price; m – the number of time cycles of the forecast.

$R^2 = 1 - \frac{\sum_{t=1}^m (e_t)^2}{3\sigma^2} = 0.885$, where $\sigma = 29.63$.

Table 1. Adequacy of the collocation model assessment.

Period	Factual price, \$ per sq. m	Estimated average selling price, \$ per sq. m	The error of approximation, %
July 2020	1223.3	1131.5	7.5
June 2020	1221.0	1224.3	0.3
May 2020	1224.4	1226.8	0.2
April 2020	1238.8	1242.3	0.3
March 2020	1253.8	1252.3	0.1
February 2020	1242.4	1173.4	5.6
January 2020	1224.8	1208.9	1.3
December 2019	1212.0	1178.6	2.8
November 2019	1177.6	1143.6	2.9
October 2019	1142.0	1114.0	2.4
September 2019	1108.4	1084.7	2.1
August 2019	1086.3	1071.2	1.4

Thus, it makes possible to use the RMS model to forecast real estate prices in the short (up to one year) and in the medium (from one to three years).

4. Conclusions

The article deals with the development of an informative web application for forecasting the dynamics of prices in the residential sector of Ukraine. The classification of economic forecasting methods according to which they are divided into formalized, extrapolated, intuitive methods of forecasting the financial state is presented. A web-based application for forecasting the dynamics of prices in Ukrainian housing sector has been developed and tested.

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Use of augmented reality-enabled prototyping of cyber-physical systems for improving cyber-security education

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Abstract. The use of augmented reality-enabled scenarios in cybersecurity teaching is proposed in the article to respond to new requirements for the rapid adoption of new technologies and profound knowledge of cybersecurity issues by professionals. Implementation of project-type activities based on real cybersecurity issues in application fields of cyber-physical systems is suggested to improve the competence forming. A use-case of agricultural cyber-physical system of systems is discussed as a viable example of augmented reality-enabled prototyping of cybersecurity risk-aware architecture. The necessary steps are analysis of general and business-specific tasks on cybersecurity, creation of a list of competencies, formalized in educational standards and curricula, development of gaming scenarios for the formation of hard and soft skills, development of the scenario management system for AR interfaces. The system using AR tools can be easily adapted to different cybersecurity training activities. Industrial cyber-physical systems may be vulnerable due to insecure wireless connectivity, lack of encryption, inadequate access policy. The project-based learning complex is focused on the implementation of a data acquisition, storage and processing platform for new sensor networks and instruments. Representing all the diverse information on different layers will be greatly improved by use of the developed holographic projection AR tools.

1. Introduction

In industry and academia, multi-faceted use of cyber-physical Systems (CPS) which combine cybernetic and physical components in 3C (computation, communication and control) triad, includes sensing and monitoring environmental factors, tracking resources and tools, security management and more [18]. Offering easy physical access to data which in many cases are stored locally, CPS platforms are also prone to insecure wireless connectivity, lack of encryption, inadequate patching and slow reaction to exposed vulnerabilities as many CPS run their own operating systems and applications [12], [20]. The most topical issue is the privacy and cyber-safety problems for health-services-related CPSs which may be used not only as part of secured proprietary solutions but can also be connected to e-health sensor shields for Arduino or Raspberry Pi platforms by start-up developers, underestimating the information safety risks. Nowadays, the need of incorporating security aspects as essential functional requirements (see figure 1) into device development cycles is commonly acknowledged [2]. At the same time, training of the competent cybersecurity specialist is a costly and time-consuming endeavour. Many organisations have a shortage of skilled cybersecurity staff and the problem may further aggravate in future.

Cybersecurity issues affect every business, every organisation and every citizen. So far, educational systems do not match market demand for cybersecurity specialists and requirements to their competences with traditionally taught university graduates. A way to resolve such inconsistency is the



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technology-enhanced learning, especially the one with immersive augmented reality (AR) toolkit implemented [3], [8]. Cybersecurity education will essentially benefit from this, in particular, by improving motivation and computer-human interaction efficiency during the competence-building process. In the present paper we propose implementation of a holographic 3D projection as a layer in the AR tool for technology-enhanced training of cybersecurity students.

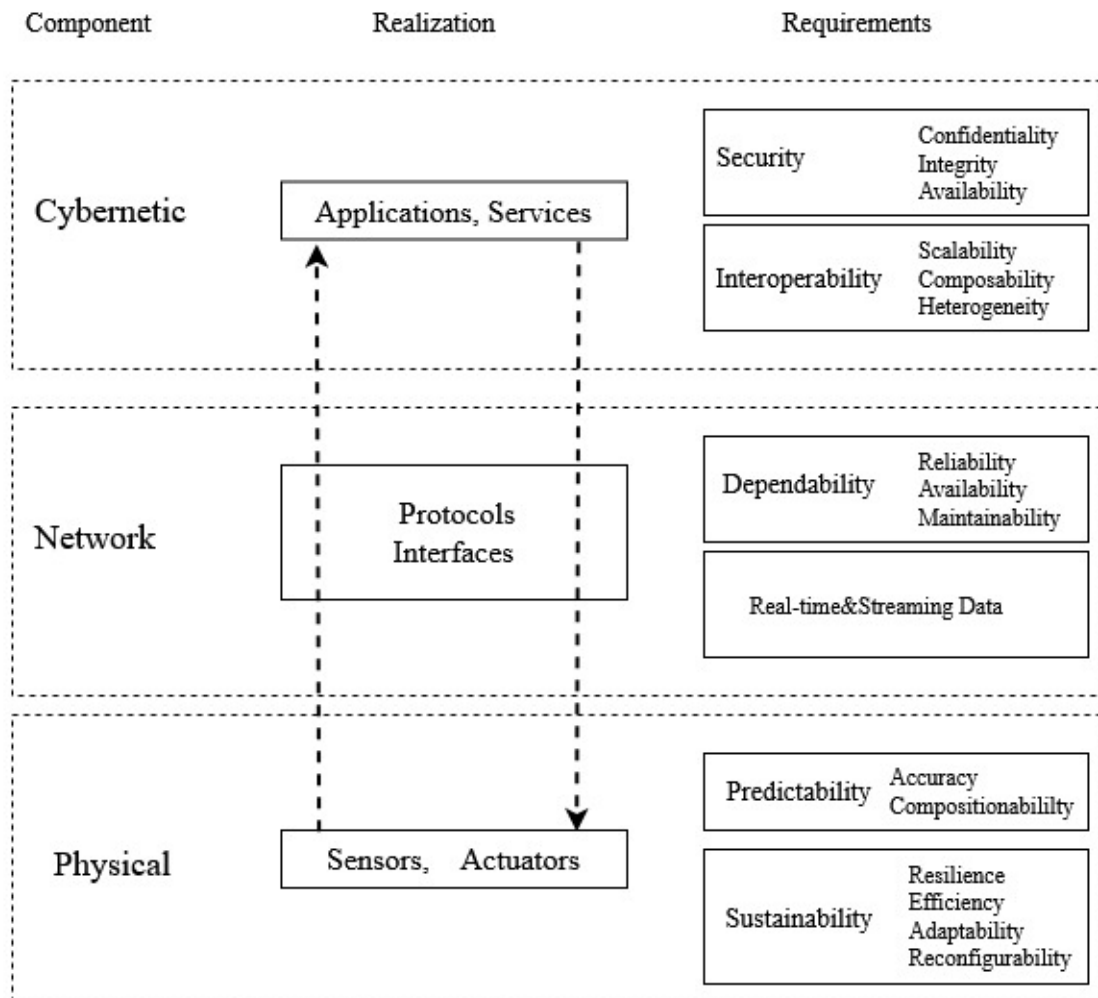


Figure 1. Functional requirements to cyber-physical System realisations.

2. Methodology improvements in cybersecurity training

Currently, technical training is the major trend in cybersecurity education. Oftentimes, university study programs do not include development cycle requirements, professional standards and regulations. At the same time, flexibility is needed for modern cybersecurity specialist and the technical skills are relatively easy to master using available IT tools. While considering specific cybersecurity subjects in which the intensive interaction of instructors and students is required, urgency of the problem increases. In modern day industries, business processes impose new requirements for the rapid adoption of new technologies by a professional with knowledge of cybersecurity issues and procedures. Educational methodologies are to provide cross-disciplinary technology competencies and project experience.

The difficulties of cybersecurity education have been resolved by the NICE Framework of Building Blocks for a Capable and Ready Cybersecurity Workforce [16] shown in figure 2. The use of game forming the set of required competences, skills and abilities may be the appropriate method of implementing this framework into study program. Use of augmented reality interfaces, as well as special

scenarios with the content intended to reflect the context [7], [19], environment and roles are needed for the representation of particular professional activities. The necessary steps are analysis of general and business-specific tasks on cybersecurity, creation of a list of competencies, development of gaming scenarios for the formation of hard and soft skills, development of the scenario management system for AR interfaces. The proposed game scenario model, shown in figure 3, is to be implemented into software system architecture.

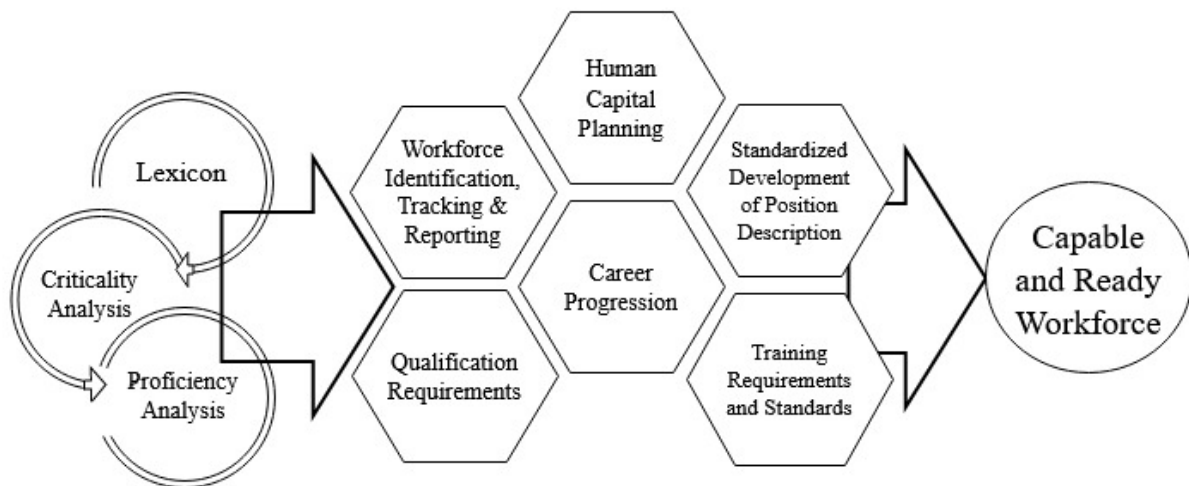


Figure 2. NICE Framework of Building Blocks for a Capable and Ready Cybersecurity Workforce.

For development of a particular set of competences needed to protect a large-scale cyber-physical system from a complex and well-organised cyber-attack, a game scenario can be elaborated along the scenario model shown in figure 3. This will allow modelling the strategic nature of intelligent attackers, design techniques for prediction of attacks and devising countermeasures [6], [15]. The concept of the scenario model has been elaborated by authors to assure essential competencies forming in the process of professional trainings of cybersecurity students as well as major parts of the serious game scenarios. The latter are based on the specific objectives and modules of the study program and define interactions of student, instructor and the context-aware system which is to be responsible for handling various data collected by sensors and obtained through user-machine interfaces. The same context-aware system functional is being developed to assure interaction with knowledge base, maintenance and updates of the interactions history and user-specific dataset for effective training activities control. All actors involved into activity, for example, a cybersecurity incident simulation, are subjects to tracking and multivariate analysis based on the data accumulated by various sensors, human-computer interaction history and the knowledge base of the learning management system.

3. Concept of AR use for learning tools enhancement

There are studies about implementation of augmented reality tools in education (see [3], [8] and references therein), in particular, natural sciences [13] and vocational training [9]. However, AR has not been used in cybersecurity education until now. AR use for data visualisation in cybersecurity creates an immersive interface, which facilitates comprehension of a process – the effect not achievable by 2D visualisation tools. Elaboration of new (advanced and accelerated) teaching and training programs with implemented AR tools has a potential to solve the problem of insufficient supply of skilled cybersecurity professionals.

VR and AR data visualisations are currently used in industry, to enable intuitive and efficient human-machine interactions [10], [17] as well as for workforce training [5]. In real time, AR superimposes images of real objects with virtual images or computer-generated text. The system using AR tools can

be easily adapted to different categories of cybersecurity training elements that would make adaptation of new employees easier and help them to catch new terminology faster. For example, for a network or computer system the relevant analytics can be presented visually so the cybersecurity professional may assess in real-time what the data are communicating and whether any risks are present.

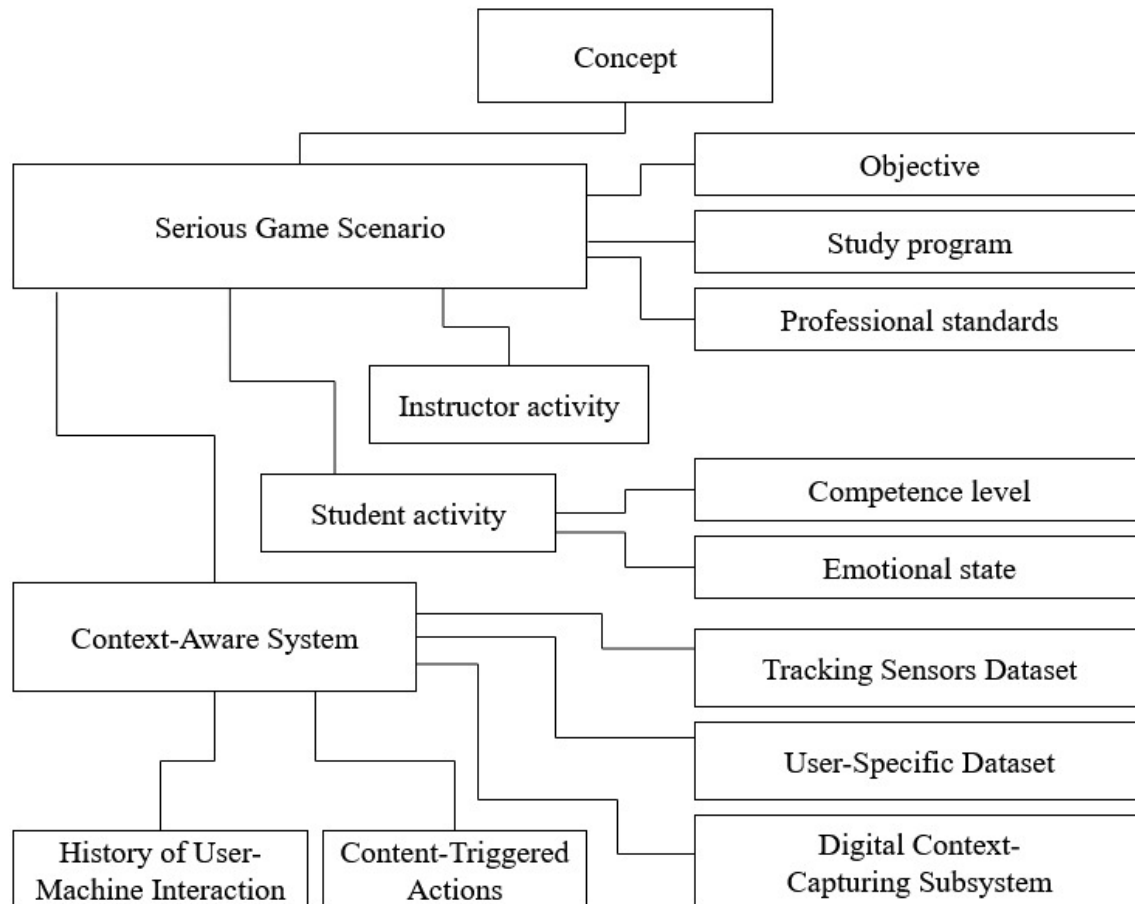


Figure 3. Serious game scenario model for cybersecurity training project.

Up to now, various AR user interface types have been developed, including traditional screens or monitors, windows and windshields, head-mounted displays including helmets and facemasks, glasses, etc. The largest share belongs to handheld AR displays of smartphones due to their unmatched portability, improved cameras, high quality displays, increased computing power. Eyeglasses with AR technology (Google Glass, Vizix, Optinvent, Meta-Space, Reckon Jet) have also received much attention but are now in decline due to privacy issues. Every of the mentioned AR technologies creates a 2D image, which is very similar, but not true representation of real world. Visual perception may misinform the user, observing the 2D picture, about real environment, as it happens with anamorphic optical illusions. A projection holography (more precisely, a false hologram technique) implementation as a layer into an augmented reality pattern is desirable for instructional design in cybersecurity training.

AR can also enhance a development of new intuitive methods to design complex systems and networks based on human-computer kinetic interaction. The holographic 3D environments to be built and tested are to enhance human abilities in different engineering fields as well as in creative endeavours. Not only spatial and temporal dimensions are to be visualised by the designed holograms but also other measurable properties, extending natural human senses and improving decision-making procedures. Among possible augmented reality interfaces, those using 3D false holograms for mixing

virtual and real objects have not received sufficient attention. As a realisation of such holographic AR interfaces, half-silvered mirrors can be used as see-through displays in which users can see reflections of themselves and surrounding objects mixed with rear-projected virtual content. The most widely used methods make use of Microsoft Kinect system to determine user position and align virtual objects to reflections of the real ones. Capturing position, movement and collective behaviour of users require intensive exchange of data between sensors and servers, with data pre-processing, sorting and anonymization. In our Cyber-Physical Systems Laboratory, a 45° polymer pyramid screen and a video projector (high-definition display) are used to create 3D holograms. Currently, only pre-recorded videos and animations are transformed into 3D false holograms. The setup can be used for full-fledged cybersecurity training or prototyping [11], [14]. Improvement of the current setup configuration can be achieved by adjustment of light transmittance with additional partially transparent films [1], [4].

4. Agricultural CPSoS use case for AR-enabled CPS prototyping

In modern times climate changes as well as soil pollution, erosion and devastation make conditions for organic food production by agricultural means quite severe. To improve agricultural products quality, input efficiency, environmental sustainability and farmer income, the information technology solutions are being adopted in agriculture. Besides enacting machinery and irrigation systems, sensors can provide essential information for decision-making for social networks of farmers, agronomists, managers and customers. Availability of and advancements in Internet of Things sensors and communication devices allows acquisition of complete and informative data and their real-time analysis for fast and effective implementation of localised actions. Real time processing of data acquired by software-defined dynamic networks of sensors will allow faster and more efficient management of agricultural businesses, energy saving and quality improvements for a range of stakeholders. Within this study an approach has been developed for the provision of real-time digital services to smallholder farmers, agricultural and food-processing businesses and customers. This use-case, based on real datasets obtained from one of agricultural holdings as well as surveillance data from satellite images taken by Sentinel-2 and Landsat 8, available through the Application Programming Interface, and raw multi-spectral images provided by the Parrot Sequoia+ camera of SKIF unmanned aerial vehicles, can serve as a testing ground for prototyping cyber-physical systems within cybersecurity risks-aware design flow.

The project-based learning complex is focused on the implementation of a data acquisition, storage and processing platform for new sensor networks and instruments, able to remotely detect crop and soil properties in real time and facilitate or make informed decisions quickly and autonomously. It is to enhance the ability of an agronomist and a farmer to correctly evaluate the current state of a crop, make informed decisions and authorise appropriate and timely actions. Agricultural vehicles-based and stationary sensors allow one to remotely obtain information about current and past weather conditions, accumulated temperature and precipitation, soil temperature and moisture, visualise vegetation cover and calculate the most common indicators for assessing vegetation progress over time. Unmanned Aerial Vehicles (UAV) which allow both high spatial resolution and on-demand timing of aerial passes and quadcopters used as an auxiliary instrument for smaller and fragmented areas to be monitored directly from ultra-low altitudes, may be misused if the controls confidentiality is compromised, therefore represent the security-critical component in the agricultural cyber-physical system of systems (CPSoS). For example, unauthorised access to the UAV flight control must be immediately blocked and potentially damaging instructions must be identified and corrected or ignored. The framework prototype is to be designed to allow building dynamic networks of wireless sensors and actuators for agricultural purposes, segmenting data for local processing or transmitting to data warehouses or data lakes for storage and further processing. For a digital farming platform with a distributed system of personal workstations, sensors at different levels, highly specialised controls, moving units, warehouses, applications enabling business decisions by managers etc, the cloud solutions meet the needs for the heterogeneous distributed architecture. Representing all the diverse information on different layers will be greatly improved by use of the developed holographic projection AR tools. For example, for the specific task of coordination in a drone swarm, every single drone communicates not only the data

collected from the crop but also its individual position and velocity. The latter are not informative for a human operator but are crucial for the CPSoS to guarantee fulfilment of both interoperability and predictability requirements (see figure 1). Representing all the diverse information on different layers as a superimposed content can be greatly improved by use of the developed holographic projection AR tools.

Testing of the developed models of CPS components and contents will be performed to check and set-up both functional and non-functional (e.g., efficiency, reliability, security, etc.) technical requirements (figure 4), identify usability problems. Realisation of such a training method, in our opinion, will increase student’s motivation and allow him or her to develop the needed competences, experience and soft skills. The choice of an agricultural CPSoS use case as the first example of a project-type activity for cybersecurity training is caused by the abundance of data needed for creation of realistic serious game scenario and the growing importance of cyber-physical systems in agriculture. In principle, for every use case with sufficient amount of data collected for model elaboration and tuning the corresponding serious game scenarios and requirement analyses can be designed.

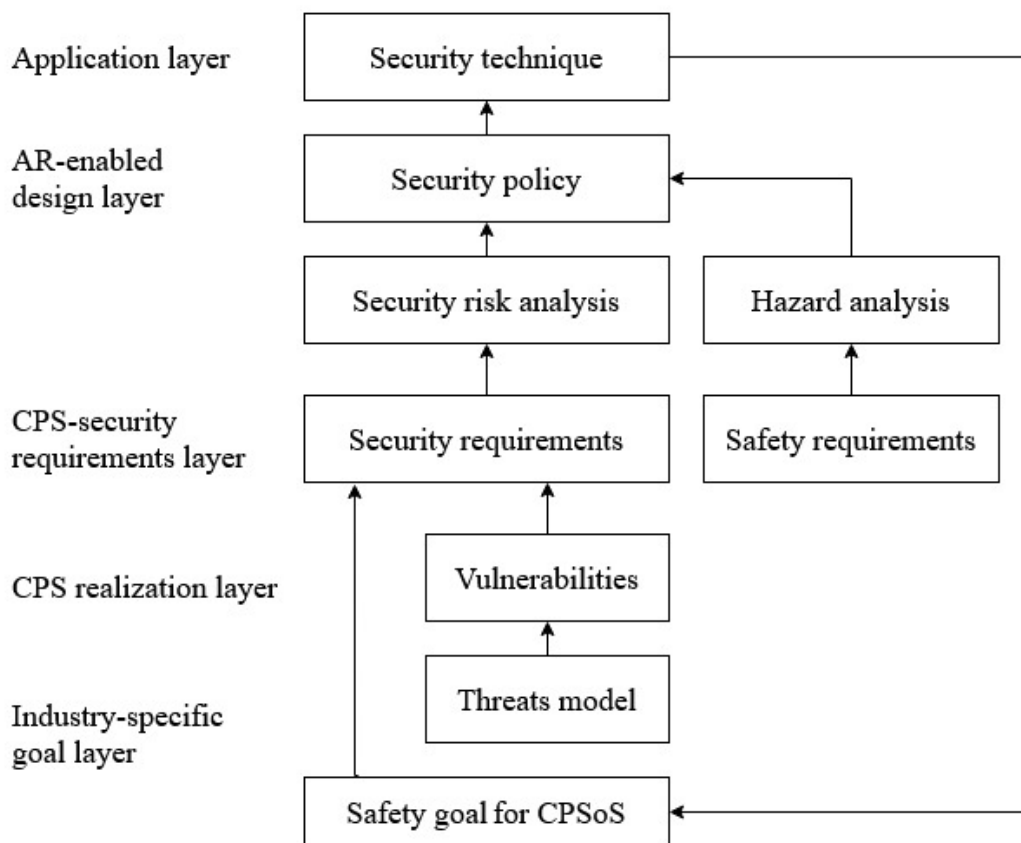


Figure 4. Requirement analysis schema for design of agricultural CPSoS cybersecurity.

5. Conclusions

Nowadays, business processes and industrial developments impose new requirements for professional training and higher education. Demand of cybersecurity specialists is constantly growing but their training is expensive and time-consuming, which tendency is likely to grow with increasing complexity of cybernetic systems. In particular, widely used CPS platforms may be vulnerable due to insecure wireless connectivity, lack of encryption, inadequate access policy, etc.

Despite the urgency of cyber-attack prevention, personal data protection, e-finance fraudulence, there are still no immersive visualisation systems for development of competencies in information security.

The suggested concept of mapping of AR-assisted serious game scenarios onto competency framework and new 3D user interfaces (physical devices) can improve the situation. The necessary steps for the serious game design are analysis of general and business-specific tasks on cybersecurity in connection of specific competencies, formalized in educational standards and curricula and development, on this basis, of the scenario management system for AR interfaces. AR tools can be easily adapted to different project-type activities in cybersecurity training. Within this study an approach has been developed for serious game scenario design and cybersecurity requirements analysis for modern agricultural businesses with intense use of information technology with inherent cybersecurity risks. The project-based learning complex is focused on the implementation of a data acquisition, storage and processing platform for new sensor networks and instruments. Representing all the diverse information on different layers will be greatly improved by use of the developed holographic projection AR tools.

Creating a framework for implementation of AR tools into educational curricula and training scenarios can provide faster and more effective training methodologies of new and certification training of acting IT professionals in the field of cybersecurity. Moreover, an approach based on AR tools eliminates barriers between professionals of different qualifications and makes the coordination within a team easier. Instruments for enriching experiences and mutual knowledge exchange during the (real or simulated) incident prevention or vulnerability detection are very promising for cybersecurity education and professional training.

The proposed approach can also foster the tech-enabled teaching in general by facilitating development of AR educational resources (including distance learning, computer-aided design, customer assistance) which will provide a leverage for many innovative industries, in particular due to increased resilience towards the cybersecurity risks, enabling effective and secure remote work toolkit development for creative industries.

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Using augmented reality technologies for STEM education organization

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Abstract. Modernization of the education system and the emergence of innovative learning technologies can improve the educational process. The use of augmented reality technology improves the learning of individual students, their motivation, as well as helps in organizing teamwork, group cooperation. As the topic of augmented reality in education is quite new and little studied for STEM education, the study reviews publications on this topic, describes the concept of augmented reality, the analysis of augmented reality technologies is carried out, which are adapted to the teaching of natural and mathematical disciplines. The role of STEM approach with augmented reality in the educational process is determined. An example of the use of augmented reality as part of a robotics project is given.

1. Introduction

According to the Strategy of development of informational society in Ukraine [3], Project Europe 2030 [7] and Education 2030 Agenda [33], establishment and utilization of computer systems, particularly systems that are based on grid- and cloud technologies, are one of the stages of those strategies for next years. It infers the formation of the new digital infrastructure and digital sphere reassessment including educational sphere. Educational programs should be adapted to these changes. So, YouTube service [5] and mobile applications [11], virtual and augmented reality (AR) are free for students and teachers during classes. It allows to make lessons more interesting [14]. For virtual event recreation, AR elements can be built-in to websites [29], they can be uploaded to social media and work on PC, notebooks, tablets or VR devices.

In Ukrainian educational sphere, presence of educational and methodical materials which are dedicated to AR organization issues is quite limited due to high dependency of technical equipment, organization of practical part and lack of teachers' preparation. There are relatively a few popular software and available technical equipment for deployment this technology in educational institutions. Therefore, the aim of the research is overview and generalizations of AR technologies utilization methods for STEM education. There are following tasks which were set for aim achievement:

1. Make content-analysis of scientific, scientific-methodical publications related to AR technologies in STEM education.
2. Make analytical overview of AR systems utilization for educational and extracurricular activities of STEM education.
3. Describe existing practices regarding the AR usage during mathematical disciplines, such as robotics.



2. Related works

The organizational base of STEM education [34] is project-related activity where different pedagogical approaches and technological solutions are used [9].

Pedagogical approaches are based on grouped practical work organization for projects. All kinds of activities are united with the ability of student involvement during education process. It is described in analyzed research that efficient studying (studying with practice) raises effectiveness of studying. Moreover, most of teachers who use efficient studying are refusing the traditional lectures making preference to the active studying. So, usual kinds of cognitive activities related to different forms of studying should be first characterized by students' activity and involvement of students for active discussion and problem solving [19].

There are different kinds of interaction between participants within project activity. In work [27], this activity is represented by social interaction. In authors' opinion, interdisciplinary research is team one, which causes social interaction between research team to achieve the interaction between different disciplinary goals. Therefore, social and cognitive elements are used for integration achievement.

Specification of STEM education requires practical activity in laboratories using specialized tools. In case of limited access to technical tools, different approaches to organization of practical activity are used. Authors [4] propose solutions including the flipped classroom model, online practice questions, teleconferencing in place of in-person lectures, involving residents in telemedicine clinics, procedural simulation, and the facilitated use of surgical videos for distance learning. A repository of video lectures the can be watched remotely at any time and learning with simulation in various forms are became the base. But authors notice that limitation is number of video libraries the vary widely in content and quality, with particular concern over the quality of freely available videos on platforms during available simulation.

Among pedagogical factors, vast role plays the 'logistics' of classrooms in AR utilization. Miguel Nussbaum and Anita Diaz providing teachers with different strategies to maintain student interest throughout a range of challenges: the time budget and time segmentation, the physical constraints of the classroom space, and the need to maintain a reasonable level of discipline, to minimize the teachers' workload, or to cope with the heterogeneity of the class [21].

To implement AR technologies to learning process it is needed to familiarize with special software or platforms, that can be used to create one's own mobile applications for its further deployment [20]. It's particularly important during learning 'difficult' disciplines of natural, mathematical branches [17], [16], [25]. Utilization of modern educational trends i.e., innovative technologies such as AR technology itself and STEM technology, gives an opportunity to stimulate students to creativity, to develop their scientific and research skills and abilities, to create motivational conditions for self-determination in future occupation [23], self-development and self-realization, to implement current competence in everyday life.

Technologies of full or partial diving into different kinds of virtual, augmented, mixed reality (AR/VR/MR) are also called immersive methods of learning. AR/VR/MR are interactive instruments of immersive methods of learning.

Immersive methods of learning gained vast popularity in number of countries worldwide. During biological, ecological, evolutionary or other natural sciences classes, field practice, students use virtual reality observing and learning organisms in their habitat [35]. Project Physics Playground is oriented to learning sciences using AR and VR technologies, in particular, modeling physical experiments in mechanics [24], laws such as friction, inertia, velocity, trajectory, mass, force and other objects' characteristics in physical world. There are tools in application that gives an opportunity to learn physical processes, do experiments in 3D virtual space [10].

In chemistry sphere, AR applications allow learning a structure of atoms and molecules, perform experiments which are costly or dangerous in real world observing chemical transformations etc. [20]

In biology sphere, AR technologies allow an opportunity to scale organs, cells or even DNA molecules. Interactive features of applications give an opportunity to observe static and dynamic plots, for example, the process of DNA replication [13].

During mathematical learning process with the help of AR technologies it is possible to visualize algebraic surfaces of different degrees [14]. There is a possibility to learn surface as real object, not on a computer's screen or book changing parameters in real time and observe the result. Interactive change of parameters speeds the understanding of equation structure and 3D surfaces [6], [26].

For theoretical basics of AR usage in world formation, authors [8] look at the related fields of e-learning [1] and m-learning [30]. Based on learning object term it was developed the classification of AR tools by group:

- Fundamental: individual digital resource (only content);
- Combined-Closed: small amount of united but not available separately digital resources;
- Combined-Open: big amount of combined and directly available separately digital resources;
- Generative-Presentation: fundamental and combined digital resources combined with logic and structure
- Generative-Instructional: digital resources combined with rated interactions, created for realization of abstract studying strategies (content, context, studying activity and mark) maintenance

Besides the classification authors group resources by user activity: active creation of AR content and passive consumption of AR content. In the first case, user can interact with AR actively studying or creating them. In the second case, AR carries demonstrative, informative or entertaining character.

Teemu H. Laine and Hae Jung Suk [15] consider AR as gamification technology and its organization in game mechanics point of view. Authors rely on inner motivators such as challenge, competition, control, cooperation, curiosity, fantasy and recognition for involvement of students for creating AR. Students implement Immersion, Scientificity, Competitiveness, Adaptivity and Learning (LSCAL) model.

In work [6], authors consider abilities of usage AR applications in usability at the classroom level, design principles, the hardware environment point of view. In usability point view authors define the circles of usability: consideration individual constraints such as the user's previous experience and his or her cognitive load; the quality of conversations, the richness of deictic gestures, and the smoothness of turn taking; the constraints of the classroom. In the system design authors make general design principle: "Classroom usability increases if the learning environment satisfies all classroom constraints". Authors define intrinsic as a list of constraints (i.e., how to make people cognitively learn) and extrinsic (how to effectively shape classroom practices with the presence of technologies). In the article was proposed five principles proved to be good design choices: integration, empowerment, awareness, flexibility, minimalism [36].

Lucinda Kerawalla, Rosemary Luckin, Simon Seljeflot and Adrian Woolard research [12] focuses on the exploitation of individuals-using-technology-in-settings. Their work presents using the TinkerLamp: an environment developed to train vocational apprentices in the domain of logistics. During development and deployment of this tool there were made following design requirements:

- content flexibility and ability of its adaptation to different students' needs;
- Studying AR material should be used in parallel with traditional studying methods;
- AR content should be interactive for maximization of studying methods effectiveness;
- AR development should consider concrete user studying traits such as age.

AR technology combined with STEM education and ICT greatly widen the list and possibilities of available methodology, technics, work format which contribute the modernization of educational sphere, gives the possibility to enhance educational process.

However, there is unresolved issue in mentioned works related to abilities of AR technologies in STEM education usage, in particular robotics which is quite popular. Using these new technologies in STEM education is possible to widen the specter of available teaching methods, work formats and learning approaches, to modernize its content.

3. Results

AR elements deployment into STEM education requires corresponding changes in usage of different organizational forms and being oriented to formation and expansion of mentioned resources. Each of these forms influence the development and formation new competences. In particular, it is common for all formats of learning to have the development of cognitive skills by bridging theoretical and practical activities [31].

Realization of STEM education tasks requires utilization of different types of cognitive activities which provide the formation of corresponding STEM competences. Among the kinds of activities, it is needed to mention the activities that make difference between STEM education and other ways:

- Explaining of usage of physical phenomena and laws. In most cases, these types of activities are provided by AR content demonstration and manipulation with it.
- Natural, physical and technical laboratory works, experiment demonstration using models and mock-ups. One of the features of STEM education is the usage of technical resources, in particular measurement devices, robotics constructors etc. In case of absence of technical resources utilization ability, AR aims to construct the skills of controlling and measurements with these devices.
- Project activity performance. Creation of objects with AR gives an opportunity to student to build objects oneself, geometric objects as well, creation of digital content using the predefined patterns encourage students to deeper learning of learning material, creating one's own action plot develops skills of planning and process organization, using ready AR programs allows using qualitative content for experiment performance, make them more observable without diving to inner structure.

The usage of AR in STEM education research showed that it is needed to make available 3 types of resources:

1. *Electronic educational resources* and their search, creation and fulfilment of course. Working with electronic materials is usually quite long. Is possible to use existing models, or creating one's own.

2. *Methodical supervision* (control and quality of education recommendations, content). There are changes in traditional forms of learning – forms that were not widely used un educational process before are becoming more popular such as distance learning.

3. Teaching specialists to create content, teachers. Advanced training pre- and in-service teachers is actual. Is also important to teach specialists who can help teachers in projecting of educational environment and its formation. The environment should satisfy main criteria: simple management of educational resources, understandable and qualitative instructions for tasks, obvious criteria of evaluation.

According to this, there are different existing AR tools: development tools and reading tools. There are systems that support both functions where AR function is implemented. We have done solution search that would allow to create elements of AR in robotics classes.

We have analyzed AR applications on Google Play for STEM lessons. Among the results there were found 146 applications which implement principles and approaches of STEM education. From found applications a part (12%) were applications for books. A part of applications uses AR images for material illustration (53%). Those images can represent basic movements such as rotation or user interaction. There is wider category – game-like learning applications. They contain materials in test format or learning occasions (35%). Those applications are more comfortable to use for concrete topics within discipline plan. It is possible to create and manipulate virtual objects. As the example, there is applications (AR VR Molecules Editor) where it is possible to create substances or demonstration of other learning topics (StanLear: AR Books & VR Worlds). Table 1 contains an overview of applications.

Building any robotics device requires knowledge of following aspects: mechanics (construction building, form definition), electronics (utilization of electric schemes and devices that manage mechanisms), programming (creating plot/rules of actions triggered on environmental changes). The process of creation robotics schemes consists of several stages [22]. Elements of AR can be used on each stage.

Table 1. Systems for AR, VR development.

Application name	Description
CreatorAVR	Users are able to create interactive and immersive lessons AR and VR lessons without needing any coding or advanced technological knowledge.
AVRplatform	AR and VR library for education purposes
Vuforia	In real-time tracks flat images and simple three-dimensional objects, recognizes cylindrical markers and text.
Blippar	AR constructor
STEM Kids: Science, Technology, Engineering & Math	STEM Kids contains hundreds of articles, videos and pictures to kick start your child's education in STEM subjects. Early education in sciences. Kids can read the interesting facts and explanations themselves
SnapLearn: AR Books & VR Worlds	STEM – Visualize abstract concepts with interactive 3D Models Geography/History/Architecture – Travel across time & distance on virtual tours. Language – Practise listening and speaking skills in immersive context. Picture Books – Watch your favorite characters pop up from the pages.
Augment - 3D Augmented Reality	Visualize your 3D models in AR, integrated in real time in their actual size and environment
AR-3D Science	Learners can build selective compounds by combining elements flashcards. Narration in the app helps learners to understand the relevance of chemistry to everyday life.
LearnLive AR	The digitized renditions of concepts, theories, and processes.
UniteAR	AR platform where you can build your own AR experience without writing a single line of code
ScanAR - The Augmented Reality Scanner	The app enables you to scan special products, images and illustrations and discover secret content using AR
Paint Draw AR	In this app, you can paint and draw in 3D space using AR. Using the app is as simple as touching on the screen to paint in 3D space
360ed's Elements AR	Learners can build selective compounds by combining elements flashcards. Narration in the app helps learners to understand the relevance of chemistry to everyday life.
3DBear	All the lesson plans and challenges for assignments. Creating AR scenes with various 3D model collections. Import millions of models (Sketchfab, Thingiverse, Import own models) to create engaging homework for students
AR GPS Compass Map 3D	The AR 3D Compass with an integrated split-screen map. Locating landmarks (e.g. via latitude / longitude)
AR Ruler App	Uses AR technology to tape measure the real world with your smartphone's camera
AR VR Molecules Editor	AR VR Molecules Editor allows one to build and manipulate 3D molecules models of organic and inorganic compounds in a smartphone VR headset
Sparklab - Chemistry app in AR/VR	Interactive chemical experiments in AR/VR. Interactive and futuristic Periodic Table in Sparklab chemistry app. Chemistry quizzes. Informative and interesting videos about Science

The following list shows applications for organization of mentioned stages:

1. *Formation and research the problem, search for a technical solution.* On this stage, the problem is defined, corresponding material is learned, solution methods for the problem are defined, existing solutions are observed. At this stage, a learning scenario is built, which is then implemented by students.

- Google Lens – AR neural network based image recognition technology developed by the Google [2]
- Anatomy – structure of human body and organs, “expedition” into body
- Google Expeditions – virtual expeditions and observing objects in AR with the effect of diving, or observing objects in AR. It can be used for learning natural and local conditions for measurement constructions. It can be used for quest organization as well [28]
- Augmented Reality Development Lab is an experimental laboratory where projects are created. Usually they are three-dimension objects which can be used in learning

2. *Modeling or constructions, planning actions.* On this stage technical solution is created which will be the base of robotics system. The distinction of the stage is detailing the plan of creation of engineering and technological aspects, choice of materials for construction, justification of chosen scheme of detail joining reliability, creation of instructional scheme of construction assembly. On this stage, issues about functionality, ergonomics and interface of future construction are resolved. This influences the aspects of technical solution such as comfort, security and simplicity of usage. The outlook design is also important on the stage.

- Occupational Safety Scaffolding is the reliability of engineer constructions. It is possible to build a construction in examine its hardness
- Melchemistry – application, for chemical experiments with wide range of features for observing different kinds of processes. For example, virtual process of photo-polymerization where multi-layer disk which is built with stacking layers, which are formed from “thin traces” (or informative layers)

3. *Constructing, building mock-up.* This stage carries applied character, in the result, prototype of solution and physical model are created. On this stage includes the creation of construction, mechanical and electric nodes as assembly, functional nodes assembly, construction assembly. The important aspect is construction testing and construction amending, if necessary.

- Electricity AR – application which helps to teach how to work with analogue scale of measurement devices and to make measurements with AR, to understand electrical scheme bitmaps
- CG-physics – demonstration of physical laws. Ability to perform one’s own physical (electronics) experiments
- Physics Playground – physics reference where physical forces and mechanical interaction can be observed

The example of a project of vehicle with autonomous control building is presented. It was implemented by students to participate in the Robotraffic competitions [22]. One of the stages of the competition is the movement of autonomous transport. It was necessary to develop an autonomous robotic vehicle capable of moving along the line (without leaving its lane) and be part of the urban transport model, following the road traffic regulations. The development of such project consists of two interrelated processes: the physical model construction (the vehicle is made to technical requirements) and the model programming (the rules of behavior in certain situations are described). It is necessary to consider the requirements of the environment. For example, traffic lights, road signs, and a pedestrian model should be used to build the urban traffic model. At this stage, it was built in AR environment, which determined the path that the vehicle should take (figure 1).

As a result of the project, students developed the model of a vehicle with autonomous driving, which was tested and participated in competitions. They conducted an empirical study of the concept of vehicle autonomy: collecting information on various implementations of autonomous traffic and systems that support it, development of options for implementing autonomous traffic using different hardware, experimental work to test hypotheses about the suitability of a variant of autonomous control system,

testing and evaluation of the vehicle. In the course of this design and research work, a holistic view of the problem of solving road safety was formed as a complex scientific task that requires the integration of knowledge in physics, mathematics, algorithmization, and programming and has a socially significant component.

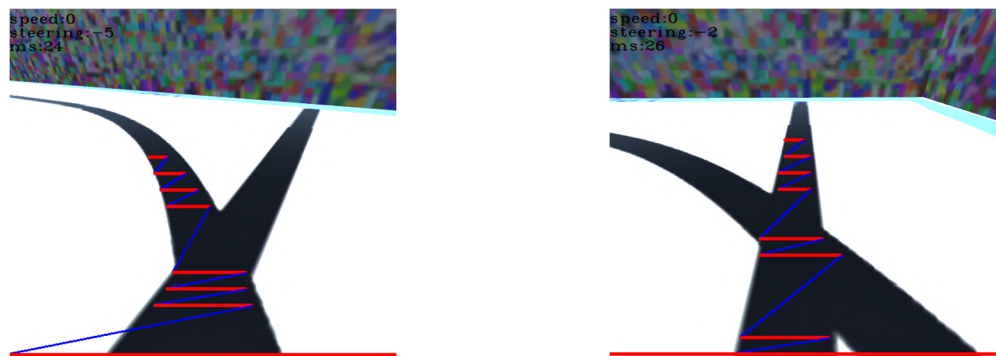


Figure 1. Path simulation in AR.

In this way, integration of AR into educational process is possible for robotics projects. This help to join not only scientific researches and different kinds of experimental activity but to make them more visual and available, according to current level of technological achievements. This helps with involving the young people to innovational activity.

4. Conclusions and outlook

During the problem of professional training of future pedagogical and mathematical teachers to utilization of AR technologies in education worldwide research all issues were resolved and the results were received. Based on the results there were made following conclusions:

1. Analysis of utilization of AR experience for interactive learning materials development concluded the conception of AR induced the development of new access interfaces to computer system for human. At the same time, regardless of long (more than 60 years) period of theory and practice development of such systems, only during last 20 years there were technological conditions for their wide deployment due to mass spread of mobile Internet devices [18], [32]. Methodical conditions of usage of virtual reality systems worldwide were tested in laboratory conditions, today they also need correction in mass technologization of pedagogical process.
2. Analyzed the experience of usage of AR worldwide, in particular during natural or mathematics classes. Among problems existing with deployment of those technologies worldwide, first of all, it is needed to note the deficit of specialists in educational projects preparation, limited technological preparation of teachers in this way. To make AR inseparable part of educational process, it is necessary to form strong interest for teachers to utilization of AR and show its advantages as versatile learning approach.

Method definition and forms of deployment augmented reality into process of preparation of future natural and mathematical disciplines teachers belong to further researches.

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Development of career guidance quests using WebAR

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Abstract. Career guidance quests that involve solving intellectual and search problems in a game are associated with one's future career, being one of modern means of recruiting school leavers to vocational and higher educational institutions. Such specific computer tools of virtual and augmented reality as pupils' mobile Internet gadgets can enhance visual character and interactivity of quest problems. The article deals with applying augmented reality in the web environment to solving these tasks. The authors propose a prototype of a career guidance quest system using WebAR technology.

1. Introduction

Nowadays, augmented, or mixed, reality is a popular technology which is gaining in popularity among educators as well. The basic application of augmented reality (AR) to education is provision of visualization by visualizing computer models of systems and objects using general (a computer equipped with an integrated or external web-camera) and specific (AR goggles, VR helmets) tools, and adapted devices (mobile phones).

The latter are the most widespread devices among participants of the academic process. As of May 2020, there are 8.3 mln users of mobile games, 26.2% of which are 18-24-year olds [27]. According to 2019 data, Ukrainian mobile users at the age of 16-25 are the most frequent users of social networks



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(92%), message exchange tools (66%), video applications (64%) and mobile games (50%) [11]. Comparison of the two latter sources enables drawing a conclusion that there are from 16 to 16.6 mobile users in Ukraine who are senior school pupils, students of all educational levels or young people. According to the Government Statistics of Ukraine, at the beginning of the 2019-2020 academic year, there are 1.440 mln students of colleges, secondary technical schools, universities, academies and institutes [9], 4.163 mln of which are 16-25-year-olds ([9], p. 26).

Comparison of the given statistics indicates that each student has two mobile numbers on average attached to one of the popular stores of mobile applications. It can be either a single mobile phone with two SIM-cards or two mobile phones. As of December 2020, 79.8% of mobile devices in Ukraine had the operating system Android installed [26], while the leading web browser was Chrome (67.8%) [24]. Considering that the third most popular browser, Opera, is built on the Chrome core [21], Chrome accounts for 80%.

In spite of some specific clients for social networking, message exchange, video watching and mobile games, a browser is a universal tool for performing relevant tasks and developing new software in the web-environment quickly. The main advantage of web-clients is their universality as there are Chrome versions for all mobile platforms. Low operating speed of programmes has been the basic disadvantage until recently. Appearance of WebAssembly in March 2017 enabled acceleration of web-programmes and transition of software designed for other platforms into the web-environment.

Access to high-quality libraries of computer vision, image recognition and monitoring (ARToolKit and its web-version JSARToolKit5 [2]) is the key to designing WebAR software. At the same time, joint application of JSARToolKit5 and WebGL reveals that:

- markers applied by JSARToolKit5 are a two-dimensional type of a barcode of low visualization;
- visualization of objects by means of WebGL requires in-depth understanding of principles of 3D graphics and greater amounts of a software code.

Thus, the mentioned WebAR development tools are aimed at enhancing visualization of the teaching process, yet they lack visualization and accessibility themselves, this fact indicating the research problem of selecting and testing software tools of WebAR development designed for beginners mastering the basics of web-design – students of lyceums and junior Informatics students.

The following article sections are aimed at solving the following tasks:

1. Performing a comparative analysis of WebAR designing tools in order to select those suitable for beginners.
2. Designing software prototypes with marker and markerless WebAR.

2. Review of WebAR designing tools

2.1. *Augmented reality: its notion and hardware for Web*

For the recent 60 years, it has been innovative (trendy, interesting, useful, etc.) to program AR, while its application to the web-environment is conditioned by current development of technology. To start this process, one needs an AR-compatible browser like Firefox or Chrome and a text editor (like mcedit or Sublime). Beginners need basic knowledge of web-design (HTML, CSS and JavaScript), while experience of working with web API and GitHub is also applicable.

Hereafter, by AR, we mean an ability of a device (a mobile device or a web browser) to monitor an image or represent a 3D object over the image. The main aim of AR is to show a computer model online in the real-mode space to establish interaction of a user in the real-mode space and a 3D model in the virtual one.

AR can be both marker and markerless. In case of the marker AR, a device tracks a 2D marker: when it is found, a 3D object is visualized. In the markerless variant, a device searches for a flat surface (a table, a floor, etc.) and place a 3D object there.

Using a camera, AR enables visualization of computer-generated objects in games, marketing and other software as in case of arranging furniture in a living room or trying on new clothes before buying. It is a great opportunity for business as it demonstrates a product before a customer really buys it [16].

There are specific devices designed for AR like helmets and headsets enabling a user to plunge into a modelled environment.

AR supplies a real-life world with 3D models controlled by mobile devices anywhere. Virtual reality (VR) makes a user get involved into a modelled world by means of head mounted devices (HMD).

Interactivity in AR and VR software is provided in a similar way. For example, VR actually uses controllers and occasionally hand-tracking enabling a user to interact with 3D objects inside a scene they are situated in.

Major hazards of using HMD in VR include:

- eye strain;
- dizziness and headaches after using HMD.

Unlike VR, AR does not possess any of these hazards for health. Yet, the ability of users to remain concentrated on what they are doing is disturbing, in particular, while using AR, for safety reasons.

Smartphones with iOS (11 and higher under iPhone and iPad control) and Android (7.0 and higher) are the most widespread type of devices for AR.

For web browsers, like Google Chrome and Mozilla Firefox, AR is applicable if they support WebRTC [18] and WebGL [17].

Microsoft HoloLens is an HMD-like AR headset which is designed currently [15]. Like Google Glass [14], it is designated for corporate use, yet, unlike Glass, it is compatible with Windows 10, not with Android.

2.2. Tools of visualizing computer models in the Web

WebGL (OpenGL ES for the Web) is API for 3D graphics in the web browser designed by the Khronos Group Inc [31]. WebGL uses a shader programming language GLSL (OpenGL Shader Language) and is part of a document object model (DOM API) of the browser. All the leading browser designers – Apple (Safari), Google (Chrome), Microsoft (Edge), and Mozilla (Firefox) are members of WebGL Working Group. The current version WebGL 2.0 corresponds to the standard OpenGL ES 3.0 API.

The programme described by WebGL contains both a JavaScript code and a C-like code GLSL. The example of simple software for building a triangle (figure 1) from [32] contains 105 rows of the code comprising five blocks:

1. Preparing a canvas (HTML object canvas) and obtaining a rendering context of WebGL.
2. Defining geometry attributes such as vertexes, indices, etc., and storing them in buffer objects.
3. Designing and compiling software for vertex and fragment shaders.
4. Connecting shader software and buffer objects.
5. Rendering a required image.

Application of WebGL for visualizing computer models in the Web is not the easiest way to do it: the code will account for thousands of rows and require high-level skills in designing 3D graphics by means of OpenGL. Considering the fact that the first research task involves selection of tools for beginners, it is reasonable to use libraries that make application of WebGL simpler.

Table 1 contains results of assessing efficiency of using JavaScript libraries for WebGL objects.

Considering the fact that the conducted analysis is designated for teaching beginners, there are the best-rated non-commercial libraries determined for working with WebGL – Babylon.js, Three.js and A-Frame.

Babylon.js [5] enables designing complex 2D-objects by using an essentially smaller code size than that for WebGL: the code size shown in figure 2 is 5-fold smaller than that of the WebGL-code for a simpler scene in figure 1. The designed scene is controlled by simple controlling elements. Unlike other rating participants, Babylon.js is a “physical” mover widely applied to designing computer games for the Web.

Three.js is a free 3D graphics library of general application written in JavaScript. On <https://threejs.org/>, one can find many high-quality demonstrations designed by using it [6]. Its author, Ricardo Miguel Cabello, known also as Mr.doob, is one of the WebGL pioneers. For this reason, this library is often used for designing other libraries.



Figure 1. The source code and the result of the simple WebGL programme running.

Table 1. Assessment of efficiency of using libraries for WebGL.

Title	Animation	Native audio	Access to the	Considering laws of physics	WebGL version	WebVR	Import	Export	License	General
A-Frame	+	+	-	-	1.0	+	Many formats (3)	HTML, three.js (2)	Free	10
CopperLicht	+	+	-	+	1.0	-	-	-	Free	5
OSG.JS	+	+	-	-	1.0	+	-	-	Free	5
Three.js	+	+	-	-	2.0	+	Many formats (9)	Many formats (4)	Free	19
Verge3D	+	+	-	+	1.0	+	Many formats (3)	gITF (1)	Commercial	9
Clara.io	+	-	-	+	1.0	+	Many formats (5)	Many formats (6)	Commercial	15
Babylon.js	+	+	-	+	2.0	+	Many formats (5)	Many formats (9)	Free	21

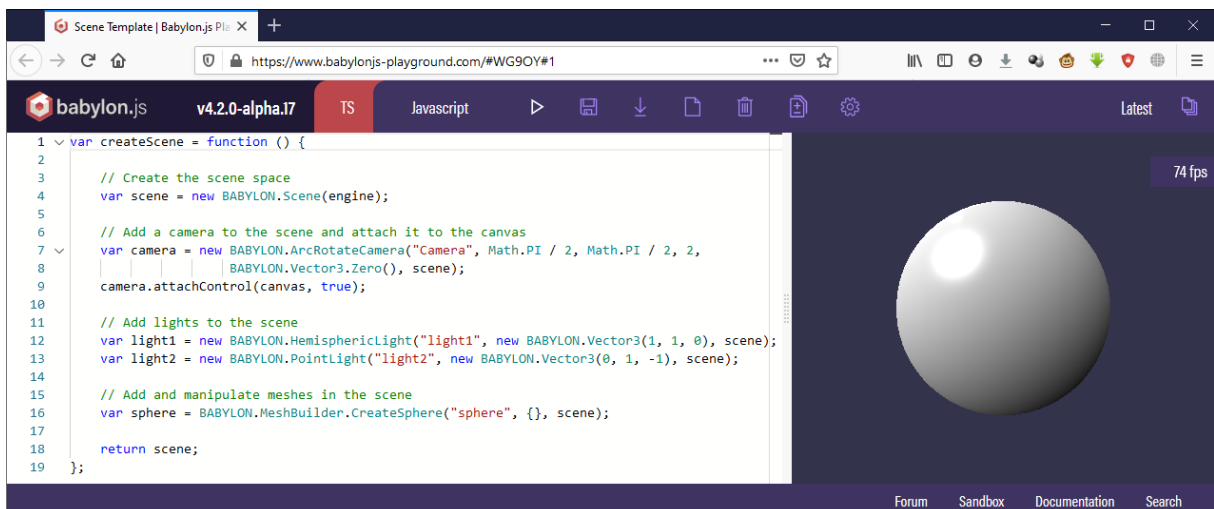


Figure 2. The source code and the result of the simple programme running in Babylon.js. Object designing in Three.js involves three steps:

- 1) determining object geometry – vectors, colours, etc.
- 2) determining materials – a rendering method for an object;
- 3) composing geometry and materials.

The code size required for designing the 3D scene by Three.js (figure 3) is a bit larger than that of Babylon.js. It is explained by combining in Babylon.js the operations of designing an object and those of adding it to the scene into a single call of a constructor of a relevant class.

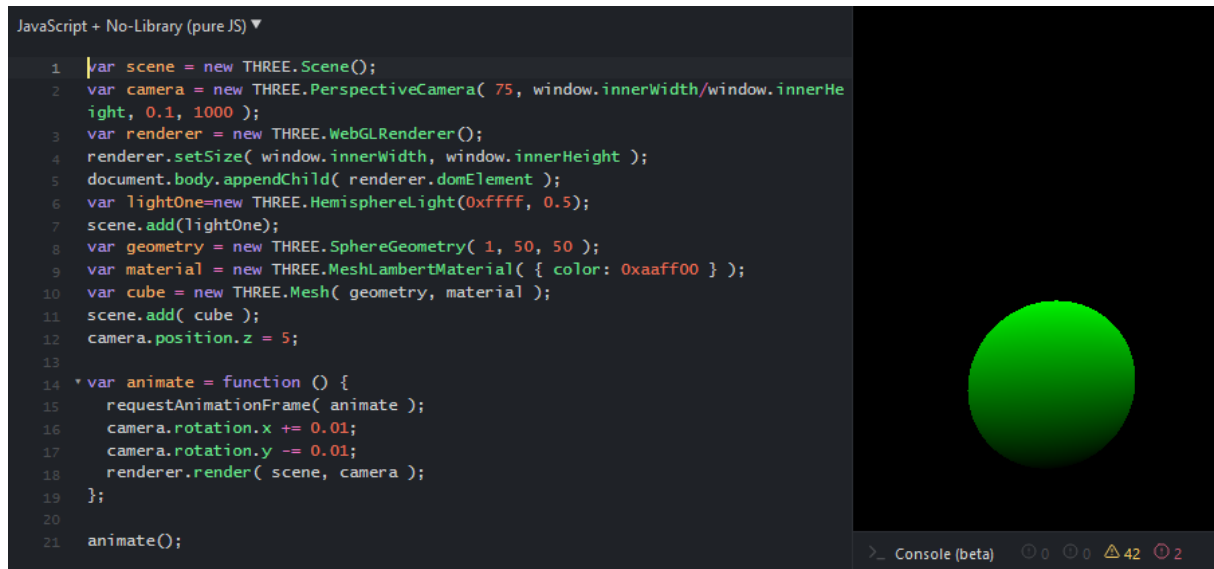


Figure 3. The source code and the result of a simple programme running in Three.js.

A-Frame is actually a tool of rapid prototyping: a greater part of its application is a HTML-like code. A-Frame commands are described by tags similar to HTML ones, yet, unlike the latter, are interpreted not in a client-side browser, but are a means of accessing JavaScript on the server side [29].

Figure 4 is significant as the A-Frame code size required for designing the same sphere is a three-fold less than that of Babylon.js/Three.js:



Figure 4. The output source code and the result of the simple programme running in A-Frame.

Thus, in spite of the third place in the rating of functional opportunities, A-Frame is the leader in terms of visualization and accessibility among the considered libraries for 3D graphics on the Web. Considering the fact that A-Frame is a superstructure over Three.js, it is reasonable to master them in a loop mode starting from A-Frame.

2.3. Tools for tracking real-life objects

As [30] contains comparative analysis of the most widespread AR SDK, let us focus on those applicable to designing on the Web – WebAR SDK. Unfortunately, as of January 2021, there are only three free tools, each of which is associated with considered tools of building computer models.

In August 2019, Babylon.js announced **Babylon AR** [20], the project integrating Babylon.js and the computer vision library OpenCV. At present, there is implemented tracking of standard markers similar to QR-codes. In spite of the fact that designers of Babylon.js consider Babylon AR project being on the early stage, web-programmes designed are efficient only on WebXR-supporting devices [19]. This narrows the scope of applying Babylon AR to 8.1 and higher Android devices. In January 2021, there were 74% of such devices among Android ones in Ukraine [25]. Considering the trend of increasing this share, Babylon AR can be considered a promising project of WebAR software development starting from 2021-2022 [25].

ARToolKit, which is 20 years older than Babylon AR, is one of the most applicable AR libraries. **JSARToolKit** (ARToolKit.js) is currently supporting three types of square markers (with arbitrary drawing, a 2D code and markers) and NFT-markers (natural feature tracking) [2]. JSARToolKit is not specific for a WebGL library, yet, it is most frequently used together with Three.js: the example [28] of their joint work developed by Lee Stemkoski is given in figure 5.



Figure 5. The cube on the Hiro marker (joint application of Three.js and JSARToolKit).

The code size required for implementing functionality of the example makes about 100 rows and is much smaller than in case of JSARToolKit. This is due to applying THREE.js library – extension of Three.js for designing computer games, this fact making its functionality similar to Babylon.js [13].

Its author, Jerome Etienne [12], is the main designer of the first and the second version of AR.js, which, as of January 2021, has versions adapted to both A-Frame and Three.js. In the same way as A-Frame is a superstructure over Three.js, AR is based on JSARToolKit. Thus, this library supports all types of square (marker tracking) and NFT markers (image tracking) as in JSARToolKit, and also enables locating computer models according to their geospatial coordinates (location-based AR) [1].

When applied with A-Frame, the code required for the example similar to that in figure 5 takes several rows:

```

<a-scene embedded arjs>
  <a-marker preset="hiro">
    <a-box></a-box>
  </a-marker>
  <a-entity camera></a-entity>
</a-scene>

```

3. Designing a software prototype for career guidance AR-quests

3.1. The concept of a career guidance quest

A quest is a journey aimed at performing a certain mission or achieving a goal. In literature, a quest is most often used to indicate a character's growth – how they change themselves and change others. Propp mentions that such fairy tales (tales of quests) have a general structure composed of about 150 steps ([23], p. 134).

The Quest Federation of Ukraine defines a quest as an amateur sport and intellectual competition based on consecutive accomplishment of prepared tasks by teams or individuals [3].

During the game, teams solve logical tasks, perform a search in the field, design optimal routes, search for original solutions and prompts. After fulfilling a task, teams proceed to the next one. The team that accomplishes all the tasks fastest wins.

During career guidance events at Kryvyi Rih State Pedagogical University, there are arranged walking quests both in- and out-of-doors. Quest organizers should control time, task performance, check a team's presence at relevant points and task confirmation codes. Quest participants are to solve intellectual and search tasks in the form of a game associated with their future career, this quest type being called career guidance.

3.2. WebAR tools for a career guidance quest

A career-guidance quest is to cover a set route with fixed stations passed by teams. Activated GPS-navigators of quest participants' mobile phones will monitor their passage and help them gather in a certain point of the route marked by an AR object with relevant geospatial coordinates.

The code prototype performing these actions is presented in [1]:

```

<script src="https://aframe.io/releases/1.0.4/aframe.min.js"> </script>
<script src="https://unpkg.com/aframe-look-at-component@0.8.0/dist/aframe-look-at-component.min.js"></script>
<script src="https://raw.githubusercontent.com/AR-js-org/AR.js/master/aframe/build/aframe-ar-nft.js"></script>
<a-scene vr-mode-ui="enabled: false" embedded
  arjs="sourceType: webcam; debugUIEnabled: false;">
  <a-text
    value="TEXT WITH MARKERS OF STATION AND NEXT TASK"
    look-at="[gps-camera]"
    scale="120 120 120"
    gps-entity-place="latitude: 47.908387; longitude: 33.411848;">
</a-text>
  <a-camera gps-camera rotation-reader> </a-camera>
</a-scene>

```

Figure 6 contains a place on the square in front of the University main building that corresponds to the coordinates given in the code. Unfortunately, application of GPS location only to reach a station (an intermediate stage of the quest for which points are scored) is not always possible as in multistoried buildings of the University, which make the majority, one and the same coordinate corresponds to stations on different storeys.

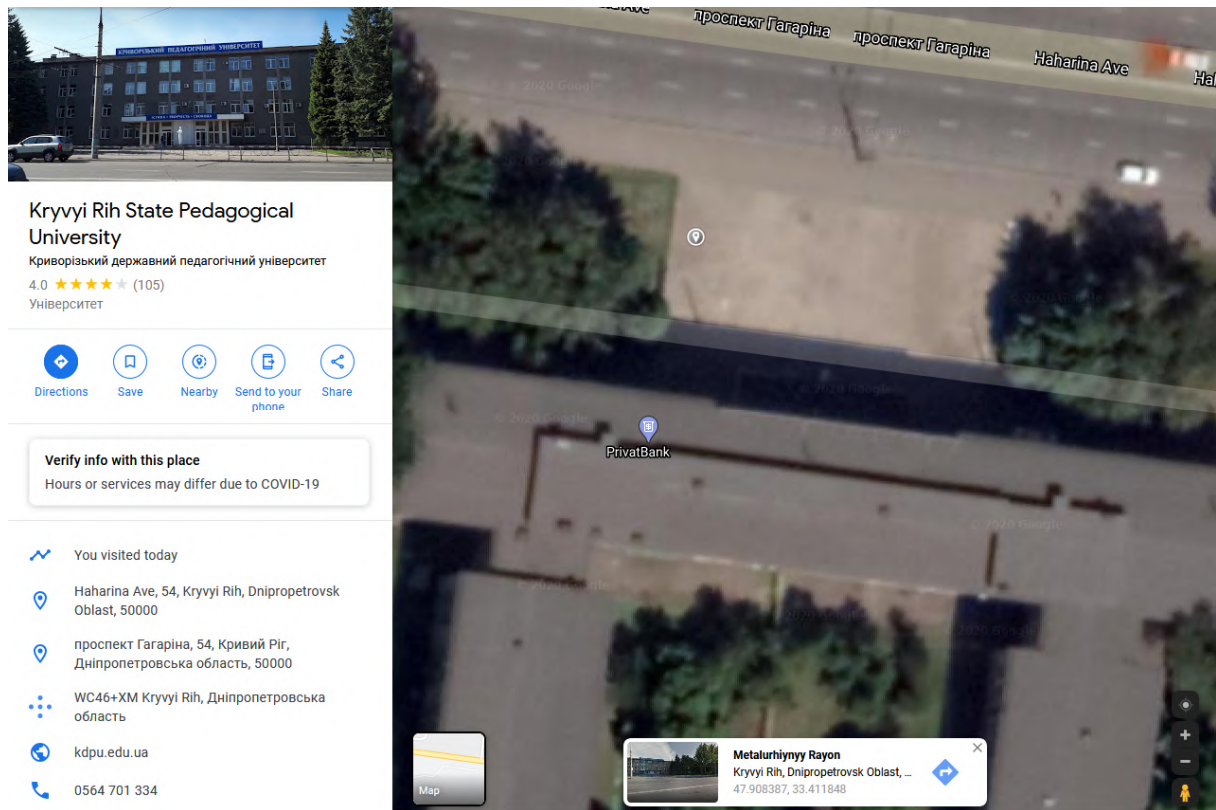


Figure 6. Finding coordinates of the quest-station by using Google Maps.

To determine the station, it is expedient to combine several types of AR – either the location and the square marker one (aframe-ar.js is the version of AR.js 3 for this combination) or the location and the NFT marker one (aframe-ar-nft.js is the version of AR.js 3 for this combination).

The traditional square marker can be easily determined, but its presence indicates a task for quest participants. To avoid falsification of the results by transferring a marker to another place, auxiliary determination of coordinates is used.

The option of Ar.js 3 to track natural images that can be part of the interior makes quests more complicated, yet, more interesting. To use these images as NFT-markers, one should apply a generator from <https://carnaux.github.io/NFT-Marker-Creator/> and study recommendations on designing good markers [8].

NFT Marker Creator (figure 7) has a confidence meter that indicates whether a marker will be good: the more stars it shows, the better the marker will be recognized.

In case of good lighting and a camera, images with a single star are also recognized well, yet, it is better to select images with four or five stars of confidence. The image should be visually complicated and have a high isolation capability, as, unlike square markers, details are essential here. Visually complicated images provide software with a great number of opportunities to track unique elements of the image that are easily recognized.

The physical size of a marker also affects its recognition. A device should be held closer to smaller images, while it is vice versa with larger ones.

Recognition quality also depends on screen illumination. Besides, cameras with low isolation capability usually function better when they are close to markers.

Printed markers can be located either on nontransparent paper or on a stand. Stands are a natural source of markers as all the University faculties have stands.

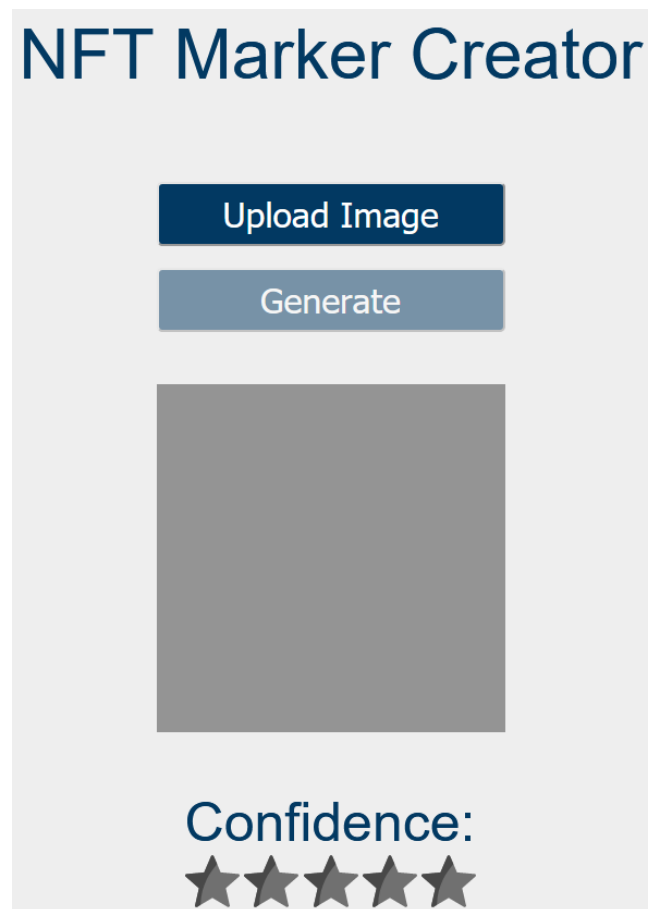


Figure 7. NFT Marker Creator.

3.3. Software development and testing

Let us consider development a software prototype of a quest element associated with the stand of the Faculty of Physics and Mathematics of Kryvyi Rih State Pedagogical University (figure 8).



Figure 8. Department of Computer Science and Applied Mathematics in front of the stand of the Faculty of Physics and Mathematics.

Figure 8 has the highest confidence factor – 5 stars. After printing on nontransparent paper, colour chord of the image changes causing deterioration of the factor to 2 stars (figure 9).



Figure 9. Generation of a marker for the original photographic image (a) and the one scanned after printing (b).

Comparison of images in figures 9a and 9b provides an additional conclusion on importance of external lighting to correct balance of the white recognition and the high-quality one of NFT-markers.

After processing the image, the generator creates three files of the marker (in our case - kafera.fset, kafera.fset3 and kafera.iset) that are required for recognition. The last file contains the original image transformed with grey shades (figure 10b).



Figure 10. The high-quality image (a) and the internal representation of the image (b).

In the following code fragment, after recognizing the photographic NFT-marker, there appear data on people in the photo (figure 11) as an AR object (the plane with the texture) activated by pressing – there are web links to the Department of Computer Science and Applied Mathematics in a new browser window (figures 12, 13).

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15. Хараджян Наталя Анатоліївна - к.пед.н.,доцент.

Figure 11. The AR object for the NFT-marker.

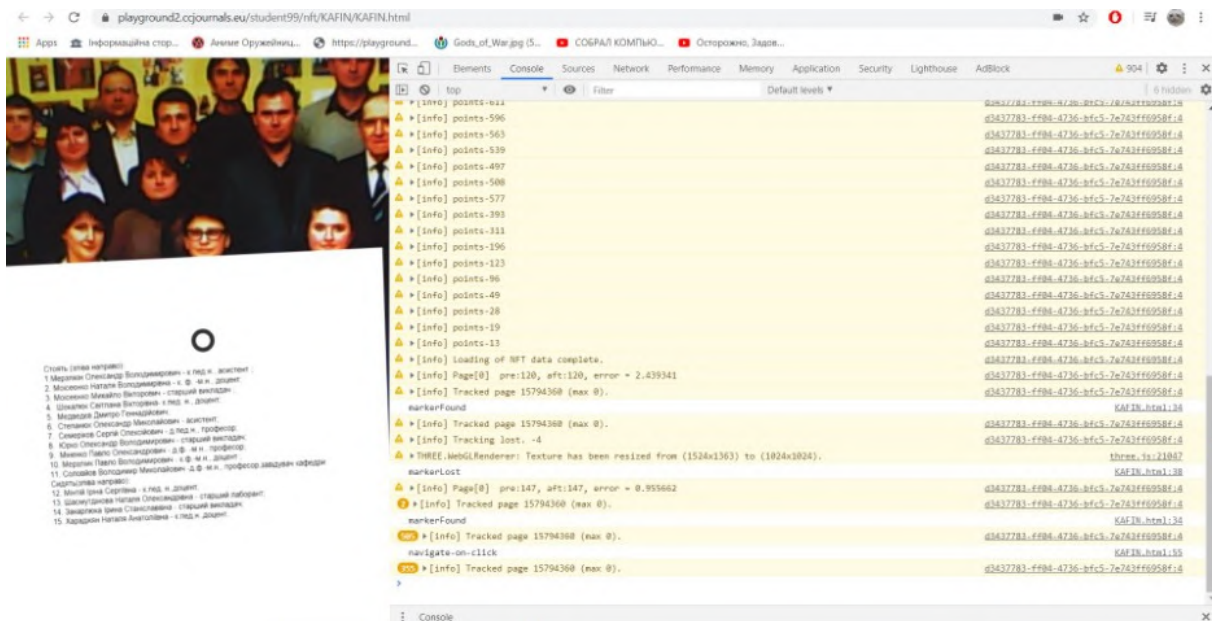


Figure 12. Software testing in the development mode.

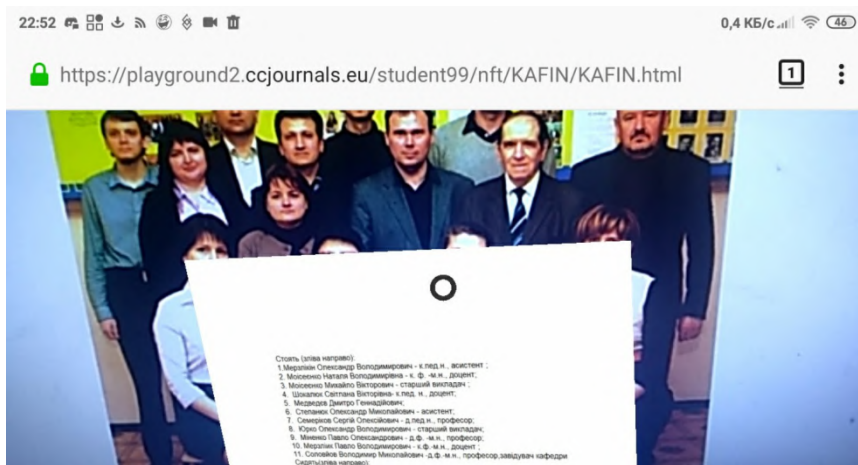


Figure 13. Software testing on a mobile Internet device.

The code snippet of the career guidance quest:

```
<script
src="https://cdn.jsdelivr.net/gh/aframevr/aframe@1c2407b26c61958baa93967b54
12487cd94b290b/dist/aframe-master.min.js"></script>

<script src="https://raw.githubusercontent.com/AR-js-
org/AR.js/master/aframe/build/aframe-ar-nft.js"></script>

<style>
  .arjs-loader {
    height: 100%;
    width: 100%;
    position: absolute;
    top: 0;
    left: 0;
    background-color: rgba(0, 0, 0, 0.8);
    z-index: 9999;
    display: flex;
    justify-content: center;
    align-items: center;
  }

  .arjs-loader div {
    text-align: center;
    font-size: 1.25em;
    color: white;
  }
</style>

<body style="margin : 0px; overflow: hidden;">

<script>
  AFRAME.registerComponent('registerevents', {
    init: function () {
      var marker = this.el;

      marker.addEventListener('markerFound', function() {
        console.log('markerFound', marker.id);
      });

      marker.addEventListener('markerLost', function() {
        console.log('markerLost', marker.id);
      });
    }
  });

  AFRAME.registerComponent('navigate-on-click', {
    schema: {
      url: {default: ''}
    },
    init: function () {
      var data = this.data;
      var el = this.el;
```



```

        el.addEventListener('click', function () {
            console.log('navigate-on-click');
            window.open(data.url, '_blank' );
        });
    }
});

AFRAME.registerComponent('jump', {
  init: function () {
    var obj = this.el;
    obj.addEventListener('click', function () {
      this.setAttribute('position', 150+100*(Math.random()-0.5)+ " 150 0");
      console.log('jump');
    });
  }
});
</script>

<!-- minimal loader shown until image descriptors are loaded -->
<div class="arjs-loader">
  <div>Loading, please wait...</div>
</div>
<a-scene vr-mode-ui="enabled: false;"
  renderer="logarithmicDepthBuffer: true;" embedded
  arjs="trackingMethod: best; sourceType: webcam; debugUIEnabled: false;">
  <!-- url should contain 3 files: .fset, .fset3 and .iset -->

  <a-nft registerevents
    type="nft"
    url= "https://playground2.ccjournals.eu/student99/nft/KAFIN/kafera"
    smooth="true"
    smoothCount="10"
    smoothTolerance=".01"
    smoothThreshold="5">

  <a-entity geometry="primitive: box; width: 150; height: 150; depth: 1"
    material="src: url(kaferain.png)" position= "150 -100 0"
    scale = "4 4 2" rotation="-90 0 0"
    navigate-on-click="url:https://kdpu.edu.ua/informatyky-ta-prykladnoi-
matematyky/zahalna-informatsiia/vykladachi-kafedry"> </a-entity>

</a-nft>

  <a-entity camera><a-cursor></a-cursor></a-entity>
</a-scene>
</body>

```

Figure 14 reveals examples of joint application of different marker types: there are matrix markers (QR-codes) on the left to access corresponding WebAR programmes and NFT-markers on the right to process corresponding WebAR programmes.



Figure 14. Joint application of different markers in WebAR.

4. Conclusions

1. The review of WebAR software design enables recommendations for beginners to master the following combinations of visualization tools of computer models and tools for tracking real-life objects:

– A-Frame and AR.js is API for fast prototyping most software of which is a HTML-like code. A-Frame is applied to designing scenes, objects, animation and other 3D elements in the web browser. AR.js is aimed at tracking markers and enables a scene designed by A-Frame to be rendered directly on the marker;

– Three.js and ARToolKit.js are used for a deeper level to design software using JavaScript. Three.js uses WebGL to create high-quality 3D scenes in the web browser. JSARToolKit is used for marker tracking and low-level access to data from a camera of a device.

2. Technological conditions of teaching software development with WebAR involve an arbitrary operating system, Internet access, using of cloud storages to deposit materials and availability of at least two classes of devices to test programmes. To master the basics of WebAR software development, it is reasonable to combine A-Frame and AR.js, the scene testing in VR proceeding its AR design. With the scene complexity increasing, JavaScript application to designing A-Frame objects and processing events is accentuated. Designing multi-marker scenes requires different types of matrix markers provided by JSARToolKit, while joint functioning of models attached to different markers requires application of Three.js library. This reveals a dialectic character of teaching WebAR software development: new methods are introduced to overcome problems unsolved by available ones.

3. A quest is an amateur sport-intellectual competition based on accomplishing prepared tasks by teams or individual players. There are some walking quests, both in- and out-of-doors, organized by Kryvyi Rih State Pedagogical University as part of career guidance activity. Quest organizers should control time, task performance, check a team's presence at relevant points and task confirmation codes. Quest participants are to solve intellectual and search tasks in the form of a game associated with their future career, this quest type being called career guidance.

4. A career guidance quest should follow a set route with required fixation of stations passed by teams. Activated GPS-navigators in quest participants' mobile devices help their monitoring and make them gather in a certain route point marked by an AR object attached to certain geographic coordinates. To locate a station, it is expedient to combine several types of AR – the location and square-marker or the location and NFT-marker one. To complicate and facilitate quests is possible by using the option of Ar.js 3 to track natural images as parts of the interior by means of NFT-markers. The images should be visually complex and possess high isolation capacity. Recognition quality of NFT-markers also depends on their physical size, screen illumination, distance between a device and a marker, isolation capacity of a camera, external lighting, screen brightness and paper quality for a printed marker.

5. Designed software prototypes of the career guidance quest enable determining a participant's quest coordinates as AR objects attached as well as any other images of photographic quality in the career guidance quest space.

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The use of online coding platforms as additional distance tools in programming education

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Abstract. This study analyzes various publications of scientists on the training of future IT specialists and the features of training programming using online simulators. The authors of the article made a comparative description of different online platforms for teaching programming according to certain criteria, selected interesting tasks from the online platform hackerrank.com, which have already been used to teach students. Online programming simulators have significant potential in organizing an effective distance learning system in Ukrainian universities. It is important to use online simulators in the learning process as an additional tool for the formation of professional competencies, which provides more intensive involvement of students in the process of writing code and practical (situational) application of existing knowledge. Gamification of the process of training future IT specialists helps to increase cognitive activity, and hence – the quality of the educational process and distance learning in particular. The authors recommend the use of online programming simulators as an additional tool for teaching computer science disciplines, taking into account their functionality, as well as the level of preparation of students and the expected learning outcomes.

1. Introduction

The modern world, as events in early 2020 have shown, was not ready for extreme challenges of various kinds. For example, the situation with the spread of COVID-19 showed that most countries around the world were unprepared for such events. The economic recession and social turbulence have affected all spheres of human activity [26]. Ukraine's higher education system was no exception, as it was neither morally nor technically ready for an emergency transition to distance learning. It is clear that higher education institutions (abbreviated – HEI) in our country are quite diversified, so some, mostly private and leading national universities, were able to mobilize faster and within a few weeks to transfer their students to distance learning platforms such as Moodle, Google Classroom, iSpring Online, etc. [11] A



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number of free educational institutions, not having sufficient resources and time, approached the problem of organizing distance education by using a variety of cloud services that provide support for conferencing such as Zoom, Google Meet, MS Teams, Skype, as well as streaming lectures and teaching educational video content on YouTube. In other cases, HEI or a separate category of scientific and pedagogical staff was limited to the use of various managers (Viber, Telegram), social networks, as well as e-mail. We are not currently evaluating the effectiveness of the use of certain ways, we can talk about this later, including the results of higher education students in the summer session, but it should also be noted that the choice of one or another approach in the organization of distance education largely depends on specialties, educational and professional programs, the profile of the Free Economic Zone, the expected learning outcomes.

Specialty 122 “Computer Science” focuses on the acquisition of in-depth theoretical and practical knowledge, skills, computer science, information technology, general principles of professional methodology, other competencies sufficient for the effective implementation of professional tasks in the design of information systems and their components. At the Kyiv National Economic University named after V. Hetman anonymous survey among students of the first (bachelor's) level of higher education (March 2020) showed that 2/3 of the students as a key motive for choosing a specialty identified knowledge of programming languages of different levels, which, in principle, is logical. On the other hand, as the practice has shown, the absence of a teacher (mentor, curator) in mastering the components of the educational and professional program related to the study of programming languages, including independent, practical and laboratory tasks in students constantly causes difficulties. According to the results of the survey, it was found that 73% of respondents have problems with distance learning and independent performance of practical tasks, of which 58% – full-time students. These data show that for students of full-time form of education a sharp transition to distance learning is a certain “stress”, which likely can affect the final learning outcomes. The most common problems of students, identified during an anonymous survey of students, are presented in figure 1. Specialty 122 “Computer Science” focuses on the acquisition of in-depth theoretical and practical knowledge, skills, computer science, information technology, general principles of professional methodology, other competencies sufficient for the effective implementation of professional tasks in the design of information systems and their components. At the Kyiv National Economic University named after V. Hetman anonymous survey among students of the first (bachelor's) level of higher education (March 2020) showed that 2/3 of the students as a key motive for choosing a specialty identified knowledge of programming languages of different levels, which, in principle, is logical. On the other hand, as the practice has shown, the absence of a teacher (mentor, curator) in mastering the components of the educational and professional program related to the study of programming languages, including independent, practical and laboratory tasks in students constantly causes difficulties. According to the results of the survey, it was found that 73% of respondents have problems with distance learning and independent performance of practical tasks, of which 58% – full-time students. These data show that for students of full-time form of education a sharp transition to distance learning is a certain “stress”, which likely can affect the final learning outcomes. The most common problems of students, identified during an anonymous survey of students, are presented in figure 1.

These data made us think about how much higher education students are ready to work independently in mastering specialized disciplines and distance learning, as well as initiated the search for effective ways to improve the quality of the educational process and the effectiveness of faculty in professional computer disciplines. Effectively, in our subjective opinion, and taking into account the feedback of students, online coding platforms (abbreviated – OCP) have proven themselves to master and consolidate programming skills.

The purpose of the article is to explore the experience of using OCP, to compare the characteristics of different online platforms, which should be used for distance learning programming of future computer scientists and programmers.

2. Literature survey

The issue of finding modern and popular tools to improve the quality of the educational process, mastering programming languages and developing technical skills is quite relevant, both for Ukraine ([13], [22], [23], [25], [27], [37]) and for the world as a whole. Referring to foreign practice, scientists emphasize the expediency of diversifying the ways and methods of teaching programming, among which are the relevant interactive online simulators and coding platforms. In particular, in [2], the experience of using an interactive learning platform for the development of parallel programming skills – Parapple is described. The authors emphasize that the use of the game form of learning implemented in the platform significantly increases the efficiency of students' learning of programming languages.

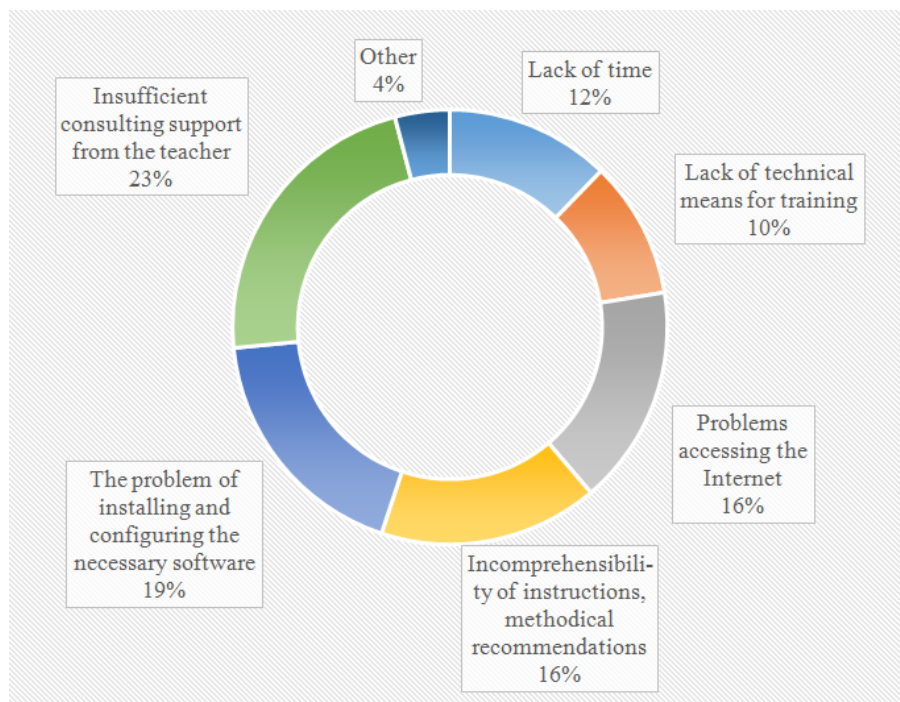


Figure 1. Problems that prevent students from mastering computer disciplines in distance learning.

In [5] and [36] it is emphasized the need to involve students studying computer science in competitions (contests, competitions), for which there are a number of web platforms, in particular: Coderbyte, CodeFights, Codeforces, E-Olymp, Facebook Hacker Cup, Google Code Jam, etc. The high efficiency of using special interactive programming simulators, in particular, the CodeWrite web resource, at the stage of acquaintance with the basic rules and syntax of the Java program code is emphasized in [4]. In [1] it is noted that the use of online simulators to master and consolidate programming skills greatly simplifies the procedure for teachers to check the code written by students, identify errors, and help to detect in the early stages of lag in mastering the code by individual students.

Despite the popularity of online platforms for learning programming, there is still a lack of thorough research to analyze what skills are acquired through the use of different platforms. The article [6] analyzed clickstream data from 3,355 participants who studied in several seminars on computational thinking using the online platform Kodetu. Participants used Kodetu coding blocks to solve problems with increasing complexity. The results after evaluation of data on the characteristics of participants (age, gender, previous knowledge), the similarity with previously made decisions, and the degree of inconsistency with the optimal solution are presented.

Nowadays, various companies have increased their requirements for IT professionals. Despite this, many jobs remain unfilled. In addition, we need workers with programming skills, even if they do not have official professional diplomas. Also, there is no secret that gender disparities in technology-related

industries are a serious problem. Even if companies want to hire women in digital technology, the number of women involved in programming is extremely low. In secondary schools, most adolescents acquire only low-level programming skills. Therefore, many teens exclude programming as a career path. This study presents two promising concepts for overcoming these problems. In 2018, the University of Graz introduced a voluntary lecture “Create your own application” for students of all degree programs. A total of 202 students took part. We have applied a Gaming Learning Approach (GDBL) with the Pocket Code visual coding tool, a mobile application developed at the Graz University of Technology. Students had to create simple games directly on smartphones. The course received positive marks. In January 2019, we began developing a MOOC (Massive Open Online Course) called “Get a FIT in Computer Science.” MOOC will be launched in August 2019 on the platform iMooX.at and will provide a general introduction to the CS field. For exercises and the final presentation, students need to apply game design strategies using Pocket Code. The MOOC has several target groups: 1) can be used to encourage young women who have almost prior programming knowledge; 2) it should help all adolescents to get a more realistic picture of programming and basic concepts; 3) teachers can use teaching materials for classes in secondary schools (Open educational resources). The MOOC can be accessed by anyone interested in programming, so students of other specialties can acquire such skills [32].

The publication [28] states that more and more high school teachers are using existing mass open online courses (MOOCs) on the basics of programming. Most MOOCs cover programming languages and general concepts or patterns. MOOC platforms typically provide their own code writing environment and thus have complete control over the capabilities and appearance available to students. However, MOOC uses only a subset of the tools available to professional software engineers. Although reduced capabilities are useful to facilitate navigation for beginners, in the final stage of the learning process, students benefit from more advanced features. To help pupils and students minimize errors, it is suggested to perform programming in pairs. Also, professional tools and methods have been integrated into MOOCs.

The cloud-based online platform is discussed in the article [19], which has its own environment that allows students to practice programming online without any specific configurations. This platform provides online coding services and can bring faculty and students together in a unique social experience, tracking and transmitting updates in the real-time programming process. In particular, the recently proposed platform makes it easy to uncover interesting and unexpected input values during students' internships and help them understand what their codes actually do. As a result, students can effectively study courses related to coding and write high-quality programs.

In article [20], as part of a study on the design and use of cloud environment in student learning, based on expert assessment, it was determined that the most important for the learning of programming are web-oriented and cloud-oriented compilers: Codepad.org, ideone.com, AWS Cloud 9, and automated systems E-Olymp, Algotester, TopCoder, NetOI Olympiad are effective for checking programming tasks.

The E-Olymp Internet portal was created by Ukrainian specialists to optimize and automate the process of testing programming tasks. The E-Olymp portal helps the teacher in teaching students programming, in preparation for tests, exams, modular work, etc. Students have the opportunity to solve problems and prepare for classes, as well as test their solutions without the help of a teacher, compare the level of their skills with the level of other users of the site, which, in turn, stimulates knowledge in this area and promotes development. self-esteem. Provides control and independent work, limited in time, while the teacher does not waste time checking the work, students can get the result immediately (and students see the results of other classmates registered in the system and participated in the competition), and if there are several tasks, the teacher is offered a total score obtained by the student. The main advantages of this Internet portal for programming training: currently contains more than 7,000 tasks; the possibility of creating competitions from the list of available tasks with the ability to choose the type of competition according to the rules of the Olympiad: the best solution, the last solution; availability of a general rating of registered participants; the automated system for checking solutions

implemented in programming languages Pascal, C#, C++, Java, PHP, Python, Ruby, Haskell; the existence of a queue of solutions, where you can see which task is credited and which is not, and, accordingly, by what percentage; availability of classification of programming tasks by known sections; availability of information about all attempts to solve problems; the existence of a methodical and an assistance section; the possibility of creating groups [20].

The study [3] shows many problems in teaching programming to schoolchildren and students: great diversity in abilities and skills; a large number of different tools (online platforms); time-consuming nature of programming; difficulties in motivating schoolchildren and students. There are various platforms that offer to learn coding and programming, in particular gaming platforms, which are becoming increasingly popular. Gamification of the programming process is aimed at increasing the motivation and involvement of more schoolchildren and students. Researchers have considered the main types of online platforms for learning programming and illustrated the review with specific examples of platforms.

The study [35] is devoted to the use of game simulators in the formation of professional competencies of future software engineers. Various scientific researches are described, in particular, the following list of game simulators is allocated: “Ameise” – management of the project of development of software (with an emphasis on quality); “ANUKARNA” – a game-simulator for training students in the best practice of expert evaluation of code; “Problems and Programmers”, “SimjavaSP”, “SimSE” – software development processes; “SimVBSE” – value-based software development; “PRODEC” – software project management, etc.

In addition to the research described above, various aspects of training future IT professionals are considered in [7], [12], [14], [15], [21], [23], [24], [25], [34], including programming training [18], [31], [33].

In the context of this study, it is not about finding a full-fledged resource for distance education, but about enriching teaching tools and diversifying the teaching process through the use of user-friendly web resources that develop students' programming skills. Therefore, in the course of the study, the authors deliberately singled out online programming simulators (or OCP) as a separate group, as there are many different resources on the Internet for distance learning of programming languages. For clarity, we highlight the key groups:

- distance learning courses on different educational platforms and from different free educational institutions (for example, Coursera, edX, Codecademy, Udacity, Khan Academy, HTML Academy, etc.). These resources teach full-fledged ready-made training courses, which contain both theoretical and practical components of training a future programmer;
- online programming judge system – web resources used, primarily, for competitions, hackathons, group competitions, tournaments, etc. The web resources of this group include UVA Online Judge, Sphere Online Judge, Google Code Jam, E-Olymp, CDOJ, etc.;
- online simulators (or OCP) for mastering and consolidating programming skills – web resources aimed at developing students' professional competence in programming languages. These resources contain sets of exercises and tasks of different content and nature to hone practical skills in working with program code, as programming requires constant practice. These simulators are not an independent tool for mastering the programming language, because still, the student must have basic theoretical concepts, understanding of algorithmization, syntax, and semantics of a programming language, operators and more.

To work with program code and to hone programming skills, the student must master the syntax and design, understand the principles and methods of problem-solving, their context, while performing only laboratory or practical work, it is not always sufficient. And in the case of distance learning, teachers for productive work with students of computer specialties need, on the one hand, to take measures to increase the cognitive activity of higher education, on the other – not to overload students. The ideal tool, according to the authors, is to diversify the learning process through the use of online programming simulators (or OCP).

3. Current work

In English literature, the term “online coding platform” is used to denote the concept of online simulators for mastering and consolidating programming skills. There is no fixed phrase in Ukrainian–language practice, so we use the concept of online programming simulators (abbreviated – simulators, or “online coding platform” as in English), which will denote a web resource that gives the user free or paid access to various types of tasks (group and doubles tournaments, games, static situations, search for errors, testing, etc.), which allow getting acquainted with the basic concepts of writing program code and deepen existing knowledge. The peculiarity of these OCP is:

- they are publicly available, their use does not require the installation of any additional software, the availability of powerful computer equipment, installed operating system, the need to use proprietary software products. These web resources can be accessed from anywhere in the world;
- for use, students must have access to the Internet (sufficient at the level of services provided by the mobile operator) and a convenient device. Note that a laptop or computer is not necessary, a smartphone with a more or less user-friendly screen is enough to work with OCP;
- tasks are visualized, students do not have to spend a lot of time studying instructions and teaching materials to perform a specific task, just get acquainted with the problem statement, input constraints (e.g., RAM, program execution time, etc.) and go to write code that corresponds initial conditions. Visualization of tasks in simulators is various, it all depends on the creativity of developers, the orientation of a web resource and its popularity, etc. For example, in modern simulators tasks can be presented in the form of animations, graphs, game scenes, the actual code and visual representation of results, crossword puzzles, tests, quizzes;
- performance of tasks on OCP is not trivial. A student can write a code to solve a problem that satisfies the input conditions by copying it, for example, from a textbook or finding it on a forum. If the simulators are aimed at developing existing programming skills, then in addition to the formal implementation of the task, the evaluation algorithms embedded in them analyze the originality of the proposed code, for which you can get additional points in the ranking. This develops in students a tendency to creativity, self-realization and critical thinking;
- tasks are performed in an interactive mode “task-writing code-evaluation of results”, which promotes greater involvement of students in the programming environment, causes some excitement and develops motivation, as each registered user is assigned a certain rating and with increasing student success and knowledge in programming this rating is rising;
- the counseling support available to students when working with program code is very important. The functionality of most simulators expands the teacher's ability to provide such support, in addition to the student's direct contact with his teacher, he has access to reference materials and books on the programming language being studied; it is possible to seek advice from the community that also works with this simulator;
- tasks are differentiated both by programming languages and by the initial level of students' knowledge. At the same time, if a student sees that he cannot cope with a specific task, it is always possible to go back and fill the gaps in knowledge;
- most OCP check students' performance of tasks automatically, so teachers have time to focus on the content of their own distance learning courses, to explain the difficult points and help solve problems that are unclear to students while studying on such simulators;
- most OCP provide employment services free of charge or for a fee. That is employers, following the TOP-ratings of participants, analyzing their logic and software solutions can offer work in their companies to future programmers and IT professionals. In addition, some web resources have the option of sending a resume.

In table 1, the authors of this article made a comparative description of several online programming simulators. The criteria for choosing these resources were the following circumstances: first, the subjective experience of the authors in the use of these resources based on their own experience;

secondly, the requirements of the educational-professional program “Computer Science” (2018) to the program results and the acquisition of professional competencies of applicants for the higher education of the first (bachelor's) level at the Kyiv National Economic University named after Vadym Hetman (in particular, knowledge of programming languages Java, JavaScript, PHP, C#, C++) [17]; third, the popularity of web resources on the Internet by the number of unique visitors and traffic statistics rated by Alexa (<https://www.alexa.com/>), a company that is part of Amazon.com. A similar approach to the selection of web resources for online learning is used in [16]; fourth, the free basic set of features for training.

Table 1. Comparative characteristics of online programming simulators (“+” is yes, “-” is no or very bad, “±” is partial or exact information not found).

Categories	OCP									
	leetcode.com	checkio.org	hackerrank.com	codechef.com	codeforces.com	codewars.com	freecodecamp.org	repl.it	codingbat.com	exercism.io
A set of skills practiced in the exercises:										
▪ syntax;	±	-	+	+	+	+	+	+	+	+
▪ semantics;	±	-	±	±	+	+	+	+	-	+
▪ algorithmization;	+	-	±	+	+	+	+	+	-	+
▪ logic;	+	+	±	±	+	+	+	+	+	+
▪ variables;	±	+	+	+	+	+	+	+	+	+
▪ arrays;	±	+	+	+	+	+	+	+	+	+
▪ loops;	±	+	+	+	+	+	+	+	+	+
▪ functions;	±	+	+	+	+	+	+	+	+	+
▪ objects.	±	+	+	+	+	+	+	+	+	+
Types of training exercises:										
▪ challenge;	±	-	+	+	+	+	+	+	-	+
▪ static problems;	+	-	+	+	+	+	+	+	+	-
▪ story games;	-	+	-	-	±	+	-	-	-	-
▪ tests;	±	-	-	+	±	-	+	-	-	-
▪ other.	+	+	+	-	+	-	-	-	-	+
Support for group work on the task	+	+	±	±	+	±	-	+	-	+
Additional training and explanatory material (tutorial)	+	+	+	+	+	+	+	+	+	+
Evaluation of training success (leaderboard)	+	+	+	±	+	+	+	+	+	+
Skills certification	±	-	+	+	-	-	+	-	-	-
Feedback	±	+	+	±	+	+	+	+	+	+
Available programming languages	9	JavaScript (TypeScript), Python	47	50+	±	51	21	50+	Java, Python	50
Recruitment options	+	-	+	+	-	+	+	-	-	-

4. Results

The obtained results testify to the difference between OCP. In particular, the fundamental difference is in the most important, in terms of teaching and organizing quality distance education, as a set of skills covered by the exercises, the ability to support group (joint, including with a teacher or classmates) work on tasks, a variety of available to learn programming languages.

The fact that these OCP support a different set of programming skills does not indicate their ineffectiveness for educational purposes, but the need for students to have basic knowledge of the basics of programming, syntax, semantics. It follows that students of 1-2 courses of free economic education, who are just mastering programming (for example, learning their first language – C ++), it is advisable to offer to work with simulators such as Exercism.io and Repl.it. They have an intuitive interface, the tasks are offered to solve, mainly as challenges and support the support of a mentor or teacher. Exercism.io gives the student the opportunity to share the results with the teacher so that he can check the written code and give recommendations for possible improvement. For its part, Repl.it, in its free license, supports collective cooperation with a restriction of two people, and subject to payment of a group license, it is possible for teachers to organize an individual room for joint and individual work with their students (Repl.it Classroom).

For students who master the knowledge of Java and JavaScript within the educational-professional program, it is mainly students of 2-3 courses, we recommend to turn to OCP built on a game basis – SheckIO (the result of Ukrainian developers) and Codewars. The ideology of both simulators involves immersion in the programming environment through a game scenario of exercises. And if for SheckIO it is a game like RPG, where a student performing various tasks masters the map of the islands, complicating the task as he develops programming skills. The idea of Codewars is for a student to create their own karate clan or join an existing clan to work together on applied problems. The simulator also supports changes in the form of sparring between karate players, for example, when the code is alternately refactored or bugs are fixed. As for the possibilities of collective work of teachers and students, it is somewhat limited in these simulators. For example, ScheckIO supports the creation of an individual teacher's office only for mastering the Python language. Codewars has the ability to create teaching Code Classrooms but on a fee basis.

Students of 3-4 courses can be recommended to develop programming skills in HackerRank simulators. This web resource contains tasks of medium and advanced complexity, there are fewer tips and tricks for completing tasks, which encourages students to develop imagination and creativity in writing code. In addition to basic programming languages, it allows us to deepen knowledge of the basics of algorithmization, databases, and SQL, functional programming, mathematics, etc. This simulator contains good recruitment support, which means an opportunity for students to demonstrate their skills to potential employers.

5. An example own experience of using online coding platforms

One of the authors of this publication has been using one of these platforms for over 5 years in order to improve their programming skills and to select assignments for students in which he teaches programming.

This platform is hackerrank.com, which positions itself as follows “HackerRank is technology hiring platform that is the standard for assessing developer skills for over 2,000+ companies around the world. By enabling tech recruiters and hiring managers to objectively evaluate talent at every stage of the recruiting process, HackerRank helps companies hire skilled developers and innovate faster” [8].

It should be noted that, indeed, as a result of some competitions, the author received letters with proposals for cooperation from various companies.

In addition to a significant number of different tasks and competitions, it is worth noting the excellent visualization of various aspects of the results [10]. In figures 2-5 show variants of such visualization.

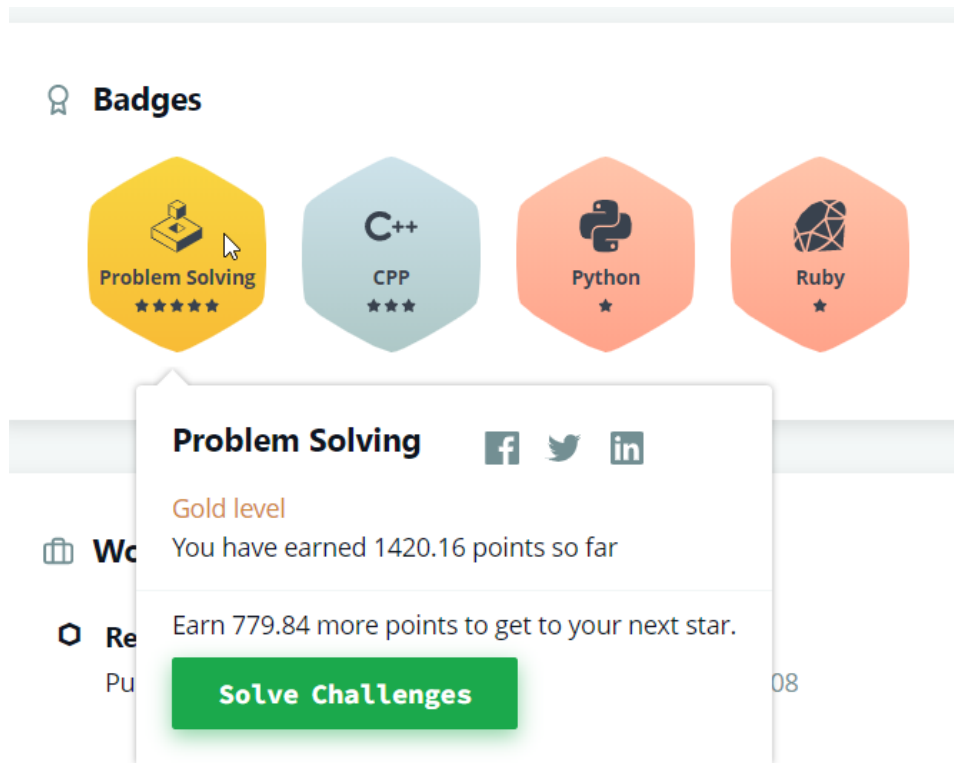


Figure 2. Example of Badges visualization on HackerRank [10].

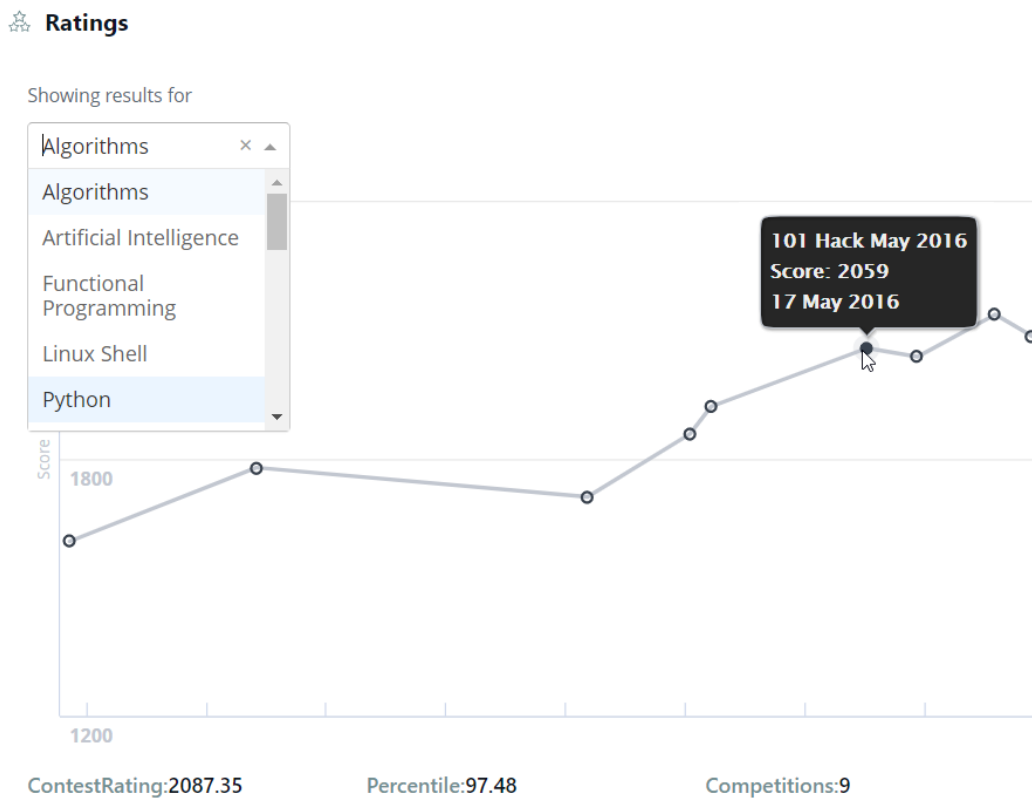


Figure 3. Example of Ratings visualization on HackerRank [10].



Figure 4. Example of Contest History visualization on HackerRank [10].

All Contests > Ad Infinitum 15 - Math Programming Contest

Leaderboard

Filter by

Rank	User	Score	Time	Country
61	06_Nirjhor	164.09	39:05:20	
62	davkh	163.60	42:32:00	
63	pcelayes	163.00	15:31:20	
64	ak24avo	163.00	28:25:00	
65	lurker	160.14	35:43:50	

Figure 5. Example of Leaderboard visualization on HackerRank [10].

Also, on the HackerRank platform, you can get a certificate confirming the acquired programming skills. As an example, in figure 6 presents a Problem Solving (Basic) Certificate. It covers basic topics of Data Structures (such as Arrays, Strings) and Algorithms (such as Sorting and Searching).



Figure 6. Example of Problem Solving (Basic) Certificate on HackerRank [9].

5.1. Examples of problems from hackerrank.com

Here are some examples of simple interesting tasks from hackerrank.com, which were also offered to students and received positive feedback from them.

5.1.1. Summing the N series [30]

The algorithm for solving this problem (the condition of which is shown in Figure 7), at first glance, does not require anything special: just read the number of tests T , for each i -th test read n , and then by formulas from the condition find S_n for each test, perform the operation $S_n \bmod(10^9+7)$ and display the result. However, in this case, we will not invest in limiting memory and time. Therefore, it is necessary to look for another, more optimal, approach. Indeed, if you look at the presented formulas, you can see that:

$$T_n = n^2 - (n - 1)^2 = n^2 - (n^2 - 2n + 1) = 2n - 1 = n + n - 1$$

Then, to find the sum of S_n you need to find two sums of arithmetic progressions from 1 to n , and then subtract from the result n :

$$S_n = T_1 + T_2 + \dots + T_n = \left(2 \sum_{i=1}^n i \right) - n = \left(2 \cdot \frac{1+n}{2} \cdot n \right) - n = n^2$$

Then, applying the property of the \bmod operation to the product, we obtain a concise solution to this problem (code in C++, figure 8).

5.1.2. Rectangular Game [29]

The algorithm for solving this problem (the condition as shown in figure 9), at first glance, also seems simple: you just need to model this game, perform all its operations, determine the maximum value in the matrix and find the number of such maximum values. However, in this case, we will not invest in limiting memory and time. And, therefore, it is necessary to look for another, more optimal, approach. Indeed, based on the rules of the game, the maximum value of the matrix will be in the lower-left cell. And the number of these values is the product $\min(a) \cdot \min(b)$. Thus, we get the desired result actually during the input of the initial data of the problem (code in C++, figure 10).

You are given a sequence whose n^{th} term is

$$T_n = n^2 - (n - 1)^2$$

You have to evaluate the series

$$S_n = T_1 + T_2 + T_3 + \dots + T_n$$

Find $S_n \bmod (10^9 + 7)$.

Input Format

The first line of input contains T , the number of test cases.

Each test case consists of one line containing a single integer n .

Constraints

- $1 \leq T \leq 10$
- $1 \leq n \leq 10^{16}$

Output Format

For each test case, print the required answer in a line.

Sample Input 0

```
2
2
1
```

Sample Output 0

```
4
1
```

Explanation 0

Case 1: We have $4 = 1 + 3$

Case 2: We have $1 = 1$

Figure 7. The problem “Summing the N series” on HackerRank [30].

```

1  #include <iostream>
2  using namespace std;
3  int main() {
4      long int i, T, n, d=1000000007;
5      cin>>T;
6      for(i=0; i<T; i++)
7          {
8              cin>>n;
9              cout<<( (n%d) * (n%d) ) %d<<endl;
10         }
11     }
```

Figure 8. The decision of the problem “Summing the N series”.

You are given an infinite 2-d grid with the bottom left cell referenced as (1,1). All the cells contain a value of zero initially. Let's play a game?

The game consists of **N** steps wherein each step you are given two integers **a** and **b**. The value of each of the cells in the co-ordinate (u, v) satisfying $1 \leq u \leq a$ and $1 \leq v \leq b$, is increased by 1. After **N** such steps, if **X** is the largest number amongst all the cells in the rectangular board, can you print the number of **X**'s in the board?

Input Format

The first line of input contains a single integer N. N lines follow. Each line contains two integers a and b separated by a single space.

Output Format

Output a single integer - the number of X's.

Constraints

- $1 \leq N \leq 100$
- $1 \leq a \leq 10^6$
- $1 \leq b \leq 10^6$

Sample Input

```
3
2 3
3 7
4 1
```

Sample Output

```
2
```

Explanation

Assume that the following board corresponds to cells (i, j) where $1 \leq i \leq 4$ and $1 \leq j \leq 7$.



So, the maximum number is 3 and there are exactly two cells which correspond to 3. Hence 2.

Figure 9. The problem “Rectangular Game” on HackerRank [29].

```
1 #include <iostream>
2 using namespace std;
3 int main() {
4     long N, minA, minB, a, b;
5     cin>>N>>a>>b;
6     minA=a; minB=b;
7     for(int i=1; i<N;i++)
8     {
9         cin>>a; cin>>b;
10        if(minA>a) minA=a;
11        if(minB>b) minB=b;
12    }
13    cout<<minA*minB<<endl;
14 }
```

Figure 10. The decision of the problem “Rectangular Game”.

6. Conclusion

In connection with the all-Ukrainian quarantine related to the spread of COVID-19 and the transfer of the educational process in HEI completely into a remote format, the authors organized an anonymous survey of students of the first (bachelor's) level of higher education (March 2020) specialty 122 “Computer Science”. According to the results of the survey, it was found that 73% of respondents had problems with distance learning and independent performance of practical tasks, of which 58% – full-time students. Thus, for students of full-time form of education, the abrupt transition to a complete

distance form of education is a certain “stress”, which is likely to negatively affect the final learning outcomes.

Various researches of scientists on the preparation of future IT-specialists and features of training of programming on the application of online-simulators are analyzed.

The authors of the article made a comparative description of different online platforms for teaching programming according to certain criteria, namely: the subjective experience of the authors in using these resources to teach students; requirements of the educational-professional program “Computer Science” (2018) for bachelors (in particular, knowledge of programming languages Java, JavaScript, PHP, C#, C++); the popularity of web resources on the Internet by the number of unique visitors and traffic statistics by Alexa rating (<https://www.alexa.com/>); free basic set of functions for training. Presented selection of interesting tasks from the online platform [hackerrank.com](https://www.hackerrank.com), which have already been used to teach students.

We also note that online programming simulators (or OCP) have significant potential in organizing an effective distance learning system in Ukrainian free educational institutions, where students master computer disciplines. The use of these simulators in the educational process as an additional tool for the formation of professional competencies provides more intensive involvement of students in the process of writing code and practical (situational) application of existing knowledge in a more informal and more convenient environment for higher education. Playful and interactive forms of learning contribute to the increase of cognitive activity, and hence – the quality of the educational process and distance learning in particular. Of course, in most cases, applicants for higher education are required to know a foreign language, including English. From the point of view of teaching, it is also inconvenient that the teacher does not have access to all student work in a single room, except for simulators such as CheckIO, Repl.it Classroom (paid), Exercism. We recommend using online programming simulators as an additional tool for teaching computer science, taking into account their functionality, as well as the level of preparation of students and the expected learning outcomes.

The examples of the use of studied online coding platforms that are mentioned in the research of individual disciplines of programming will be disclosed by the authors in subsequent publications.

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The effectiveness of GitHub cloud services for implementing a programming training project: students' point of view

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The effectiveness of GitHub cloud services for implementing a programming training project: students' point of view

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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

The World Economic Forum in 2019 revealed that it is important to pay attention to the ways and forms of organizing the educational process, among which are the study of information technology with an emphasis on teamwork. 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.

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 [13] become part of the cloud-oriented scientific and educational environment of the university if used on a regular basis [5]. 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.



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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 [15]. GitHub has been embraced by the software development community as an important social platform for managing software projects and to support collaborative development [4]. 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 [2].

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 [7]. Git and GitHub into data science workflows is considered best practice, and provides thoughtful advice on how to conceptualize the GitHub workflow [5]. 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 [9].

The most important skills employers seek in engineering are creativity, teamwork and critical thinking. The paper [12] 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 [10]. 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 [5]. 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 [14].

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. 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.

3. Methodology of research

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 among the 3rd year students of the Faculty of Information Technologies of the National University of Life and Environmental Sciences of Ukraine (NUBiP of Ukraine) during the second academic term of 2019.

3.2. Sample selection

There were 6 academic groups of students specializing in Computer Science and Software Engineering of the third year of studies at the Department of Information Technologies of NUBiP of Ukraine, but only two of them carried out educational projects in programming using the GitHub cloud service. Thus, only one group of 29 students was elected, which was a participant in the pedagogical study, based on a representative sample, as it was one group, which developed the skills to work with the GitHub cloud service. The participants in the study were confident that the results of their participation in the programming training projects using the cloud service, and their peer review by GitHub, would not affect their final results in the academic disciplines for the current term.

3.3. Instrument and procedures

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. 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.

3.4. 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

$S = \left(\sum x_{ij} - \frac{\sum \sum x_{ij}}{n} \right)^2$, 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 $s_{ij} = x_{max} - x_{ij}$.

4. Findings

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 [1]. 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 ([3], [8], [11]).

4.1 Educational projects with programming

In order to complete the programming projects, students were asked to combine ETC resources in different academic disciplines with the GitHub service. 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.

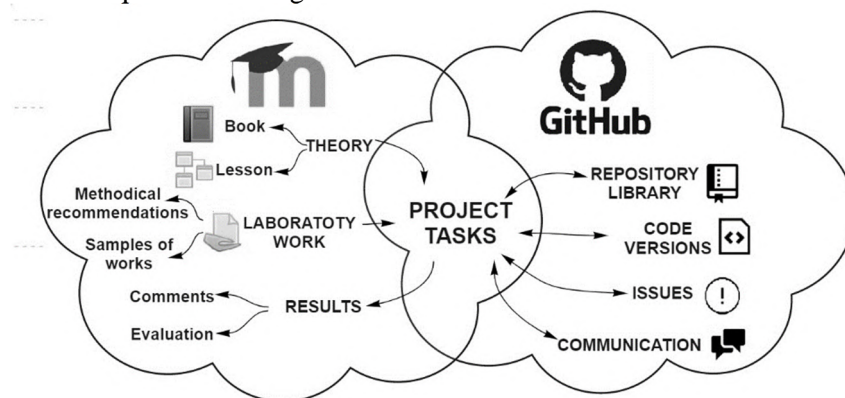


Figure 1. The scheme of combining Moodle resources with the GitHub cloud service.

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.

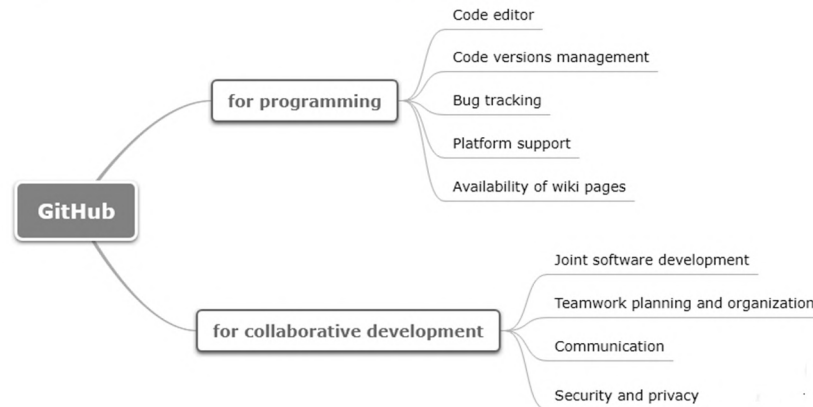


Figure 2. Classification of GitHub cloud service features.

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.

While studying “Object Oriented Programming” and “Database Organization” academic disciplines students were asked to complete a 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.

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 multi-user access.

4.2 Experimental results

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;
- 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.

Table 1. Evaluation of the results of determining the effectiveness of cloud service for GitHub team development.

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
Σ	1305	42688	1044	1			

The concordance coefficient $W = \frac{12 \cdot 42688}{29^2(9^3 - 9)} = 0.85$, 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.

5. 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. Further research may be related to the specificities of group projects using GitHub cloud service and their impact on the future professional and personal skills of future IT specialists.

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Formation of communication and teamwork skills of future IT-specialists using project technology

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Formation of communication and teamwork skills of future IT-specialists using project technology

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Abstract. The subject of the study is the formation of communication and teamwork skills of future IT-specialists, using project technology in teaching the administration of computer systems and networks. Content analysis of research has shown that communication and teamwork skills are the most requested and necessary soft skills for future IT professionals. It is offered to use project technology of training for their formation. This technology consists of the approaches and tools application used in real-world software development. To implement this technology, we propose to use mind maps for design. The organization of the working process on the project is implemented in Jira Software, Asana or Trello. Communication among project participants should be implemented with the help of several means: video chats (Zoom, Skype, Google Meet) and written communication in corporate messengers (Slack, Zulip). Experimental verification has shown the efficiency of the proposed design technology implementation.

1. Introduction

Information technologies are evolving rapidly. Computer networks, software, databases play an important role in many areas of modern life: public administration, banking, finance, education, transport, medicine, agriculture, entertainment, law etc. Varieties of computer technologies, their number and volume of implementation are constantly growing. As a result, hundreds of millions of hours of IT work are spent on software development, implementation and maintenance.

Software products are complex systems created by humans. Software by its nature has a number of essential properties (complexity, variability) that make the work of professionals more complicated. Modern software cannot be developed by one person, both small development teams (5-10 people) and large ones, consisting of several hundred developers, can take part in the development. The interaction of specialists in such teams, speed and quality of work are complex processes, which are caused not only by professional practical competencies, but also soft skills.

“Soft skills” are centrally important for human capital development and workforce success. A growing evidence base shows that these qualities rival academic or technical skills in their ability to predict employment and earnings, among other outcomes [17].

Many researchers note that employers are not satisfied with the level of soft skills development of employees. They note that potential employees have lack of or poorly developed competencies necessary for available vacancies. Similar requirements concern the work in the IT field, software development and administration of computer networks and databases [8], [9], [14].

Soft skills include a fairly wide range of competencies. However, today there is no defined list of competencies that should be formed in an IT-specialist. The study by Gerardo Matturro, Florencia Raschetti and Carina Fontán [11] determines that the most important soft skills for the future IT



specialist are communication skills, teamwork and analytical skills. Cheryl Aasheim, Jordan Shropshire, Lixin Li and Christopher Kadlec [1] determine that there is a demand at the labor market for IT professionals with such established soft skills as: ethics, professionalism, communication skills, and the ability to work in teams.

The Global Competency Model for Graduate Degree Programs in Information Systems [16] defines the concept of individual foundational competencies. Individual foundational competencies are those competencies necessary for all knowledge professionals in a variety of professions, such as communication, collaboration, and problem solving.

In the process of learning using project technology students gain experience in solving practical problems in future professional activities and learn to organize teamwork. The feature of students' project activities is forecasting its results, analysis and application of necessary informational sources, argumentation of their own judgments and decision-making in nonstandard situations, creating conditions to achieve the goal, presenting results to the audience, self-evaluation and project partners' evaluation [4], [5].

“According to the recent research, project work meets, to some degree, the expectations of its proponents in that the method improves – besides factual learning – the students' motivation, self-confidence, and critical thinking as well as their problem solving, decision making, investigative, collaborative skills. But there is evidence, too, that there exist barriers hindering the achievement of the objectives intended and striven for since neither students nor teachers always fulfill the necessary premises and qualifications completely.” [18].

The purpose of the article is to theoretically prove, develop and experimentally test the efficiency of the project technology implementation for the formation of communication and teamwork skills of future IT-specialists.

2. Methods

The following main methods were used in the research process: content analysis of scientific and methodological literature, generalization and systematization to clarify the state of the problem development; survey of applicants for higher education and initial statistical processing of the obtained results to determine the efficiency of project technology implementation for the formation of communication and teamwork skills of future IT-specialists while computer systems and networks administration training.

3. Material

The implementation of the project technology involves the development and presentation of the project on the problems of computer systems and networks administration by students. We propose to link the topics of projects with the problems of implementing a secure network infrastructure of the enterprise, deploying network software, creating cloud services for teamwork and conditions for the through use of corporate network resources in a remote access.

We propose to use cloud computing technologies as the main platform for students to implement network projects.

Cloud computing services are divided into:

- Cloud Software as a Service (SaaS). The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.
- Cloud Platform as a Service (PaaS). The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but

has control over the deployed applications and possibly application hosting environment configurations.

- Cloud Infrastructure as a Service (IaaS). The capability provided to the consumer is to provide processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls) [10].

Cloud Infrastructure as a Service (IaaS) is required for computer systems and network administration projects. For students we offer the following options for IaaS platforms: IBM Cloud, Microsoft Azure, Amazon EC2 and Google Cloud. If the school has a powerful server equipment using private clouds is possible.

During the research a cloud environment built with the application of open-source virtualization management platform Proxmox VE (<https://www.proxmox.com/>) was used as a platform for students to implement projects. A separate virtual network with a server and client hosts was created for each group of students using KVM hypervisor and LXC containers.

Each project has a corresponding content and structure. The process of project activity fully models the real production process of designing, set-up and implementing network software at the enterprises. The e-portfolio [2] with a set of tasks, developed design solutions, task schedules, etc. is created for each project.

We propose to implement project technology based on an approach founded on the constant teamwork of students applying communication tools used by software developers.

Here is an example of the task: 'Configure the corporate network of the enterprise, providing the required level of security, install and configure services: DNS-server (Bind9), DHCP-server (isc-dhcp-server), remote access server (OpenVPN, OpenSSH), database server (Mariadb), Nginx Web Proxy Server, Apache Web Server, Postfix Email Server and Web Interface, Git-repository Server (GitLab). Configure interaction among installed services.' All tasks have a similar structure and differ with software components.

The first stage includes the division of students into groups of 3-4 participants and roles distribution (project manager, developers and tester). Some roles can be combined. The teacher recommends a list of software for organizing communication in the project, maintaining project documentation, tasks and deadlines tracking and managing.

At the next stage, the groups are given the tasks for network software design, set-up and implementation. Participants discuss the project task in order to identify and structure the components of the project. During the meeting, the group should determine which network tools to use. The group has also to determine the server operating system, routing, security technologies, server solutions for project implementation.

At this stage, we propose to use MindMapping technology [15] to display a complex hierarchy of project tasks and proposed software solutions for each task. As software tools for building a mind map, students are recommended to use the following cloud platforms: GitMind (<https://gitmind.com/>), MindMeister (<https://www.mindmeister.com/>), MindMup (<https://www.mindmup.com/>), diagrams.net (<https://www.diagrams.net/>) and others [6].

The organization of the working process on the project involves tasks' distribution and contractors' appointments as well as determining the timing of project parts fulfillment. Timing, monitoring, testing and project parts control, teamwork management are proposed to be implemented using cloud services Jira Software (<https://www.atlassian.com/>), Asana (<https://asana.com/>), Trello (<https://trello.com/>) and others.

Using teamwork software allows you to create user stories and issues, plan sprints, and distribute tasks among software teams. Prioritize and discuss your team's work in full context with complete visibility.

The student performing the role of the project manager assigns the task in the selected cloud service to each participant and monitors the status of the development process (input tasks, in the process, on the test, ready, etc.).

A high level of communication among project participants is one of the most important factors in the successful project implementation and completion. The purpose of the teacher is to encourage project participants to interact using various means of communication: live discussions at the beginning and at all stages of the project, applying video chats (Zoom, Skype, Google Meet, etc.), written communication using corporate messengers (Slack, Zulip and etc.). The teacher should act as a moderator of student communication, and can also act as a customer of the system being developed.

Project development ends with the presentation of the project by the team of developers. They must demonstrate the design solutions that have been implemented during the work. For this purpose, the presentation demonstrating the work of the developed project is created. Each participant should demonstrate their contribution to the development and describe the difficulties encountered in the process. That is, to share their experience of teamwork and communication in the process of project implementation.

Each project includes the creation of a portfolio that should illustrate all stages of students' group work: mind map, examples of tasks in Trello or Asana and the final project presentation.

4. Results

A pedagogical experiment was conducted to evaluate the efficiency of the project technology implementation for the formation of communication and teamwork skills of future IT-specialists while training of computer systems and networks administration.

The following tasks of the experimental research were defined:

- To determine the parameters of evaluating the efficiency of the formation of communication and teamwork skills of future IT-specialists.
- To evaluate the efficiency of traditional methods of forming communication and teamwork skills of future IT-specialists while teaching the administration of computer systems and networks.
- To evaluate the effectiveness of the developed approaches to the formation of communication and teamwork skills of future IT-specialists while teaching the administration of computer systems and networks.
- To carry out a comparative analysis of the obtained experimental results with the purpose of identifying the efficiency of the study.

During the pedagogical experiment a formative experiment was conducted.

The organization of the educational process in the control group was carried out according to the traditional system of education. This system consists of the application of similar tasks same as in the experimental group, but each student performed the task by himself and the design technology was not used.

The training in the experimental group was carried out using project technology in the training of computer systems and networks. It has been proposed and discussed above.

Upon completion of the molding experiment, a comparative experiment was performed. It provided the analysis of the obtained experimental results; mathematical and statistical processing of experimental results; generalization and analytical presentation of the obtained results and conclusions.

The experimental study was carried out in a real time learning process in order to ensure the reliability of the experimental data. The conditions of the study in the control and experimental groups were the same. Berdyansk State Pedagogical University was chosen as the experimental base. The experiment involved students studying the specialty 015 Vocational Education (Computer Technology) and the sample size was 46 people.

To achieve the validity of the obtained experimental results, all the main influencing factors (student contingent, level of training, conditions of organization and conducting of experimental pedagogical

research) in the control and experimental groups were the same, except using the developed design technology for training in the experimental group.

In order to achieve reliability, possibility and validity of the results, the groups were chosen with a random selection (randomization) of study groups, as well as with the mandatory input and output control in the control and experimental groups.

The experiment plan provided the application of the same tasks in the control and experimental groups.

The level of communication skills formation was studied using a standardized method for determining the level of communication proposed by V. F. Riakhovskii [7]. The following scale was used for this technique: very low sociability (25-32), low sociability (17-24), medium sociability (9-16) and high sociability (0-8).

The level of teamwork skills formation was studied using the standardized research methodology “Acceptance of Others Scale” proposed by William F. Fey [13]. The following scale was used for this technique: low level (18-30), medium level with a trend to the low (31-40), medium level with a trend to the high (45-59) and high level (60-90).

A specialized program was used for automation the students’ survey [13]. The programming language R [12] was used for data analysis and diagrams construction.

We will carry out statistical processing of the received data. The analysis of the results provided the division of the results of the sample diagnosis into frequency intervals in accordance with the values provided in the standardized methods.

Input control showed almost the same level of communication skills and teamwork skills for the control and experimental groups, as shown in tables 1 and 2.

Table 1. Comparative analysis of the communication skills formation level in the control and experimental groups (input control).

Level of formation	Control group, number of students (%)	Experimental group, number of students (%)
Very Low (25-32)	40.91	41.67
Low (17-24)	36.36	37.50
Average (9-16)	13.64	12.50
High (0-8)	9.09	8.33

Table 2. Comparative analysis of the teamwork skills formation level in the control and experimental groups (input control).

Level of formation	Control group, number of students (%)	Experimental group, number of students (%)
Low (18-30)	27.27	29.17
Average level with a trend to the low (31-40)	54.55	54.17
Average level with a trend to the high (45-59)	13.64	8.33
High level (60-90)	4.55	8.33

In accordance with the experimental plan, the homogeneity of the experimental and control groups was checked. To analyze the homogeneity of the experimental data, the hypotheses about the equality of the average values were tested by Student’s t-test.

The results of the statistical analysis have shown the equality of the average values of communication and teamwork skills for the control and experimental groups (tables 3, 4). The critical value of Student’s t-test for our sample equals to 2.015 at a significance level of 0.05.

Table 3. Checking the equality of the average values of the communication skills formation level (input control).

Groups	Number of students	Average	Variance
Control	22	22.32	57.75
Experimental	24	20.045	58.99

The calculated value of the Student's t-test equals to 0.073. The critical value of Student's t-test is greater than the experimental one, so, the hypothesis of the average values equality of the communication skills formation level in the control and experimental groups has been confirmed at the level of significance of 0.05.

Table 4. Checking the equality of the average values of the communication skills formation level (input control).

Groups	Number of students	Average	Variance
Control	22	36.32	135.66
Experimental	24	37.38	87.134

The calculated value of the Student's t-test equals to 1.472. The critical value of Student's t-test is greater than the experimental one, so, the hypothesis of the average values equality of the teamwork skills formation level in the control and experimental groups has been confirmed at the significance level of 0.05.

The obtained results of the input control of the forming experiment have confirmed the representativeness and homogeneity of the samples, which allows us to proceed to the comparative stage of the experimental research.

After using the design technology to form communication and teamwork skills, the initial diagnostics was performed for the control and experimental groups. Generalized data on the level of students' communication skills formation after the study are given in table 5, and teamwork skills in table 4 accordingly.

Table 5. Comparative analysis of the communication skills formation level in the control and experimental groups (initial control).

Level of formation	Control group, number of students (%)	Experimental group, number of students (%)
Very low (25-32)	36.36	29.17
Low (17-24)	36.36	37.50
Average (9-16)	18.18	20.83
High (0-8)	9.09	12.50

The corresponding diagram is shown in figure 1.

The level of communication skills formation in the experimental group compared to the control (table 6) increased by 14.39%. The corresponding diagram is shown in figure 2.

The level of teamwork skills formation in the experimental group compared to the control increased by 20.45%.

Statistical analysis of the results of the initial control was performed using Student's t-test to check the hypothesis of average values equality (tables 7, 8). The critical value of Student's t-test for our sample for the results of the initial control equals to 2.015 at a significance level of 0.05.

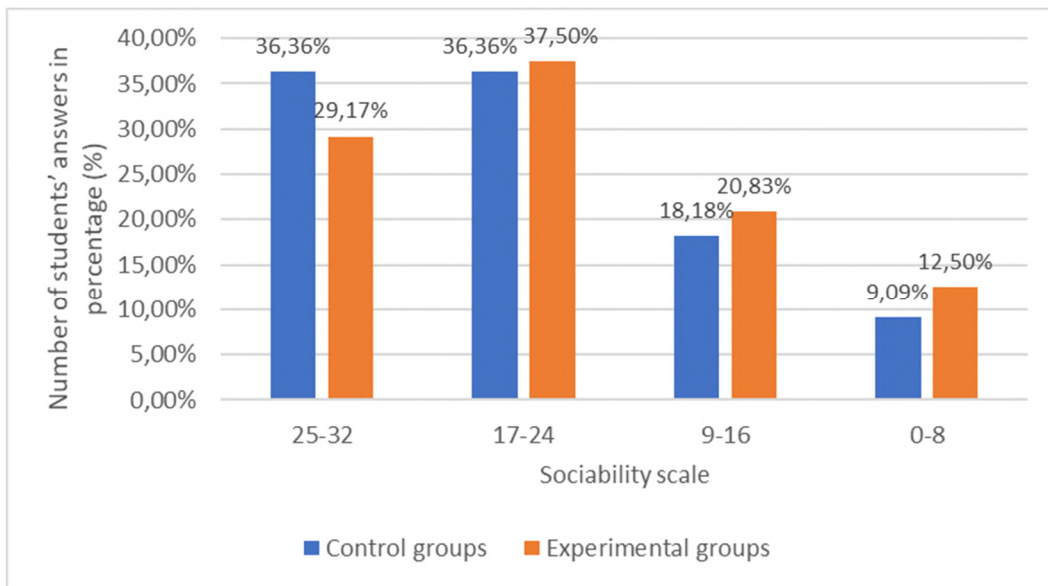


Figure 1. Diagram of the communication skills formation level in the control and experimental groups at the end of the experiment.

Table 6. Comparative analysis of the teamwork skills formation level in the control and experimental groups (initial control).

Level of formation	Control group, number of students (%)	Experimental group, number of students (%)
Low level (18-30)	22.73	20.83
Average level with a trend to the low (31-40)	50.00	41.67
Average level with a trend to the high (45-59)	18.18	20.83
high level (60-90)	9.09	16.67

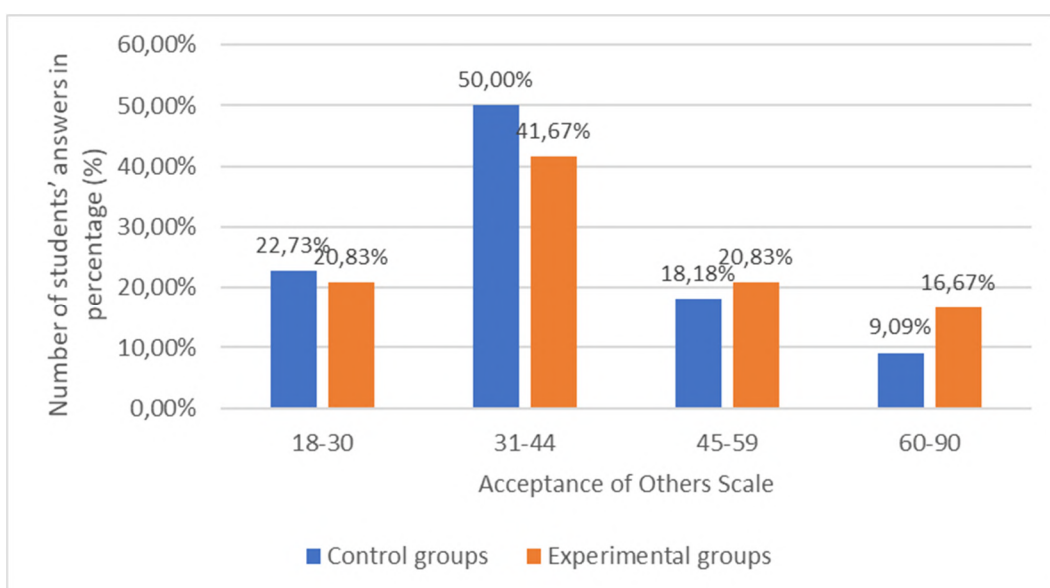


Figure 2. Diagram of the teamwork skills formation level in the control and experimental groups at the end of the experiment.

Table 7. Checking the average values equality of the communication skills formation level (initial control).

Groups	Number of students	Average	Variance
Control	22	20.36	38.528
Experimental	24	17.32	77.656

The calculated value of the Student's t-test equals to 2.158. The critical value of Student's t-test is less than the experimental one, so, the average values of the level of communication skills in the control and experimental groups differ in a significant way (significance level 0.05).

Table 8. Checking the average values equality of the teamwork skills formation level (initial control).

Groups	Number of students	Average	Variance
Control	22	40.09	118.658
Experimental	24	40.41	317.681

The calculated value of Student's t-test equals to 2.796. The critical value of Student's t-test is greater than the experimental one, so, the average values of the level of communication skills in the control and experimental groups differ in a significant way (significance level 0.05).

Thus, the conducted experimental research confirmed the efficiency of using design technology for the formation of communication and teamwork skills of future IT-specialists while the training of computer systems and networks administration.

5. Conclusions

During the research the efficiency of the project technology implementation for the formation of communication and teamwork skills of future IT-specialists in the training of computer systems and networks administration has been theoretically substantiated, developed and experimentally tested.

During the study it was defined that communication and teamwork skills are one of the main soft skills for future IT professionals. Their formation is a necessary and important stage of the professional training.

The proposed approach to using project technology for the formation of communication and teamwork skills of future IT-specialists is based on the application of professionally-oriented tasks with the help of technologies and tools of group work in software development used in real production.

In further research we plan to explore the possibility of project technology application to form a number of other soft skills.

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Project-based learning in a computer modelling course

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Abstract. The paper reports authors' experience of implementing educational projects in a computer modelling course offered to the students majoring in "Secondary Education (Computer Science)" at Ternopil Volodymyr Hnatiuk National Pedagogical University. We analyze approaches to teaching mathematical and computer modelling such as: integration of modelling tasks, naturalistic case study, using of role-playing games, possibilities of STEM-education, motivation and positive attitude to modelling training, etc. Then we illustrate the implementation of the project to study the population dynamics of the grape snail *Helix pomatia*. The implementation of the project splits into several stages: formulation of the problem, presentation of project tasks, brainstorming, development, testing, presentation of results. The study was conducted at Ternopil Volodymyr Hnatiuk National Pedagogical University within the Norwegian-Ukrainian Project "Development of students' mathematical competencies through Digital Mathematical Modelling" (DeDiMaMo) in partnership with the University of Agder (Norway) and Borys Grinchenko Kyiv University.

1. Problem statement

Nowadays computer technology plays an important role in all areas of professional activities and contributes to the economic development. Most modern professions require the knowledge of computer technology and its use in applications. The study of ICT technologies at universities and colleges has a significant impact on the improvement of the quality of higher education. Currently, project-based learning is activities is one of the most effective methods of developing ICT competencies. The implementation of the project work in teaching requires thorough preparation and training of the teacher. S/he needs to develop a detailed plan for studying the topic, design presentations, develop exercises and tasks, define evaluation criteria, etc.

Contemporary problems of the development of mathematics and IT education were investigated in the recent work of Ukrainian researchers Kramarenko [16], Lovianova [51], Ponomareva [31], Rashevskaya [33], Shokaliuk [32], Soloviev [42], Vlasenko [50], Zhaldak [53] and others. Approaches to the use of software for demonstrations of physical phenomena were suggested by Kravtsov [15], Kuznietsov [18], Merzlykin [14], Moiseienko [9], Velychko [49], Yechkalo [11] and others. The development and implementation of virtual laboratories for process modelling has been the subject of research of Modlo [27], Nechypurenko [26], Semerikov [25], to mention a few. Today, the competency approach is basic in higher education in many countries (e.g., [12], [13], [19], [22], [23], [39], [47]). Its



practical implementation actualizes the task of creating for each course a methodological system which should correspond to the model of professional competence.

Many theoretical and practical problems of training IT specialists have been addressed in the research of Semerikov and his colleagues. In particular, they designed the system of general professional competencies which constitute sustainable professional competence of software engineering specialist [37]. Another important component of the methodological system is modern ICT tools. Modlo [21] analyzed mobile Internet devices as a learning tool for Bachelor's of Electromechanics modeling of technical objects. Yashchuk [52] developed model for the professional competence formation of Master's students in Technology education identifying pedagogical (design, interactive, positional, contextual, training) and information (computer multimedia, Web) technologies.

The **purpose of this paper** is to present the authors' experience in using project-based learning methodology. It was used to teach computer modeling to students majoring in "Secondary Education (Computer Science)". The paper contains list of software offered for learning according to the authors' methodology.

2. Theoretical foundations of the research

The literature analysis shows that mathematics and computer modeling courses are important components in the training of a modern IT specialist. The culture of "teacher-student" relations in the educational systems of the European Union is based on the ideas of democracy and cooperation in the teacher-student interaction centered around student learning [54]. In the study "Mathematical modelling in Germany and France", the authors emphasized the significance of the integration of modeling tasks into particular examples from everyday life [8].

Eckhardt et al. [5] examined the effect of support for scientific discovery learning using computer simulations demonstrating that particular instructional interventions for data interpretation and self-regulation can effectively support learning with scientific computer simulations. Srisawasdi and Kroothkeaw [44] explored the learning process with the support of computer simulation and demonstrated its benefits for the development of students' learning of physics.

Buteau et al. [4] present a naturalistic case study of an undergraduate student enrolled in a sequence of three programming, project-based mathematics courses at the Brock University where students learn to design, program, and use interactive environments for the investigation of a mathematics concept, theorem, conjecture, or a real-world situation.

In his article "Quality Teaching of Mathematical Modelling: What Do We Know, What Can We Do?", Werner Blum points out the following important aspects of the teaching methodology for modelling [3]:

- effective and learner-oriented classroom management;
- cognitive and meta-cognitive activation of the learners;
- variety of suitable examples, individual solutions of modeling tasks;
- long-term learning process for development of the competencies;
- parallel development of competencies and appropriate beliefs and attitudes;
- systematic demonstration that digital technologies can be used as powerful tools for modeling activities.

One of the main factors affecting the efficiency of education in a modern university is the introduction of simulation and role-playing games, various types of models of processes or situations ([45], [46]). We believe that the use of tools for the development of students' project and research activities are important in the methodology of teaching computer modeling. In this context, it is appropriate to use methods and technologies such as project, modular, rating and problem learning; suggestive, cooperative and case technologies ([6], [10], [29], [40]).

In recent years, problem-based and project-based learning technologies have gained popularity in higher education institutions. The implementation of projects using ICT expands the content of learning through the comprehensive mastery of the theory, followed by its further implementation in professional activities [10]. Project work and group learning promote the development of important skills of

participants in the educational process teaching them to interact, cooperate and be creative in joint learning activities. At the present stage of education development, STEM-education is a progressive concept which rapidly evolves contributing to the integration of different disciplines in study curricula ([1], [17], [28], [38], [41], [48]). It is in great demand in today's educational world and it often requires creation of a blended learning environment within which students can better understand how to apply scientific methods [2]. Thanks to this combination with blended learning, STEM education becomes more effective through the setting of challenging tasks challenge, high motivation which motivate students and encourage collaboration towards common educational goals [24].

Rogovchenko et al. [34] pointed out the importance of enjoyment component in the process of mathematical modelling. They argue that motivation and positive attitude are especially important for teaching and learning of mathematical modeling where students solve open ended, real-world problems and may experience the whole spectrum of emotions – from curiosity and puzzlement to frustration and despair to pleasure and satisfaction.

The use of the project-based learning method for computer modelling of neural networks has been studied in the paper by Semerikov et al [36]. The authors' methodology in an elective course includes the presentation of individual educational and research projects on the artificial neural networks architecture. The topics for the projects include modelling of continuous, discrete-continuous and discrete neural networks, time series forecasting, pattern recognition, functions approximation, dependency identification, medical diagnostics, decision-making under conditions of incomplete data, data compression, etc. [20].

3. Methodology of using projects for teaching computer modelling

Project-based learning allows students to gain valuable modelling experience, develop research competencies and information processing expertise and improve communication skills related to the modelling of the population size. The feasibility of using the proposed method is justified by the following factors ([7], [43]):

- conducting comparative analysis of mathematical methods by students;
- making decisions on the advantages and limitations of the use of a particular method;
- implementation of joint activities for modelling and development of software applications;
- mutual testing, debugging of developed software products;
- analysis and reporting of results.

During the project work on computer modelling, it is advisable to use the following forms of educational and cognitive activity: a) work in pairs or small groups; b) group work; c) individual work. We have chosen a laboratory workshop as the form of organization of students learning activities. Students may fail to consider many important factors that affect the likelihood of a model. As a result, the model may not meet all the requirements of scientific research. However, the main goals can be achieved through the well-thought and clear distribution of the tasks among students in the project.

The choice of population dynamics for modelling meets the basic requirements for the project-based learning method:

- The presence of a significant problem. In terms of research, the project requires mastering mathematical methods and modern programming tools.
- The tasks of the project are not static, i.e. they can change at the initiative of students.
- Practical, theoretical, and cognitive significance of the expected results of the activity for the environmentalists and ecologists.
- The use of a group work organization with the possibilities for using individual work within the group.
- Defining basic knowledge required for the work on the project.
- Structuring the content of the project.
- Realism of the project, its connection with educational resources.

The students work on the projects in small groups. To achieve the optimal division of the class into small groups, a preliminary survey of students can be conducted to determine individual psychological characteristics and collect information on individual study and work preferences. Each group is responsible for the development of one of the project components:

- Research of the subject area, specification of tasks.
- The choice of modelling approach and its formalization.
- Exploration of the existing software solutions.
- Defining the requirements for the application and its modules.
- Choice of programming tools.
- Direct development.
- Testing applications.
- Analysis of the obtained results, verification of their trustworthiness.
- Presentation of the obtained results.

The prerequisites for the successful work on the projects are the disciplines in computer science where the following components of professional competence must be formed:

- ability to carry out information retrieval activities;
- skills of formalization and design of algorithms;
- knowledge of several programming languages;
- skills of using digital technologies in solving practical problems;
- development of mathematical apparatus and understanding of fundamental mathematical concepts.

The latter competence can be successfully formed in pedagogical universities by combining the subject specialization Secondary Education (Computer Science) with the subject specialization Secondary Education (Mathematics) within one professional educational program (the names of subject specializations correspond to those currently used by the Ukrainian education authorities).

For the teaching of computer modelling, the following software products and digital technologies are used:

- Programming environments which help teachers and students to design and develop various software products. It should be noted that the use of programming language for achieving these goals requires special knowledge, skills and significant labour costs. Using in their education the languages Python, C#, Java, HTML, PHP master's students majoring in "Secondary Education (Computer Science)" have the opportunity to develop methodological materials for further use at the workplace. Examples of such interactive teaching materials are student-developed projects, project materials, textbooks and monographs containing the materials for a deeper study of selected topics of the school curriculum in computer science, and so on.
- Ready-made software solutions (encyclopaedias, educational programs, specialized mathematical packages Mathcad, MATLAB, Mathematica, Microsoft Office software package, etc.), access to the Internet and reference materials, video tutorials, educational films.
- Cloud services (in particular, Google Suite and Microsoft Office 365 services) for the organization of the students' individual and group work, relevant Web-sites with the materials for the use in the educational process.

We decided to focus our research on the application of project methodology for the development of professional competences of future specialists. One of the characteristics of students' competence is the ability to synthesize the knowledge and use the skills acquired in the disciplines "Programming", "Computer Graphics", "Applied Software", "Graph Theory". The most efficient training of future specialists in computer science is achieved through the interdisciplinary integration implemented with the support of information and communication technologies.

4. Practical aspects of the project implementation

The project-based learning in computer (mathematics) modelling classes can be successful when it

fits students' general and specific intellectual skills. This can be done at different levels: individual work, discussions and work in small groups, presentation of individual and small group results to the whole class. Students mostly complete the project independently (both individual and group work are used), but the teacher monitors the work, advises, monitors, adjusts and evaluates. All projects are stored in the database of student works at the department. The implementation of the project splits into several stages.

Stage 1: formulation of the problem. The project work starts with the formulation of the task of the project aimed at the development of the computer model to study the dynamics of the population. In the process of formulation, the teacher suggests possible ways to approach the task.

- conceptual – models of population dynamics (Malthusian model, Verhulst model, Ricker model, Leslie model) including theoretical substantiation of the advantages of the Leslie model;
- organizational – creation of working groups (teams) for the implementation of the parts of the project and setting of specific tasks for each group;
- technological – selection of the necessary specialized software and digital technologies for each group.

The teacher informs students about the knowledge and skills they should acquire in the process of project implementation.

Stage 2: presentation of project tasks. The purpose of this stage is to introduce the object of the study to students. It is important to draw students' attention to the need for joined collective efforts to achieve the desired results. Preliminary preparation of project participants is also required; students have to review relevant research literature and available software solutions. The easiest way to get useful tips and guidance is to talk to teachers who have previously worked with the project participants.

Stage 3: brainstorming. Students put forward general ideas regarding the project implementation, discuss the possibility and necessity of using certain tools and technology, suggest approaches to tackle the task. All student proposals must be thoroughly explained and carefully substantiated; the ideas that are approved should be mapped onto the project's timeline to achieve their feasibility. As a result, several ideas that can potentially lead to the solution to the problem are selected. Due attention should be paid to the design and graphical presentation of the results in the project. To this end, it is preferable to form a dedicated group of students dealing with this task. Interim and final results are recorded, organized and substantiated.

Stage 4: development. In order to structure the educational process in the project-based learning, the workshop can be organized in the form of laboratory work with the tasks as parts of the project. The teacher offers two components of the project organization: invariant and variable.

Stage 5: testing. Based on the requirements of the practical usefulness of the project results, its implementation requires not only the functionality of the software components, but also the verification of the results. To this end, the results of the population forecast are compared with real data. If needed, the model should be adjusted and tested again.

Stage 6: presentation of results. In our opinion, it should be organized in the format of a seminar or mini-conference. For example, during the work on the project "Application of the Leslie model to the study of dynamic systems" students used the service <http://www.easel.ly> to prepare infographics that can be used for a variety of purposes: drawing attention to the problem; a quick overview of the topic; explanation of a complex process; presentation of research results; report generation; comparison of results. This and similar services facilitate the presentation of project results, ideas and related concepts.

The students' programming knowledge and skills are formed in a sequence of course distributed through the study program. First year students study programming in Python and application packages Mathcad, MATLAB, from the second year they start working with computer graphics in 3DS Max and Web-programming. All computer simulation projects must be accompanied by relevant graphs or charts. Therefore, the Mathcad system and the Python programming environment remain popular. In the Mathcad system, calculations were performed using the knowledge of linear algebra; the results of these calculations are further used in the developed software applications. In our case, students found the

eigenvalues and eigenvectors of the matrices of the orders three to seven, seventh and eighth powers of matrices.

To illustrate the methodology used in the project-based course, we discuss as an example one of the projects where students worked within the laboratory workshop.

Assignment. Suggest a realistic Leslie model for the population of the grape snail *Helix pomatia* (*Helicidae, Gastropoda, Mollusca*) in the vicinity of the village Velyki Chornokintsi in Chortkiv district located on the Ternopil plateau and investigate the dynamics of this population based on the following demographic table.

Table 1. Demographic table for the population of the grape snail *Helix pomatia*.

Age group	2017	2018	2019
1	181	157	144
2	118	104	97
3	104	89	86
4	95	82	80
5	79	68	66
6	68	53	55
7	53	47	40
Total	698	600	568

The population is divided into 7 age groups. At each fixed point in time, it can be characterized by a column vector

$$X(t) = (x_1(t); x_2(t); \dots ; x_7(t))^T,$$

where $x_i(t)$ – the number of i -th age group at the time t .

To build the Leslie model, one uses the data from the table to calculate the survival rates based on the formula:

$$x_{i+1}(t + 1) = S_i \cdot x_i(t), \quad S_i = \frac{x_{i+1}(t+1)}{x_i(t)},$$

where t is the year 2017 or 2018.

As a result, one obtains $S_1 (2017-2018) = \frac{104}{181} = 0.57$; $S_2 (2017-2018) = \frac{89}{118} = 0.75$;
 $S_3 (2017-2018) = \frac{82}{104} = 0.79$; $S_4 (2017-2018) = \frac{68}{95} = 0.72$ etc.;

$S_1 (2018-2019) = \frac{97}{157} = 0.62$; $S_2 (2018-2019) = \frac{86}{104} = 0.83$; $S_3 (2018-2019) = \frac{80}{89} = 0.9$;
 $S_4 (2018-2019) = \frac{66}{82} = 0.8$ etc.

Table 2. Survival rates.

Survival rates	2017-2018	2018-2019	Average value
S_1	0.57	0.62	0.6
S_2	0.75	0.83	0.8
S_3	0.79	0.9	0.85
S_4	0.72	0.8	0.76
S_5	0.67	0.81	0.74
S_6	0.69	0.75	0.72

The fertility rate for the first age group is assumed to be 0, for all other classes – the fertility rates are equal and are calculated with the help of the formula

$$x_1(t + 1) = \sum_{i=1}^n b_i x_i(t); \quad b_i = \frac{x_1(t+1)}{\sum_{i=1}^n x_i(t) - x_1(t)}.$$

Consequently, the fertility rates for two years are given by

$$b(2018) = \frac{157}{698-181} = 0.3; \quad b(2019) = \frac{144}{600-157} = 0.33$$

and the average value of the fertility rate equals $\frac{(0.3+0.33)}{2} \approx 0.32$.

The Leslie matrix for a homogeneous model has the form

$$L = \begin{pmatrix} 0 & 0.32 & 0.32 & 0.32 & 0.32 & 0.32 & 0.32 \\ 0.6 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.8 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.85 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.76 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.74 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.72 & 0 \end{pmatrix}$$

The first row in this matrix contains fertility rates for all age groups, the numbers below the main diagonal represent survival rates for the respective age groups, all other entries in the matrix are zeros. The structure of the matrix is determined from the assumptions that during a period of time, individuals from the j -th age group move to the next, $(j+1)$ -th age group. During this period, some individuals die and the offspring are born for individuals in the i -th group.

The age structure of the population for a homogeneous model of Leslie is given by the formulas

$$X(t_1) = L \cdot X(t_0); \quad X(t_2) = L \cdot X(t_1) = L^2 \cdot X(t_0); \quad \dots \quad X(t_i) = L \cdot X(t_{i-1}) = L^i \cdot X(t_0)$$

For the initial distribution, data from table 1 are used: $X(t_0) = (181; 118; 104; 95; 79; 68; 53)^T$.

$$X(t_1) = L \cdot X(t_0) = \begin{pmatrix} 0 & 0.32 & 0.32 & 0.32 & 0.32 & 0.32 & 0.32 \\ 0.6 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.8 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.85 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.76 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.74 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.72 & 0 \end{pmatrix} * \begin{pmatrix} 181 \\ 118 \\ 104 \\ 95 \\ 79 \\ 68 \\ 53 \end{pmatrix} = \begin{pmatrix} 165 \\ 109 \\ 94 \\ 88 \\ 73 \\ 58 \\ 49 \end{pmatrix};$$

$$X(t_2) = L^2 \cdot X(t_0) = \begin{pmatrix} 150 \\ 98 \\ 87 \\ 80 \\ 68 \\ 53 \\ 42 \end{pmatrix}; \quad X(t_3) = L^3 \cdot X(t_0) = \begin{pmatrix} 137 \\ 91 \\ 80 \\ 74 \\ 61 \\ 49 \\ 38 \end{pmatrix};$$

$$X(t_4) = L^4 \cdot X(t_0) = \begin{pmatrix} 125 \\ 82 \\ 72 \\ 67 \\ 56 \\ 45 \\ 36 \end{pmatrix}; \quad X(t_5) = L^5 \cdot X(t_0) = \begin{pmatrix} 115 \\ 76 \\ 64 \\ 62 \\ 52 \\ 42 \\ 33 \end{pmatrix}; \text{ etc.}$$

At the ninth iterate, stabilization will take place for a homogeneous model, after which one can use the formula

$$X(t) = \lambda^t \cdot X(t_0),$$

where λ is the eigenvalue of the Leslie matrix for predicting the population dynamics.

The characteristic equation for the Leslie matrix assumes the form

$$\begin{vmatrix} 0 - \lambda & \frac{8}{25} & \frac{8}{25} & \frac{8}{25} & \frac{8}{25} & \frac{8}{25} & \frac{8}{25} \\ \frac{3}{5} & 0 - \lambda & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{4}{5} & 0 - \lambda & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{17}{20} & 0 - \lambda & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{19}{25} & 0 - \lambda & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{37}{50} & 0 - \lambda & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{18}{25} & 0 - \lambda \end{vmatrix} =$$

$$= -\lambda^7 + \frac{24}{125} \cdot \lambda^5 + \frac{96}{625} \cdot \lambda^4 + \frac{408}{3125} \cdot \lambda^3 + \frac{7752}{78125} \cdot \lambda^2 + \frac{143412}{1953125} \cdot \lambda + \frac{2581416}{48828125} =$$

$$= \frac{-1}{44828125} \cdot (48828125 \cdot \lambda^7 - 9375000 \cdot \lambda^5 - 7500000 \cdot \lambda^4 -$$

$$-6375000 \cdot \lambda^3 - 4845000 \cdot \lambda^2 - 3585300 \cdot \lambda - 2581416) = 0.$$

According to the Perron-Frobenius theorem [30], the Leslie matrix has a single positive eigenvalue λ such that for any other eigenvalue r of the same matrix the condition $|r| \leq \lambda$ holds. This eigenvalue is called dominant (major) and characterizes the rate of population reproduction.

If all elements of the matrix are constants, depending on the dominant value λ , one of the three scenarios of population dynamics is possible. If $\lambda < 1$, then the population size will decay to zero, if $\lambda > 1$, it will increase indefinitely. If $\lambda = 1$, starting from some point in time, the population size will approach the constant value and the ratio between different age groups will stabilize. In reality, birth and death rates can depend on the total population, the ratio of its components, as well as changes in habitat conditions.

In our case, the dominant eigenvalue $\lambda = 0.914$. This means that the population size will decline over time.

As can be seen from figure 1, according to the Leslie model, the population of snails in the coming years will decline and in 2020 will be 450 and in 2021 – about 400.

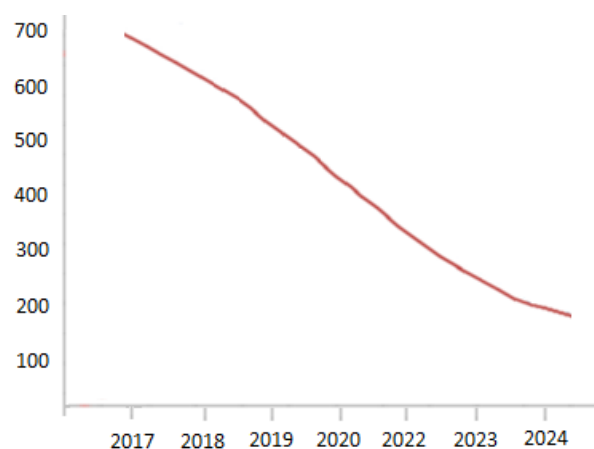


Figure 1. Forecasted population size data.

5. Conclusions

Project-based learning is widely used in higher education. The use of information and communication technologies is an integral part of the modern educational process. In combination with the use of modern technology, it contributes to the formation of professional-oriented experience. The use of correct methodology for applications of digital technologies in the classroom and students' individual work is nowadays an important competence for teachers, lecturers and computer science specialists. In this paper, we report the use of information and communication technologies in the education of students majoring in Secondary Education with the specialization in Computer Science. The methodological features of the organization of information and communication support of the educational process are illustrated on the example of the project on computer modelling of the population dynamics.

Project work best fits into the competency approach, which includes the development of the ability to work with and critically assess different sources of information, ability to work efficiently in a group and individually. Therefore, the project-based learning allows to personalize the educational process providing students with the opportunities of independent planning, organization and control of their educational activities. The application of project methodology in the classroom stimulates and maintains a long-lasting interest in computer modelling, deepens and systematizes students' knowledge of various subjects and contributes to the formation of a holistic perception and integrated approach to the scientific analysis of phenomena and processes in the world.

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Petri Nets Android application as a mobile aid for students' mastering modelling

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Abstract. Building models of various processes and their further investigation has been always in focus of different specialists' training. There are some quite well known mechanisms and tools of modelling. However, Petri nets theory has found its wide application to the real-life parallel processes modelling. Petri nets give powerful facilities for dynamic models building and enable comprehensive learning of the process peculiarities. Hence, it is important to have relevant tools which allow to apply Petri nets potential to educational practice on purpose of earning by students skills of models building and investigation. The aim of the paper is to depict the functionality of the authors' mobile Android application "Petri Nets Tool-Kit", and to specify facilities and examples of its using for mastering modelling by students. Developed and represented in the paper mobile application provides students with the set of tools which enables to create, edit, save their own Petri nets as well as to change their parameters, visualize changing and play various scenarios of the modelled process. The "Petri Nets Tool-Kit" also contains relevant theoretical materials and the set of ready-made Petri nets examples, which makes the application attractive for mobile learning both in classroom activity and in students' independent work in the context of their vocational training in terms of different specialties. The proper stages of learning activity for step-by-step mastering by students the basics of modelling and simulation are disclosed. It is shown that "Petri Nets Tool-Kit" is available exactly in its portable form for Android OS, which encourages students to mobile learning and arms them with a convenient simulation tool provoking them to improve their modelling and investigative skills anywhere during the day. The prospects of the work are outlined in terms of the empirical research as for validating the impact of modelling activity in the elaborated application on the trainees' level of modelling skills.

1. Introduction

Models and simulations have always been in focus of different specialists' training, and have become integral part of an advanced learning environment. According to studies, modeling activities must be incorporated into training process due to their high didactic potential. In particular, authors ([6], [7], [12] and others) point out that including students in the models creating and providing opportunities for them to experiment with it enables to increase students' comprehension of the modeled process (phenomena).



It is also emphasized the essential role of computer models building and simulation as a process of executing of the mathematical model which enables representation of the real system (process) and its behavior in real time by means of computer. The computer simulation provides facilities of dynamic visualization and modification of the model which allow students understand deeper the basic features of the modeled processes and develop their investigative intuition ([4], [6]). Computer simulations are also seen as an opportunity to explore complex processes without having access to their real prototypes, and to understand the peculiarities of interaction of its different elements.

In the context of computer models building and simulation, nowadays priorities tend to shift in favor of mobile aids using on learning purposes. It is explained by the rapid growth of across-the-curriculum mobile gadgets use, BYOD strategy spreading in all levels of education, current needs for integration of different educational technologies, flexible forms of learning and tools for students' personal independent work. In the studies it is pointed out some common features of mobile learning which seem to be beneficial for computer simulation mastering by the students: opportunity to study always and everywhere provoking trainees to generate and test your ideas instantly; portability of devices and immediate availability of learning mobile aids; facilities of easy content renewing and sharing the results of your work within the mobile applications etc.

There are some quite well known mechanisms and tools of modeling and simulation that has been used effectively for relevant investigation practice. Among them there is Petri nets theory which has found its wide application to the real-life parallel processes modeling. Petri nets give powerful facilities for dynamic models building and enable comprehensive learning of the process peculiarities. Hence, it is important to have relevant computer tools which allow to apply Petri nets potential to educational practice on purpose of developing students' skills of models building and investigation. In addition, regarding the contemporary tendencies in favor of mobile learning, it seems to be essential to develop and implement a mobile application with necessary tools and content.

However, the analysis of the available software (given, in particular, in [11]) testifies the lack of proper aids which could satisfy the needs of Petri nets using on educational purpose of modelling skills earning by students, and exactly in terms of mobile learning. In particular, the existed environments are mostly web-oriented software which are Internet-dependent and cannot be equally used by all the students everywhere. Some of the current applications are desktop ones and hence, are not usable on the purpose of mobile learning. Besides, all of the said Petri nets available software provides a user with necessary tools for Petri net design and analysis, but without proper didactic support (e.g. short theory, examples, instructions, tasks for independent modelling etc.), which decreases their educational value. It is also important to point out, that according to studies, Petri nets potential is currently applied to solving of urgent educational tasks (e.g. modelling educational processes in the learning management systems [2]; modelling students' learning paths [3]; students' scoring and evaluation at e-courses doing [1]; inclusive education IT-support [10] and others). However, there is a lack of studies describing the Petri nets using on purpose of developing students' computer modelling skills.

Thus, due to the urgency of the problems mentioned above, the elaboration of the aids which are able to provide mobile learning for students' modelling and simulation based on Petri nets seem to be of current importance.

The aim of the paper is to depict the functionality of the mobile Android application "Petri Nets Tool-Kit" developed by the authors, and to specify means and examples of its using for mastering modelling by students.

2. Petri nets as a modelling instrument

Developing the application, we addressed to the fundamentals of Petri nets theory which provided us the mathematical basics of the nets building and their application to the processes modeling. Petri nets make a modeling formalism with a graphical representation and a precise syntax and semantics.

According to the theory ([8], [9], [3], [10]), a Petri net can be defined as a two-partite oriented graph $N = \langle P, T, R \rangle$, where $P = \{p_i\}$, $T = \{t_i\}$ are finite nonempty sets of a graph vertices among

which there are distinguished two types of vertices: places (P) and transitions (T). R -component determines a relationship between the vertices corresponding to the arcs. In a graphical representation of a Petri net, places are indicated with circles, whereas transitions are denoted with bars. Due to the rules of Petri nets theory, vertices of the same type cannot be connected. The places (circles) can accommodate tokens that can move around the net via transitions (bars). Disposition of tokens in places is determined by the marking set M which assigns an integer number to each place: $M = \langle M(p_1), \dots, M(p_i) \rangle$, where i is a number of places of the net, and $M(p_i)$ is the number of tokens in the place p_i . Thus, the number of tokens and their disposition around the net control the net execution.

Various markings of the Petri net characterize the states of the corresponding dynamic system, and the dynamics of state changes is modelled by the movement of the tokens around places. Net marking may be changed as its transitions are triggered. When a transition is triggered, one token is deleted from each input place and is added to each output place.

The main features of Petri nets briefly covered above, demonstrate their core advantages to be effectively used for modelling of parallel and consequent processes to solve real-life practical tasks. In the educational context, we would like to emphasize some essential Petri nets benefits. The formalism has intuitively clear facilities which correspond to real objects (process elements), events and their interaction, which encourages building of the real process model. In addition, Petri nets enable to demonstrate the interaction of the process components in its dynamics that can be visualized in computer interpretation of the net. Finally, facilities of manipulation with the nets parameters and changing its state with immediate visualization make them really powerful instrument for students' learning to model and simulate various processes during their vocational training in terms of different specialties.

3. Authors' mobile application "Petri nets tool-kit" and modelling activities within its environment

The basics of Petri nets theory were applied by the authors to the development of the mobile application "Petri Nets Tool-Kit". The requirements to the application which determined its functionality were formulated due to didactic needs as for incorporation of modelling activity into the students' training with the aim of the forming of their modelling skills. So, the application has to provide a trainee with (1) necessary tools to build a Petri net as a model of a process, to validate its functionality, to manipulate with its parameters, to edit, and save the built Petri net; (2) a set of ready-made examples of Petri nets with the learning tasks to explore the nets behavior and use as a base for trainee's own models; (3) concise theoretical materials on Petri nets formalism. In terms of technical needs, the application must be running on all Android OS since version 5, and the net overload should not exceed 300ms.

3.1. Main stages of the application development

Coming from the formulated requirements, the main phases of the application development were outlined which can be characterized as follows.

At the first stage the didactic functions of the application were specified due to the requirements, which made the basis for interface specifications.

At the next stage the general architecture of the application was developed. It defined the core structure of the application, links between the components which were determined by the basic application functions. In particular, the general architecture is represented by two main components: data (Petri net) component and graphical support. Data component includes four subcomponents, which respectively provide (1) internal net representation, (2) its storing, (3) execution, and (4) utilities for users' nets manipulation respectively. The data component makes a basis for graphical support component that realizes proper visual representation of the said data component parts.

Then object-oriented analysis and design were provided. In the process of the analysis the technical functions of the application were determined in terms of concepts and objects of the subject area, based on the depicted concepts and revealed links between them.

The use case diagram was built at this stage to describe in details a potential user's behavior. In particular, it was determined that the user is expected to initiate such use cases as: (1) to run the application; (2) to get familiar with Petri nets basics; (3) to work with ready-made examples of the nets (to choose them from the library, to obtain their graphical image, to solve modelling problems from the library upon the chosen net, to change the net states to solve the problem, to see the visualized graphical image of the changed net etc.); (4) to design their own Petri net (to locate on the screen places, transitions, and to join them with arcs, to set up marking allocating tokens in the proper places, to test and check the net correctness, to trigger fired transitions, to manipulate the net parameters and monitor the changes, to save the net and later download it, to edit the net via adding/deleting vertices, changing links and the net marking); (5) to simulate various processes (to work with their own net or the net from the library, to play different scenarios, to solve problems, to fill up the examples library with their own nets). Apparently, all the use cases are connected with each other, which is also reflected at the diagram (that is not included into the paper for the sake of conciseness). As a result, the conceptual model of the subject area "Process modeling by the means of Petri nets" was created. On the stage of object-oriented design the obtained conceptual model was used to determine application classes, objects, and proper links between them.

Next phase was devoted to the application interface design coming from the requirements and the use case diagram. Design of all application screens was developed in accordance with all use cases and links between them. All of the elements of graphical interface were tested as for their usability to make sure that the design solutions are ergonomical ones and enable a user to solve their tasks efficiently. Then the program realization of the application "Petri Nets Tool-Kit" was undertaken in Java within Android Studio platform: class diagram (figure 1) was built, and the class and methods description was done along with their program implementation.

Then necessary didactic content for the aid was created and proper components were filled in with the theoretical material, Petri nets examples, learning tasks, instructions etc.

At the final stage the application was tested, according to the didactic and technical requirements formulated above. Then the application was introduced into practice of students' classroom and independent learning activities.

3.2. Didactic potential of "Petri Nets Tool-Kit" as for students' modelling learning

As a result, the Android mobile application "Petri Nets Tool-Kit" allows a trainee to work in three main modes which determine basic functions of the application. The first core mode (Petri nets design) enables to design your own Petri net in order to model a process in order to solve a suggested modelling problem. A trainee is provided with necessary tools to create proper places, transitions and arcs, and to set initial marking of the net. Afterwards the application allows to test created net's execution, to verify its correctness via comparing with the state matrixes, and to edit the net (if necessary).

Then the student can modify the net parameters with the aim of simulation of various scenarios of the process evolution, and to explore their peculiarities. There is a possibility to save the designed net and then to restore it in order to go on working upon it later.

Besides, a trainee can work with ready-made Petri nets which are available in the library of examples of our application (the second mode). Working in this mode (Examples Library), students can simulate various processes and solve simple tasks on learning the basics of Petri nets theory. The examples from the Library can be also used as a base for trainee's own models. In addition, there is a realized facility to fill up the Library with student's own nets, created during their work in the design mode of the application.

Students are also provided with the third mode of learning fundamentals of Petri nets theory where they are supported by the concise theoretical materials on the topic and the facility to implement them on simple examples.

Characterizing the didactic potential of the developed application, we would like to recommend some stages of learning activity for step-by-step mastering by students the basics of modelling and

simulation based on Petri nets formalism. Below we are illustrating the learning activity on some examples of modelling problems within the environment of the “Petri Nets Tool-Kit” that were offered to the students within their classroom or independent mobile learning.

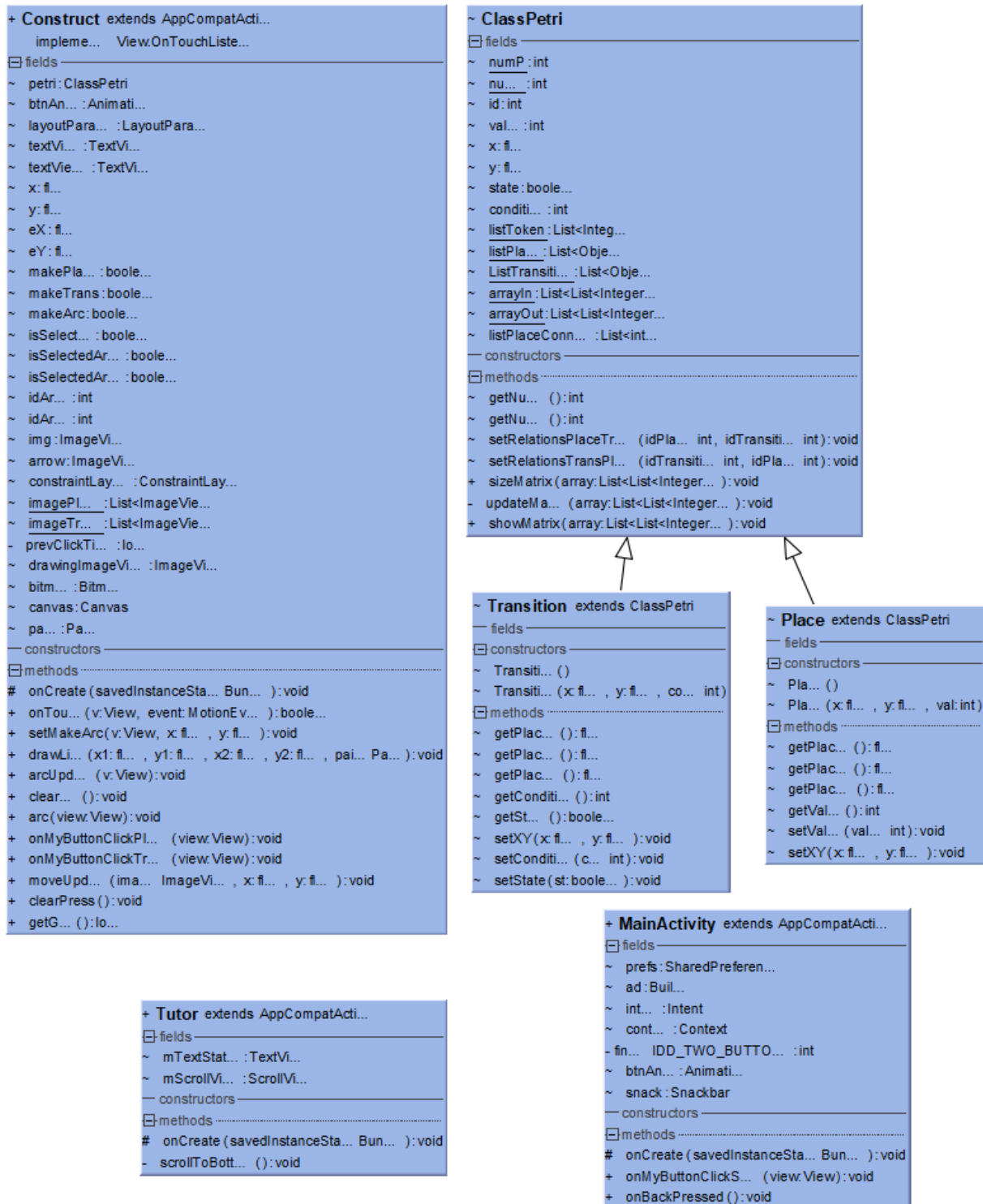


Figure 1. Class diagram for the program realization of the application “Petri Nets Tool-Kit”.

In particular, we would recommend to start with the work in the third mode within “Petri Nets Tool-Kit” and master the formalism as a main tool for processes modelling. Theory learning is enhanced here with the work upon simple samples provided by the Examples Library along with modeling tasks for students.

For instance, at this stage a trainee can be proposed to model the traffic control with the traffic lights using simple net from the Library. Here students are asked to determine which places refer to the traffic lights, what functions of transitions are etc. Then students are encouraged to add independently proper places and transitions in order to simulate triggering of traffic movement, to set up initial marking, and execute the net. In figure 2 the episodes of the students’ learning activity upon the sample are shown, where places 1-3 refer to red, yellow and green lights of the traffic lights, places 4-5 refer to traffic movement, transition 1 corresponds the green light arriving, and transition 4 triggers the traffic movement. Using the slider students can change initial marking of the net and explore the states of the net.

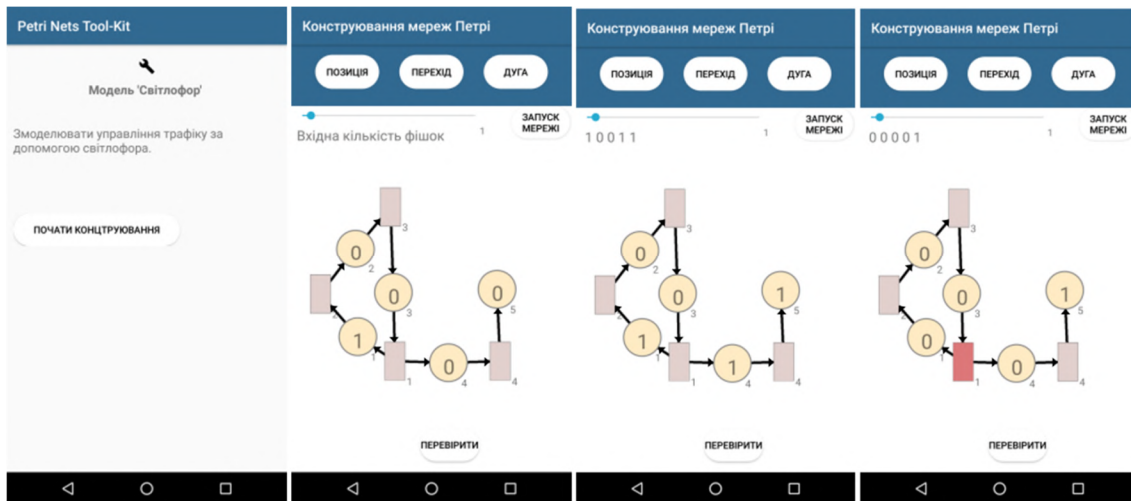


Figure 2. The episodes of the students’ learning activity upon the modelling of traffic control with the traffic lights.

At the next stage of learning activity students can be offered to solve independently some simple modeling problems on Petri nets design within our application with their consequent exploring. In particular, for students of different specialties it might be beneficial to learn how to model the processes of mass service on the example of colloquial exam passing. The problem may be formulated in such a way [12]: to build a model of passing an exam by four students to a teacher. In order to solve such a problem and to design proper net, the trainees have to detect themselves how many places and transitions they will need, how to join them, what the role of the initial marking is etc. Students design the net using the instruments of our tool-kit. Afterwards, trainees are asked to imitate different scenarios of the given process, for example, when (1) all four students are waiting for their turn, (2) two students are waiting, one student is passing his exam (the teacher is busy and unavailable to other students), and one student has already passed it, (3) three students are ready to pass the exam and one student is queuing etc. (see figure 3 below).

At the next stage, in order to advance students’ modeling skills we would recommend them to solve more complicated real-life problems. For instance, it might be the problem [12] as for simulation of safe one-way movement on the railway segment of given configuration (see figure 3 below) that consists of railway drives with semaphores and indicators of occupation. To provide effective modeling and simulation activity, it is relevant to encourage trainees to analyze the given configuration and to determine the purpose of places and transitions they need, how to join them to

obtain the necessary shape of the road, what kind of initial marking to assign etc. The results of the model building on its different stages are given in the figure 4.

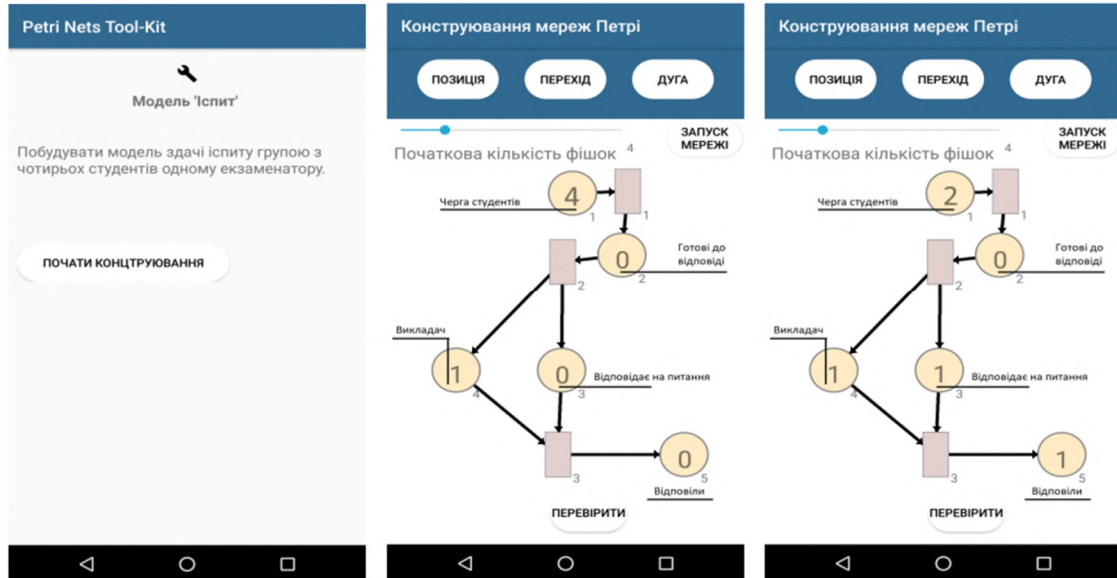


Figure 3. Various scenarios of the evolution of the process of passing an exam within the environment “Petri nets tool-kit”.

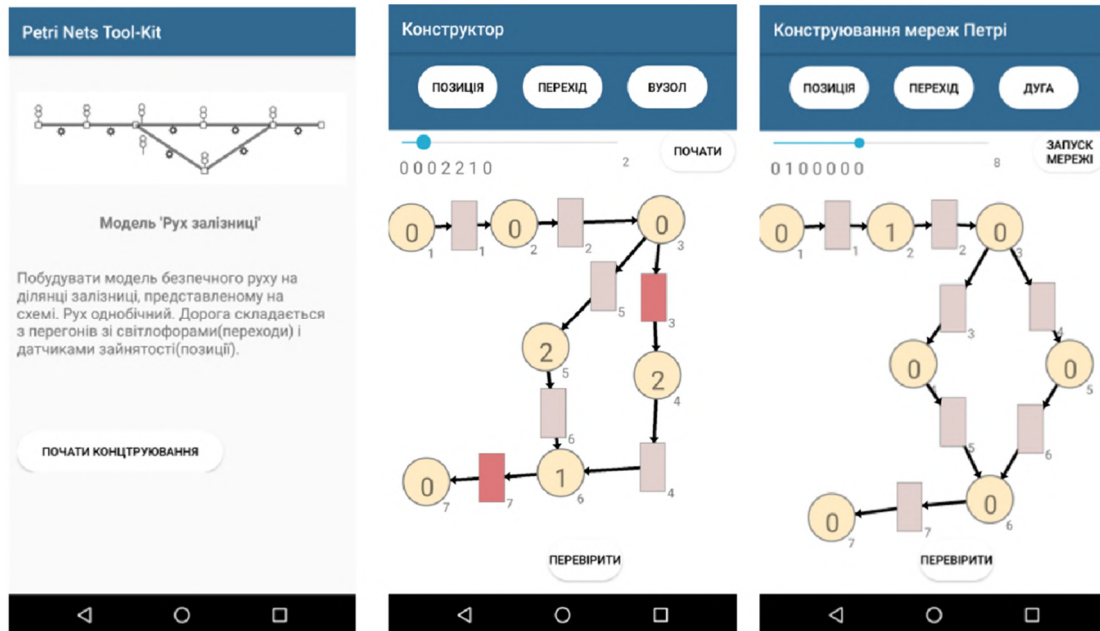


Figure 4. Various stages of students’ design of the Petri net which models safe one way movement on the railway segment of given configuration.

After the model building it is recommended to offer students to imitate and investigate various scenarios of the process, emphasizing the conditions of safe movement for this exact segment of railway.

At the level of advanced modelling in pre-service IT specialists' training, special tasks can include algorithmic problems solving. The Examples Library of the application provides students with the primitives of basic algorithmic constructions (sequence, selection, repetition) in the form of ready-made Petri nets which can be used by trainees to design themselves and investigate various real-life algorithms including parallel ones.

In fact, the didactic components of the developed application contain variety of examples and modeling problems which can be changed and renewed due to the needs of proper specialists' training.

Thus, depicted above functionality of mobile application "Petri Nets Tool-Kit" and examples of modelling activities in its environment, testify its significant facilities as for earning simulation habits and investigative skills for students of various (technical, engineering, IT) specialties within the set of curriculum subjects (such as Discrete Mathematics, Computer Modelling, Programming, Operations Investigation, Systems Modelling etc.). In fact, modelling and simulation activities provided by the application are able to awake students' interest as for processes exploring, imitating their different scenarios, their critical estimation, and revealing their weak points. In such a way these activities within the application encourage students to enquiry-based learning and develop their modelling and investigative skills. Obviously, it can be beneficial for their real professional activities.

We would like also to underline some special benefits of the application using in the training of pre-service teachers (especially Science, Math, and Informatics teachers). Modeling activities, based on Petri nets formalism within our mobile tool-kit, arm them with powerful tool of various processes simulation and exploring. In long run, it can be extended by the pre-service teachers in their own training activity with schoolchildren. In addition, using Petri nets tools, teachers can incorporate the elements of gamification into the learning process. Finally, Petri nets mechanism enables to model academic disciplines structure and build optimal individual students' paths, which can be applied by teachers in their professional activity, as it was offered in some of studies, in particular in [2], [3].

Special emphasis should be put on the advantages of exactly mobile learning of Petri nets modeling, provided by the aid "Petri Nets Tool-Kit". Obviously, it enables all the common benefits of mobile learning (mentioned in the Introduction). Besides, we could point out some special features of the application which are really beneficial from the standpoint of modelling skills developing within mobile learning. In particular, it supplies a trainee with all necessary theoretical, didactical and instrumental means to design and to explore a process model easily and in thought-provoking way. The application can be downloaded to Android device, so it is Internet-independent, and can be used completely everywhere and free. In addition, a student is enabled and encouraged to fill up the Examples Library with his own Petri nets models to use them for further elaboration and exploration. It makes the application an attractive instrument for individually-driven mobile learning which motivates a student to master modelling skills according to his personal interests and needs. On the whole, the Android mobile application "Petri Nets Tool-Kit" represents a portable convenient tool for instant and permanent model design, experimenting, hypothesis testing, provoking students to improve their modeling and investigative skills anywhere during the day.

4. Prospects of the research

The application has been developed in its pilot version with the set of functions presented above. It was implemented into the pre-service teachers' training within the classroom and independent work on the courses of "Computer modelling", "Discrete Mathematics", and "Programming". Our observations as for the students' mobile learning activity within the "Petri Nets Tool-Kit" and students' preliminary academic results allow to predict its positive impact on the trainees' level of modelling skills and cognitive eagerness.

Hence, it turns up necessity of the empirical research to validate our prediction which makes the prospects of our work. On the preparation stage, it is elaborated the indicators base for the research. In particular, it is developed the set of questionnaires (based on the work [5]) with proper scale of modeling skills measuring. In addition, the program of observation and assessment of students' cognitive eagerness during classroom and independent work is created. Thus, empirical research as for

the impact of modelling activity in the elaborated application “Petri Nets Tool-Kit” is ready to get started and will be covered in further papers. Due to the results of the future empirical research, the application will be elaborated.

5. Conclusions

According to the aim of the paper, it is depicted the functionality of the mobile application “Petri Nets Tool-Kit” developed by the authors resting on the Petri nets fundamentals and minding their advantages as for modelling of parallel and consequent processes. The basic stages of the application development are covered. The functionality and examples of the application using to provide modelling activities for students within their mobile learning are specified. The advantages and benefits of processes modelling based on Petri nets mechanism and provided by “Petri Nets Tool-Kit” are emphasized in the context of students’ vocational training in terms of different specialties. The proper stages of learning activity for step-by-step mastering by students the basics of modelling and simulation are disclosed.

In particular, “Petri Nets Tool-Kit” provides students with the set of tools which enable to solve modelling problems: to create, edit, save their own Petri nets as well as to change their parameters, visualize changing and play various scenarios of the modeled process. The application also contains the library of ready-made Petri nets examples and learning tasks for the models exploration, and relevant theoretical materials, which makes the application attractive both for classroom activity and for students’ independent work in terms of their mobile learning. It is also important to point out, that “Petri Nets Tool-Kit” is available exactly in its portable form for Android OS, which encourages students to mobile learning, and arms them with a convenient simulation tool provoking them to improve their modeling and investigative skills anywhere during the day.

The prospects of the work are outlined in terms of the empirical research as for validating the impact of modelling activity in the elaborated application on the trainees’ level of modelling skills.

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Approaches, models, methods and means of training of future IT-specialists with the use of elements of dual education

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Approaches, models, methods and means of training of future IT-specialists with the use of elements of dual education

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Abstract. The article substantiates the necessity and expediency of using the dual form of education in training specialists in the field of information technology in technical universities of Ukraine, interprets the concept of "dual education" from various sources, including UNESCO documents and the Law of Ukraine "On Education", analyzes some international experience of using dual study in higher education, in particular in Germany, considers the tasks to be solved for successful implementation of the dual form of higher education in Ukraine, and the main stages of this implementation for the period up to 2023. The paper considers some existing models of dual education that can be used in domestic universities. Also considered one of the approaches to the formation of methodological and information support for training of future specialists in information technology in the dual form of education based on distance learning support system developed on the basis of Moodle system, presented experience in implementing elements of dual education at the Faculty of Information Technology and Systems of Cherkasy State Technological University.

1. Introduction

The Ukrainian higher education gradually withdraws from the authoritarian pedagogy and implements democratic and humanistic values in the educational process. The nature of pedagogical relationships in education is fundamentally changing. The necessity of taking into account the age and individual characteristics of students, the development of their creative potential, abilities and talents, providing the best conditions for training and the future employment become of primary importance. Today higher educational institutions should strive to adapt to the students' needs and be promptly responsive to the socio-cultural changes occurring in Ukraine and worldwide.

Thus, universities are in an active search for new educational approaches, shapes, technologies and techniques the use of which will provide an opportunity to reorient higher education to meet the most significant social, economic and educational needs and, at the same time, effectively apply numerous innovative, theoretical and methodical results that are accumulated in professional pedagogy over the last decade.

Lately many developed countries are actively implementing the dual model of training in higher education. The dual education model is understood as a model in which the entire process of mastering the profession comes in two establishments: vocational-theoretical parts of preparation are organized in the educational institution and the practical part takes place at some enterprise.

The dual form of higher education is especially relevant in the training of specialists in the field of information technology, which is changing and evolving so rapidly that the classical models of organization of higher technical education cannot meet the needs of employers – IT companies.



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Today, the Ukrainian IT industry employs about 190 thousand highly qualified specialists. According to statistics, every year this number increases by 25-30 thousand specialists [13], while Ukrainian universities annually graduate only 12-16 thousand students of IT specialties. At the same time, the implementation of high-quality professional training of such specialists takes place in the conditions of dynamic development of the information and communication technology (ICT) industry, which necessitates continuous training throughout the professional activity of the specialist.

Within the conference “Synergy: Business and Universities” member companies of the Association “IT Ukraine” presented a unified list of requirements and recommendations for junior-level specialists [18]. Unfortunately, the analysis of these requirements and recommendations showed that they are aimed only at the current needs of the IT industry and do not require future professionals to have fundamental knowledge of information technology. Support parity between the current requirements of the IT industry for the training of future information technology professionals and their fundamental training, which is the basis not only of those software technologies that are relevant today, but also those ICT that will appear in the future, is the higher technical education task. Only fundamental technical education based on scientific bases of mathematics, computer science, engineering, modeling, forecasting, planning, theory and methods of optimization and decision making, artificial intelligence is a guarantee that domestic IT specialists will be in demand in the international and domestic labor markets not only today, but also in the future [27].

Therefore, the research of problems related to theoretical, methodological and practical tasks to the training of future IT professionals in technical universities in modern conditions is relevant.

According to the authors, it is the dual form of education that will help solve the problem of in-depth and effective cooperation between the university and IT employers.

2. What is dual education?

The term “dual education” is widely used as an umbrella term, referring to the fact that teaching and learning in vocational education and training (VET) is characterized by “duality” in two regards [23]:

- the duality of learning venues (schools/VET providers and training companies), sharing the responsibility of providing theoretical and practical training; and
- the duality of actors (public and private actors), sharing the responsibility for VET policy and practice.

The duality of the learning venues is the basis for the definitions used in European and international literature.

According to UNESCO, the “dual education system programmes” are called “programmes that combine school- or college- and work-based education”. Both components are substantial (i.e. go beyond a single internship or occasional class), although the work-based part usually occupies 50% of the programme time or more [28].

At the company, the apprentice receives practical training, which is supplemented by theoretical instruction at the vocational school. According to Cedefop, “dual education” concerns “education or training combining periods in an educational institution or training centre and in the workplace” [14]. Cedefop also refers to dual education as “alternance training”, underlining that the term “dual education” may be used interchangeably with “alternance training”, “apprenticeships” or “work-based learning”. There are, however, some small but significant differences between these terms, as they differ with regard to the two aspects mentioned above.

The dual form of education means the education oriented on practice, built on the principles of social partnership of the university and the enterprise (organization, institution), aimed at the formation of a new model of training of students with the mandatory periods of production training and manufacturing practice, conducted on the basis of the enterprises (organizations, institutions) and provides for the strengthening ties with the production, the definition of the leading roles and increasing the responsibility of employers for the training quality [5].

The dual form of education is a method of education that provides a combination of training in educational institutions (in other subjects of educational activities) with training in the workplace in

enterprises, institutions and organizations for specific qualifications, as a rule, on the basis of the contract [29].

The purpose of this article is to analyse some approaches, models, methods and means of preparing future IT-specialists with the help of a dual form of training, as well as the experience of this form of study implementation at the Faculty of Information Technologies and Systems (FITIS) at Cherkasy State Technological University (ChSTU).

3. The international implementation experience of the dual education system

Due to their pedagogical and economic potential, apprenticeships and similar schemes are currently in the spotlight among both policymakers and researchers. The difficult situation of young people on the labour market today requires solutions that support school-to-work transition. A great deal of hope is placed in the development of apprenticeships and work-based learning more generally [23].

While all the member states (MSs) of the European Union (EU) have programmes that integrate work-based learning, their scale, popularity and outcomes vary greatly. There is no single model for apprenticeships, and apprenticeships are far from being a core track of VET in most MSs.

How can a country successfully move its young people from education to employment? What are the problems? Which interventions work? How can these be scaled up? These and other pertinent issues are addressed in the study commissioned by the EP: “Dual Education: a bridge over troubled waters?” [7].

The aim of this EU-wide study is to provide the EP Committee on Culture and Education with concise data on the state of play of vocational education and training in the Member States to serve as background information for ongoing and upcoming debates on the new generation of education and training programmes.

More specifically, the study addresses the following aspects:

- the main obstacles hampering the implementation of dual education in some MSs;
- why some MSs decide to implement/not to implement dual education systems;
- establishing links between excellence in VET, dual education and economic growth;
- identified trends and changes in dual education; and
- innovative approaches on how to foster and increase the attractiveness of this type of education.

The study explores the strengths and weaknesses of dual education/apprenticeships and explores policy developments within the context of countries own educational, social and economic characteristics. It also presents examples of good practice that may be of interest to countries looking to develop their vocational education and training offer.

Although alternance schemes across Europe are adjusted to the country VET system, four main types of VET pathways can be identified, concerning if and how work-place learning is embedded [7]:

- a fully-fledged apprenticeship system (Austria, Denmark, Germany and Switzerland);
- systems where apprenticeships are parallel to other VET tracks (Greece, France, Italy, Netherlands, Poland, England);
- school-based VET tracks with high shares of work-based learning (Finland, France, Netherlands);
- predominantly school-based VET systems/programmes (for example the Czech Republic, Slovakia).

For example, a schematic presentation of fully-fledged apprenticeships' place in there of the education and training systems shown in figure 1.

The dual education form originated in Germany where it enjoys a wide popularity because it provides students with an excellent chance to obtain work experience while studying at the university [30]. Moreover, the company with which the student signs a contract pays for the tuition and also pays wages to the student during training. The dual training in Germany is regulated by the following legislative acts as [1]:

- Vocational Training Act (Das Berufsbildungsgesetz (BBiG));

- Promotion of Professional Training Act (Das Berufsbildungsförderungsgesetz (BerBiFG));
- Young Persons Employment Act (Das Jugendarbeitsschutzgesetz (JArbSchG));
- Handicrafts Code (Die Handwerksordnung (HWO)).

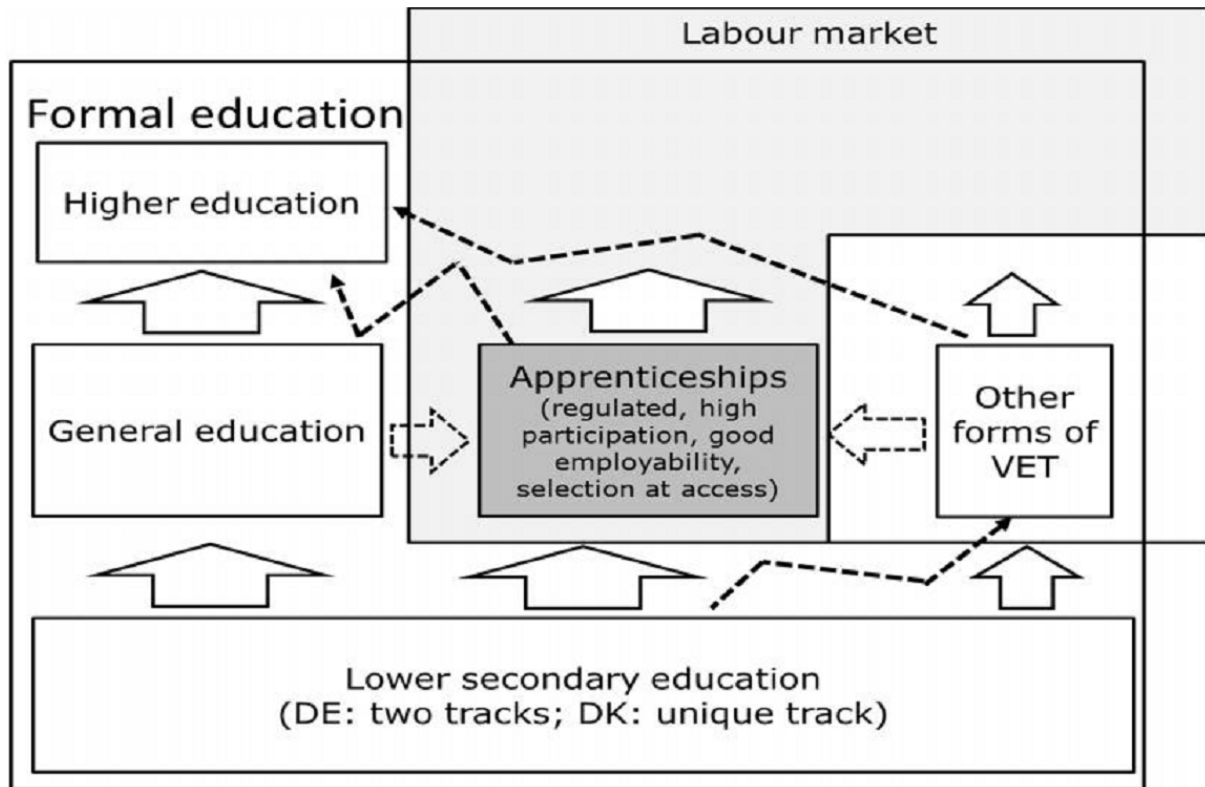


Figure 1. Schematic presentation of fully fledged apprenticeships' place in the rest of the education and training system ([7], p. 102).

The programs of the dual training are offered in a variety of technical and economical directions. After three or four years of study the student receives a Bachelor's degree (B.A., B. Sc., B. Eng.) and can get a permanent position at the company.

Therefore, the graduates of the programs have not only a valuable practical experience, obtained during their training, but also a further place of employment.

Many companies in Germany offer employment within dual training. The choice of companies ranges from small and medium sized enterprises to large international corporations like IBM, SAP, Daimler, Siemens, Volkswagen, etc.

Each university with dual training programs has a list of partners it cooperates with.

Applying for the dual training is similar to the job search. The student must independently establish the contact with the important for him companies and send them the application. As a rule, the candidate must produce the following list of required documents:

- a cover letter;
- curriculum vitae (CV);
- statement of estimates;
- a language certificate that validates the knowledge of German (and/or English);
- additional certificates suitable for the filed application (confirmation of practical work experience, participation in projects, seminars, etc.).

Some problems with the introduction of the dual forms of training emerge in the sectors of the economy with low wages. Depending on the area and scope of activities from time to time there is a lack of volunteers to get dual training or the parties concerned on the part of employers.

A striking example of the implementation of the classical dual education system in Germany is the Duale Hochschule Gera-Eisenach (DHGE) – Gera-Eisenach University of Applied Sciences [12]. DHGE is a state higher education institution specializing in dual practical training programs. In cooperation with companies and institutions, DHGE provides a large number of accredited bachelor's programs in business, social sciences and technology, including ICT.

Interesting experiences with the introduction of dual training system exists on Philippines [2].

4. The tasks for the implementation of the dual forms of higher education in Ukraine

Taking into account the relevance and sustainability of the dual forms of higher education, the Government of Ukraine on September 19, 2018 approved the Concept of training specialists in the dual form of education [5], which aims to develop the principles of the State policy for improving the training quality of specialists on the basis of the dual educational forms.

This Concept is supposed to establish an equal partnership of institutions of higher, professional pre-higher, vocational (professional) education, employers and all those who study with the aim of acquiring the experience of practical application of the competencies and their adaptation in the conditions of a real professional activity. The developed concept uses the German experience of the dual educational forms, presented through the representative office of the Friedrich Ebert Foundation, a German-Ukrainian agropolitical dialogue, the Eastern Partnership Project “Dual education in the dialogue” with the participation of educational institutions of different levels, the Federation of employers of Ukraine and was used by the Working Group established by the Ministry of Education and Science of Ukraine.

Ministry of Education of Ukraine made an indicative timeline for the implementation of the dual form in full as a part of the Concept which envisages the following main stages [5]:

- Stage I. Development of normative-legal base for the introduction of dual education in full (2018);
- Stage II. Development of standard models of the dual form of education in institutions of higher education, vocational and professional pre-college education. Piloting of models. Efficiency assessment (2019-2020);
- Stage III. The creation of dual education clusters on the basis of wealthy educational institutions and interested business entities (2020-2023).

For the distribution of dual forms of higher education in Ukraine the following tasks must be solved:

- to study the experience of innovative development of higher school in Germany, which is of interest to such innovations as: the integration of science and education, social partnership, training in the enterprise;
- to summarize the advanced foreign and domestic experience of formation and development of dual forms of higher education;
- in each industry to clearly define the list of specialties which can apply the dual form of higher education;
- to assess the state of higher education in Ukraine and the possibility of diversification of the educational system and the phased introduction of elements of dual education in preparing future professionals;
- to define the core list of companies willing to become partners for the implementation of dual forms of higher education and to develop common rules of cooperation of universities with these businesses;
- universities together with enterprises need to develop recommendations for the implementation of elements of the dual form of higher education;
- to ensure the establishment or selection of training classrooms, landfills and laboratories for training in the dual form of education at the enterprises;

- to conclude contracts with the enterprises to ensure production practices at their bases;
- to introduce a mandatory (once a year) training of teachers of vocational-oriented disciplines in courses, or at the leading enterprises of the relevant industry;
- to prepare scientific and pedagogical staff for the organization and teaching methods in the framework of the dual form of higher education.

If the above mentioned conditions are fulfilled, the introduction of dual forms of higher education could solve many existing problems in the field of education in Ukraine.

The purpose of this implementation is to overcome disparities between the supply of educational services by the university and the needs of employers in terms of the structure of the educational process, the content and scope of curricula and programs, quality of students' preparation, provide a mobile response to changes in production technology and modernization of the content of higher education, given the requirements of the relevant enterprises (organizations, institutions) in the organization of the education process.

Some Ukrainian universities have already introduced elements of a dual education system. Among them is the National Technical University of Ukraine “Kyiv Polytechnic Institute named after Igor Sikorsky”, in which the master's program of dual education “Dynamics and strength of machines” received a certificate of European accreditation. The dual education provided by this program gives students the opportunity not only to study theory in classrooms, but also to gain practical skills on the basis of “Progrestech-Ukraine” and “Boeing-Ukraine”, where students of the program are already their full-time employees. The master's program “Dynamics and Strength of Machines” trains mechanical engineers and researchers whose knowledge is required in the aerospace industry, nuclear energy and more. The program benefits of the European accreditation giving the diploma greater value to employers, and therefore graduates of the program will have a competitive advantage in employment in foreign companies [22].

Since 2016, the National Technical University “Kharkiv Polytechnic Institute” has a training program in the dual form of education. Under this program, students have the opportunity to legally combine training and work – to obtain the necessary theoretical and practical knowledge in the company in the field of study. As a pilot project of the dual form of education, the training of masters at the Department of Software Engineering and Information Technology of Management was started, according to which in 2017-2018 there were 66 students majoring in 121 “Software engineering” and 122 “Computer science” with practical experience in projects of various IT companies [25].

In the pedagogical field, the need to improve the training system of modern highly qualified teachers and ensure the successful adaptation of graduate students to their professional activities are no less acute than in the industrial sphere. To this end, the National Pedagogical University named after M.P. Drahomanov on the basis of the Faculty of Computer Science concluded agreements on the pilot implementation of a dual system of education during the training of masters of informatics to cooperate with lyceums, gymnasiums, high schools, where students already work in full-time positions as computer science teachers [20].

5. Model of the dual form of education in higher school

The introduction of elements of dual education in higher schools is based on the combination of vocational theoretical and vocational practical training in the educational process in the proportion of 30% (40%) of theoretical lessons and 70% (60%) of practical classes (or the proportion of learning at the enterprise 25% to 50% credits). Industrial training and industrial practice are carried out directly in production using a material-technical base and human resource of the enterprise (organization, institution), it provides students with the opportunity to simultaneously study at the university and to master the basics of a chosen profession directly at the enterprise.

In contrast to this scheme, the standard of dual education system of Germany is more business-like because it is interrelated (figure 2) [19]. Thus, there is a further evolution: the employer not only pays for training and employs the students but also provides an educational process. Practical knowledge and skills (75-80% of the total training time) are created at the enterprise. The educational institution creates

conditions for the formation of the necessary theoretical knowledge and basic practical skills (20-25% of the time).

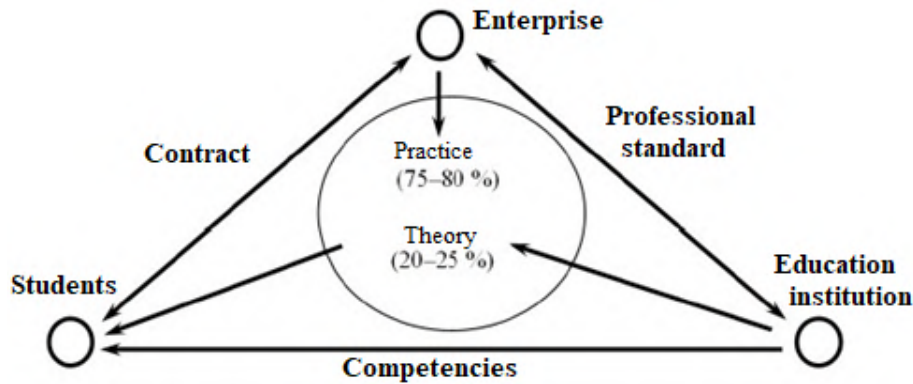


Figure 2. Scheme of German dual education system [19].

The relationship between the employer and the student are governed by the contract between the employer and the higher educational institution that is by the professional standard. Educational standards of the professions are the prerogative of the Federal Institute of Vocational Education of Germany. The institute includes an equal number of participants and an equal number of votes in three groups: employers, trade unions and public authorities. They work together to develop educational standards approved by the Ministry of Economy of Germany but not by the Ministry of Education.

Thus, all components of the educational process in the dual form are located in the same area and the methodological support is the responsibility solely of institutions of higher education.

The authors of this research [19] suggest on the basis of the relations: “the institution of higher education” – “enterprise” – “training center” – “student” to create a unified educational field of dual forms of higher education (figure 3).

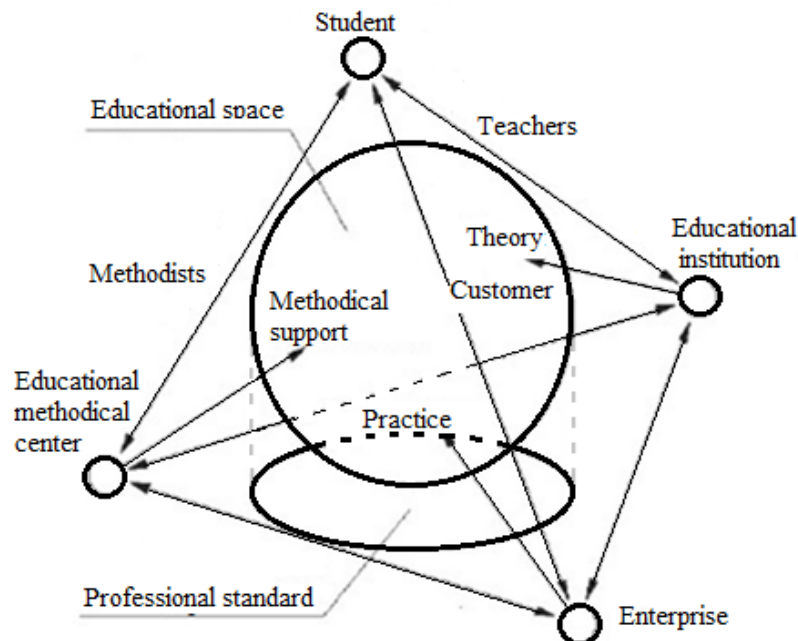


Figure 3. The scheme of the unified educational space of dual training forms: “institution of higher education” – “enterprise” – “teaching center” – “a student” [19].

Each of the participants makes a contribution to the creation of this educational area: the educational institution provides the theoretical training, the company reinforces its practice, a training center (TC) on behalf of the Ministry of Education and Science develops a complete method of training in the dual form. The student, who studies on this basis, rises to a qualitatively new level, based on the interaction with teachers, the employer and a coordinator.

Institutions of higher education, the company and TC are the basis of the educational pyramid atop of which is the student. Projection of the educational area on this field is the professional standard. It is clearly seen that it should be developed jointly by all members of the triad. This confirms the thesis that the dual form of higher education is an association of interests on a parity basis of business, a young man and the State. From this point of view the professional standards form the educational area. It is presented in the dialectical unity and interaction of the educational area and the professional standard. They mutually develop each other resulting in the improvement of educational services. This should facilitate the harmonious combination of the main elements of higher education.

Projection of the educational area from the company on the plane “the institution of higher education” – “TC” – “a student” is a set of general and professional competences acquired by the student in the learning process.

Projection of the educational area on the plane “enterprise” – “TC” – “a student” by the institution of higher education provides a fundamental and professionally-oriented theoretical basis, which has to be mastered by a student.

Projection of the educational area from the TC on a plane “institution of higher education” – “enterprise” – “a student” provides a complex of training materials on the organization of the dual form of higher education, which should be provided at the enterprise and in the institution of higher education.

Based on the mentioned above it can be concluded that any bias in one direction or another immediately reveals the incompetence of the relevant side of the process, thus the system becomes self-regulating. The feedback between all parties makes the system flexible which makes it possible to take into account any changes in education and in business (industrial sector).

The model of a single educational space of the dual form of higher education for students can be applied in the universities of Ukraine.

6. Methodical and information provision of the dual forms of higher education in ChSTU

The environment of a person has the greatest impact on his/her formation and development. So, today an important and topical issue for the university is creating such a high-tech information-communication educational environment where a student studies during the entire period at the higher technical school.

The priorities in building an information and educational environment should be: widespread use of computer-based tools and ICT learning in the educational process, practical implementation of distance learning technologies, providing ICT support for research, widespread implementation of ICT in education management at different levels, in different industries, for all types of educational institutions [3].

The information and educational environment should be formed on new technologies and provide the educational process with electronic textbooks, electronic teaching and methodological complexes on relevant subjects, list and guidelines for the use of various web and cloud services, broadband Internet, and create conditions for the introduction of pedagogically balanced teaching models; use of cloud and mobile-oriented learning environments for the formation of key competencies and life skills of students; use of various virtual and research laboratories; reveal the personal abilities of students, monitoring personal and academic achievements; take into account the own needs of informatization of each educational institution [4].

An example of such an information and educational environment is the environment created at Ternopil Volodymyr Hnatiuk National Pedagogical University (see, for example, [26], where private and public cloud technologies are integrated into the university's academic cloud to support the implementation of group methodology in the educational process.

An important component of the information and educational environment, where students can access learning materials anytime and anywhere, is a Support System of Distance Learning (SSDL) that is a multifunctional, modular, multimedia hardware and software system to support distance learning of students, built using network and web technologies [16].

SSDL as an essential component of information and communication educational environment of a University should include the following subsystems: the subsystem of user management, messages subsystem, subsystem of access to the distance learning courses, testing subsystem, subsystem of students' learning outcomes, subsystem of distance learning courses management.

The authors offer to create a system of methodological and information support of dual forms of training of future specialists in information technology on the basis of SSDL. SSDL must not only provide a student with an access to educational materials and provide a remote communication with the teacher so that he could ask questions, to quickly get comments and communicate with other students studying the same course.

The efficiency of the SSDL use is determined by the input, editing and layout of educational material, including modern multimedia and hypertext, tools for creating exercises and tests, convenience of the interface for a user, etc., which in the conditions of Informatization of educational process become a means to provide new educational services and access to electronic educational resources (EER) in any place with the Internet access.

SSDL of ChSTU [8] and SSDL of FITIS [9] placed on the web server of the University are based on the Moodle [21] system of ChSTU. The choice of Moodle system is due to the availability of convenient content development tools, management subsystems for the educational process, SCORM support, the localization on the Ukrainian language, modularity, multimedia, open-source code that provides it with the highest popularity ratings in most countries of the world [6], as a platform for distance learning.

One of the components of the didactic provision of the educational process of the future computer science bachelors are e-learning courses in certain disciplines or the disciplines placed in SSDL.

E-learning course (ELC) is an electronic educational resource as a set of teaching materials in an electronic form and educational services for individual and group learning using distance learning technologies [17].

The particularity of ELC use in comparison with other electronic educational resources is that ELC is designed for an independent and systematic mastering of educational materials under the guidance of a teacher during the studies.

In the process of teaching ELC constantly changes and improves both by the teachers of the course and by the students themselves, in particular through the use of Wiki technology, the creation of a course glossary.

As a rule, several distance learning technologies are used in the electronic training course. The teacher should be guided by the following principle: if the didactic task can be implemented through the use of more simple technologies, preference should be given to them.

Table 1 shows the list of psychological and pedagogical technologies that might be used in a distant and dual training of future bachelors in computer sciences and Moodle system tools [17].

The educational content of ELC are the course resources that is informational, educational, methodical and other materials in the text form, in the form of HTML pages, hyperlinks, presentations created in SSDL or loaded into it. The content of the training course is shown on the basis of these materials.

ELC contains the materials of the practical training of students on the course and tasks for independent preparation of students. Training materials for laboratory and practical works are provided with all necessary concepts and definitions, mathematical formulas, the necessary examples of how to perform certain tasks and control questions.

Online tutorials, guides and manuals posted to ELC, are educational resources that provide the opportunity to apply the basic volume of the studied material, independent work which contributes to deeper learning and understanding.

Table 1. Pedagogical technologies and means of Moodle to implement them.

Pedagogical technologies	Tools of pedagogical technologies implementation in the system Moodle
Technology of problem study	Lesson, Workshop, External tool
Cooperative learning technologies	Lesson, Workshop, Feedback
“Brainstorming” method	Chat, Forum
Method of projects	Assignment, Workshop, External tool
Even training:	
• review	Workshop
• pal friends	Internal mailing list of messages
Collective training:	
• report (presentation)	Workshop
• discussion	Forum
Training in cooperation:	
• training in small groups	Mode “Grouping”

Manuals designed so that students could move from the activity carried out under the guidance of the teacher, to the activities organized by the students themselves independently with the ability to exercise self-control. This is why they contain a detailed description of rational methods and activities and recommendations for their effective use.

ELC realizes the possibility of automated control of students' knowledge: input, current, modular, rating, final and deferred carried out, usually in the form of a computer test Bank with test questions at different levels of complexity.

In modern conditions the learning outcomes of students of higher education are determined by the level of completeness of their general and professional competencies. Therefore, in terms of distance and dual training an important issue is the availability of technologies that would provide the opportunity to monitor the process of formation of students competencies and evaluation of their development level. Moodle system, starting with version 2.7.9, includes the module of users' competencies control (figure 4).

The basis of the tool is the concept of competencies accumulation:

- each student at the beginning of the study course is characterized by a set of already formed competencies;
- each course specifies the list of input methods which are necessary for the student of the course and a list of basic competencies that must be formed by the student after successful completion of the course;
- after specifying the target set of competencies a student receives a recommended set of study materials and tasks as well as his own path of course from the system.

The student can see current and target competencies in his personal account. They are available for the teacher through each user's profile. The system calculates the development level of each competency on the basis of the final grade for the course and the necessary time for this.

The functional of learning trajectories management according to the competencies in the Moodle system provides the ability to organize adaptive learning. It can be used for the independent preparation for exams, for certification and re-training of specialists, for organization of remote and dual training and continuous education.

In addition to the facilities provided by SSDL for the organization of blended learning, the university needs to provide online communication of teachers, students and employers during internships, or students' stay in IT companies during practical training in a dual form. Web-based video conferencing tools are used to provide such communication and feedback when staying out of university, in particular: Skype, Zoom, Cisco WebEx, Google Class, Google Meet, Big Blue Button, Microsoft Teams, etc., as well as mobile tools (Viber, Telegram, Messenger, etc.). These tools allow teachers to organize audio,

video, and web conferencing, use features such as online meeting scheduling, note-taking, screen sharing, recording and instant messaging between participants.

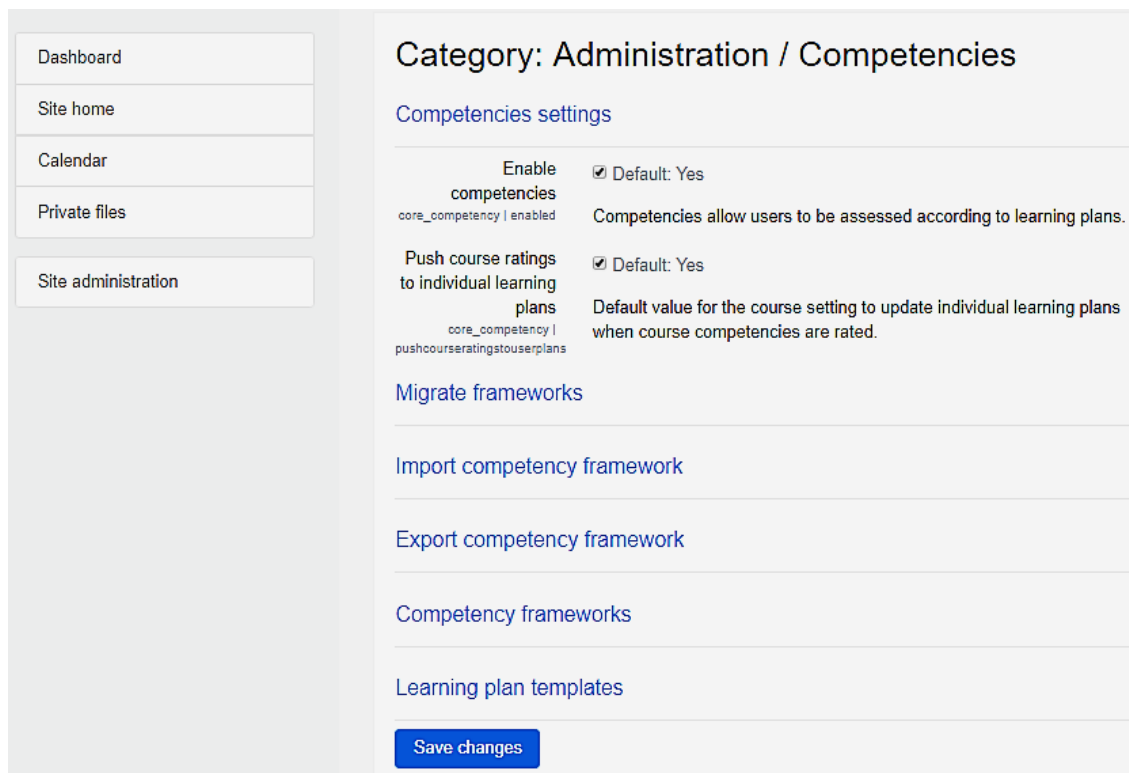


Figure 4. The configuration window of the competencies in the Moodle.

7. Experience of implementing elements of the dual forms of higher education in ChSTU

In today's information society there is a great demand for competent professionals in the field of information technologies, able to apply existing technologies to solve problems in various spheres of a social production, to maintain and adapt them to practical needs and to be ready to accept new solutions and develop technologies of the future.

Training of such specialists is based on the dynamic development of the industry of information communication technology, underlining the need for continuous learning throughout professional activity. In these circumstances the relevant issue is the problem of professional training of future specialists in the field of information technology.

Therefore, the dual form of higher education is especially relevant when training for the information technology industry that is so rapidly changing and developing that the classical model of education organization of the higher technical school cannot meet the needs of employers – IT companies.

The dual form of training requires even more in-depth cooperation between the university and employers. If the student participated in production only during the summer and winter practices, term papers and dissertations or projects, now the modern world requires a more in-depth synergy in teaching students beginning from the first year of study.

Four years ago at the Faculty of Information Technologies and Systems ChSTU the emphasis was placed on cooperation and collaboration with leading IT companies, in particular, on retraining of teachers and on attracting of practical teachers to the teaching process. Two years ago own volunteer project of the additional professional education for students and the dual degree program with Polish universities for future masters of information technology was introduced.

In 2016-2017 academic year the FITIS team focused attention on the experiment on the introduction of elements of dual forms of higher education and on creation of the environment for the students that will help them develop and promote their own IT projects.

Before the experiment the FITIS students were surveyed regarding their employment in the periods of 2016-2017 and 2017-2018 and in the context of specialties (figure 5, 6).

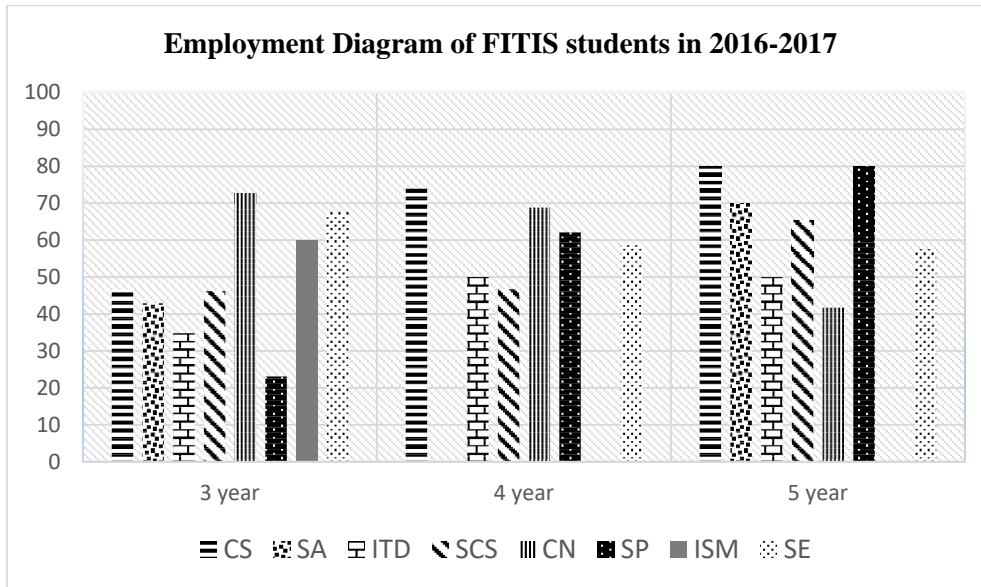


Figure 5. Employment Diagram of FITIS students in 2016-2017.

Note: Designations used in Figure 7 and Figure 8: CS – computer science; SA – system analysis; ITD – information technology design; SCS – specialized computer systems; CN – computer networks; SP – system programming; ISM – information security management; SE – software engineering.

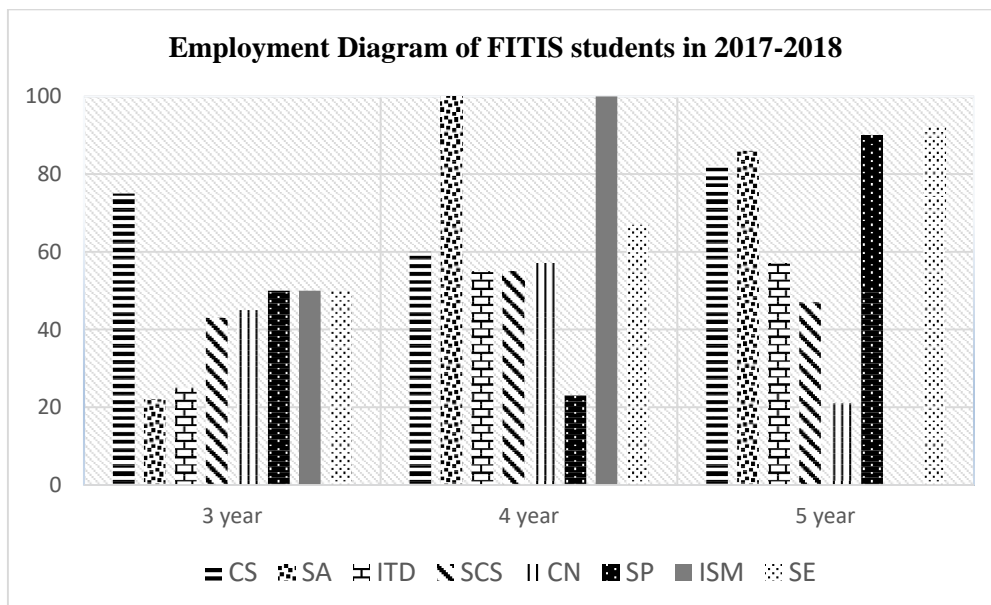


Figure 6. Employment Diagram of FITIS students in 2017-2018.

From the above data on the graph (figure 7) it can be seen that already during the third year of study a significant proportion of students works and on the 4th and 5th courses this figure increases every year. The increase of working students is due to the fact that the practical training takes place directly in IT companies or with their support, as well as through the introduction of elements of dual training.

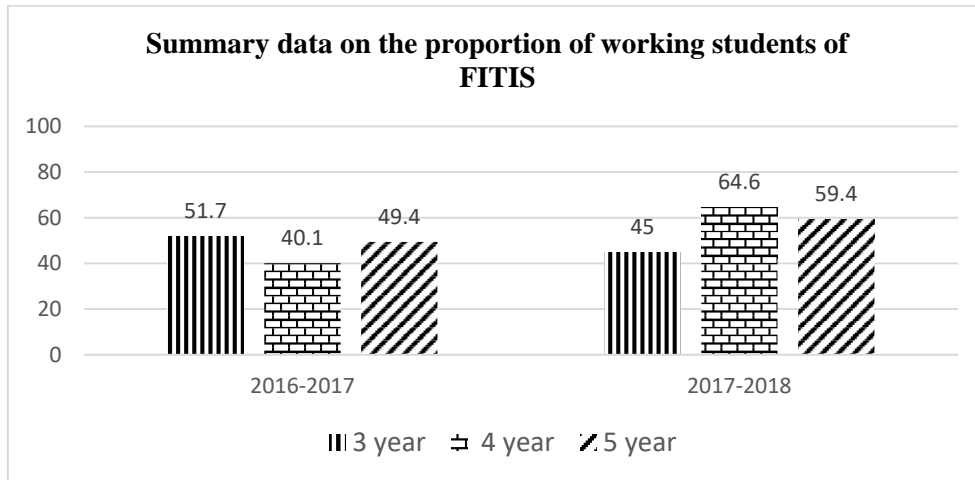


Figure 7. Summary data on the proportion of working students of FITIS.

The basic principle of dual education for future specialists in information technology is that the theoretical part will be learnt at the university and the practical part will be learnt at the enterprise, that is, lectures on professionally-oriented disciplines must be organized in the university classrooms, practical and laboratory classes in these disciplines – in the IT company or IT-department of the enterprise.

According to a survey among students of 1st-4th years of the FITIS ChSTU (about 500 respondents), the majority of them would like to visit enterprises in the framework of dual forms of training, starting with the second year (43.8%) and first year (34.4%), (figure 8), citing the opportunity to work on real projects and learn using innovative techniques under the guidance of leading practitioners. But the least number of respondents would like to visit enterprises in the framework of dual training forms, starting with the third year of study (18.7%) and fourth year of study (3.1%), that is, the majority of students believe that it is too late to start the dual education during the third and fourth years of study.

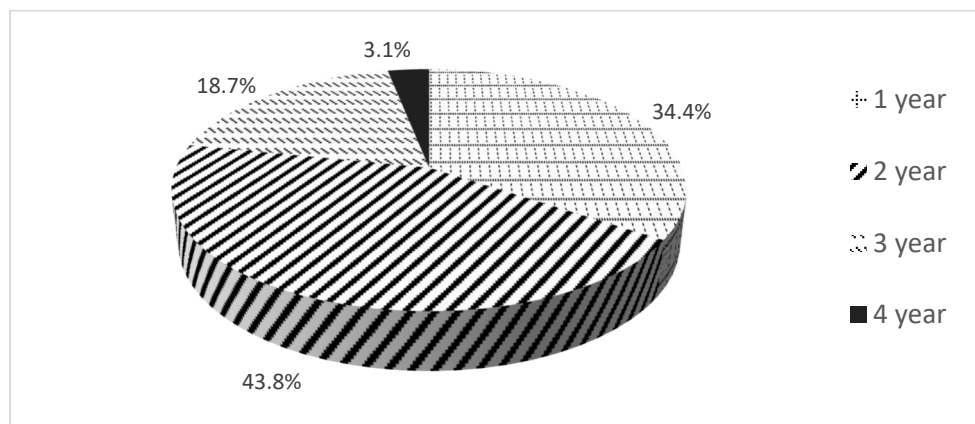


Figure 8. A chart survey of students in the dual form of training.

The introduction of elements of dual forms of higher education at the Faculty of Information Technologies and Systems provides the organization of learning in professionally-oriented disciplines, programs and participation of specialists (mentors) of IT companies, training of students with representatives of companies-manufacturers of hardware and software during production practices and extracurricular time with a view to their preparation for professional certifications from different areas of it, specifically in software testing (for the Ukrainian HI-Tech Initiative and QATestlab) [24], management information systems, configuration and maintenance of network equipment and cloud technologies (according to CISCO Networking Academy program) [10].

During September-December the students of specialty 121 “Software Engineering”, 122 “Computer Science” and 124 “System Analysis” took the course “Technology of software testing” at the University provided by IT company QATestLab in the framework of the cooperation agreement using appropriate teaching materials [15]. The course covered the main topics in software testing (testing techniques, test-design, test plans, preparation of report on testing results), working with bug-tracking systems, check-lists. The most interesting topics for students were related to mobile testing and game testing. All tasks were performed on the learning platform QATestLab and with the local access to their software. After each block of tasks students had to upload the reports on the performance of their work. All the obtained points the students could check on the company's website in their own cabinet. After a successful completion of the course, students had the opportunity to obtain appropriate certificates.

At the Centre of Health Information Systems of ChSTU, which operates under the Department of Computer Science and System Analysis (DCSSA), extracurricular training was provided for undergraduate and graduate students for certification in the administration of the medical information system “Doctor Eleks”, with the participation of specialists of the company “Doctor Eleks” (Lviv, Ukraine) [11], which is the developer of the medical system and the representatives of the DCSSA. The learning outcome was the successful delivery of audience certification exam, awarding them with the relevant document.

In agreement with IT partners of ChSTU some FITIS students of different courses, including specialties 122 “Computer science” and 124 “System analysis”, did an internship in IT companies “Master of Code Global”, “SPD-Ukraine”, “InterLink”, “Andersen” and “Triumph IT”.

The faculty has introduced the practice of forming project groups of students of different IT specialties and years to implement real projects during their studies. Although this is a voluntary and additional workload for students and teachers, project teams are still popular. Faculty teachers and professional mentors from IT companies, who are needed for these projects, constantly work with project groups.

The most powerful at the faculty now is the “Dean Office” project, in which students gain the knowledge and skills expected of them in IT companies.

The “Dean Office” project aims the development of a web-based software system working with the dean's offices and student learning activities information. The project started in November 2017 as a “Project Workshop on Programming”, and is now implemented as part of research work of the Department of Computer Science and System Analysis (CS and SA) “Development of information and analytical system to support educational activities of university structural units” (#110118U002315) [31] under mentoring of three Cherkasy IT companies: Master of Code, SPD-Ukraine and InterLink. Representatives of local IT teams advise students and motivate them to work. Representatives of IT companies note that the main advantage of the project is that inside university the students can work as real developers of software products using a stack of modern technologies. Because as soon as they are employed with an IT company, they are already expected to have that experience. By participating in such a project, students have the opportunity to consult with the supervisor and mentors from IT companies that communicate closely with them. Participation in such joint educational projects is an investment in the future by both students and IT businesses. While studying and participating in the project, students have good training and enter the IT market with a set of knowledge and skills necessary for a successful start of their career in IT companies. About 25 students of the faculty have already got such training within the project, most of them are employed in IT companies – the partners of the project.

Another element of dual education can be considered the participation of students of computer specialties in research and technological contracts of departments with IT companies for software development and implementation in enterprises where the informatization of production and management processes is made.

Thus, since 2016, CS and SA Department has performed four contracts for technological work to adapt and implement medical information systems in health care facilities in Cherkasy and Cherkasy region. More than 20 students of 3-4 courses and master's students took part in the implementation of these contracts. As a result of this work, a significant number of graduates were employed as software engineers in medical institutions, and 8 masters became employees of Triumph IT LLC as a computer systems analyst.

In general, this approach is in line with the concept of introducing dual education in Ukraine and gives FITIS students confidence in their professional future, because they see the results of their own developments in real IT companies. Students are more consciously beginning to relate to the formation of their individual educational trajectory, in particular when choosing the elective disciplines necessary for their own development, which is 25% of the disciplines of the curriculum of each specialty. In addition, students actively use the opportunity to study in vocational-oriented courses, trainings and webinars within the non-formal education offered by IT companies, and the faculty always supports them and creates favorable conditions.

8. Conclusion

The study on the implementation of the dual model of training in higher education at the university on the example of IT showed that the majority of companies willingly agreed to cooperate, if there were a wider variation of the terms of the agreement on cooperation between the enterprise and the institution of higher education.

It is impossible to fully organize the practical part of dual training due to the production particularities of some enterprises and due to the reason that the manufacturing processes or material base make it impossible to work out all the required competencies, necessary for the students in accordance with their specialty. In certain cases some of the competencies require admission of students to work on expensive equipment which is available only for experienced professionals, but an attempt to train students to work with it can result in significant material damage to the enterprise. Some businesses are willing to accept for training only a small number of students. All this must be considered when concluding agreements on cooperation between higher education institutions and enterprises in the framework of the dual form of higher education, in particular in the preparation of future specialists in information technology.

We hope that the first experience of introduction of dual forms of higher education in FITIS will give positive results and the computer science graduates will become more competitive in the IT market and innovative approaches in organization of educational process will find wide application in the university; therefore it will be interesting and useful for both present and future students.

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Role and place of Informatics in the training of future teachers of mathematics

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Abstract. The announcement of the 2020/2021 academic year as the Year of Mathematical Education in Ukraine and the adoption of the Concept for the Development of Natural and Mathematical Education (STEM-education) until 2027 were a response to the systemic crisis of mathematical training in general secondary education and training of mathematics teachers in Ukraine. The World focus on the integration of natural and mathematics, informatical and engineering education requires rethinking of the role and place of Informatics as a science, as a study discipline and as a basis of computer engineering in training future mathematics teachers. Nowadays, the teacher of mathematics should be capable for effective professional activity in a rapidly changing technology, educational paradigms and catastrophic educational disruptions, such as the current COVID-19 pandemic.

1. Introduction

The Law of Ukraine “On Basic Principles of Information Society Development in Ukraine for 2007-2015” defines the main strategic goal of information society development in Ukraine as the creation of an education system focused on the use of the latest ICT in the formation of a fully developed personality [19]. “Strategy for the development of the information society in Ukraine” [3] identifies a number of priority measures aimed at implementation of this strategic goal for improving the educational process, accessibility and efficiency of education: development of informational educational environment in the system of general secondary and higher education; creation of an information system to support the educational process; creation of a distance learning system with the effective use of information and communication technologies at all educational levels of all forms of education; development of methodological support for the use of computer technology in teaching of every disciplines; improvement of curricula, etc.

The State National Program “Education” (“Ukraine of the XXI Century”) [2] among the priority areas of education reform identifies, in particular, achieving a qualitatively new level in the study of mathematics. There are assumed the optimal combination of humanitarian, natural and mathematical components of education; widespread use of new pedagogical and information technologies with appropriate scientific and pedagogical, methodological and information support.

Decree of the President of Ukraine “On declaring the 2020/2021 academic year the Year of Mathematical Education in Ukraine” is directed at the creation of conditions for equal access to modern high-quality mathematics education and ensuring a modern level of teaching mathematics. Effective



teaching technologies should be based on best domestic and international practices [14].

Thus, there is a socially determined and legally justified need to improve the training quality for future mathematics teachers. One of the main components of this training is Informatics. So, the purpose of this article – to determine the role and place of computer science in training future teachers of mathematics.

2. Digitalisation as a basis for changes in natural and mathematics education

The meeting of the World Economic Forum in 2019 emphasized the changes in modern life and education in the era of the fourth industrial revolution (Industry 4.0). Manifestations of these changes was divided into physical, digital and biological by Klaus Schwab.

In particular, he includes to the physical innovations:

a) unmanned vehicles, which are controlled by user distantly or by software (based on machine learning methods);

b) 3D-printing, which provides the ability to materialize models created in computer-aided design systems;

c) advanced robotics, which is based on machine vision technologies, machine learning methods and other artificial intelligence technologies.

Klaus Schwab considers that such a representative of the digital block as the Internet of Things is “one of the main bridges between physical and digital reality” [15]. To build this bridge, workers of the near future must have the following leading skills: solving complex problems (projected demand – 36%), communication skills (19%), information processing skills (18%), system skills (17%), etc. Among other digital technologies in Industry 4.0, Schwab includes new computing technologies (mobile, cloud, and quantum computing), as well as blockchain and other distributed technologies. Among the technologies that change human existence, he identifies neurotechnology, augmented and virtual reality technology as the leading [16].

The development, implementation and effective use of Industry 4.0 technologies requires advanced key competences in mathematics, science, technology and engineering, and digital competence. This requires the transformation of education as a component of social transformation: from a society of steel and oil (III and IV technological stage) to the information society with computers, telecommunications and nanotechnology (V and VI technological stage). The main characteristic this society is a high level of information technology, developed infrastructures that provide the production of information resources and access to them, the processes of accelerated automation and robotisation of all branches of production and management, radical changes in socio-professional structures, resulting in the expansion of information activities.

The Recommendations of the 2016 Parliamentary Hearings on “Information and Communication Technologies Reforms and the Development of the Ukraine Information Space” [4] state that ICTs are becoming one of the most important factors of stimulating economic growth at the present stage of the global community’s transition to the information society. It is also stated that ICT help to bridge the “digital divide”. Regarding education and formation of ICT skills in the information society, it is recommended, in particular, to introduce compulsory study of programming principles in secondary schools within the subject “Informatics” and the subject “Programming” in senior classes of schools that specialise in physics and mathematics, information and communication technologies.

Among the especially relevant scientific, technical and socio-economic problems Myroslav I. Zhaldak refers to “problems of informatisation – the creation of a system of effective provision of timely, reliable and comprehensive information and data of all socially significant human activities, conditions for operational, thorough and comprehensive analysis of researched processes and phenomena, forecasting their development, predicting the consequences of decisions made. Their solution is inseparable from the solution of the problems of informatisation of the education system, which on the one hand reflects the achieved level of scientific, technical and socio-economic development of society and depends on it, and, on the other hand, significantly determines it” ([22], p. 8).

According to the Concept of Development of the Digital Economy and Society of Ukraine for 2018-

2020, the concept of digitalization was defined as the saturation of the physical world with electronic-digital devices, tools, systems and the establishment of electronic-communication exchange between them, which actually enables integrated interaction of virtual and physical, i.e., creates cyberphysical space [13].

The implementation of this Concept envisages radical changes in the field of education. Modern students need an interesting school filled with research and experiments using modern technologies. The use of digital technologies in school should be cross-platform in nature, i.e., to be used not only in Informatics lessons in a separate computer science class, as usual, but when teaching other subjects, when students interact with each other, with teachers, and with real experts, when students research and learn individually [6].

According to the Concept of development of digital economy and society of Ukraine for 2018-2020 [6] the main directions of digitalisation of education are:

- development and implementation of innovative computer, multimedia and computer-oriented learning tools and equipment for creating a digital learning environment (multimedia classes, research STEM-centers, laboratories, inclusive classes, blended learning classes);
- development of distance education using cognitive and multimedia technologies.

3. Relationships between mathematics and Informatics in the natural and mathematical field

Vladimir V. Laptev, Natalia I. Ryzhova and Mikhail V. Shvetckii [11] adhere to the definition of information technology as a set of systematic and mass methods of creating, accumulating, processing, storing, transmitting and distributing information (knowledge and data) by means of computer technology and communication, as well as the means of their integration and rational combination with non-machine information processing.

Zhaldak defines information technology as a set of methods, tools and techniques used for collection, storage organisation, processing, transferring and presentation of all kinds of messages and data [21].

The definition of new information technologies is also provided in the explanatory dictionary [1] as the technology for processing information and solving problems with use of computers, which is based on the achievements of artificial intelligence.

According to Andrey P. Ershov, applied informatics is a set of all types of human activity related to the use of software and hardware of the infosphere. The development of applied informatics finds its expression in the transfer to society of new information technologies of systematic or automated data processing in the interests of a particular human activity [9].

Laptev, Ryzhova and Shvetckii define informatics as a fundamental natural discipline, the object of which is the information processes that take place in the world. The basic concepts of informatics Laptev, Ryzhova and Shvetckii include information processes, structures of constructive mathematics (constructive objects and constructive processes), computer information models (data structures and algorithms), architecture of computing systems, and computational experiment [11].

We propose the definition of informatics as a complex scientific and engineering discipline, the object of which is information processes of any nature, and the subject is new information technologies that are implemented using computer systems, and the methodology of informatics is a computational experiment.

Ershov notes the relationship of informatics to natural sciences: “Realizing some relativity of the division of science into natural and social, we assume informatics as natural science, according to the idea of the unity of the laws of information processing in artificial, biological and social systems” [8].

Laptev, Ryzhova and Shvetckii refer to informatics as a fundamental science, which reflects the general scientific nature of the concepts of “information” and information processes. As a fundamental science, informatics is associated with many other scientific fields, such as philosophy (in particular, epistemology and the doctrine of information), mathematics (in particular, algebra, mathematical logic and algorithm theory, the theory of mathematical modeling), linguistics (in particular, the doctrine of formal systems and formal languages), as well as information and management theory [11].

Mathematics is not only a parent science for informatics. This opinion is shared, in particular, by

Ershov, who believes that informatics itself in its formation necessarily uses mathematics in its basic principles and methods. That is why the methods of informatics penetrate into the depths of mathematics and affect some features of style, technique and content of mathematical education and activities: “the whole course of objective development of informatics shows that mathematics was not only the mother science for her, but also informatics itself are steadily mathematized in process of its formation and separation in its grounds and methods. Moreover, there is more and more evidence that the methods of informatics, certain information technologies penetrate into the depths of mathematics, affect some features of style, technique and content of mathematical work” ([9], p. 2).

Ershov demonstrated a parallel set of concepts of mathematics and informatics (table 1), which support the most important for informatics concept of performer (mathematical analogue – the concept of “algebraic system”), at the Sixth International Congress on Mathematical Education in the Plenary Report [9]. Ershov believed that the development of this connection is the mathematisation of the basics of informatics [8].

Table 1. Equivalence of concepts in mathematics and informatics.

<i>Mathematics</i>	<i>Informatics</i>
Algebraic system (Algebraic structure)	Executor (robot, computer, person in a certain role)
Set (Domain)	circumstance
Occurrence of a set	State of circumstance
Operation	Action that change the circumstance
Predicate	Questions to the circumstance
Signature	System of executive commands
Protocol (Sequence of operations and predicates with their values + initial element)	Activity (the sequence of actions and questions to the circumstance, starting from the initial state)
Predicate – precondition	Condition of the problem
Predicate – postcondition	Purpose of the problem
Valid protocol that implements the corresponding predicates of precondition and postcondition at the ends	Solving the problem (activity that leads from a state that satisfies the conditions to a state that satisfies the purpose)
Program (subcursive set, which includes a large number of valid protocols)	Program (finite instruction that defines the activity leading to the purpose for each state that satisfies the condition)

The relationship between computer science and mathematics was also pointed out by Aleksei L. Semenov. He emphasized that informatics has a theoretical core, which is closely related to mathematics, explaining that “the fundamental natural science part of informatics builds theoretical models of the processes of processing, accumulation and transmission of information. By its object, concepts and methods, it is a branch of mathematics. The subject of its study are the final (constructive) objects and algorithmically described (constructive) processes that occur in the environment of these objects” ([17], p. 54). Semenov calls this part of informatics “mathematical informatics” and notes that the foundation of mathematical computer science was laid in attempts to model the processes of human algorithmic activity.

In the development of mathematics as a science, Mikhael Gromov notes the role of informatics: “As the body of mathematics grew, it became itself subject to a logical and mathematical analysis. This has led to the creation of mathematical logic and then of the theoretical computer science. ... It absorbs ideas from the classical mathematics and benefits from the technological progress in the computer hardware which leads to a practical implementation of theoretically devised algorithms. ... And the logical computational ideas interact with other fields, such as the quantum computer project, DNA-based molecular design, pattern formation in biology, the dynamics of the brain, etc. One expects that in

several decades computer science will develop ideas on even deeper mathematical levels which will be followed by radical progress in the industrial application of computers, e.g., a (long overdue) breakthrough in artificial intelligence and robotics. ... As the power of computers approaches the theoretical limit and as we turn to more realistic (and thus more complicated) problems, we face the "curse of dimension" ... Here one needs a much higher level of mathematical sophistication in computer architecture as well as in computer programming ... Successes here may provide theoretical means for performing computations with high power growing arrays of data." [10].

4. Informatics in the modernization of training of future teachers of mathematics

There are higher education institutions of various types in Ukraine. Thus, the training of future teachers is conducted in multidisciplinary (classical) universities and branch (pedagogical). According to the Concept of development of pedagogical education [5], pedagogical education is a system of professional training of pedagogical workers to carry out pedagogical activity. At the same time, the professional qualification of a pedagogical worker is a standardized set of acquired competencies (dynamic combination of knowledge, skills and practical skills, ways of thinking, professional, ideological and civic qualities, moral and ethical values [20]) that is certified by the relevant document and allows to carry out professional pedagogical activities.

The training of future teachers must meet the public demands formulated in professional and educational standards, take into account global trends and recommendations of influential international organizations for teacher training. Teacher training programs contain components of psychological, pedagogical and practical training, including teaching methods and the use of information and communication and digital technologies. Modernization of educational programs should include, in particular, their focus on the formation of future teachers' research skills and mastery of information and communication technologies [5].

The importance of mathematics for the socio-economic and technological development of Ukraine is noted in the Law of Ukraine "On Higher Education", the list of acutely deficient specialties of which includes specialties of the fields of knowledge 01 – Education/Pedagogy, 11 – Mathematics and Statistics, 10 – Natural Sciences and Engineering. In particular, for entrants to natural-mathematical and engineering-technical specialties the corresponding privileges are provided.

The focus on improving the mathematical training of entrants is also reflected in the fact that, starting in 2021, external independent assessment in mathematics in Ukraine will be mandatory. As Liliia M. Hrynevych pointed out, "... from 2021 we plan to introduce a mandatory state final examination in mathematics in the form of external independent assessment. ... Mathematics plays a special role in the cognitive development of children, so its study is extremely important. Basic skills in mathematics are necessary for everyone – it develops logical and abstract thinking. And these are the skills that all people need. And more and more countries are making the external math exam compulsory for all children after school. ... We are now seriously preparing to strengthen from 2021 both the study of mathematics and English. These subjects are extremely important for a person, who wants to be competitive in today's world" [13].

The formation of mathematical competence of pupils requires a high level of professional competencies of mathematics teachers. The Concept of the State Targeted Social Program for Improving the Quality of School Natural and Mathematical Education for the Period up to 2015 emphasized that improving the quality of school mathematical education is a necessary condition for the formation of an innovative society and increasing the competitiveness of the economy. The Program was implemented together with the Action Plan to improve the quality of physical and mathematical education [12], which, in particular, provided for the need:

- to modernize the standards of higher education in the areas and specialties of physics and mathematics, including pedagogical profile;
- to bring the content of school physical and mathematical education in line with the modern development of science and social needs of society, to ensure the applied orientation of the content of curricula in mathematics and natural sciences;

- to improve the content of curricula in basic mathematical disciplines, taking into account the computerisation of all types of engineering activities (discrete and computer mathematics, fuzzy methods and “soft” calculations);

- to provide informatization of higher physical and mathematical education by including in physical and mathematical disciplines laboratory workshops with the system of computer mathematics, means of visualization of calculations;

- to ensure the teachers training for the formation of pupils' skills to interpretate quantitative information presented in tables, charts and graphs; to teach pupils to obtain the necessary information independently, analyze it, perform calculations and choose the best solution.

The realization of the tasks set in the Program and the Plan is impossible without thorough computer training of future mathematics teachers. The analysis of normative documents provides an opportunity to identify the following areas of modernisation of training of future teachers of mathematics:

- improving the system of professional information competencies of future mathematics teachers;
- introduction of computer mathematics systems in methodical systems of teaching mathematical disciplines with their subsequent transformation into computer-oriented ones;

- renewal of computer-oriented systems of teaching informatics of future mathematics teachers based on the widespread use of models and methods of mathematical computer science, in particular, through the integration of programming systems and computer mathematics in a cloud-based environment.

According to the Decree of the President of Ukraine “On declaring the 2020/2021 academic year as the Year of Mathematical Education in Ukraine”, the Cabinet of Ministers of Ukraine developed an appropriate action plan [7] to achieve given aims: ensuring equal access of pupils to mathematics; implementing modern technologies of mathematics; improving resource providing the educational process; increasing the motivation of pupils to study mathematics and its application in life; popularization of mathematics education. Among these actions the such:

- ensuring the introduction of training courses “Logic” and “Mathematical Logic” in the curricula of grades 1-11 of general secondary education;

- organization of summer “mathematical schools” for professional growth and formation of a professional community of teachers;

- development of methodical recommendations and practical tools for the use of interdisciplinary connections of mathematics with other educational disciplines;

- equipping general secondary education institutions with equipment for STEM laboratories.

According to Myroslav I. Zhaldak, such problems become important: 1) integration of educational disciplines, in particular mathematics, physics, informatics and others; 2) differentiation of training in accordance with the inclinations, requests and abilities of pupils. Informatics to some extent solves the problems of such integration, studying the general properties of information processes, laws and rules of search, creation, storage, analysis, systematization, processing, transmission, presentation and use of various messages and data. The integration of mathematics and informatics and other subjects cannot be reduced to their mechanical combining in the existing form. Existing modern computer-oriented methodological systems of training, on the contrary, are aimed primarily at the holistic perception of the studied phenomena, elucidation of their essence, the links between their individual manifestations, in particular: analysis of the semantic side of obtained formal solutions; development of synthetic, figurative thinking along with logical, analytical; abstraction from the technical details of the analysis of models of the studied phenomenon; problem statement; putting forward hypotheses, construction of information (including mathematical) models of researched processes and phenomena; material interpretation of the results obtained with help of computers ([22], p. 10).

Characterizing the impact of computerisation on mathematical education, Andrey P. Ershov outlines the following areas of influence [9]:

1. Sharp expansion of mathematical practice: “computerization is both a means and an expression of the expansion of mathematical knowledge”.

2. Changing the nomenclature of mathematical knowledge: “Abstractions of human activity, the

properties of artificial and living (biological and socio-technical) systems are included to substantive part of mathematics through programming and construction of information models. All this sharply enhances the role and place of discrete mathematics. This is facilitated by the shift in physics towards the quantum properties of matter”.

3. Systemic role of mathematical theory.

4. Computational experiment with a mathematical model: “its role in engineering practice is well known”; “its practicality as a new method of cognitive activity in the educational process is also confirmed by pedagogical practice”; “in recent years, the computational experiment has increasingly become a source of purely mathematical discoveries”.

5. Visualization of abstractions “... must be observed at the educational level between the abstract mathematical object and its visual model ... The importance of a bright visible image for the activation of the young mind is well known to every teacher, educator and psychologist”.

6. Dynamization of mathematical objects: “The computer with its means of visualization and computation help the observer to extract from the static packaging of mathematical relations all sorts of trajectories of the dynamic process in time and space, thus enriching his experience, intuition and ability to predict. All this brings the learning process closer to research and experiment”.

7. Formation of a structure out of chaos: “Among the possibilities provided by mathematical experimentation and the ability of the computer to visualize, special mention should be made of experiments to observe the formation of regular structures from the initial disorder. ... Here is formed a completely new and extremely powerful channel for the spread of mathematical knowledge to a huge class of natural phenomena: the movement of continents, the formation of the coastline, mountain landscapes, aurora borealis, plant formation, animal coloring, evolution of conflicts and genesis of crises. ... the material supplied by the synergetics and mathematics of the nonlinear give us possibility to draw an important educational conclusion about the fundamental importance of computational experiment as a cognitive tool: if the source of everything new in nature is nonlinearity, then speculative prediction of the extrapolation type is linear in nature and therefore it is limited in its cognitive power, for example, any conclusion in existing axiomatics. Therefore, the extraction of truly new knowledge requires a nonlinear synergistic process either in the human brain or in computer memory”.

8. Forming of basic abilities and skills: “... a computer with the possibility of direct manipulation with visual images of mathematical objects in artificial worlds can make ... the task of pre-mathematical ... education a subject component of the educational process, especially in primary education and in early adolescence. These are logical tasks and competitions in calculations in mind, drawing up and following the “rules of the game”, constructing artificial worlds, direct manipulation with mathematical objects, managing executors, planning their activities and much more”.

9. Awakening of primary interest: “... the dynamic, visual, obedient and stimulating style of computer behavior makes it an ideal tool for awakening the initial interest in mathematics, its beauty, surprise, prophetic power and magical connection with everything around”.

Vladimir M. Tikhomirov notes: “Mathematical education should include teaching computers, computer technology and modern information capabilities. These are the trends of the new time, and there is no doubt that the new century will be the age of Computers, as well as the centuries of Steam, Electricity, Atom. And it must be borne in mind that in mathematics itself there are events of paramount importance that must be included in mathematical education (catastrophe theory, fractals, discrete mathematics, etc.)” [18].

Considering the trend of mathematics development, attention is drawn to the close links between mathematics and informatics, which are manifested in the introduction of mathematical methods into informatical disciplines, and informatics methods penetrate into mathematics, influencing the content and means of mathematical activity. This is evidenced by the emergence of a new field – computer mathematics. The use of computers and information technologies make it possible to enrich mathematical science, expand its application, and significantly influence the mathematical activity itself (content, methods and means).

That is why high-quality training of a mathematics teacher is impossible without the formation of

key and professional informatics competencies. To do this, the student must have a range of knowledge and skills for the full use of ICT in the educational process.

5. Conclusion

The analysis of the current state of informatisation of society, the development of informatics and areas of reform of science and mathematics education provided an opportunity to draw the following conclusions:

1. Digitalising of education as a component of society requires a comprehensive integrated use of models, methods and means of informatics in teaching subjects of any field. At the same time, the prospects for the development of digitalising means should be reflected in the advanced content of teaching informatics disciplines at all levels of education. As a result of the analysis it is safe to say that the problem of training of future teachers in informatics needs special attention, because it is the teacher who must implement information and communication technologies directly into the educational process, form pupils' competencies in informatics, prepare a new generation for life in today's information society.

2. 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 technology. The definition of informatics as a complex scientific and engineering discipline, the object of which is information processes of any nature, and the subject is new information technologies that are implemented using computer systems, and the methodology of informatics is a computational experiment, provides an opportunity to consider it as a basis for integration natural sciences, ICT, engineering and mathematics in STEM education.

3. The main directions of modernisation of professional training of mathematics teachers are digitalising of research-oriented study of mathematics, informatisation of the learning content of mathematical disciplines and strengthening of training of mathematics teachers in informatics, in particular, programming of cyberphysical systems. Thus, it can be argued about the decisive role and place of computer science in the training of future mathematics teachers in Ukraine and around the world.

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Methodic quest: Reinventing the system

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Abstract. This article is an attempt to rethink the concepts of “methodic” and “methodologic / methodical system” as basic to educational technology. What should be the structure of a methodical system? What is primary – the methodical system or the methodology? How are methodical systems created and developed? How do educational technology and a methodical system relate? How does changing the components of a system make it emergent? These and other issues are explored through the development of a new class of teaching methods – computer-based training systems.

Essentially, all models are wrong, but some are useful [6]
George E. P. Box (1919 – 2013)

1. Instead of introduction: What is method?

A quest is a journey to complete a specific mission or achieve a goal. In literary works, the quest is most often used to show the development of the protagonist – he changes himself and changes others. Vladimir Ia. Propp points out that in all such tales (or, more correctly, tales of quests) there is a common structure of about 150 steps ([25], p. 134).

The protagonist of our quest will be the “method”, or rather the “Method of Teaching” and its journey between the science of learning and the art of teaching [33]. As noted by Beatrice H. Barrett in the preface to the 2003 reprint of the paper by B. F. Skinner, “It represented the first attempt to apply a scientifically validated conceptual methodologic system to classroom instruction. ... His methods form a fundamental component in the mosaic of success fulprocedures which, when combined by those fluent in experimental and conceptual ... analysis, produces more dramatic gains than ever before documented – at all education levels” ([34], p. 11).



The Grand Explanatory Dictionary of the Ukrainian Language defines *methodic* as: a) a set of interrelated methods and techniques for carrying out any work; b) a document that describes a sequence of methods, rules and tools for carrying out work; c) the teaching of a particular science, subject matter ([8], p. 664). The first interpretation of methodic is the most general, the second reflects the level of its formalisation in written methodic, and the third specifies written methodic related to the teaching of a particular science or subject. Thus, the teaching methodic of informatics, mathematics, economics, history, German, etc. is a particular (specified at science and subject level) written methodic.

The auxiliary concepts are:

- *mode* – a) a particular action, technique or system of techniques that enables something to be done, accomplished, achieved; b) something that serves as a tool, means, etc., in an action ([8], p. 1375);
- *technique* – a way of doing or carrying out something; a method of researching, studying something ([8], p. 1117);
- *method* – a technique or system of techniques used in an area of activity ([8], p. 664);
- *rule* – a) a regulation that conveys a regularity, a constant relationship of certain phenomena; b) a principle that guides; c) a collection of regulations that define the conduct or observance of something ([8], p. 1100);
- *means/tools* – a) a special action that makes it possible to do something, to achieve something; b) something that serves as a tool in any action, cause; mechanisms, devices, etc., needed to do something, for any activity ([8], p. 420).

The synonymy of some of the above concepts is related to their dual interpretation:

- the mode can be as a system of action or as a means of action, mental or material,
- the technique combines a mode and a method of research,
- method is equivalent to technique,
- the rule is both a principle and part of the methodic,
- the means is equivalent in content to the method.

In order to avoid undesirable duplication, we will assume that the leading concepts of methodic are the interrelated concepts of “means” (mode or tool of activity, mental or material) and “method”, while the auxiliary concept is “principle”. For each particular teaching methodic, these concepts should be made more specific.

The essential characteristic of a methodic is the interrelation of means and methods, which, for a written methodic, should be defined in a specific order of their application to carry out the work – the algorithm for achieving the goal. This makes it possible to identify additional components of the methodic that reflect the described content of the activity, its purpose and result, and also raises the question of the existence of links between them and the interrelated means and methods.

For teaching methods, the activity content is the content reflecting the core activity – the learning content. Learning outcomes can be formalised in different ways – e.g., in terms of competencies.

The Grand Explanatory Dictionary of the Ukrainian Language defines order, due to the correct, orderly arrangement and interconnectedness of something, as a system ([8], p. 1320). However, a system is also: a) a form of organisation, a structure of something; b) a set of elements, units, parts united by a common feature, or purpose; c) a set of principles that form the basis of a certain doctrine; a set of modes, methods, techniques for implementing something; d) a composition, a structure that constitutes a unity of regularly arranged and functioning parts.

Thus, a methodic is by definition a system, so we can talk about methodical systems in general and methodical training systems in particular, about the methodical training systems of a particular academic course.

2. Modelling teaching systems: from hierarchy to multidimensionality

The *traditional methodical system* of teaching is defined by Yurii V. Tryus as a set of interrelated components: learning objectives, content, methods, tools and forms of learning organisation, which create a unified holistic functional structure oriented towards the achievement of learning objectives [41].

According to Anatolii M. Pyshkalo [26], the objectives, content and educational process (methods, tools and forms of organisation of learning) together form a methodical training system, which can be represented as a linear hierarchical structure (figure 1).

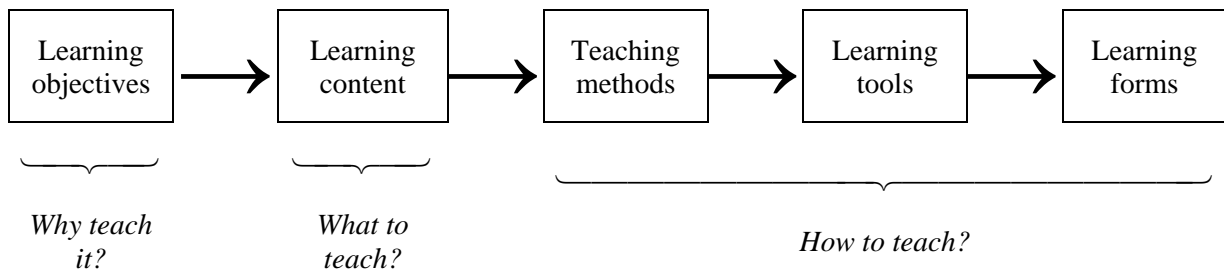


Figure 1. A hierarchical model of a methodical training system.

The hierarchical model does not reflect the inherent relationship between methods and tools, but can be seen as an option for subordinating the components of a methodic (ordering by importance). According to the hierarchical model:

- the learning objectives determine the content, which can be varied because the same objectives can be achieved by mastering different learning content,
- an analysis of learning content enables the best combination of teaching methods to be chosen,
- the effective implementation of a particular teaching method takes place in certain forms of organisation of the learning process,
- the methods and forms of organisation used determine the use of appropriate learning tools.

The problems of the hierarchical model are most significant in informatics teaching, where computer-based learning tools are often the object of study, the mastering of which determines the appropriate learning objectives. Therefore, at the present stage of development of the education system and its informatization, the hierarchical model of the teaching methodical system is no longer adequate to the situation in teaching not only informatics, but also other courses, and needs to be developed accordingly ([19], p. 184).

Yurii V. Tryus defines *computer-oriented methodical training system* as a methodical system of training which provides a purposeful process of acquiring knowledge, gaining abilities and skills, mastering ways of cognitive activity by a subject and developing his creative abilities through extensive use of information and communication technologies [41], which involves changes in both individual components of the methodical training system and the nature of links between them.

Alexander A. Kuznetsov and Tatiana N. Suvorova emphasises that significant changes in educational outcomes are only possible with the transition to a modern information and education environment, and only in such an environment will the use of innovative forms of organisation, new methods and corresponding learning tools, which meet the needs of the subjects of the environment, enable a significant impact on the achievement of educational outcomes ([19], p. 186).

Tatiana Yu. Kitaevskaya notes that at the present stage education is transformed from a means of mastering ready-to-use generally accepted knowledge into a means of information exchange of a personality with the surrounding world, and the educational environment is transformed into a multi-component information and educational environment. In this connection, the methodical training system is becoming an open system under the conditions of wide informatization of society. Thus, it is advisable to consider the structure and functioning of an informatics teaching system from the perspective of a *system approach*, in particular, the theory of dynamic open systems, the main features of which include the following two main factors:

- 1) the presence of bifurcation points, i.e. unstable positions from which the development of the system can, with equal probability, follow one of the possible alternatives,
- 2) the existence of attractors – stable dynamic structures that emerge during the development of the system ([16], p. 296).

There should be a *dynamic balance* between all components of the methodical system – a system state characterised by: a) optimal content of the methodical system components: goals, methods, tools and forms of learning organisation; b) potential opportunities for their change under the influence of external information and educational environment; c) striving of the methodical system to find the optimal balancing state and to stay in it by using both traditional and new methodical resources ([16], p. 297).

Tatiana Yu. Kitaevskaya understands the development of the methodical training system as a transition to a new qualitative level based on advanced informatization tools and information technologies, aimed at achieving the predictable result. “The development of a methodical system for teaching informatics in higher education institutions based on the model of an integral system of the educational process, which ensures the organisation, management and orderliness of all elements, as well as its improvement, is a natural step in the development of the education system” ([16], p. 296). System stability is interpreted by the author as a state of sustainable movement, development of the system due to the interaction of system components as well as the interaction of the system with the external information environment ([16], p. 297). In accordance with the general principles of effective functioning of the system, which include *the integrity of the system* (a high degree of interconnection of all its components), *strengthening the integrity of the system* (constant strengthening of the durability of the links between its components), *compatibility of the system with the conditions of functioning* (ensuring compliance of the internal organization of the system and external conditions of its functioning with objective system needs, necessary for its existence and development as an organic integrity), *optimisation of the system* (ensuring a high degree of compliance of the system components with the objectives for which it was created), Tatiana Yu. Kitaevskaya proposes the following principles as the basis for the methodic system of teaching informatics, which ensure the effectiveness of the system:

- focusing on the final goals of informatics training in higher education institutions,
- structuring the informatics teaching process as a goal-oriented programme,
- aiming to achieve harmonious interaction between all elements of the informatics methodical training system, both within a single course and over the whole period of study of the informatics cycle courses,
- correspondence of the methodical system for teaching informatics in higher education institutions to the changing conditions of its functioning (ideology of higher education development, structure and organisational forms of higher education institutions, general trends of scientific development, regional and university peculiarities, etc.) ([16], p. 296).

Sergei V. Shcherbatykh supplements them with the principles of:

- the comprehensiveness of the five components of the methodical system and the coherence of its components (objectives, content, forms, methods and learning tools),
- universality: the designed methodical training system should fit into any individual methodical system, developing and improving it rather than destroying it,
- extensibility: revealing material that is important for future careers by superimposing it on the core content,
- invariance and variation: identifying, selecting and constructing invariant forms, methods and tools that are necessary to achieve the learning objectives,
- predictability: anticipating learning outcomes through a professional application orientation in order to make the necessary adjustments to the content and learning process to achieve the expected outcome ([32], p. 19-20).

Natalia A. Burmistrova adds the principles of professionally directed teaching:

- continuity: the professional orientation of learning should be realised through all forms of organisation and teaching methods, forming the cognitive motivation of students,
- contextuality: defines the orientation of education towards a professional context, which implies considering the content of subject (e.g. informatics) training as a subsystem of professional education content and makes it possible to identify professionally relevant topics and rationally allocate time for studying theoretical and applied sections,

– integrativity: reveals the interdisciplinary integrative nature of mathematics training and is manifested in the links between the courses implemented by means of mathematical modelling and computer technologies, taking into account orientation and vocational education,

– priority for creative activities: aimed at enabling students to gain experience of creative activities in order to develop the ability to adapt to non-standard life and professional situations ([7], p. 19).

Yurii V. Tryus identified the main conceptual statements for the creation and implementation of computer-oriented methodical training systems [41]:

1) constructing on the principles of:

– gradual and non-antagonistic incorporation of information and communication technologies into existing didactic systems,

– a harmonious combination of traditional and computer-based learning technologies,

– the continuity of pedagogical achievements (classical and new promising), not contesting or rejecting past experience, but on the contrary, improving and strengthening it, including through the use of advances in computer and communication technology development;

2) taking into account of:

– the main principles and main trends in the development of higher education in the world at the beginning of the twenty-first century,

– the main ways to reform the higher education system in order to overcome its most characteristic shortcomings,

– the basic principles for building forward-looking higher education systems,

– the basic principles of higher education development in Ukraine;

4) based on contemporary concepts, approaches and principles of higher education pedagogy and psychology, such as:

– the concept of integrity of the learning and upbringing process of a higher education institution,

– the concept of enhancing students' learning and research activities,

– the concept of flexible pedagogical technology,

– systemic, structural and integrated approaches,

– activity-based, developmental (creative) and subjective-subjective approaches,

– a differentiated and individualised approach,

– person-centred and competence-based approaches.

The design of computer-oriented training systems should be based on the basic principles, patterns and approaches used in designing and creating methodical training systems.

The openness of a methodical training system immersed in a multi-component information and education environment is manifested through the internal dynamics of its elements: objectives, content, methods, tools and forms of learning organisation, as well as the links between them. The methodical system of informatics teaching should be considered in dynamics, and its design should include the analysis and correction of components and links between them, as one of the necessary stages of the technological chain of construction, ensuring the productive functioning of the system; take into account the interaction of the system with the environment; its changes over time, the possibility of evolution ([16], p. 297).

Tatiana Yu. Kitaevskaya believes that the ways for improvement in the methodical system of informatics teaching include:

– the model for a methodical system for teaching informatics is based on the fact that it is, on the one hand, a complex system and, on the other hand, an integral part of the informatization of education,

– structural and functional changes to the components of the system should be aimed at the technologization of the learning process,

– the components of the system are modelled on the principle of differentiation,

– the system model takes into account the need to move towards new principles and technologies of content selection, allowing for constant modification and flexible structuring with a view to selecting individual learning paths,

– the system components are designed taking into account the main factors affecting their dynamics ([16], p. 298).

The process of improving a methodical system of teaching a particular subject follows the below regularities:

1. Changing one or more of the components of a methodical training system involves changing other components and possibly the whole methodical system ([18], p. 17). Thus, a change in objectives entails a change in content, which in turn leads to a change in the methods, means and forms of teaching the course, and consequently in the links between them. At the same time, it is important that the constructed system is *structurally stable*, i.e. that small changes in its components do not affect the performance of the system as a whole: “the isolated design of individual components of a methodical system can lead not only to structural instability of the system, but even to a breakdown of its integrity and thus to the destruction of the system” ([16], p. 297). Thus, the design of an open methodical system aimed at a coherent change in the main components of the system should be based on the principles of dynamic balance, structural stability of the system and feedback.

2. Any methodical training system is inextricably linked to reality, which has a decisive influence on it. The main teaching objectives of a methodical system are the learning objectives in which society shapes the social order for the education system ([18], p. 17). The ability to adapt to rapidly changing external conditions (adaptability) is one of the necessary properties of a methodical system ([16], p. 297).

Oleg A. Kozlov believes that it is advisable to base the formation of training objectives in general and, in particular, of basic informatics training on the activity-based approach: “it makes it possible to construct an invariant information component of the model ... of a specialist in the form of a fragment of a qualification characteristic” ([18], p. 32). Thus, defining training objectives in terms of a specialist model – in particular his/her professional competencies – corresponds to the application of an *activity-based* and *competence-based approach* to specialist training. The approach proposed by Oleg A. Kozlov, which ensures that the learning objectives are reflected in the content of the basic informatics course, is based on a parallel specification of learning objectives and content, which uses *the modular principle* of building the content of the course ([18], p. 32).

Nataliia A. Burmistrova points out that when applying the “competence-based approach there is a need to change ... learning objectives ... in connection with the transition ... to integrative learning outcomes, which, in turn, provides for the implementation of technological approach to learning, which highlights as one of the requirements to the formulation of objectives its diagnosticity (objectives should reflect the projected learning outcomes). In the logic of competence approach the goal of learning ..., consisting in the construction of students ... knowledge, skills, abilities, personal qualities included in the content of general cultural and professional competences” ([7], pp. 18-19), individual experiences of which form the basis of the informatics competencies of future mathematics teachers.

Aleksandra A. Tolsteneva divides learning objectives into educational (improving students' level of education), upbringing (forming professional orientation of personality and value attitude to the study of the course) and developing (formation of informational mobility) ([39], p. 24).

The main *objectives of informatics teaching* in higher education institutions are dictated by the social and economic needs of society, the level of technological development, the trends in the development of the methodical system of teaching the subject, the prospects for the development of the higher education system and are formulated through the social order for training specialists ([16], p. 296). The transformation of learning objectives begins with changing the starting points of their genesis and establishing a link to the predicted learning outcomes. Defining objectives then requires not only an analysis of relevant educational development documents (indicating social demand on the level and nature of education), but also a description in terms of measurability and diagnosability ([19], p. 185). Thus, the projected methodology defines levels of informatics competencies and diagnostic tools – matrices describing each competency component at the corresponding level.

The learning content is changing to take account of prospective developments in technologies in order to provide advanced training with the extensive use of e-learning resources. Liudmila L. Bosova

defines the following set of requirements for selecting and structuring informatics learning content: coherence (the learning content of a particular informatics course should be interlinked with others), continuity (all informatics courses should have cross-curricular content lines), meta-disciplinary focus (learning content should be selected to ensure the development of both key and professional competences), taking into account the needs of the subject of learning for self-realisation and self-development, and the foundation of learning content on the basis of a didactic spiral ([5], pp. 27-28).

The main changes regarding *learning forms* are related to the gradual loss of importance and absolute priority of the classroom-based (lecture and class) system over other forms, in particular individual learning. The current level of ICT development makes it possible to create electronic educational resources for adaptive learning, in which in the process of modelling the learner (student) is individualized learning by taking into account his or her diagnosed individual characteristics in achieving learning objectives. In addition, modern ICT tools make it possible to apply such forms of learning organisation as video lecture, webinar, remote consultation, etc. ([19], p. 185).

Teaching methods change considerably: traditional methods are being implemented in new contexts, e.g. illustrative method is actively supported by demonstration software and information retrieval systems; project method, which started long before the development of modern technologies, is now implemented through a wide range of software tools. Moreover, the implementation of ICTs has brought to life a number of new teaching methods (training computer modelling, falsification method, precedent method, associative method, etc.). ([19], p. 185).

Traditionally, *learning tools* have been clearly defined by teaching methods, but as learning tools have become much more capable, the situation has changed and they have a much higher degree of influence on computer-oriented teaching methods, which are more characterised by a flexible system in which formerly lower hierarchical elements begin to influence higher ones and even change their position in the system. This trend is particularly evident in the increasing role of e-learning resources as learning tools that are beginning to largely shape technology components (learning forms and teaching methods) and learning content ([19], p. 185).

Alexander A. Kuznetsov proposes a two-level model of a computer-oriented methodical training system in which the learning objectives are the determining ones (figure 2). However, in modern conditions, the components of the methodical system are in a specific relationship, far from top-down hierarchical subordination, and mutually influence each other, as reflected in Illia O. Teplytskyi's model (figure 3).

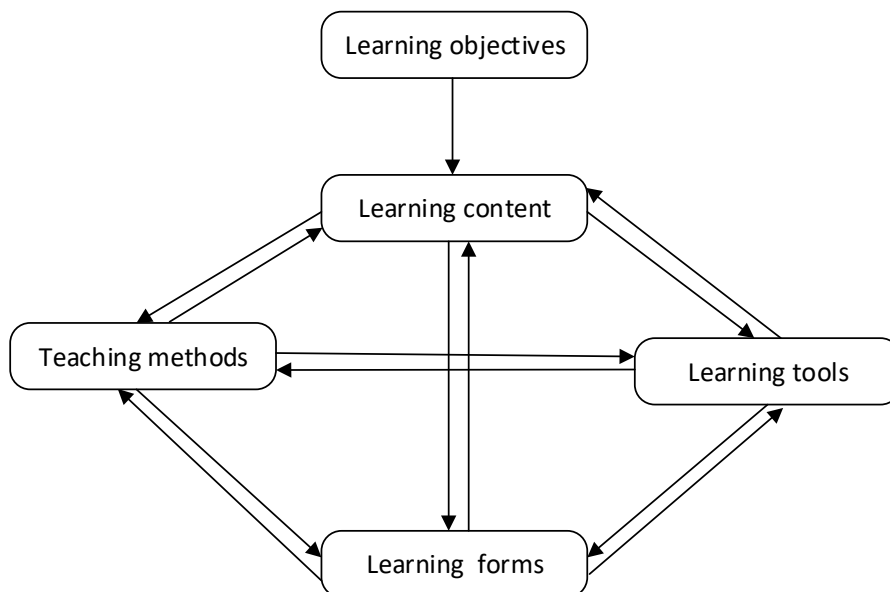


Figure 2. Links between the elements of a methodical training system in an informal learning context (model by Alexander A. Kuznetsov ([19], p. 186)).

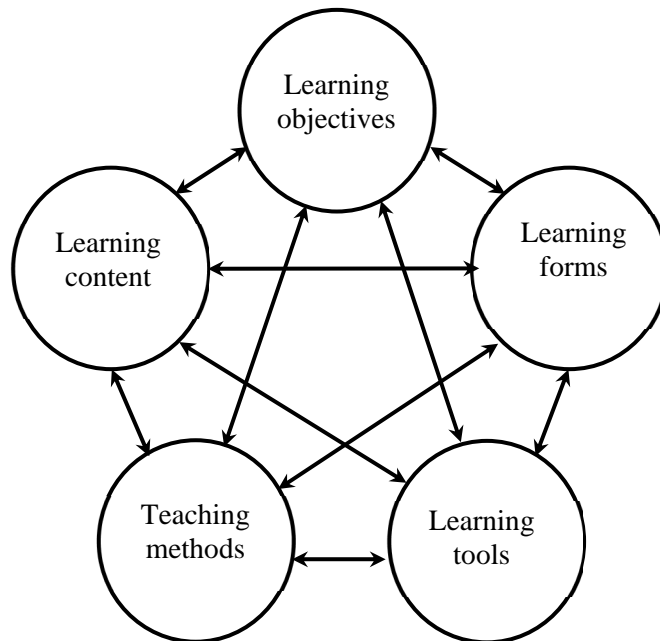


Figure 3. A full-linked five-component model of a methodical training system (by Illia O. Teplytskyi ([36], p. 90)).

Nataliia A. Burmistrova proposes a similar model, consisting of purposive (learning objectives), organisational (learning forms), procedural (teaching methods and learning tools) and content (learning content) components linked through learning outcomes (figure 4). The model by Nataliia A. Burmistrova, unlike the model by Illia O. Teplytskyi, attempts to technologize the methodical training system, but the proposed structure violates the interconnectedness of the main components of the model: some of them are connected directly and some are connected only through learning outcomes.

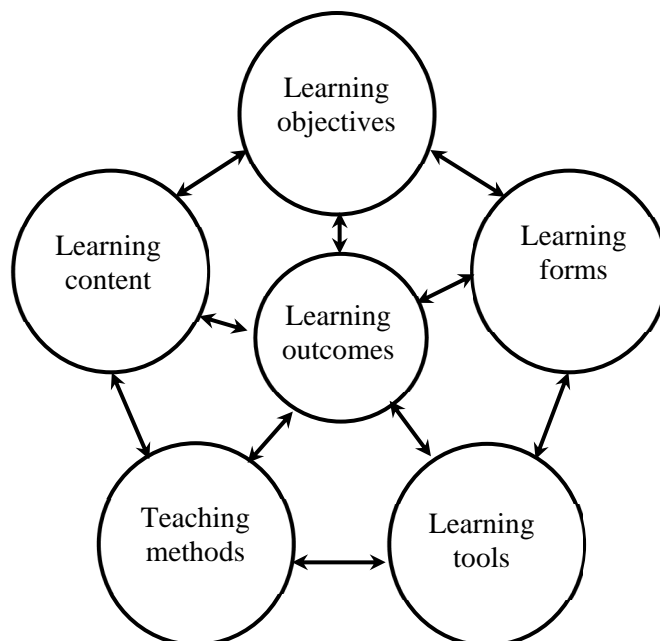


Figure 4. The five-component model of the methodical training system, supplemented by learning outcomes (according to Nataliia A. Burmistrova ([7], p. 20)).

A more reasonable approach to the technologization of the methodical system is suggested by Larysa O. Chernykh, who, considering the totality of those components of the traditional methodical system that answer the question “how to teach”, believes that they form some subsystem of a unified system: “We will call *teaching technology* a subsystem of the methodical system that includes methods, tools and learning forms and should answer the question ‘How to teach?’” ([10], p. 18). A schematic representation of the methodical system structure with a dedicated technological subsystem is shown in figure 5.

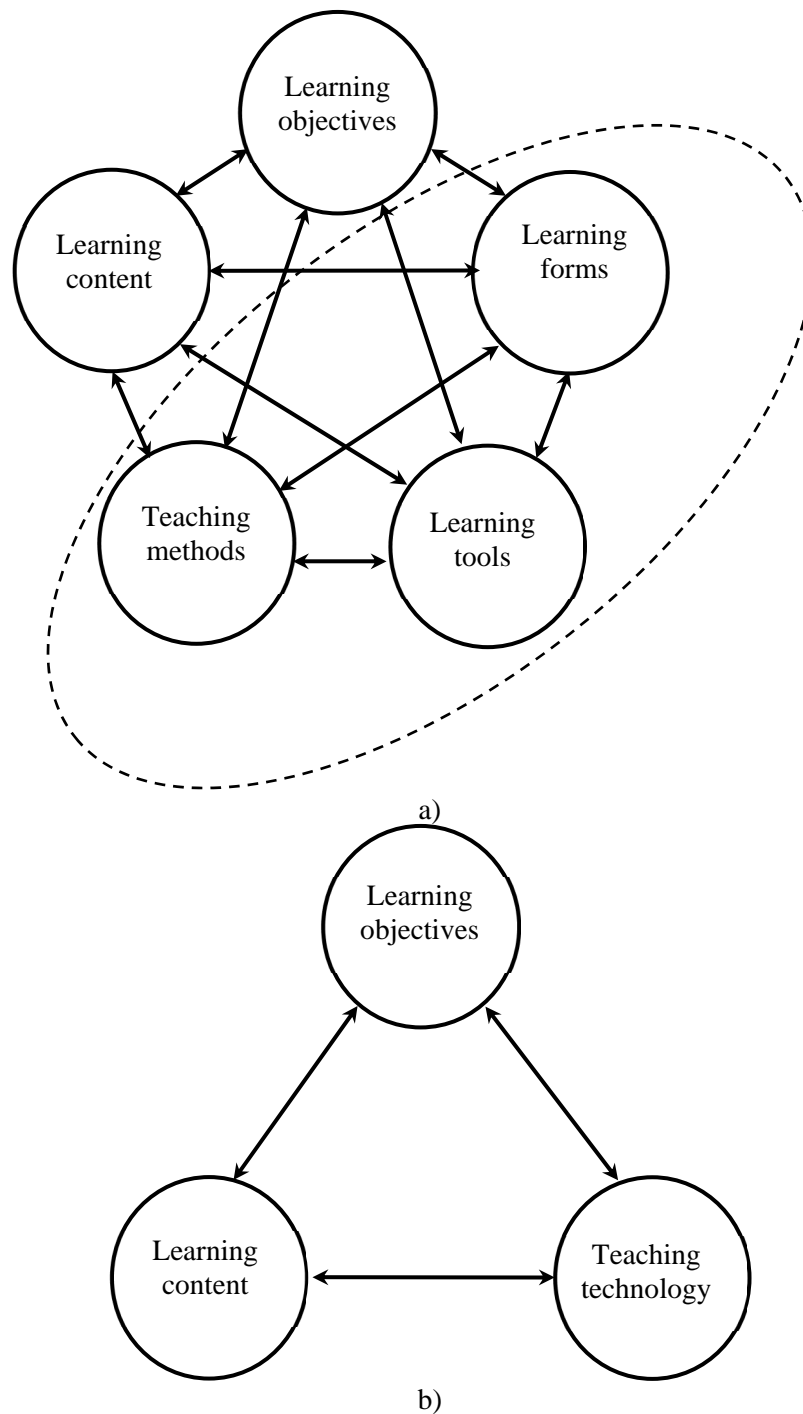


Figure 5. The structure of a methodical system with a distinguished subsystem of "teaching technology" (according to Larysa O. Chernykh ([10], p. 18)).

Margarita A. Ariian suggests a hierarchical multilevel model with feedbacks: 1) the level of the system, combining the needs of society at large and the individual, 2) the level of objectives, 3) the level of teaching approaches and principles, 4) the level of subjects of the pedagogical process, combined with learning content, 5) the level of organizational and pedagogical conditions of education, 6) the level of outcome ([2], p. 30).

Irina B. Mylova's leading idea for building a methodical system is the definition of a planned result through professional information-technological competence of a teacher, the implementation of which is proposed through the integration of information technology education with professional teacher training ([22], p. 24). Accordingly, the author's model consists of the regulatory elements which influence the interrelated process elements and learning outcomes. Figure 6 presents a generalised scheme of the links between the elements of the methodical system. Irina B. Mylova's model does not explicitly contain learning objectives – it is the second level of Alexander A. Kuznetsov's model, interlinked with learning outcomes.

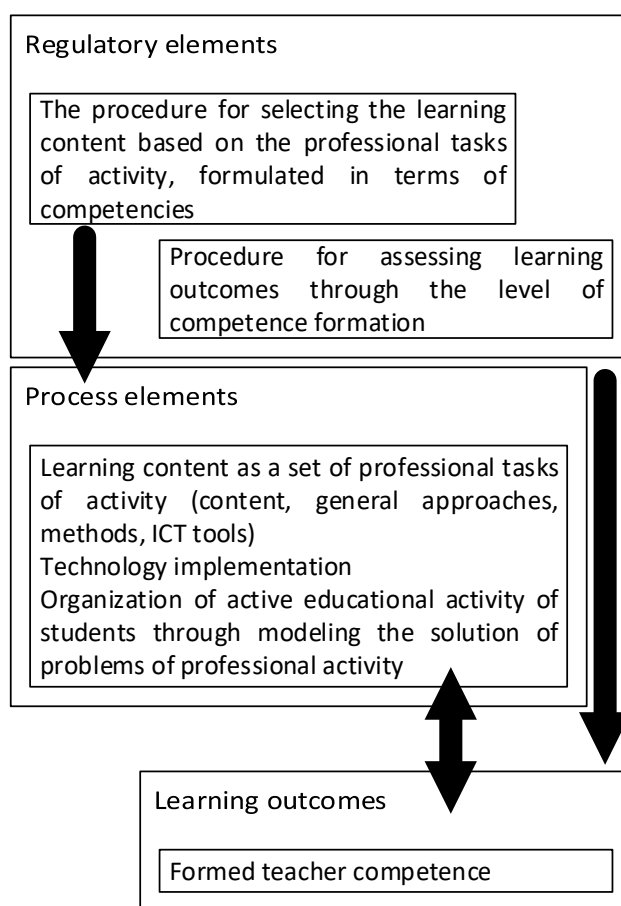


Figure 6. The links between the elements of the methodical system of teaching information technologies (interpretation of Irina B. Mylova's model).

Aleksandra A. Tolsteneva incorporates the following general principles into the methodical training system: scholarship; consistency; systematicity and consistency; unity and optimum combination of collective, group and individual learning forms; optimum combination of verbal, visual and practical methods; solidity of knowledge; differentiation; interdisciplinary integration; principles of content selection and structuring ([39], p. 18).

Maria A. Urban suggests the following components as part of a methodical training system ([43], p. 8):

- purposeful (a learning objective that has a knowledge-based, activity-based, competence-based and personality-based component),
- content (list of skills),
- procedural (methodic for forming the necessary skills through a set of tasks, the techniques included in the methods and the corresponding skills, the forms of interaction between the subjects), highlighted in terms of the combination of visual and practical verbal methods,
- control (criteria for evaluating the effectiveness of the methodical system – learning ability in the subject area, competence, motivation to learn).

Figure 7 shows the model developed by Maria A. Urban for a methodical system of elementary mathematics teaching using educational modelling ([43], p. 18). In contrast to Alexander A. Kuznetsov's two-level model, Maria A. Urban's model contains feedback of the objective component with all other components. At the same time: the content component of the model includes both learning content and requirements for training subjects; the objective component is formulated in terms of competencies; the control component provides multilevel diagnostics – input control, current monitoring and control of learning achievements, as well as evaluation of the effectiveness of the system as a whole; the process component does not include learning tools separately in explicit form, but includes all technological components within the method of modelling skills formation.

Marina V. Egupova proposes a similar model of methodical system, including objective, content, methodical (instrumental) and results-evaluation components ([11], pp. 30-31). Additionally, the model contains learning levels and the specification of content modules, and the learning objectives are defined by the competencies to be formed by the future mathematics teacher and concretised in the learning content.

Tatiana Yu. Kitaevskaya identifies the following main structural components of a methodical training system (figure 8): goals and planned learning outcomes, learning content, subjects of learning, as well as information design technology for differentiated learning content as the main integrating component of the system, which structures the tasks of teaching the subject (methodical task) teaching methods, learning tools, learning forms, technology selection, which structure the technology to solve the methodical task (informatics teaching technology), the result of the functioning of the methodical system (evaluation and outcome component). The basis for linking the elements of the system is the learning objectives of the subject and the informatics learning process itself ([16], p. 299).

The development of methodical training system occurs under the influence of external factors affecting the development of methodical system in general, as well as its individual components ([48], p. 12), therefore, the model of methodical informatics training system proposed by Tatiana Yu. Kitaevskaya's takes into account specific non-hierarchical relations between the system components: teaching objectives, which are a higher degree of abstraction than other elements of the methodical system, turn from a leading system element into a subordinate one and are gradually adjusted along with the teaching content. At the same time, in spite of the declared connection of the methodical system of informatics teaching with the corresponding information and educational environment, this model lacks the essential for such an environment direct links between the learning subjects. In addition, the diagnostic and monitoring tools for learning outcomes do not have an operational feedback with the technological component of the methodical training system.

Aleksandra A. Tolsteneva includes independent work of students as a separate component of the methodical training system, interconnected with the methods and forms of learning organisation ([39], p. 21). The conditions that make it possible to organise students' independent work effectively include the creation of new types of textbooks and teaching guides, the implementation of new forms of learning organisation, work to improve teachers' psychological and pedagogical qualifications and skills, etc. ([16], p. 296).

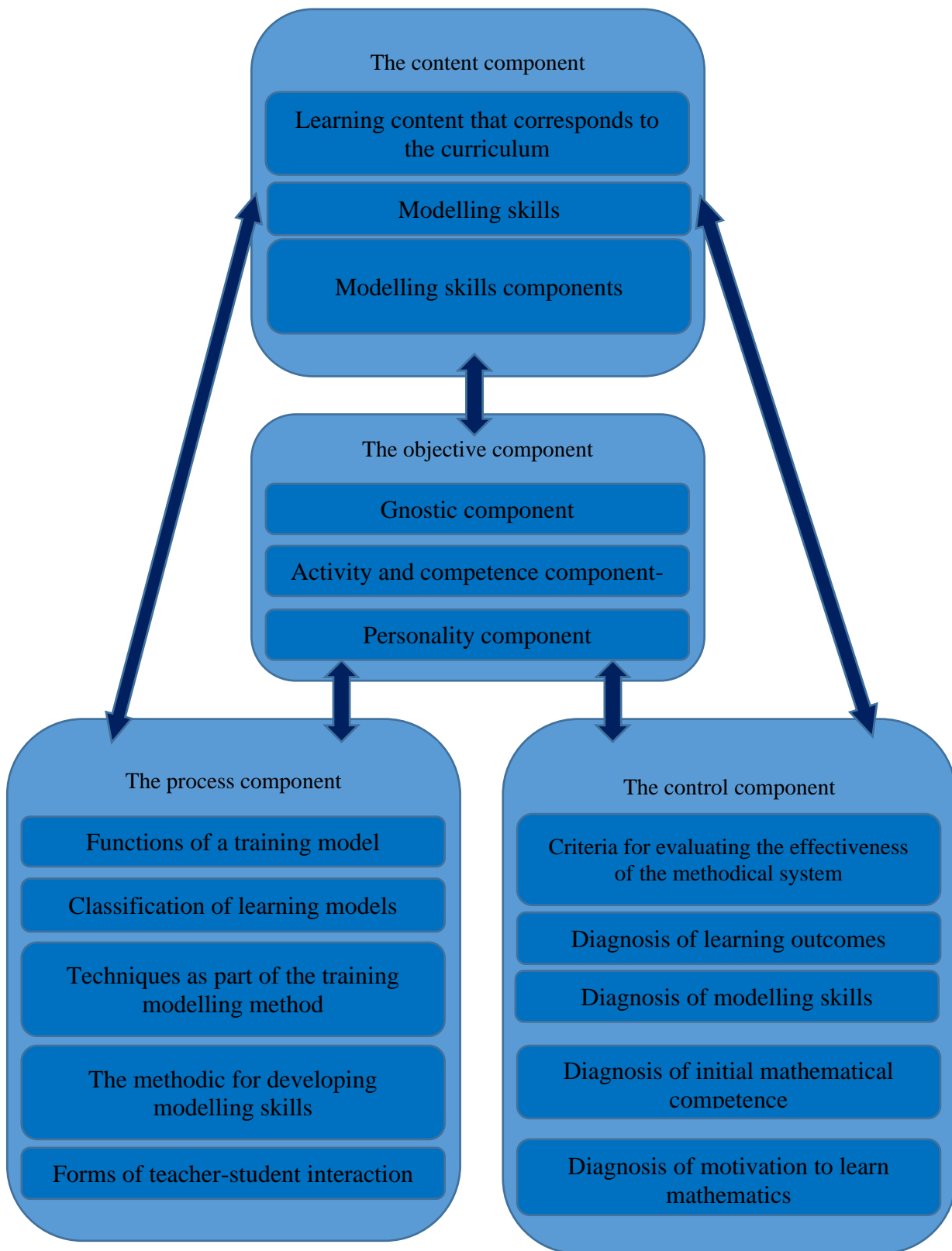


Figure 7. The structure of a methodical system of elementary mathematics teaching using educational modelling (by Maria A. Urban ([43], p. 18)).

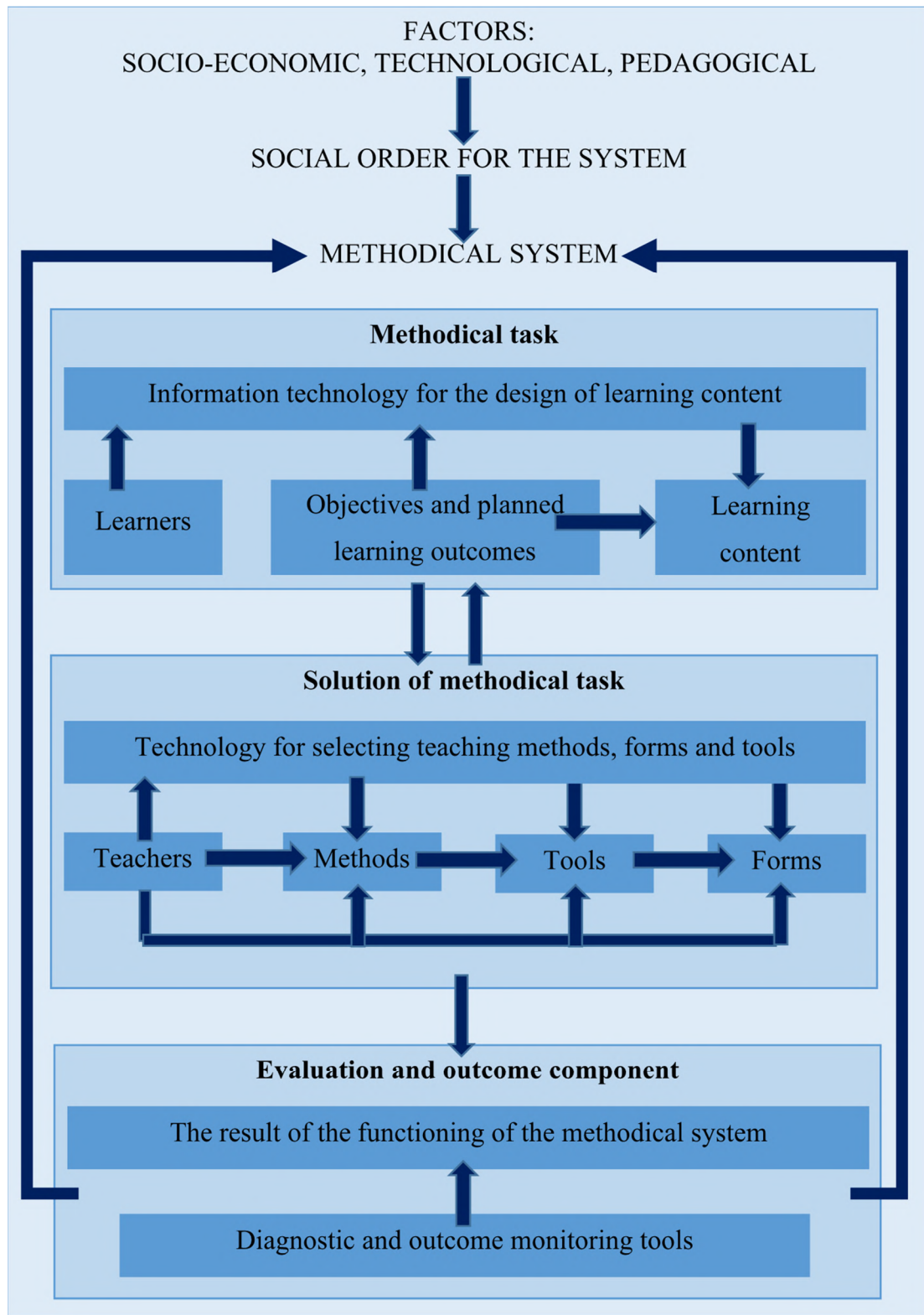


Figure 8. Model of a methodical informatics training system with highlighted external influencing factors (by Tatiana Yu. Kitaevskaya ([16], p. 299)).

Iurii B. Altshuler understands methodical training system as a complex of interrelated structural (reflecting objectives, methods, forms and learning tools, modular structure of the section and content of learning material) and functional (reflecting learning and cognitive activity of the student and developing, diagnostic and controlling activity of the teacher to achieve the objectives) components ([1], p. 23). The model of methodical training system he proposes consists of the following components: motivational and objective, structural and content, procedural and activity-based (including independent work) and evaluative and results-based ([1], p. 21). Iurii B. Altshuler links the first component with the social order through state educational standards, approaches (competence-based, activity-based, systemic, and integrative) and principles (in particular, cyclicity, generalization, modularity). The author specifies the result through the desired level of a certain competence. Unlike Tatiana Yu. Kitaevskaya's model, Iurii B. Altshuler's model provides for a possibility of returning to any of its levels ([1], p. 22), which corresponds to Winston Walker Royce's cascade model structuring [28].

Vita I. Glizburg in the model of methodical system of teaching topology and differential geometry of the future teacher of mathematics in the aspect of humanitarianization of continuous mathematical education ([13], p. 28), in contrast to the model of Tatiana Yu. Kitaevskaya, considers both direct connection of learning subjects (teachers and students), and indirect technology (methods, tools and forms of organization of learning).

Thus, in the process of its journey between the science of education and the art of teaching, our teaching method has found companions and formed a team with them – a methodical system, whose further expansion and advancement in the forest of teaching practice has necessitated taking into account numerous external influences and internal restructuring; the appearing of sub-systems capable of self-development. What is the composition of this methodical troop?

3. Example: A model for a computer-oriented methodic for training prospective mathematics teachers in informatics

Let us try to concretise what the development of modern teaching methodic looks like with the example of informatics education for prospective teachers of mathematics. Why did we choose them in particular?

1. The State National Programme “Education” (“Ukraine of the XXI century”) among the priority areas of education reform determines, in particular, the achievement of a qualitatively new level in the study of mathematics through the optimal combination of humanitarian and natural and mathematical components of education and wide use of new educational, information technologies through appropriate teaching, methodical and information support [9], and The Presidential Decree on declaring the academic year 2020/2021 the Year of Mathematics Education in Ukraine provides for the creation of conditions for equal access to modern and quality mathematics education and for ensuring a modern level of mathematics teaching, in particular through the use of effective technologies, taking into account the best national and international practices [24].

2. Analysis of the current state and prospects of development of information society in Ukraine and the world (Klaus Schwab and Nicholas Davis [29]), the potential of information technology as a means of integrating mathematics, computer science and natural sciences (Mikhael Gromov [14], Vladimir V. Laptev, Natalia I. Ryzhova and Mikhail V. Shvetckii [20], Aleksei L. Semenov [30]), as well as problems of informatics training of future mathematics teachers (Andrey P. Ershov [12], Vladimir M. Tikhomirov [38], Myroslav I. Zhaldak [46]) discovered, that the prospects of development of digitalization means should be reflected in the advanced content of informatics disciplines at all levels of education, therefore special attention requires modernization of information training and an appropriate system of informatics competences of prospective teachers (Yurii S. Ramskyi [27], Viktoriia M. Zhukova [47]), since the teacher is responsible for introducing ICTs directly into the learning process, shaping the informatics competencies of students, and preparing a new generation to live fully in an information society.

3. Mathematics and informatics are related sciences that significantly influence each other in their development and largely determine the development of natural sciences and technologies. The main source of change in the education system is social demand, reflecting the development of technologies, science and socio-economic relations. In the 20s of the 21st century this complex, called Industry 4.0, is extremely informatized, which necessitates refining the informatics competencies of prospective teachers by reflecting new content and new abilities in them. The development of core and subject-specific ICT (digital) and mathematical competencies in the European educational space is seen as a component of the fundamental literacy of employees demanded in the labour market of the future [37]. Therefore, in the process of developing general professional digital competencies of a teacher, the following important ICT innovations, such as open educational resources, social networks, mobile technologies, Internet of Things, artificial intelligence, virtual and augmented reality, big data, programming, ethics and privacy protection, should be considered through the content of the training [42].

Thus, there is a socially conditioned and legally justified need to improve the quality of prospective mathematics teachers' training, in particular – informatics training. One of the leading directions of achieving this goal is the development and implementation of computer-oriented methodical systems and tools for training prospective teachers of mathematics aimed at the formation and development of their informatics competencies.

Through an analysis of French, US and Australian teacher education standards, we have identified components and indicators of general digital competencies such as the ability to: assess, implement and use ICT-based learning platforms; apply e-learning in social media; teacher design for e-learning; assess, implement and evaluate e-assessment; apply ICT-related knowledge; implement enhanced learning practices; analysis of production implementations and e-learning systems. The recommendations of the Association of Mathematics Teacher Educators [3] and the National Council of Teachers of Mathematics [47], aimed at a pedagogically appropriate and balanced use of ICT in mathematics teaching in general secondary education, are particularly noteworthy.

The carried out analysis of models of methodical training systems provided an opportunity to develop a model of computer-oriented methodic for teaching informatics to prospective teachers of mathematics (figure 9). The choice of methodic as a modelling object is related to the need to reflect in the model the structural components of a methodical training system, technologized in terms of competence outcomes and objectives, external factors affecting the system, principles and approaches to its design.

The methodic is computer-based because ICT:

a) define the aim – the formation of informatics competencies of prospective mathematics teachers through external factors: on the one hand, there is a need to change the system of professional informatics competencies to reflect the current and future development of ICT, in particular Industry 4.0 tools, and on the other – the crisis of science and mathematics education in Ukraine and the lack of highly qualified mathematics teachers need to modernise the professional training of mathematics teachers,

b) act as design factors – the system of informatics competencies of future mathematics teachers is projected on the basis of a comprehensive analysis of the sphere of knowledge “Information Technology”, taking into account the professional orientation of informatics teaching courses,

c) are leading teaching tools for information technology courses.

The model reflects the main stages of the process of formation of informatics competencies of a mathematics teacher.

The first stage defines the **aim**: formation of informatics competencies of prospective mathematics teachers, which are an integral part of professional competencies of a mathematics teacher, which are generalized in integral competency: ability to solve complex specialized tasks and practical problems in general secondary education in the process of teaching mathematics, which involves application of psychological and pedagogical theories and teaching methods and is characterized by complexity and uncertainty of conditions. The formulation of the aim is the result of socio-technological factors external to the methodical system and methodic (crisis phenomena in science and mathematics education, public

demand for competent teachers, the need to change professional informatics competencies and the new tools of Industry 4.0).

The aim determines the actions to be carried out in the second stage – **systems design**. The choice of the name of the component is connected with the fact that the objective predetermines the necessity of designing the system of informatics competences of a mathematics teacher, while the methodic determines the necessity of designing a computer-oriented methodical system of informatics training of prospective mathematics teachers. The design of the two systems is based on:

a) methodological approaches:

– *the system approach* (based on the idea that the whole surrounding world consists of interconnected and interacting objects that form a dynamic whole that is more important than its parts [35]) applies to design: a) to overcome the complexity of a prospective mathematics teacher's integral competence by breaking it down into its individual components, using abstraction and hierarchies of subordination and emulation, b) for the “theoretical construction of [methodical] system components, its internal and external links, and the subsequent implementation of such an idealised system in the real learning process” ([10], p. 19),

– *the competence-based approach* (based on the idea that knowledge and activities that are personally relevant form more stable structures [45]) is used to structure the content of IT training, formulate learning objectives, define learning outcomes, and monitor and diagnose learning activities,

– *the activity-based approach* (based on the idea that learning activity is a specific form of cognitive activity in which a person achieves consciously set learning objectives, which are formed as a result of self-development needs [31]) is used to design mandatory and variable (learnt independently) components of the system of informatics competencies and technologies to implement students' independent learning activities in a computer-oriented informatics learning environment,

– *a person-centred approach* (based on taking into account the personal qualities, individual needs and capacities of students, and promoting their self-development [15]) is used in the implementation phase to adjust the components of the methodical training system: “the cyclical nature of ... activities at the methodical level involves the repetition of ... cycle [of methodical system development and implementation], but already in conditions of a qualitatively new learning process” ([10], p. 19),

– *structured-modular approach* (based on structuring the educational programme into documented, meaningfully completed, relatively independent parts, characterised by their coordination of objectives, content, methods, tools and learning forms [40]) is used to highlight the components of computer-oriented methodic for teaching informatics to prospective mathematics teachers (specific methods for forming individual groups of informatics competencies),

b) principles:

– *the principle of harmonious combination of traditional and innovative technologies* (based on bringing established and emergent methods, tools and forms of learning organisation into a state of correspondence, coherence in order to increase the effectiveness of the methodical system) is applied when selecting the components of informatics teaching technology,

– *the principle of continuity* (based on the idea that the different stages of development are interlinked, with the essence of the new stage restoring and preserving elements and characteristics of the previous stages [4], in particular – that the development of a methodical training system should be based on an already existing training system ([20], pp. 18-19)) is applied when designing the system of informatics competencies of a mathematics teacher as an improvement of the system by Yurii S. Ramskyi and in the process of developing the methodical training system: each of its new models is based on the previous one,

– *the principles of designing an open methodical system:*

1) *the principle of dynamic balance* (based on the idea that a methodical system finds and maintains an optimal balance through a harmonious combination of traditional and innovative technologies ([16], p. 297)) used to identify the external conditions and internal contradictions that necessitate the development of a methodical training system,

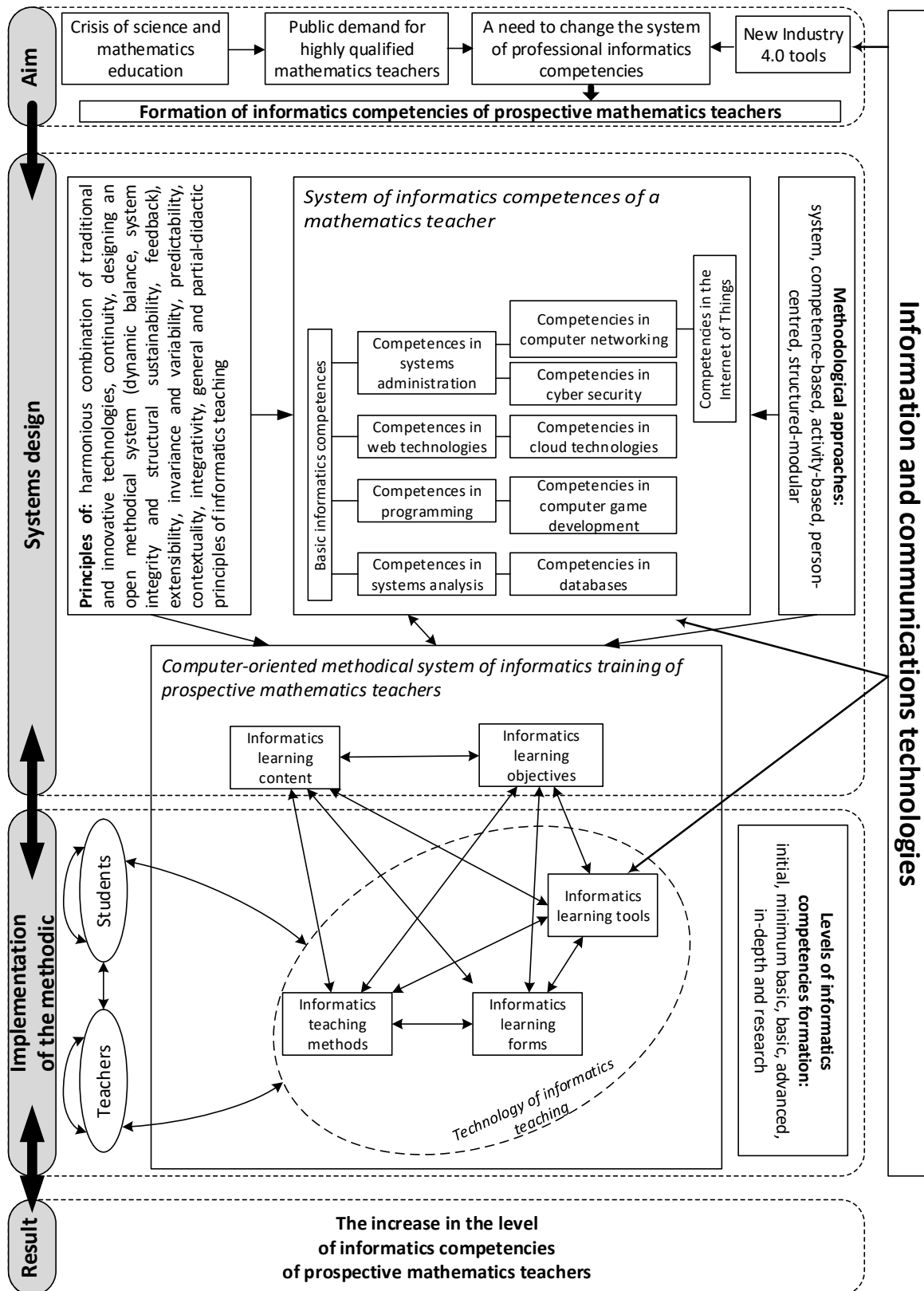


Figure 9. A model of computer-oriented methodic for teaching informatics to prospective mathematics teachers.

2) *the principle of system integrity and structural sustainability* (assumes a high degree of interconnectedness of all system components, whereby a minor change in the components does not affect the performance of the system as a whole ([16], p. 297)) is used to stabilise the methodical training system before a critical mass of changes to the system components has accumulated, prompting a re-design of the system,

3) *the feedback principle* (provides the connection between the output of the system and the input as part of a causal chain) is used to adjust the components of the methodical system when the obtained result (a certain level of formation of informatics competencies) deviates from the desired one (the predicted level of formation of informatics competencies),

– *the principle of extensibility* (based on the idea of gradation of qualification levels, in which the transition to the next level requires a change in knowledge, skills, ways of interaction and the ability to apply them independently and responsibly) is used to specify and specialise informatics competencies corresponding to different levels at system design stage, and to develop a computer-oriented learning environment for information courses at implementation stage,

– *the principle of invariance and variability* (identifying, selecting and constructing invariant forms, methods and learning tools whose use is necessary to achieve the learning objectives) ([32], p. 19-20)) applied in the selection of invariant and variable informatics competencies, as well as in the process of designing informatics learning content (slowly changing fundamental and rapidly changing technological) and combining traditional and innovative components of educational technology,

– *the principle of predictability* (based on the idea of anticipating learning outcomes in order to make the necessary adjustments in content and learning processes to achieve the expected outcome ([32], p. 19-20)) is realised by reformulating the learning outcomes from improving the level of informatics competencies of a mathematics teacher to the level desired in certain specific implementation contexts,

– *the principle of contextuality* (based on the idea of contextual learning, in which all the components of the methodical system, together with the professional and socio-cultural content of the work of prospective specialists, are modelled in their development ([44], p. 266)) is realised in informatics learning technology through professionally oriented learning activities, above all, constructive project-research activities in a computer-oriented learning environment of informatics courses,

– *the principle of integrativity* (based on the idea of interdisciplinary integrative nature of mathematics teacher training and manifested in the links between courses implemented by means of mathematical modelling and computer technologies, taking into account field and vocational education ([7], p. 19)) is applied at the level of learning technology by integrating its components into learning strategies,

– *general didactic principles of informatics teaching* [17]:

1) *the principle of the unity of the educational, developmental and upbringing functions of learning* (applied to learning, which is aimed at achieving the purposes of comprehensive personal development, at shaping his/her competencies and worldview, which are the basis for choosing life ideals and social behaviour) is reflected at the system design level in the components of each competency: knowledge and skills reflect the educational function, attitude – the upbringing function, and at the methodic implementation level – the developmental function through the competence formation process,

2) *the principle of scientific content and teaching methods* (applied in connection with modern scientific knowledge and social practices, according to which the content of teaching should correspond to the current state of science, determine the mastery of methods of scientific knowledge and involve the disclosure of scientific phenomena and facts in relationships and interrelations, the use of problem-based learning and research methods in the organisation of activities) is reflected at design level: The following is reflected: scientific content – in the content of informatics competencies, which was selected in accordance with the current state and future developments in ICTs; scientifically based teaching methods – due to the application of the contextuality principle and the research nature of learning activities in higher education,

3) *the principle of systematicity and consistency* (based on the fact that teaching and learning should be carried out in a logical sequence, according to the system, which ensures the continuity of substantive

and procedural aspects of learning, consolidation of knowledge, skills, personal qualities of the student, their consistent development and improvement, where each lesson is a logical continuation of the previous one both in terms of the content of learning material and the nature and methods of cognitive activity) is reflected in the structural-modular approach and multilevel system of competencies, in which the transition to the next level is possible only after mastering the previous one, and the hierarchical structure of competency system reflects the relationship of concretization and specialization,

4) *the principle of solidity of knowledge* (reflecting the thoroughness of the acquisition of knowledge, skills and abilities, sustainable fixation of the acquired in memory, free reproduction and application of it in practice, where during the preparation for familiarisation with the new material the interests of students are appropriately directed, a positive attitude towards what is being studied is formed, and assimilation of the content should be organized so that students take the most active part in it, in a sufficient number of exercises, with vivid examples, on visual material) is reflected at the design level in the components of each competence as a dynamic combination of knowledge, skills and relations, and at the implementation level – in informatics teaching technology,

5) *the principle of accessibility* (it determines the specificity of students, it is related to the need for teachers to find ways to establish contact with each student, to select such methods and teaching tools that promote optimal learning of educational material in accordance with a particular stage of their mental, moral, social and physical development, in compliance with the following rules: in teaching it is necessary to pass from easy to difficult, from known to new, to unknown; take into account the difference in levels of progress in the learning process of individual students) at the design level is reflected in a personality-centered approach, and at the level of the methodic implementation is considered in the computer-oriented environment of informatics teaching through monitoring and diagnostics of the student component of the environment in order to adjust components of informatics teaching technology to achieve the desired level of informatics competencies formation,

6) *the principle of awareness and activity* (based on the fact that the student is a subject of the learning process, is aware of the learning objectives, is able to plan and organise his/her own work, is aware of the personal importance of its results, and cognitive activity is active for students only when they perform it independently, when it is fundamentally new for the student, when it is organised consciously and purposefully) specifies the main provisions of activity approach at the level of methodical implementation,

7) *the principle of visibility* (based on the fact that the effectiveness of learning depends on the appropriate involvement of human senses in the perception and processing of educational material, and provides for the use in the learning process of various visual tools: natural (objects of objective reality), experimental (experiments), volumetric (models, figures, etc.), visual (paintings, photographs, drawings), sound, symbolic and graphic (maps, graphics, diagrams, formulas), internal (images created by the teacher's speech)) is implemented in the technology of informatics teaching through the use of ICT as a universal learning tool, provides an opportunity to increase its mobility,

8) *the principle of connection between learning and practice* (expresses the need to prepare students to apply knowledge in solving practical problems by analysing situations and examples from real life, familiarity with production, social institutions, involvement in useful activities within and outside the institution of higher education, using the surrounding reality as a source of knowledge and as a field of its practical application) at the system design level concretises the principle of contextuality and the professionally relevant content of informatics learning,

9) *the principle of individualisation* (aimed at taking into account individual characteristics and creating conditions for the development of each student, which requires the teacher to have a clear understanding of the nature, interests and abilities of the student, and the methods, techniques and pace of learning are selected taking into account the differences of students, the development levels of their cognitive abilities) at the level of system design specifies a person-centred approach to learning, and at the level of methodic implementation is considered similar to the principle of accessibility,

– *partial-didactic principles of informatics teaching*, in particular

10) *the basic principle of teaching theoretical informatics*, formulated by its authors as “Theorem + Proof of Theorem + Algorithm + Proof of Algorithm Correctness + Investigation of Algorithm Complexity” ([20], p. 130), is applied in the content of teaching functional programming (λ -calculus and combinatorial calculus), system programming (especially regular expression calculus, calculus of grammars), algorithm theory (Turing machine, etc.) ([20], p. 130).

The system of informatics competencies of a mathematics teacher is designed as a hierarchy, with each level being a certain specialization or concretization of the previous one, which allows considering them as interrelated with the levels of informatics competencies formation – this explains the fact that for certain groups of competencies the indicators of their formation are not defined at all levels. The first level contains the basic informatics competences, which are concretised in the second level into competences in systems administration, web technologies, programming and systems analysis. The third level corresponds to the specialisation of: competencies in systems administration – competencies in computer networking and cyber security; competencies in web technologies – competencies in cloud technologies, competencies in programming – competencies in computer game development; competencies in systems analysis – competencies in databases. The fourth level reflects prospective competencies in the Internet of Things, a further specialisation of competencies in computer networking.

The computer-oriented methodical system of informatics training of prospective mathematics teachers is built according to Larysa O. Chernykh's model. At the level of theoretical design all its interrelated components are defined (objectives, content and technology of informatics teaching represented by tools, methods and forms of its teaching organisation).

Both systems are interlinked not only through learning objectives and technologized outcomes formulated in terms of the informatics competencies of a mathematics teacher, but also through learning content aligned to the content of the informatics competencies.

Table 1. Leading tools for forming informatics competencies

Tools	Competencies
software and hardware testing	in basic system administration and ICT systems support
text editors	in application software, computer network administration and the development of dynamic computer games
database management systems	in application software, databases, dynamic computer game development and ICT system support
communication tools	in serving client requests and organising safe collaboration
digital media tools and tools for creating interactive animations	in digital media, modelling and effects development for computer games
tools for creating and editing digital images	in digital media, web development, modelling and effects development for computer games
project management tools	in programming technology, in design activities, in the design and implementation of quality assurance processes
software development tools	in project activities and in programming technologies
tools for creating documents in the XML markup language	in the use of markup languages and in web programming
SQL relational database access tools	in database and web programming
software testing and deployment tools	in programming technologies and the development of dynamic computer games
mobile software development tools	in the development of mobile applications and dynamic computer games
computer modelling tools	in developing dynamic computer games and models and effects for them

The second stage and **the third, implementation of the methodic**, are interlinked: the implementation of the methodic involves continuous monitoring and control of its performance, the improvement of which may require adjustments to the designed systems. The competence matrices designed at the previous stage act as a comprehensive means of diagnosing the formation of informatics competencies at one of six levels: initial, minimum basic, basic, advanced, in-depth and research. The implementation of the methodic involves the creation of a computer-oriented learning environment for IT disciplines, in which direct and ICT-mediated learning communication between the main subjects of instruction – teachers and students – takes place. The constructed system of informatics learning tools, interconnected with the informatics competencies of prospective mathematics teachers, provided an opportunity to identify the leading tools (table 1).

The last stage in the model – **the result** – is interlinked with the previous one. The increase in the level of informatics competencies of prospective mathematics teachers is considered both as a current result, which is diagnosed in the process of formation of informatics competencies, and as a component of the overall result of professional training, which is diagnosed after the completion of the formation process. At this stage, the diagnostic tools are not specified because they are part of the teaching tools.

According to the constructed model of computer-oriented methodic for informatics teaching of prospective mathematics teachers aimed at the formation of their informatics competencies, it is possible to define particular methodics: methodic for forming basic informatics competencies, methodic for forming competencies in systems administration, computer networking, cyber security and Internet of Things, methodic for forming competencies in web and cloud technologies, methodic for forming competencies in programming and computer games development, methodic for forming competencies in systems analysis and databases.

In our quest, therefore, the method has evolved from the application of appropriately selected groups of teaching methods – learning strategies as sequences of effective teaching methods used in a purposeful and flexible way, which are increasingly automated but remain consciously applied – through a methodical system to a system of methodics: teaching, forming and using. But the method continues to take a step further. What will it become in the future?

4. Instead of conclusion: Quo vadis?

Informatics is like a two-faced Janus – fundamental and applied, classical and innovative, it is always at the forefront of cognitive science advances, because the meta-method of the learning process is information interaction, and human, animal and machine learning are the methodological basis of modern informatics. That is why, leaving the art of human teaching behind, we associate the future of learning sciences precisely with informatics. What will be the learning systems of the future?

1. B. F. Skinner's key idea – automated learning – is once again returning from semi-obscurity, but no longer in the form of “hard” programmed learning with a fixed algorithm, but through machine learning of mathematical models of neural networks: instead of teaching humans “think like machines” we will teach machines to think like humans. Adaptive learning platforms dynamically adjust the way instructional content is presented to students based on their responses or preferences. Adaptive learning is increasingly dependent on large-scale collection of learning data and algorithmically derived pedagogical responses. Methodical systems for adaptive learning are our immediate future which is already knocking at the door.

2. Methodic as an implementation of a methodical system of learning is embodied by the teacher, who adapts the methodic to a specific fast-changing environment with a great uncertain factor – the person who learns. Full achievement of the learning objectives is only possible if the student is fully modelled: the more adequate the student model is, the more fully the learning objectives are achieved through appropriate learning activities, but the more complete the model is, the more difficult it is for the teacher to work with it – up to the point of inability to select the learning activities promptly. The contradiction between the simultaneous need for completeness and ease of use of the model can be overcome by automating its construction with machine learning: without claiming to understand the

internal structure of the model or even how it is constructed, we will trust it because its behaviour coincides with that of the student in learning. Learning support systems and other digital tools provide the opportunity to collect an extremely big amount of data on any component of a student's learning activities. Digital credentials include different but related strands, such as digitalization of traditional diplomas and granular digital microcredentials, and other digital artefacts will help us. The big data generated in the learning process and the student models built from it will become an integral part of adaptive learning methodical systems.

3. In the somewhat more distant future, updating the tools as part of the learning technology associated with the proliferation of educational applications of deep machine learning (AI education applications). These systems analyze large amounts of data beyond simple algorithms. They are taught to identify and classify input patterns, probabilistically predict, and operate unsupervised (and are able to come up with unanticipated results). Examples of applications are specialised chatbots, natural language interfaces, virtual personal assistants, etc. – wherever precious human resources are spent on algorithmic actions. Under the influence of artificial intelligence technology, the profession of higher and secondary school teacher will also change in a predictable, but still hidden, way.

4. The transition to natural language communication as we are used to it is the next step that intelligent technologies are preparing for us: conversational user interface (CUI) is a high-level design model in which the user and machine interactions primarily occur in the user's spoken or written natural language. Sophistication of the CUI can vary from understanding just simple verbal utterances to handling complex multiturn interactions.

5. If we manage to avoid falling into the uncanny valley trap [21], in the process of approaching the ways in which human beings and software-hardware interact, we can move on to fine-tuning the student model by their emotional state. Emotion artificial intelligence technologies (also called affective computing) use AI to analyze the emotional state of a user (via computer vision, audio/voice input, sensors and/or software logic). It can initiate responses by performing specific, personalized actions to fit the mood of the user.

6. Artificial intelligence and quantum computing are now emerging from the black box into a grey area, but they are jointly influencing the future of learning. How AI and quantum computing may alter methodic's future – this is still a question for science fictionists and futurologists, and it is the task of cognitive scientists to illuminate this grey area by moving from idea to method.

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Analysis of some aspects of the implementation of the integrated course “Science” in the educational process of schools in Ukraine

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Abstract. The integrated course “Science” is being introduced into school curricula in Ukraine for the first time. The article analyzes the experience of implementing an integrated course “Science” in schools of Ukraine. The advantages and disadvantages of various curriculum projects of the integrated course “Science” are discussed. The analysis of the content of the project No 2 of the curriculum of the integrated course “Science” is made. Based on the results of two years of work on the implementation of the experimental integrated course “Science” in the profile school, the analysis of the main problems that arose during the implementation of this course and discusses possible ways to solve them.

1. Introduction

In August 2018, an all-Ukrainian level experiment “Development and implementation of educational and methodological support of the integrated course “Science” for 10-11 grades of general secondary education institutions” started in Ukraine. According to the Order of the Ministry of Education and Science of Ukraine No 863 dated 03.08.2018, the experiment is planned to be completed in October 2022 [5].

The introduction of such an integrated course was a logical continuation of the reform of profalized education in Ukrainian schools. Formally, this integrated course is analogous to the “Science” course taught in schools in the United States and Western Europe. The main purpose of the integrated course is to create in students a holistic scientific perception of the world, the development of curiosity and the ability to apply knowledge of the natural sciences in everyday life.

The integrated course “Science” is positioned as a course that combines the such disciplines: biology, physics, chemistry, astronomy, geography and ecology.

The process of integrated course “Science” learning can be carried out by a teacher of any of the disciplines of the natural cycle (physics, geography, chemistry or biology), or a pair of teachers of natural sciences discipline. Since 2019, special in-service teacher training courses have been launched, focused on preparing for the effective implementation of an integrated course in the teaching process in a profalized school.

From the fall of 2018, 141 schools in Ukraine were to take part in this experiment. There are 4 such schools in Kryvyi Rih, including a Kryvyi Rih Comprehensive School of I-III levels No 122 of the



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Kryvyi Rih City Council in Dnipropetrovsk oblast (school No 122). In the 2019-2020 academic year, there are already 5 such schools in the city. Analysis of the structure and features of the integrated course “Science”, as well as generalization of experience in its implementation in the educational process of the school No 122 in Kryvyi Rih is the main purpose of writing this article.

2. Methods

In the competition of projects of curricula of the integrated course “Science”, the Ministry of Education and Science of Ukraine selected four projects, which were recommended for implementation in educational institutions. Each educational institution chose the appropriate project independently, focusing on material and human resources, learning abilities and preferences of pupils and so on.

None of the presented projects is not without flaws. Project No 3 [11] has a significant bias towards biology and the basics of health, project No 4 [3] is only formally integrated - the whole course is divided into separate modules, each of which teaches the material of one separate discipline of the natural cycle. According to the authors of the article, the most balanced and at the same time with a high degree of interdisciplinary integration were projects No 1 [2] and No 2 [13]. But the project No 1, in our opinion, was somewhat overloaded with a physical component. Such an analysis of the projects of the integrated course programs is not thorough, as the authors of the article did not aim at a deep comparison, especially since only one of the projects could be tested. However, the choice of a specific project for implementation was based on these considerations.

A characteristic feature of almost all curriculum projects is the great freedom of choice provided to teachers for their implementation: there is the possibility of rearranging the order of studying topics, changing the number of hours to study the topic, choosing and replacing topics of practical work etc.

In addition, a certain predominance of the physical component in projects No 1 and No 2 can be explained by the typical structure of the study of natural sciences at the standard level (see table 1). As we can see, the study of physics is almost half of the study time spent on the study of all natural disciplines.

Table 1. Fragment of the curriculum for grades 10-11 of general secondary education institutions (natural cycle disciplines studied at the standard level) [4].

Educational disciplines	Number of hours per week in classes	
	10 grade	11 grade
Biology and ecology	2	2
Geography	1.5	1
Physics and astronomy	3	4
Chemistry	1.5	2
Total	8	9

Due to the introduction of the integrated course “Science” it is possible to reduce the weekly workload of pupils, or slightly increase the amount of study time for the study of profilized educational disciplines. This, as the authors rightly noted [1], causes significant dissatisfaction of teachers of natural sciences and mathematics, who lose a certain part of the rate due to the introduction of an integrated course.

The implementation of the experimental course “Natural Sciences” on the Kryvyi Rih school No 122 in 2018-2019 took place with the consent of the parents of students and taking into account the opinion of the pupils themselves – almost all unanimously agreed to study the experimental course instead of individual disciplines of the natural cycle (as a result, two 10th grades were formed: 32 students in 2018 and 34 students in 2019). Most parents justified their decision by the need to pay more attention to specialized disciplines, most pupils – the reluctance to study one or more disciplines of the natural cycle.

The key advantage of implementing an integrated course “Science” is primarily certification of the prevalence of interests, inclinations and opinions of pupils who no longer have the desire and need to study theorized, detached from reality, not provided with a practical component of natural sciences that are not relevant to them [1].

However, this is a very important problem related to the further educational trajectory of pupils. At the beginning of the experiment in 2018, normative documents [8] clearly stated that the integrated course “Science” is studied by those students who do not plan to take an external independent evaluation in any of the natural disciplines (physics, chemistry, biology and geography). In essence, the integrated course “Science” is designed to study in the classes with philology, social sciences, sports and artistic and aesthetic profiles of education.

Later in 2019, normative documents mention that students who have studied the integrated course “Science” have the right to choose one of the subjects of the natural cycle for the state final certification in the form of external independent evaluation [9]. No one has forbidden students to choose an appropriate discipline for external independent evaluation before, but now this seems to confirm that the level of knowledge gained by students during the integrated course is sufficient to be able to choose one of the natural cycle subjects for external independent evaluation.

Thus, there is a problem of compliance of the programs of the integrated course “Science” with the programs of ordinary disciplines of the natural cycle, studied in senior classes at the standard level (i.e., are not profile and not related to the learning profile of pupils).

Table 2. The list of topics of programs of educational disciplines of a natural cycle for 10-11 classes (standard level) which are not reflected in the curriculum of the integrated course “Science” (project No 2).

Educational discipline	Topics of standard level disciplines that are not considered within the integrated course “Science” (project No 2)
Biology	General plan of cell structure. Surface apparatus. Core. Cytoplasm of cells
Physics	–
Chemistry	Theory of structure of organic compounds Hydrocarbons Diversity and relationships between classes of organic matter Chemical reactions
Astronomy Geography	Methods and tools of astronomical research) Asia (section) Oceania (section) America (section) Africa (section) Ukraine in the geopolitical dimension Topography Cartography Ukrainian state The population of Ukraine Political geography and geopolitics

A comparative analysis of the project No 2 [13] with the curricula of natural cycle disciplines studied at the standard level showed quite significant differences in the content and distribution of time to study the main topics of these courses. Briefly, the results of this comparison are shown in table 2.

Geography suffered the greatest losses in the process of integration. This is not surprising, because socio-economic geography is really impossible to integrate with natural sciences. But this poses a serious problem - a significant number of students studying the humanities profile of education to take an external independent evaluation choose geography. Therefore, for them such a gap in knowledge may be crucial. A very small part of this problem is solved by the integrated course “Civic Education”, but only a very small one.

Chemistry in the integrated course “Science” is also quite reduced compared to the standard level curriculum, much fewer reductions have occurred in biology. Physics and astronomy have also been reduced, but quite slightly - mainly at the level of individual semantic parts of topics.

Also, it should be noted very significant differences in the forms of work of students: in the integrated course “Science” preference is given to descriptive methods and project activities of students – almost no forms of work associated with accurate calculations, solving computational problems. This cannot be considered a disadvantage, because modern man, the consumer never uses in everyday life calculations, for example, according to Ohm's law or the Clapeyron-Mendeleev equation. However, simple calculations that may be needed in everyday life in the curriculum of the integrated course are provided. For example, the calculation of the maximum power of electrical appliances that can be connected to the network at the same time.

Most students have a humanitarian mindset, well-developed logical thinking, and the ability to make cause-and-effect relationships, but are reluctant to solve problems that in most cases are detached from everyday life and perceived as the need to calculate abstract quantities. At the same time, according to our personal observations, students loved to do practical work. Students studying the humanities, for whom chemistry is one of the most obscure sciences, lined up to perform their own chemical experiments. The same applied to experiments in physics and biology, practical work in geography. They may not always have interpreted the results of these experiments and their theoretical background quite correctly, they may not always have thinking and calculated correctly, but they may have memorized much more learning data than when watching instructional videos or reading a textbook.

At the beginning of the school year in the 10th grade a monitoring test of residual knowledge in natural sciences was conducted. The test was a mixture of tasks of various forms (including open) from the disciplines of the natural cycle on topics studied mainly in the 9th grade. Table 3 shows the test results as a percentage of the maximum possible number.

Table 3. Results of monitoring testing on natural sciences at the beginning of 10th grade.

Year	Percentage of scored test points				Overall
	in physics	in chemistry	in biology	in geography	
2018	42	31	34	45	38
2019	41	43	36	48	42

The results of these tests showed a low level of knowledge of students, especially in biology and chemistry. The highest level of knowledge was in geography – the most humanitarian among the natural sciences. It is possible that the level of knowledge of pupils in different natural sciences depended not only on their personal preferences and the specifics of the disciplines themselves, but also on the conditions of learning and cooperation with the teacher of the discipline.

The highest score among individual students was 63% in 2018 and 59% in 2019 (two students in the class at once).

At the beginning of the 11th grade (for students who passed the monitoring test in 2018), another test was conducted in the same form, but the tasks were based on what was studied in the 10th grade. The results were slightly higher – 47% of the total score and 74% of the test scores scored by the best student.

3. Discussions

The integration of the natural sciences into any of the curriculum projects does not look perfect at present. Of course, there are topics in which there is no possibility and meaning to integrate all natural sciences, so to a greater extent they reveal the content of only one or two sciences. However, the general principles of integration of natural sciences in most projects of the curriculum of the integrated course “Science” are well thought out and effective.

There is a clear contradiction between the level of planned practical work and the material resources level of schools: starting from the lack of a separate equipped science room, and ending with the need to have for some practical work modern educational equipment, which most schools simply do not have, because they chose a profile that does not require constant use of this equipment. Of course, most of the practical work can be done with the help of improvised means and applied experimentation, in part - through virtual laboratory work. Officials of the Ministry of Education and Science of Ukraine noted that there is no need for effective organization of this course in the use of modern, complex and expensive equipment [12]. But, in our opinion, to teach students who are not interested in natural sciences with the help of a textbook, improvised tools and educational videos - is to finally finish them interested in studying sciences, and therefore reduce the effectiveness of even such a simplified course to zero. Therefore, it may not be necessary to have complex and state-of-the-art devices (they are not always available in schools with science and mathematics profile classes), but to provide schools with the simplest equipment to conduct educational experiments in sufficient quantities is a strict necessity.

A great advantage of the integrated course is the simultaneous study of related topics from different disciplines on common examples. This not only forms a holistic view of the objects of the surrounding world, but also provides an opportunity to avoid inconsistencies in the programs of individual disciplines. For example, according to the biology curriculum for 10th grade [6], the study of the properties of proteins, lipids and carbohydrates and their role in cell life occurs in early 10th grade. And a detailed study of these substances from a chemical point of view (which is important for understanding what functions they can perform) occurs only in the second semester of 10th grade [7]. In an integrated course, such a study takes place simultaneously. There are many such examples.

The weekly workload of 4 hours, which significantly saved time for the study of specialized subjects, led to a certain lack of time for quality implementation of practical work and student projects, associated with a fairly high pace of learning topics. Similar topics within individual subjects of the natural cycle would be studied much more time with almost the same amount of information. Therefore, it is quite appropriate to review the amount of weekly workload when studying the integrated course “Science” in the direction of at least a slight increase.

The lack of high motivation to study the integrated course in most students, due to the fact that this course is not relevant to them (which is logical), and will not be assessed in the form of external independent evaluation. Most students see it as an introductory course that is not required for thorough study. We see a way out of the situation in a certain simplification of the content of the integrated course, increasing its focus on the applied aspects of the natural sciences, but at the same time introducing mandatory external independent evaluation from the course “Science”. Or a comprehensive final exam in disciplines that were not specialized. A graduate of a profilled school should not be equally well versed in all areas of human knowledge, but should still be a fully developed personality. Every modern person, regardless of whether he has a humanitarian or technical nature of thinking, must have a certain minimum of knowledge about the surrounding material world - that is, knowledge of the disciplines of the natural-mathematical cycle. Therefore, it seems logical to introduce such testing, especially since for many students, unfortunately, the best motivator is the fear of failed of external independent evaluation of knowledge in a particular discipline.

Given the impossibility of full integration of social and economic geography with natural sciences, it may be necessary to develop a separate course for students in grades 10-11 “Socio-economic geography” or an integrated course of social and economic geography with economics or law.

At the end of the experiment, if successful, it is important to understand the Ministry of Education and Science of Ukraine position on the school's integrated science course: it will be mandatory for profolized education, or schools will choose between this integrated course and the study of individual disciplines at the standard level. The second option is currently quite questionable, as it will lead to a significant difference in the ability of graduates to pass the external independent evaluation in disciplines of natural sciences.

It is quite difficult for teachers to adapt to the realities of the new discipline: starting from the lack of sufficient methodological materials and ending with the need to urgently engage in self-education - increasing the level of knowledge in those natural sciences that the teacher did not teach. In Ukraine, graduates of pedagogical universities usually receive two specialties for teaching. Of all the available combinations of specialties for teaching the integrated course “Science”, the most suitable are “biology + chemistry” and “geography + biology”. It should be noted that over the two years of the experiment, the teaching community has significantly improved the teaching methods of “Science”: on teachers' personal websites, on other educational resources (including thematic groups on social networks) appeared lesson compendiums and scripts, video collections, multimedia presentations etc.

Starting from 2016, the specialty 014.15 Secondary Education (Sciences) was introduced into the system of higher education of Ukraine. Several pedagogical universities in Ukraine have introduced a bachelor's degree program in this specialty and the first scientific achievements in the practice of training specialists in teaching an integrated course “Science” arose [10]. In our opinion, the beginning of training in higher education institutions should stimulate the development and improvement of teaching methods for the integrated course “Science”, and the modernization of the content of this integrated course.

4. Conclusions

The attempt to introduce an integrated course “Science” in profile learning in schools of Ukraine is an attempt to meet global trends in education. Such integrated courses should provide not deep, but holistic insights into the relevant sciences in pupils for whom it is not the profile of their learning.

The integration of different subjects in the course of “Science” is realized through the study of natural phenomena and processes in terms of several sciences. This approach is implemented in three projects of the curriculum of the integrated course “Science” out of four (projects No 1, 2 and 3). We consider this approach to be the most successful.

The content of the integrated course “Science” more satisfies the educational needs of students in the humanitarian profile, as such students are more willing to perform observations rather than measurements, descriptions of features and logical relationships, rather than calculations. The emphasis on the implementation of project work and the predominance of qualitative judgments over quantitative in the study of “Science” is quite justified, but to completely abandon the activities associated with the implementation of calculations in the learning process is inappropriate.

Motivation to study natural sciences in the humanities can be increased by emphasizing the practical significance of the acquired knowledge and the organization of a quality laboratory workshop in the classroom.

The content of the integrated course “Science” differs significantly from the content of individual disciplines of the natural cycle, which are studied in the profile school at the level of the standard. This is especially true of geography, chemistry and biology. While the choice of chemistry as a field for further study by humanities students is highly unlikely, biology and, in particular, geography are often seen by them as necessary for external independent evaluation. This raises the problem of different opportunities for graduates who have studied the integrated course “Science” and those who studied physics, chemistry, biology and geography separately at the standard level, in obtaining the necessary points for admission to higher education institution.

Among the students who completed two years of study this year under the project No 2 of the curriculum of the integrated course “Science”, a significant number chose geography or biology as disciplines for external independent evaluation of knowledge. It would be very interesting to compare their results with the average in the city and in Ukraine. Unfortunately, due to the COVID-19 pandemic and quarantine measures, the timing of the external independent evaluation has been changed and it is not possible to obtain and analyze these results at the time of writing.

Improving the methodology of teaching the integrated course “Science” is on the part of curriculum developers and teachers participating in the experiment, as well as teams of higher education institutions, which began training bachelors in the specialty 014.15 Secondary Education (Science).

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Development of soft skills of teachers of Physics and Mathematics

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Abstract. The article considers the problem of the development of soft skills of teachers of Physics and Mathematics in higher educational institutions in the process of certification training in the system of postgraduate pedagogical education of Ukraine. The experience of foreign countries on the relevant teachers' course training has been analyzed, the essence and significance of such soft skills as sociability, creativity, empathy for the professional development of teachers of Physics and Mathematics in higher educational institutions in the process of certification training has been characterized. The state of these skills development in teachers of Physics and Mathematics was studied, the average level of the development these skills has been stated. The possibilities of the soft skills development were determined, the four-stage process of their transition from unconscious incompetence to unconscious competence in the system of postgraduate education was substantiated. The principles, forms, methods, technologies of the development of soft skills in the system of certification training of teachers of Physics and Mathematics were discussed with the emphasis placed on the role of heuristic methods and forms, creative technologies of the soft skills development.

1. Introduction

As the modern world community entered the third millennium of information technology, global computerization and digitalization, it faced the problem of the life technological complexity developing faster than the soft skills level. At the current stage of society development, the entire education system requires significant reformation, with the focus on educational science and pedagogical practice, regardless of the direction of training, being placed on an individual with their vital interests, abilities and moral values, creativity, critical thinking, integrated problem solving, analyzing and decision-making skills.

According to [37], 70% of teachers of non-pedagogical institutions of higher education in Ukraine do not have pedagogical education. It does not allow them to perform highly professional pedagogical activities due to the constantly growing professional requirements.

Due to the imperfection of the certification training system of teachers of Physics and Mathematics (lack of psychological and pedagogical component of training; the teachers' training focused on improving knowledge in the subject area only), the issue of innovative teachers' training is becoming more and more urgent. After all, in addition to deepening the knowledge of professional subjects, the modern teacher pays great attention to the soft skills development. We use the term "soft skills" in the sense of non-specialized, intangible personal qualities that ensure the success and productivity of professional activities on the basis of such documents, as the "Glossary of Curriculum Terminology of



UNESCO International Bureau of Education” [33] and “The Future Jobs Report 2018” of the World Economic Forum [4].

The current system of training teachers of special disciplines is mainly carried out through post-graduate studies (more than 90% of post-graduate students become teachers after the thesis defense). Such system cannot be considered effective, as it is aimed at the scientific activity of teachers with the degree of Philosophy Doctor (PhD), although scientific and educational activities are quite different from each other. The quality of teaching staff is directly related to their professional competence: the continuous improvement of their professional knowledge and skills, the ability to adopt and apply innovative pedagogical technologies and methods in the practical pedagogical activities, being able to find harmony between teaching and scientific research work. The system of professional development of such teachers should take into account the issues of pedagogical skills development, psychological and pedagogical readiness for performing teaching activities, communicative competence, organization of the educational process, etc. The existing traditional system of teacher training for higher educational institutions of Ukraine is still quite old-line [2].

The problem of formation and development of soft skills is relevant, particularly for college students, as it is considered the main condition for their competitiveness in the labor market [1]. Also, it is believed that high unemployment among graduates of vocational schools arises from the fact that teachers tend to ignore the necessity of the development of soft skills, especially the so-called 4C (creativity, critical thinking, communication and collaboration) [12]. From our point of view, the ideas of the development of soft skills in the process of studying natural sciences are unique as well, due to the importance of integrating these skills in science, education and future professional activity [29].

2. Theoretical background

All over the world soft skills are in great demand for various types of professional training, including engineers [34], IT specialists [27], economists. The development of such skills involves a change in the educational process and techniques of teaching special subjects by teachers of not only the humanities but also the sciences. But the problem of unreadiness for such changes creates an insufficient level of soft skills of the teachers and, consequently, leads to the negative impact on the economy. In a study conducted by McKinsey & Company [20], which involved more than 8,000 people in eight European countries (France, Germany, Greece, Italy, Portugal, Spain, Sweden and the United Kingdom), a third of employers said that the lack of soft skills causes serious problems in the economy. In addition, qualification gaps cause the most problems in countries with the highest youth unemployment rates (e.g., Italy, Greece and Spain). With this in mind, European countries as well as the United States include soft skills development in teacher training programs.

The experience of China, which is actively moving towards a service and knowledge-oriented economy and sees the inability of teachers to acquire the necessary soft skills and knowledge to make such a transition as one of the main limitations in this way, is also of value. That is why China's higher education authorities have radically changed and keep changing their approach to the regulation of the teacher training system.

The modern policy of Chinese higher educational institutions provides for the formation of not only hard skills which are very well developed by specialists in science, engineering and other fields, but also soft skills represented by innovation, creativity, management skills, high foreign language proficiency in international communication, teamwork. For example, teachers of Mathematics at Chinese universities have the opportunity to access the nationally accredited open seminars and trainings, organized and funded by the Ministry of Education and Science, and get trained in a range of subjects that are being actively implemented in the curricula. Mathematics ranks third in popularity among all subjects of accredited courses. Important courses aimed at the training of teachers of Physics and Mathematics also include management skills courses, foreign language courses, psychology courses, which allow forming the individual educational trajectory and successfully modernizing the content of education by means of combining the tasks to develop both hard and soft skills. More than 8,000 online or offline courses have been introduced in China, and more than 52,000 teachers have already been

trained. Considering the population of the country and the developmental stage of massive open online courses (MOOC), this number may seem not high enough, however it keeps growing, even though MOOC may face some problems of the interaction between the academics and listeners as well as the difficulties of assessment, materials evaluation and accreditation. Nevertheless, by the end of 2020 the Ministry of Education and Science of China is planning to have 3,000 nationally accredited MOOC [18]. The expansion of the MOOC is happening together with the development of their quality – the courses are conducted by the professional and experienced instructors in a wide range of comprehensive subjects and areas of informal education. The importance of such changes has been emphasized by Qianli Xiong. The researcher believes that the teaching based on MOOCs can be successfully combined with traditional forms of learning [38]. One more scholar Bo Gao suggests that the new teaching model based on the combination of traditional teaching model and MOOC teaching resources can be applied. This approach can significantly improve the abilities of deep analysis of the subject, awareness of the importance of self-learning, enthusiasm and initiative in cooperation with others, thus developing the soft skills [8]. American researchers can also see the perspective in MOOC. Some leading international universities like Stanford, Harvard and Massachusetts Institute of Technology have already launched MOOC platforms such as Stanford eCorner, edX, Udacity, Coursera, MIT Open Courseware [21].

In the context of ensuring student-centered higher education, we studied the levels of development of such soft skills as sociability, creativity and empathy in teachers of Physics and Mathematics, that are necessary for modern teaching.

The effectiveness of the educational process in a higher educational institution is largely determined by the nature of the teacher-student interaction, which includes a set of various connections, relationships and emotional manifestations in the process of such interaction.

As interpersonal relationships arise and develop in the process of communication, it seems obvious that successful and effective interaction between the subjects of the educational process is impossible without practical communication skills. To solve this problem, it is necessary to develop the ability to correctly interpret particular manifestations of communicative behaviour in different situations and, accordingly, to develop practical skills and abilities. It also should be noted that the main prerequisite for successful communication is the linguistic commonness of communicators, i.e., a common language of communication for both. For example, in the United States a teacher should master the second language in order to remove the language barrier.

Depending on the nature of the roles in communication, Tetiana V. Yatsula differentiates it by levels (actual, informational and personal level). The scholar notes: “The personality level of communication is characterized by the interaction, which provides subjects with the opportunity of the deepest self-disclosure and understanding of the essence of another person, themselves and the world around them. This level of interaction occurs in special situations and under certain conditions, when a person develops inspiration, enlightenment, feelings of love, a sense of unity with the world, a sense of happiness, etc. These are special situations of spiritual upturn and development of personality, so this level can still be determined as spiritual. The personal level is deeply moral: it removes any restrictions on interaction precisely because they become superfluous. The personality level of communication is largely determined by the identity of the value orientations of the interacting subjects and the ability of communicants to comprehend the essence of the phenomena of the world through enlightenment (insight) in the process of interaction” [40]. The process of communication is, however, often complicated by the emotional tension of communicants, so another important component of interpersonal interaction is the skills of behaviour in emotionally stressful situations. Irina B. Dermanova and Elena V. Sidorenko proposed a number of training materials and exercises to be used by teachers aimed at improving effective communication skills [5]. For instance, they include techniques for reducing emotional stress, which enable the transition of the interaction into another form.

Communication skills are not limited by the emotional component, but the teachers’ modulation of their emotions and positive attitudes contribute to interpersonal interaction. Interpersonal interaction has a complex structure, it integrates many psychological properties of an individual and permeates different levels of organization of the personality. Nataliia V. Yaksa notes that in the humanities, attention to

interaction as a basis, a method of cognition of processes and phenomena occurring around us often leads to the interpretation of human interaction mainly through their influence on each other. And this does not mean that the impact is extremely aggressive and oppressive. It should be built on the basis of respect, esteem, approval, when one party consciously accepts a certain dominant of another one. Thus, the interaction is interpersonal in nature, when its content is primarily a dialogue of individuals [39].

The modern educational process requires the development of the teachers' creativity. Creativity is an ability of an individual, which is manifested in the realization of his/her creative origin to develop a particular product. It is about both the quality of the latter and the process of its development [26]. In modern science, the creativity is understood as a process that has certain specific characteristics and leads to the creation of the new, and the interpretation of creativity as a potential, an internal resource of an individual [25]. The pedagogical creativity phenomenon is important in our study context. Svitlana O. Sysoieva defines teacher's pedagogical creativity as a personality-oriented developmental interaction of subjects of educational process (a teacher and a pupil/student) caused by specifics of psychological and pedagogical relations between them and aimed at the development of creative personality of a student and the increase of the level of teacher's creative pedagogical activity [30]. At the same time, the teacher's pedagogical creativity is a condition for the formation of the students' creative personality, and the educational technologies designed by the teacher are the appropriate means.

The concept of "creativity" in the context of psychological and pedagogical knowledge became significant only in the early 1950s. In fact, the concept of creativity as a universal cognitive creative ability of an individual became popular after the publication of the works of the Joy Paul Guilford [10]. This type of thinking allows varying the ways to solve the problem, leads to unexpected decisions and results [14].

Serhii D. Maksymenko offers the following definition: "Creativity is a natural property of an individual that has existed since the human life began; this is the highest form of individual's activity. Creativity is an activity that is embodied in the products of creative work. Thanks to creativity, individuals can express themselves, their inner world, while changing it. It creates not only the external world, but also their own (internal) one" [19].

According to Ellis Paul Torrance, creativity means the ability to "dig deeper, focus better, correct mistakes, talk to a cat, dive into the depths, go through walls, light the sun, build a castle on the sand, welcome the future" [32]. As Erich Fromm states, creativity is the ability to be surprised, to find solutions in an unusual situation, to focus on something new, the ability to deeply understand one's own experience. The scholar identifies the potential and current "incarnations" at the centre of the phenomenon of creativity. This happens due to the processes of assimilating a particular (new) type of activity that has social significance by the carrier of potential creativity [7]. From the standpoint of acmeology, Nataliia F. Vishniakova defines creativity as a process inherent in many individuals and a set of intellectual and personality characteristics of an individual, which contributes to the ability to raise problems independently, generate more original ideas and find unconventional solutions [36].

Thus, creativity is the ability to find and develop new original ideas, successfully solve problems in a non-standard way, as well as the ability to solve problems that arise within static systems. This is the ability to see problems from a different angle and find unique ways to solve them.

The basic means of creativity development for the teacher of Physics and Mathematics include:

- Comprehensive erudition. The knowledge of physical and mathematical sciences today can be obtained in many ways (online courses, webinars, educational resources, etc.). The knowledge in other areas (humanities, art) and the ability to combine them with the knowledge of physics and mathematics are a component of the teacher's ingenuity and comprehensive erudition.
- Constant connection (communication) with other teachers. Communication with like-minded people on Facebook and other social networks, on educational platforms stimulates the development of their own creative teaching system.
- Abreaction, deliverance from bondage. A teacher who is confident in their own creative potential is never afraid to make experiments. If there is a feeling of fear, insecurity, it is worth

working on self-esteem. As practice shows, only the teachers who are interesting for themselves, are creative and interesting for students.

- Developing creativity. The teacher of Physics and Mathematics can reach the higher level of creativity through constant work, because developing creativity has recently been compared with athletes' work on their physical shape.
- Constant analysis of own teaching. Awareness of one's own mistakes and accomplishments forms a clear idea of effective teaching methods and helps to avoid the uniformity of the methodology.
- Creativity as an everyday goal. Creativity helps to solve methodical problems. It is important that creativity becomes a part of the daily work for a teacher of Physics and Mathematics, because creativity is a solution for the problems in a completely new extraordinary way.

In order for the creativity of a teacher of Physics and Mathematics to develop as a deep (personality) ability, not only a behavioural (situational) one, the development should take place under the environment influence. Various methods of developing creativity, which involve local influence (for example, non-standard creative tasks), mostly stimulate the individual to understand the tasks given and find some solution technology for them [6]. Creativity should be a constant, not a situational characteristic of a teacher, creative behaviour should rely on a stable motivational basis. Such statements lead us to the conclusion that the process of the development of creativity includes several stages and is accompanied by the mastery of socially significant activities.

According to modern researchers, empathy is a key component in the emotional intelligence structure, as well as one of the soft skills most sought after by employers. It is a factor in professional success, effective relationships and trust between people. Vadim A. Petrovskii defines empathy in the professional reflection structure, including pedagogical empathy [24]. Empathy gives teachers of Physics and Mathematics the opportunity to design the assimilation of educational material by students, taking into account their individual features. As we know, empathy is an ability to feel another person, their psychological condition and needs, to sympathize with them. There are several scientific approaches to understanding this phenomenon, which, however, are united by the recognition of its emotional nature. Larisa A. Petrovskaia defines empathic ability as the ability to emotionally penetrate into the world of another person's experiences and the ability to respond to them emotionally [23]. Tatiana P. Gavrilova considers empathy as the ability to share the problems of other people, experiencing them with a sign of the emotional state to which the object responds [9]. According to Iuvenalii N. Kuliutkin and Galina S. Sukhobskaia, empathy is the ability to understand the world of other people and even penetrate into their feelings, respond to them and feel empathy to these people [17]. Vladimir D. Shadrikov attributes empathy to spiritual abilities, in which the individual rises above the ordinary abilities: "A person knows himself, his spiritual world through another person, while a spiritually rich person cognizes another person better than himself". He distinguishes between emotional, cognitive and predicative forms of empathy [16].

Artur E. Shteinmetc emphasizes that empathy should not only be considered as an emotional phenomenon, pointing out the gnostic component in its structure [28]. Kristina V. Verbova states that there is a cognitive and emotional empathy [35]. In the context of considering empathy as the basis of emotional intelligence and reflexive abilities, the study of Svetlana B. Borisenko is interesting for us; according to him, empathy includes the following components: emotional identification processes, personal reflection, the moral consciousness level [3].

Thus, the scientific resources analysis gives grounds to state that the authors, recognizing the reflection and empathy of the teachers' professional abilities, consider the relationship between these concepts differently: they are identified, included as the part of one or the other, or distinguished. In this research, the empathy of teachers is considered as the basis of pedagogical reflection, supporting the ideas of those researchers who interpret reflection as a generic concept regarding empathy.

3. Results and discussion

The teachers of Physics and Mathematics of such higher education institutions as Kyiv National Economic University named after Vadym Hetman, National Pedagogical Dragomanov University, Kyiv National University of Trade and Economics, National Transport University, State Institution of Higher Education “University of Educational Management” took part in the survey. The study involved 138 teachers of Physics and Mathematics who were in the process of certification training in higher education institutions.

The following methods were used to determine the soft skills levels of teachers of Physics and Mathematics:

- “Sociability Level Test” by V. F. Riakhovskii;
- “Manifestation of Creativity” method by A. Lazukin and N. Kalin;
- “Ability to Empathize” questionnaire by I. Yusupov.

These methods allowed analyzing the formation of soft skills levels, characterizing the state of the problem and justifying the relevant stages of these skills development in postgraduate education. To overcome the subjectivity in the testing process, a representative sample of subjects was formed, a formalized instruction procedure was applied, and the answers anonymity was ensured.

Communication as a means of interpersonal interaction is an important area in the professional activities of teachers of Physics and Mathematics, who interact with the subjects of the educational process. In order to determine the sociability levels, we used the “Sociability Level Test” by V. F. Riakhovskii [13].

The methodology consists of 16 questions with three possible response options: “yes”, “no”, “sometimes”. For each “yes” the respondent receives 2 points, “no” – 1 point, “sometimes” – 0. Then the total number of points is calculated (0–8 points correspond to a high sociability level; 9–24 points – medium sociability level, 25–32 points – low sociability level).

The generalized results of determining the respondents’ sociability levels are presented in figure 1.

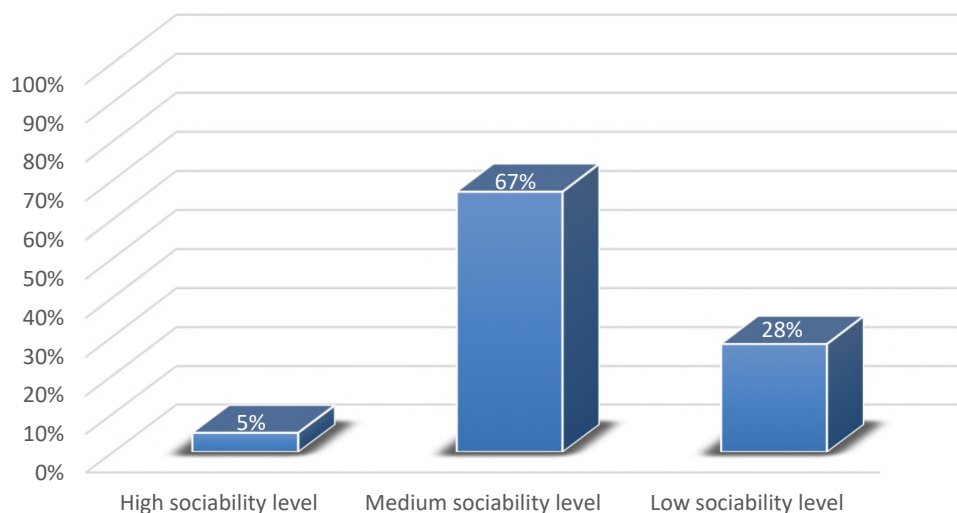


Figure 1. Sociability levels of teachers of Physics and Mathematics.

The majority of respondents – 92 people (67%) – have a medium sociability level. Teachers with an average sociability level feel quite confident in unfamiliar circumstances. We can state that they easily find common ground with other interlocutors.

The low level is typical for 39 people (28%). Such teachers are not sociable, modest, introvert, they prefer privacy and isolation but tend to suffer from it. It is difficult to communicate with such teachers. They cannot be relied upon in matters that require collective effort.

A high sociability level was stated for 7 people (5%). Such teachers feel comfortable everywhere. They take on any task, although they may not always be able to complete it, however sometimes such sociability is painful.

During the study, the creativity levels were determined using “Manifestation of Creativity” method by A. Lazukin and N. Kalin. The methodology consists of 15 questions with two statements each. The respondents had to select the one that is most acceptable to them or better consistent with their ideas, and reflects their points of view more accurately.

The level of positive attitude, desire for creativity, as well as a certain level of development of creativity as a creative potential of an individual is expressed through the selection of the answers given in a key. The greater the sum of points, the better the person’s attitude to creativity: 12–15 – high level; 4–11 – medium level; 0–3 – low level.

The results of the study of creativity, which is manifested in the realization of creativity of an individual in the particular product development, are presented in figure 2.

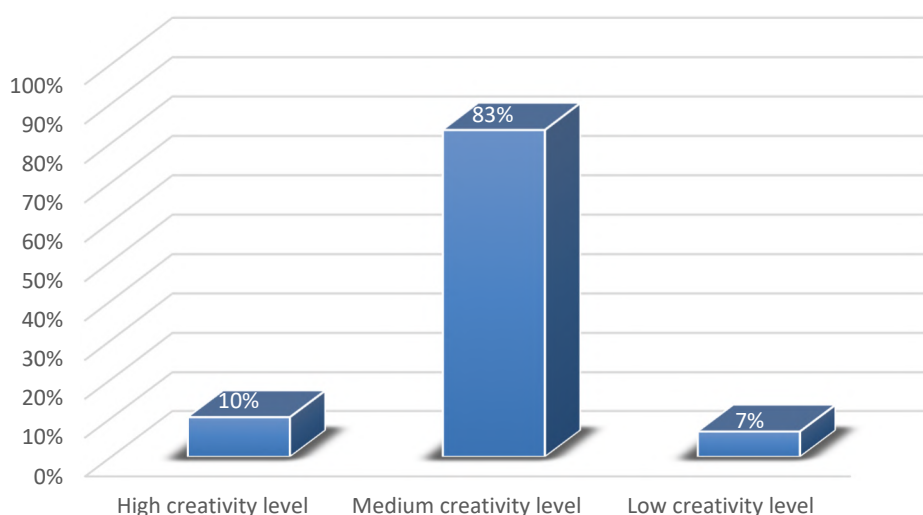


Figure 2. Creativity levels of teachers of Physics and Mathematics.

We can see that all the creativity levels are manifested among teachers, but medium level dominates – 115 people (83%), high level of manifestation ranks second – 14 people (10%), and low level is the least manifested – 9 people (7%).

The ability to empathize is directly related to the teachers’ individual approach to students in the educational process, their individual educational trajectory. Levels of empathy of teachers of Physics and Mathematics were determined with the use of the questionnaire “Ability to Empathize” by I. Yusupov. The methodology contains 18 questions with the following response options: “I don’t know”, “never”, “sometimes”, “often”, “almost always”, “always”. All points for responses are summed according to the answers: “I don't know” – 0, “never” – 1, “sometimes” – 2, “often” – 3, “almost always” – 4, “always” – 5. The level of empathy is determined by the following norms: 82–90 – very high level, 63–81 – high level, 37–62 – normal (optimal) level, 12–36 – low level, 11 and less – very low level.

The generalized results of determining the respondents’ empathy levels are presented in figure 3.

As the respondents did not show extremely high and low empathy levels, it was considered inexpedient to graphically represent the zero indicator in Figure 3.

Medium (optimal) empathy level, which dominates among the respondents, is typical for the majority of respondents – 109 people (“79%). High empathy level has a slight manifestation in the sample – 9 people (“7%), which means sensitivity to the needs of others, generosity, emotionality, but such people find it difficult to be accurate in painstaking work. Low empathy level stated for 20 people (“14%) indicates some difficulties in establishing contacts with people and sensitivity to their needs.

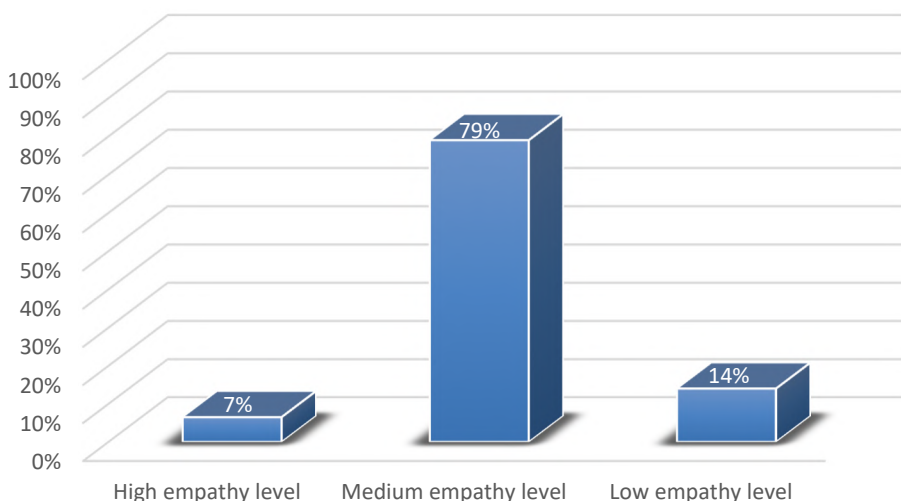


Figure 3. Empathy levels of teachers of Physics and Mathematics.

The results of diagnosing the levels of the studied soft skills of teachers of Physics and Mathematics are presented in table 1.

Table 1. Levels of the studied soft skills of teachers of Physics and Mathematics.

Item No.	Levels of soft skills	Sociability		Creativity		Empathy	
		number	%	number	%	number	%
1.	High level	7	5	14	10	9	7
2.	Medium level	92	67	115	83	109	79
3.	Low level	39	28	9	7	20	14
Total:		138	100%	138	100%	138	100%

Since the soft skills acquisition involves certain stages, it is worth paying attention to the development as a field of personality theory. Explaining the development of an individual and individual differences are some of the most serious objectives that psychologists are facing [22]. The individual development determinants are usually divided into genetic and environmental ones.

Different views on what is more important for the individual – genes (nature) or environment (education) – dominated at different points of the science development. Lawrence A. Pervin and Oliver P. John wrote that in recent years, there has been a growing attention to genetic factors, but even proponents of this view sometimes admit that the pendulum towards increasing natural determinants was swung too much [22].

Personal growth is due to many external and internal factors. External factors, or the environment determinants, include: the individual’s belonging to a particular culture, socio-economic class and the environment which is unique for each family.

According to Larry L. Hjellev and Danuel J. Ziegler, scholar’s controversy over the issue on what has the greatest impact on development – genetic factors or environment – has given impetus to the development of new theoretical ideas to explain how these factors should interact to lead to the emergence of certain characteristics of behaviour [11]. This is an interactionist position (interactionism is a direction in modern social psychology, which is characterized by consideration of the development and life of an individual in the context of social interaction). According to this position, heredity imposes restrictions on the range of development of certain characteristics, but, nevertheless, within this range, the further development of characteristics is determined by environmental factors. Igor S. Kon wrote

the following in this regard: “All these possible predictions are statistical in nature, they relate to the psyche and behaviour of the average person, with a given type of nervous system, with a given self-awareness or with a given social status. But it is impossible to deduce particular features and actions of the given particular person on their basis because all these regular relationships (genotype – phenotype; biography – individuality; social system – specific social role) are in different planes, and their intersection in a given individual is random in relation to each of them separately. A specific, original, unique result, which emerges from their intersection, cannot be predicted in advance. The same life experience gives different results in combination with different psychophysiological features and social conditions” [15].

We believe that the environment is of great importance in the teachers’ personality development, particularly in the soft skills development. However, it is difficult to exactly predict how these factors affect teachers. The only fact that remains indisputable is that such influence is inherent in the process of socialization.

Thus, soft skills are being acquired in the process of establishment and development of personality of the teacher of Physics and Mathematics under the purposeful and/or spontaneous influence of external and/or internal factors. Such development is a process of the teachers’ mental and moral growth, it covers all quantitative and qualitative changes of innate and acquired traits. We emphasize the importance of the teachers’ sociability, creativity and empathy among their personality traits.

The teachers of Physics and Mathematics were developing the soft skills within the four stages proposed. Using the concept of “stage” in the sense of a particular moment, period, stage in the development, stages of the soft skills development are understood as certain periods in the personality development of the teacher of Physics and Mathematics, which aim at the consistent activities to achieve high level of soft skills. The staged formation of an integral process of the soft skills development allows ensuring the most effective dynamics of their development in teachers of Physics and Mathematics.

The management coaches Sara Thorpe and Jackie Clifford clearly demonstrated how education can influence the process of competence development in “The Coaching handbook: An Action Kit for Trainers & Managers” [31]. The scholars compared some of the theories that underlie modern ideas about learning and development. According to this theory, learning is a four-stage process that involves the transition from unconscious incompetence to unconscious competence (see figure 4): unconscious incompetence; conscious incompetence; conscious competence; unconscious competence.



Figure 4. The process of competence development according to Sara Thorpe and Jackie Clifford.

Unconscious incompetence. With unconscious incompetence, a person is not aware that he does not know anything (or does not know how to do it). He is at the level of “*I don’t know what I don’t know*”. It is possible that a person has almost no need to acquire this skill or knowledge and therefore has not yet realized the lack of his competence.

Conscious incompetence. With conscious incompetence, a person acquires knowledge about his “ignorance”. This is usually due to the need or desire to take an action. This is the “*I know what I don’t know*” stage.

Conscious competence. In order to become consciously competent, a person needs to go through training (formal or informal). At this stage, a student of higher educational institution often copies the teacher’s actions. At every moment of time, a student realizes what he is doing, because he is at the stage of “*I know what I know*”.

Unconscious competence. In unconscious competence, knowledge and skills are used so often that they become “habits”. Performing particular actions, the person no longer feels the need to think through each step, because the algorithm of the action is embedded in the unconscious (or subconscious). Then a person can state: “*I don't know what I know*”.

Thus, unconscious competence (automatic application of acquired knowledge, skills and abilities) is the highest competence level. Achieving this level is one of the main goals of education.

The process of the soft skills development in teachers of Physics and Mathematics can be correlated with the approach to understanding the process of competence development proposed by Sara Thorpe and Jackie Clifford (see figure 5).

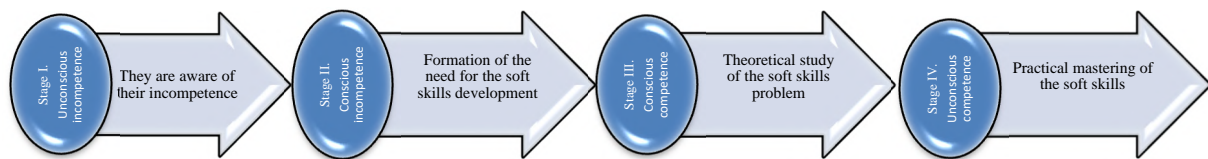


Figure 5. The process of the soft skills development.

The authors proposed four stages of development of soft skills of teachers of Physics and Mathematics, each having a specific purpose, determined in accordance with the purpose, objective, content, as well as forms and methods of implementation of the stage.

Thus, *the first stage of the soft skills development* corresponds to “*unconscious incompetence*”, because teachers of Physics and Mathematics, having not enough practical professional experience, may not be aware of the lack of their soft skills. Therefore, the purpose of this stage is making them aware of their incompetence.

The objectives of the stage:

1. Diagnose the level of sociability, creativity and empathy of teachers of Physics and Mathematics.
2. Analyze the results of input diagnosis.
3. Let teachers of Physics and Mathematics get acquainted with the stages of development of soft skills.

The content of the stage implementation:

1. Input diagnosis of sociability, creativity and empathy levels of teachers of Physics and Mathematics.
2. Analysis of the results, discussing them with respondents.
3. Delivering information lecture/seminar entitled “Soft Skills – Competencies of the 21st Century”.

The purpose of the *second stage of conscious incompetence*, when teachers of Physics and Mathematics have already realized their incompetence, is the formation of the need for the development of soft skills.

The objectives of the stage:

1. Motivate teachers of Physics and Mathematics to increase the level of sociability, creativity and empathy.
2. Understand the importance of developing soft skills as a necessary competence of a modern teacher.

The content of the stage implementation:

1. Conducting a business game to develop motivation.
2. Holding a meeting of the Discussion club on the topic “Soft Skills of Teachers of Physics and Mathematics: Realities and Prospects”.

Forms and methods of the stage implementation:

1. Business game “Motivator”.
2. Discussion club with the use of media teaching aids.

At *the next stage of “conscious competence”* teachers of Physics and Mathematics begin to theoretically study this problem.

The objectives of the stage:

1. Systematize knowledge about soft skills obtained in the process of studying related topics of other subjects.

2. Study a special course “Soft Skills of Teachers of Higher Educational Institutions”.

The content of the stage implementation:

1. Generalization of knowledge about soft skills obtained in the process of studying related topics of other subjects by teachers of Physics and Mathematics.

2. Introduction of content modules of the special course “Soft Skills of Teachers of Higher Educational Institutions” into the educational system of higher educational institutions.

The special course highlights the conceptual principles of soft skills development in teachers, substantiates their essence and structure, offers interactive forms and methods of development of these skills, including communication, creativity, empathy as the basis of emotional intelligence. The course has been designed for 30 academic hours, which corresponds to one ECTS credit. Mastering the discipline involves the study of three thematic modules, each of them includes 10 academic hours. The structure of each module provides 6 hours of in-class work (one lecture, one seminar and one practical class), 2 hours of independent work, 2 hours of control and evaluation activities. In order to check the knowledge acquired during the lectures and independent work, a list of tasks for self-assessment, continuous and modular assessment is proposed, at the end of the course it is planned to conduct a summative assessment. The first thematic module is devoted to the communicative competence of the teacher, the second one – to the creative potential of the teacher, the third one – to the emotional intelligence of the teacher, led by empathy.

Forms of the educational process organization:

- training sessions (lectures and seminars);
- independent work;
- control (continuous, thematic and summative control);

Methods and techniques for the development of sociability, creativity and empathy of teachers of Physics and Mathematics:

- methods of organization and implementation of educational and cognitive activities;
- methods of stimulating and motivating educational and cognitive activities;
- methods of control and self-control of the effectiveness of educational and cognitive activities.

Finally, *the stage of unconscious competence* involves practical skills and communication skills, the ability to apply different strategies in solving problems (creativity), the ability to empathize.

The objectives of the stage:

1. Acquire the ability to operate with theoretical knowledge about soft skills.

2. Acquire communication skills.

3. Acquire the ability to apply different strategies in solving problems.

4. Acquire the ability to empathize.

The content of the stage implementation:

1. Modelling the process of the development of soft skills.

2. Development of communication skills.

3. Development of the ability to apply different strategies in solving problems.

4. Development of the ability to empathize.

Forms and methods of the stage implementation:

1. Webinar “Modelling the Process of the Soft Skills Development”.

2. Training on the communication skills development.

3. CARUS (combination, analogy, reconstruction, universal strategy, random substitutions) training on the development of creativity developed by V. Moliako.

4. Training on empathy development.

4. Conclusion

Therefore, the problem of the soft skills development in teachers of Physics and Mathematics in the system of postgraduate pedagogical education is urgent and needs thorough research. Studies of the level of development of such soft skills as sociability, creativity, empathy, conducted with teachers of Physics and Mathematics, indicate that for most respondents their development corresponds to the medium level. The number of teachers with a low level of sociability and empathy is greater than with a high one. The opposite trend is observed for creativity, which may happen due to the technical creativity of teachers, but it has less effect on the quality of interaction with students and the feedback establishment compared to sociability and empathy.

We have determined that the soft skills development of teachers in the postgraduate education system is a four-stage process that involves the transition from unconscious incompetence to unconscious competence. The process includes diagnostics, professional development planning, its implementation, reflection, results correction of the certification training. This process should be based on andragogical principles, namely: independence of learning, joint activities, reliance on the experience of teachers, individualization and consistent learning, updating the results of educational activities, development of educational needs of every teacher. We believe that preference should be given to heuristic forms and methods of conducting classes that most contribute to the soft skills development of teachers. At the stage of presenting theoretical material, it is advisable to use active lectures with a significant role given to the students, but not to the teacher. Practice shows that theoretical material is of interest to students only when it is delivered in close cooperation with them on the basis of their pedagogical experience. Lectures should be delivered in the form of the active polemics, accompanied by discussion questions, solving various pedagogical problems, etc. In order to deepen the communicative, creative and empathic abilities of teachers of Physics and Mathematics, the preference in the postgraduate education system should be given to creative learning technologies, often conducted in simulation forms.

It is planned to further study the implementation effectiveness of the suggested stages of soft skills development in teachers of Physics and Mathematics in higher educational institutions, the possible adaptation of the suggested methodology for the teachers of other disciplines, development of such soft skills as critical thinking, decision-making, people management in teachers of other subjects and the institutions of other educational levels.

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Formation of the scientist image in modern conditions of digital society transformation

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Abstract. The publication considers factors that are influencing formation of scientists image especially: availability to inform scientist or scientific organization about the registration, scientometric indices, use of global identifiers to improve accuracy in calculating indicators, publication of papers in journals with high impact factor, publications in resources that provide visibility in global information space, involvement in global communications system, level of competence. Specialists in various fields of science developed a number of practical recommendations for various techniques and tools that can be used and are helpful to create and to make, both personal image and image of the organization, institution, firm, etc. Also, main directions of using digital technologies to create the image of scientists are identified and substantiated. Scientists formulated recommendations to make their own image using digital systems based on analysis of scientific literature and personal experience: author’s digital identifier ORCID, profiles in international scientometric systems, saved publications in electronic libraries, profiles in social and scientific electronic networks, etc.

1. Introduction

The Concept of Digital Economy and Society Development of Ukraine for 2018-2020 [8] states that integration of Ukrainian science into the European research space will provide an opportunity to develop advanced scientific ideas, participate in interdisciplinary projects focusing on promising ideas, technologies and innovations. Also, one of the important elements of the EU Digital Single Market and part of the paradigm “Open Innovation – Open Science – Openness to the World” is development of the European Open Science Cloud and European Data Infrastructure. The main areas of harmonization of Ukraine’s research initiatives with the European Research and Innovation Area include: development of interoperable digital infrastructures for educational and scientific institutions, connection to the GEANT educational network and distributed computing system, data collection, storage and processing of European grid infrastructure; opening access to data and publications made at the expense of state funding, creation of technological “road maps” of public-private partnership, commercialization of scientific developments for industry and social challenges, etc.



Today, one of digital society features is rapid flow of scientific data obtained as result of scientific research. It leads to increase in requirements for their quality and level of development of scientists' digital competence. Also, it is important to build scientist image. It is a part of its professional recognition, scientific career, as it directly affects award of scientific degrees, academic titles, various grants, awards, scholarships, etc.

Oleksandr F. Konovets [27] notes that image-dominant is number of scientist publications as well as correct choice of communication channel, target audience, authority and level of scientific publications. In the scientific environment there are criteria for professional status of a scientist: academic degree, academic title, number of publications and number of citations by other researchers, reviews, academic and state awards, etc. Scientist image can be measured in several ways: 1) through an expert survey and recognition of its results in the form of awards, prizes, grants, other forms of public recognition; 2) involvement of special, so-called quantitative and qualitative methods - content analysis, index citation, impact factor, on the basis of which the ratings of scientists on these scales are compiled; 3) use of sociological methods of public opinion research: surveys, interviews, questionnaires.

Scientists image is researched and measured by the rating of their scientific publications in various digital open systems in information society. We agree with the call made in the article [67]: "Do you want to effectively present your own scientific publications, find new colleagues, open new opportunities for funding, learn your scientometric indicators? – Start building your virtual scientist profile now!"

The research relevance on scientist image formation with use of digital technologies is due to:

- mass process of science and education digitization as an important component of the digital society development and need to ensure open access for researchers to variety of information resources and research results;
- introduction of the open education and open science concepts, which requires development of relevant competencies in scientists, as well as in future PhD;
- scientists are interested in tools for measuring citation of their own publications and open access to information resources;
- introduction of innovations in scientific activity and educational process (institutional depositories, electronic libraries, scientometric systems and databases, electronic social networks, electronic journal systems, systems for conferences, etc.);
- development of various curricula, manuals and textbooks for preparation of future PhD, which requires harmonization of training graduate students methods and use of digital technologies, taking into account their constant updating and improvement.

2. The latest publications analysis

Peculiarities of specialists image formation and universities are considered in researches [2], [4], [5], [11], [34], [37], [42], [44], [50], [51], [57], [58], [63] and others. Various aspects of digital open systems use to support scientific activities are described in: Drahomira Herrmannova [16], Valeriy Yu. Bykov [7], Svitlana M. Ivanova [22], [23], [24], Liliia A. Luparenko [33], Tetiana L. Novytska [45], [46], [47], Oleg M. Spirin [7], Andrii V. Semenets [59], Vasyl P. Martsenyuk [59], Ilami Yasna [68], Anna V. Iatsyshyn [17], Alla V. Kilchenko [26], in particular, their application in the preparation of future PhDs is covered in publications [9], [17], [20], [26], [38], [43], [48], [69], [65] and others. Features of digital technologies use for research and organization of the educational process are considered in the works: Volodymyr O. Artemchuk [18], [19], [21], [29], Isaiah T. Awidi [1], Olga V. Bondarenko [3], Oleksandr Yu. Burov [6], [21], [52], Liudmyla H. Havrilova [15], Anna V. Iatsyshyn [19], [21], [29], [32], Olena O. Lavrientieva [30], Benedetto Lepori [31], Oksana M. Markova [35], Yevhenii O. Modlo [39], Pavlo P. Nechypurenko [41], Olga P. Pinchuk [52], Svitlana I. Pochtoviuk [53], Oleksandr O. Popov [19], [21], [29], [72], Serhiy O. Semerikov [61], Mariya P. Shyshkina [19], [52], [54], Oleksandra M. Sokolyuk [19], [52], Vladimir N. Soloviev [55], Oleksandr V. Syrovatskyi [64], Michael Thai [66], Yana V. Topolnik [14], Tetiana A. Vakaliuk [60], Snizhana O. Zelinska [71]

and others. However, works analyzed above do not contain comprehensive consideration of main areas of digital systems use to build scientists image. We state that problem of scientists image formation is only under development and requires special research, as scientific research on its solution is insufficient.

The publication aim is to define and substantiate directions and means for scientist image formation in conditions of digital transformation of society.

3. Main material

First of all, let's consider concept of "image" and its components. In recent decades, the concept of "image" became widespread and was involved in various spheres of social life, initially in advertising and marketing, due to revival of business and commerce, where image is a factor influencing consumer consciousness. Subsequently, this concept began to be used in psychology, sociology, culturology, pedagogy and management. Currently, the concept of "image" is interdisciplinary, one that synthesizes features of different spheres of human existence and at the same time is special for each individual scientific field [4].

In modern conditions, image formation arises on the border of psychology, economics, sociology, philosophy, culturology, pedagogy, political science and other sciences, as evidenced by growing number of scientific publications and research on image issues and active involvement categories "image" to the conceptual apparatus of various sciences [4].

Lack of single interpretation of image leads to the fact that researchers have different approaches to determining its typology, structure, as well as functions which it performs [44]. Common definitions of the term "image": 1) advertising, representative image of someone (for example, a public figure), created for the population; 2) purposefully formed image (person, phenomenon, object), designed to exert emotional and psychological influence for the purpose of promotion, advertising, etc.; 3) image, real or imaginary appearance, attitude to them on the basis of their popularity and success, trust and sympathy of people; 4) purposefully formed image (of a person, phenomenon, object), designed to exert emotional and psychological influence on someone for the purpose of promotion, advertising, etc.; 5) specially designed and purposefully implemented image of an object or phenomenon; 6) self-promotion, etc. [4]. Related to the term "image" are several concepts, in particular, "stereotype", "image", "reputation", "representation", "authority", "brand".

The publication [44] states that idea of person as a specialist, a master of his craft allows you to create professional image, an important component of which is personal image, which contributes to professional functions of individual, its career growth and skills in a particular field. Image is a communication tool with audience, result of conscious work, especially in situations where image is part of professional success. Therefore, image, including professional, is a complex socio-psychological phenomenon. It is difficult to assess qualitatively according to certain objective criteria, although real need for this is quite high.

Positive professional image, in our opinion, can be considered as indicator of quality implementation of specialist in particular field of activity. It depends on its willingness to create such image [44]. Therefore, it is important to purposefully form image given ability of a person to change properties and qualities that create its image through modification of activities, appearance, development of certain abilities, changes in behavioral patterns and more. Image creation activity is component of any professional activity related to work of specialists in professions such as "person-person", "person-team", "person-large social groups". It helps to increase productivity of the main professional activity of subject and improving its acmeological characteristics [4].

Scientists from various fields of science developed a number of practical recommendations for various techniques and tools use. They help to create and build both personal image and image of the organization, institution, firm, etc. Let's analyze in more detail specifics of dissemination of information about scientists, directions of development, techniques and tools that should be used to build the image of a scientist in today's digital transformation of society.

The publication [56] describes methodological principles underlying the regulations adopted in Ukraine. They determine the procedure for state certification of scientific institutions. The problems of implementation of government decisions on transition to international criteria for evaluating the work of scientists are analyzed. Emphasis is placed on analysis of methodological approaches that characterize publishing activity of researchers and research institutions.

The work “Criteria of a Scholar” [28] highlights the problem of personality in science. Its contribution to the world treasury of knowledge is identified. Aspects of professional and public recognition of the scientist are revealed. The main attention is paid to analysis of modern criteria and methods of evaluation of scientists’ activity. The world experience of construction of scientometric indicators and features of their application in Ukraine are analyzed. The scientific biography as phenomenon of scientist recognition is considered.

The research [62] is devoted to study of objective and subjective factors that contribute to realization of scientific potential of young scientists. Conceptual interpretation of scientific potential is clarified. It enables its empirical measurement. Two levels of theorizing (macro- and micro-level) are taken into account, but scientific potential of micro-level is more appropriate because it is based on subjective component of scientific potential and allows to study scientific potential of scientific subjects. Macro-level approach is based on neo-institutional paradigm of social development and the resource approach. It emphasizes resource and institutional components of scientific potential. Theoretical interpretation of the concepts “subject of scientific activity”, “factors of realization”, “scientific activity” is carried out. Realization factors of scientific potential of young scientists are empirically determined and investigated.

Problem of everyday practices of science functioning as a social institution is considered in [11]. There are metaphors comparisons in this area such as: “black box” and “unconscious science”. Ethical and pragmatic implications of both approaches are analyzed and our own metaphor of science “reverse side of the mirror” is proposed. Heuristic potential of practical implementation of this metaphor is revealed on the example of presented training program of self-presentation (image creation) and self-organization for young scientists and teachers, developed for the Council of Young Scientists of the Belarusian State University.

The work [25] analyzed culturological aspect of virtual reality nature as an object of study and sphere of scientist self-presentation. Peculiarities of status of an individual transformation as a consumer of various kinds of information in network are determined. Crisis aspects of “user-virtual-user” communication is clarified. An attempt is made to outline the significance of the latest changes in the field of culture related to development and spread of virtual reality.

Analysis of network communities as sources of information communication is performed in the publication [12]. It provides brief description and comparative analysis of popular web communities. The scheme of functioning of the site “Ukrainian scientific Internet community” (<http://www.nauka-online.org>) is developed.

Development of digital infrastructure (for science and education institutions) is also crucial for ensuring open access to scientific data and knowledge, further commercialization of research, creation of innovations, products and services. New knowledge and developments carried out at the expense of financing from the state budget should be openly available and become property of society as a whole. However, lack of access to global scientific digital infrastructures – to the global knowledge base, computer services, consulting, research in fundamental and applied fields negatively affects Ukrainian science in general, is a significant limitation for Ukrainian scientists, engineers and civil servants. It does not allow assess possibilities of Ukrainian science; look for options for cooperation in international projects, etc., in particular in areas related to digital technologies [8]. Also, it is important to use resources of the European Open Science Cloud and European Data Infrastructure to obtain up-to-date research results by Ukrainian scientists and their implementation in Ukraine.

During this project the Science Europe Association noted in Plan S [10] that, from 2021, all scientific publications on research results funded by public or private grants will be provided by national, regional and international research councils and funding bodies. They must be published in

open access journals, on open access platforms or directly accessible through open access to the repository without hindrance. The document sets out ten principles of open science, namely:

- authors or their institutions retain copyright to their publications; all publications should be published under open license, preferably the Creative Commons Attribution (CC BY) license, in accordance with the requirements set out in the Berlin Declaration (<https://openaccess.mpg.de/Berlin-Declaration>);
- the fee for open access publication is paid by financiers or research institutions, not by individual researchers; it recognizes that all researchers should be able to publish their work in the public domain;
- sponsors and other research-funded campaigns develop clear criteria and requirements for services that should provide high-quality open access journals, open access platforms and open access repositories;
- financial support for various business models for magazines and open access platforms; when paying for open access publications, they should be relevant to subject matter of publications, and structure of such fees should be transparent to inform the market, finance potential standardization and limit payment fees;
- in cases where high-quality journals or open access platforms do not yet exist, those who fund them will coordinate their creation and support, where appropriate; support will also be provided for open access infrastructures as needed;
- financially encouraging governments, universities, research organizations, libraries, academies and research societies to align their strategies, policies and practices, especially to ensure the transparency of research;
- funds do not support a “hybrid” publication model, however, as a transitional path to full open access in a well-defined time frame and only as part of transformation mechanisms, financial support can facilitate such activities;
- above listed principles are applied to all types of scientific publications, but it is clear that timeframe for achieving of open access for monographs and book sections will be longer and require separate and appropriate process;
- financial commitment that it should evaluate intrinsic and external value of the work and not consider the publication channel, impact factor (or other metrics of the journal) or the publisher, during evaluating research results and making funding decisions;
- financial control of observers’ compliance and authorization.

4. Recommendations for scientist image formation

A group of researchers in the work [58] determined that scientists image formation is influenced by: availability of information about scientist and academic or scientific organization to which it belongs; scientometric indices; use of global identifiers to increase accuracy in calculating indicators; publications of scientist in journals with high impact factor; publications in resources for which visibility in the world information space is provided; involvement in the world communications system; level of competence.

Important qualification mechanism for proving of scientific significance of scientists work, trust in their results is presence of dissertations, students, monographs and regular publications in specialized scientific journals, impact rating, scientometric systems, creation of scientific school of scientists or involvement in this school, participation in various projects, programs, scientific conferences, which testifies to demand for the scientist. Also, it is important to ensure free access to scientific and creative heritage of scientist and its school. It forms high degree of confidence in authority of scientist and supports it and its students. In this aspect new opportunities open up to increase status and confidence in results of its research. In these conditions, there is such phenomenon as formation of personal web pages in the global network. It makes possible to disseminate information not only in their country but also abroad, in the world scientific community [49].

The publication [49] emphasizes that now personal information about scientists on the Internet is growing – on personal pages and websites of official institutions. It can be successfully used in the system of qualification assessments of scientific status of scientists and effectiveness of its research, development of its scientific school or direction. In science there is enough information for objective analysis. The web pages of scientist most vividly show development and personification of knowledge today, represent not only scientist image, but also serve as a source of analysis for predicting of science development, advanced technologies and areas. Personal web pages of scientists became an important component of international scientific information systems, which present scientific publications in an organized interface (Google Scholar Citations, ORCID, Microsoft Academic Search, etc.). It provides ability to enter and identify personal information. Scientists, who today understand importance of citation system, seek to deeply present results of their scientific activities and their continuous development. Bibliographic information, digital copies of publications, annotations of works, links to electronic publications on the Internet, hyperlinks to industry sites, audio files from interviews, texts of lectures, reviews are added [49]. Indeed, today personal websites and web pages of scientists are comprehensive source of biographical and bibliographic information, expanding the opportunity to present to the international scientific community information about their professional activities, scientific results and ideas in form of published and unpublished scientific papers. It greatly helps scientists to create their own image. in the scientific space.

We agree with the statement in the publication [49] that professionally structured and filled on the established principles page with information about scientist allows to significantly increase the level of qualification assessments during the scientific examination of the scientist's work. It is an important issue in the development of Ukrainian today – during discussion of methods of scientific research and efficiency research of scientific institutions. Also, it is more important to provide objective assessments of content of scientific work as an individual scientist, and to study the impact on development of particular branch of individual scientific schools.

The work [13] considered problem of searching for data in social networks. Prospects of using ontological models for a semantic approach implementation into processing of requests from users of social networks are shown. Ontological model of social network “Scientists of Ukraine” was built. It is designed to ensure coordination of scientific activities of domestic scientists. Algorithm for semantic search of information according to the developed ontological model is proposed.

The research [59] proposed approach to creation and integration of user profile data in scientific social networks and open registers. Application of this approach provides maximization of information presentation about scientific publications and research work of scientist for the world scientific community. In this way researcher gets significant opportunities to expand cooperation with domestic and foreign organizations or scientists.

Large-scale study of visibility in scientific social network ResearchGate of American and European higher education institutions is described in the publication [31]. Institutional visibility of ResearchGate is strongly related to number of academic staff. Publications presence in the Web of Science is sufficient condition for institutional profile presence in ResearchGate. For higher education and research institutions on the Internet, the ResearchGate score is more relevant to number of publications than to citations impact. The ResearchGate score should not be used to compare institutions on research quality. The ResearchGate became the most popular website among academic social networks in terms of regular users, but not all institutions joined, and therefore assessments given to scientists and institutions are contradictory. Also, presence of European and US higher education institutions in ResearchGate in 2017 was assessed and the impact and quantitative scores of these institutions in ResearchGate were reflected. Most of the 2,258 European and 4,355 U.S. higher education institutions included in sample had institutional profile in ResearchGate. For institutions with doctoral programs, the presence in ResearchGate was closely linked to number of Web of Science publications. Thus, institutional results in ResearchGate reflect volume of research more than clarity; this figure strongly correlates with number of Web of Science publications. However, value of ResearchGate scores for institutional comparisons has some limitations [31]. Therefore, it is also

important for scientific and scientific-pedagogical workers to have personal profiles in various scientometric systems and specialized social networks and to use such systems for scientific communication and personal image building.

The publication [17] explored number of services to determine those that best meet needs of scientists for publication, dissemination and use of scientific information resources. It was also emphasized importance to use open electronic systems with international recognition, including electronic libraries, international scientometric systems, open journal systems to perform scientific work.

Following quantitative and qualitative indicators of publication activity of degree seekers are used during defending dissertations, awarding academic titles, certification of graduate and doctoral students: the Hirsch index, i10-index and others. Thus, in context of development of the digital society and the improvement of digital technologies, the training of researchers of the new technological era, and in particular the training of graduate and doctoral students needs significant updating with the use of digital open systems. We believe that it is important to improve skills of scientists and future PhDs in use of digital technologies not only for research, but also to build a personal image. Figure 1 schematically shows benefits of professional image formation of scientist. It influences career growth, receiving various scholarships, awards, grants, projects, etc. Because scientist's image formation is important part of its scientific career and primarily affects its ratings in various scientometric systems, receipt of various grants, awards, scholarships or additional research funding.

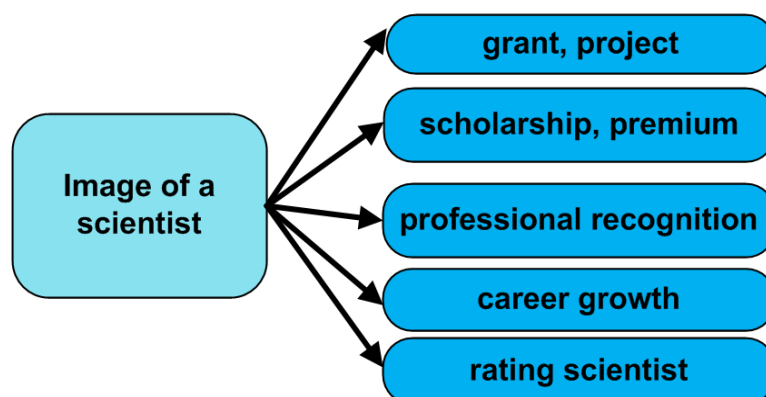


Figure 1. Benefits of professional image formation of scientists.

5. Digital technologies use as means for scientist image formation

There are recommendations based on our own experience [17], [20], [29] and analysis of the scientific literature [5], [12], [36], [49], [58], [59], [63], [68], [70] for scientists and future PhDs on the use of digital technologies for personal image building:

1. *Digital scientist ID ORCID.* It is a unique digital identifier of the author. It solves problem of correctly documents identifying of the particular author. It is advisable to exchange information between profiles and import-export of bibliographic records from profiles and other resources, using the capabilities of specialized bibliography management systems to save time (Mendeley, EndNote) [58].

The ORCID accounting system provides researchers with two main opportunities: obtaining of unique identifier and monitoring of research work results; use of application programming interface for data transfer between different accounting systems and establishment of authorship of scientific works in each of them. Project participant is provided with unique identifier and personal profile in the ORCID register after registration. It allows you to control data of your own research results. It can be entered into ORCID register, edit your personal information, transfer data from one accounting system to another and establish the authorship of scientific papers in each of them, establish communication with other researchers or organizations. Information about the ORCID should be added when sending

publications, when applying for grants, used in other research processes, entered into various search engines, scientometric databases and social network to ensure the link between the scientist's name and the results of his research. It will contribute to improvement of information links at the international level, increase the results representation of domestic research in the world scientific space [36].

2. *Information about the scientist on the official organization website where the researcher works.* One of science personalization types is creation of such pages on official institutions websites which are related to scientist activity. Important attribute of websites pages of official institutions is link to full-text resources of institutional repositories. It makes possible to increase scientist visibility in the scientific space, to increase citation rates of its works [49].

Personal pages of scientists should also include information about the Internet addresses of personal profiles in scientific information systems (Google Scholar Citations, Microsoft Academic Search, ORCID, Scopus, Publons, etc.). It will allow you to explore scientists citations network, to establish links between scientists in particular area of research. Thus, presentation and assessment completeness of personal scientist contribution depends on many components. Since bibliometric and statistical methods are common methods in the world scientific environment, the most important principle is to involve wide source base for bibliographic identification of personal contribution and development of scientific schools. Scientists themselves should be interested in presenting such important sources as dissertation abstracts, scientific papers, which are subject primarily to bibliometric analysis. Important element of personal web pages metadata of scientists should also be other forms of scientist activity: membership in the editorial boards of journals (titles of journals), related to scientific connections of the person (supervisors, opponents, editors, reviewers, students, co-authors), list of all publications of scientist and publications about its life and work with references to electronic versions of documents [49].

The work [49] emphasized that scientist personal page should contain accumulated information about results of its scientific activity (information about publications, reports, patents, etc.). Some of this information can be represented in the form of appropriate references to bibliographic databases. Data stored in system should be accessible from outside (experts, colleagues, bibliographic institutions, etc.). This approach ensures evolutionary development of the bottom-up scientific space, and existing Internet technologies make possible to implement this approach today.

It is very important to want to take on the formation of consolidated systems of personal information about scientists for a state that seeks to conquer information space of science. It helps to form idea of national science and achievements of scientific institutions and communities. Examples of such consolidated systems exist in many countries, including Russia ("Russian Scientists") and Belarus ("Belarusian Scientists") where these systems were created by integrating web page into the search documentation of scientific libraries. These systems may contain various information that expands idea of scientist identity in the authoritative file "Scientists of Belarus" maintained by the National Library of Belarus. It contains not only detailed questionnaire of the scientist but also information, for example, about scientific dynasties: the presence of relatives with degrees and scientific titles, their personal data; other relevant information is added; contact telephones, etc. in addition to the usual biographical and bibliographic data characteristic of biographical systems. Collected in authoritative file, branched and semantically related information provides comprehensive information about research teams, scientific dynasties, publishing activity of scientists, etc. [49].

Ukraine also implemented similar project called "Scientists of Ukraine" [40]. It is one of the information blocks of the complex project "Science of Ukraine: access to knowledge" (<http://www.nbu.gov.ua/node/3565>). Also, the system "Scientists of Ukraine" is systematized by fields of knowledge, scientific degrees and titles, regions, departmental and institutional subordination of the register of scientists of Ukraine. The system is designed to search for scientific publications and publications of Ukrainian scientists, related to electronic library and information resources. Retrospective information and information about scientists who do not have degree but have scientific publications may also be entered in the register of scientists. Search and information capabilities of the

system make it possible to: find colleagues engaged in relevant field of research; select lists of scientists by place of work, place of dissertation defense, institution, department, city; view list of scientists publications: abstracts, dissertations, books, scientific articles; download available full texts of scientific publications; receive information on available information sources of reference and biographical nature; determine range of scientists connected by scientific and family ties; view information of bibliometric profiles of scientists; use automatically created list of co-authors. We are impressed by appeal stated on the main page of the “Scientists of Ukraine” system, namely “We hope to make image of Ukrainian science better with your help!”.

3. *Self-archiving of scientific results (electronic libraries, depositories, etc.)*. Own scientific works (articles, monographs, manuals, experimental data, audio recordings of various scientific events, electronic presentations and abstracts, etc.) should be placed (self-archived) in electronic libraries or institutional repositories. “Self-archiving” means free copy of electronic document on the World Wide Web placement by the author in order to ensure open access to it. Mostly, this term refers to self-archiving of articles in peer-reviewed scientific journals and conference proceedings, as well as dissertations, research results to increase its availability, use and citation. In various electronic libraries there is a section of statistics. Using it you can perform operational slice of data on information resources use. Scientist can track use dynamics of its own scientific works, how often they are interested in results of scientific research, and thus assess how relevant is the problem he is working on, or his colleagues are working [17].

4. *Personal profiles in scientometric systems (Google Scholar, Scopus, Web of Science and other)*. Scientist can track bibliographic references to his publications, view citations, citation schedules of his publications after creation of personal profile in this system. Scientometric platforms can be powerful tool for publishing, disseminating and analyzing of research results use (citation). Using these systems it is possible to carry out quantitative and qualitative evaluation of scientific results of both individual researchers and research teams or organizations [17]. Indeed, the “index-citation” is a kind of rating scale that determines quantitative and qualitative contribution of scientist into science. However, this criterion is formalized and therefore seems to depend less on subjective influences. So, it is still cannot be considered only reliable one. Most experts believe that the citation index is only one of scientific level indicators that is reached by the scientist [27].

5. *Electronic social and professional networks (ResearchGate, Mendeley, Academia.edu, Facebook, etc.)*. We believe that electronic social and professional networks due to convenience of their tools and services became main ones for quick feedback from public and dissemination of their own scientific results. For example, there are electronic social networks created specifically for the scientific community, namely: ResearchGate, Ukrainian Scientists Worldwide, Computer Science Student Network, LinkedIn, Scientific Social Community, SciPeople and others. Areas of application of electronic social networks by scientists and future PhD: scientist self-presentation; search for scientific material and tracking news about scientific mass events; support of scientific contacts and organization of thematic groups or pages; evaluation and monitoring of the effectiveness of own scientific works.

We will describe some examples of application aspects of electronic social and scientific networks for scientist image formation and performance of research work [17]:

1) it is important to search scientific material and track news about scientific events. Register in it, create a private page, post information about yourself and make settings. You can have personal pages in various social networks. It all depends on your goal: communicating with other scientists or finding scientific contacts for events, etc. Many scientific mass events are held in the world every day: conferences, seminars, round tables, master classes, trainings, etc. on topics related to your research, new books and journals are published. Researchers try to disseminate their research results to colleagues by posting links to them or announcing where they can be viewed or downloaded. In scientific social networks you should subscribe to selected person or thematic page and new news will be displayed in your news feed. If you are doing research try to watch news every day and you will really know and focus on scientific research on the chosen problem;

2) to maintain scientific contacts, present themselves and organize thematic groups or pages. It is necessary that the information is comprehensive – you need to mention awards, diplomas and certificates when posting information about yourself on a personal page. Therefore, academic social networks are the best space for establishing professional contacts. You can write a message to the author whose publication you are interested in and ask additional questions. Electronic social and professional networks due to popularity can be a good tool, allowing you to use different methods: group work, discussion, solution and analysis of situational problems, getting advice and more. Also, with the help of electronic social and professional networks can be a significant information impact, which will expand the awareness of changing the worldview of users of these networks. You can create a thematic group, invite participants to it and together explore a problem, share experiences, present research results, etc.;

3) to conduct certain parts of experimental research (surveys, questionnaires, tests) or to implement a joint project. The networks functionality allows you to create closed and open groups. It can include only members defined by the administrator, so in a closed group it is possible to place the necessary material and information; texts, videos, images, links, surveys, questionnaires, etc. In addition, there is opportunity to conduct surveys, independently evaluate learning outcomes by all users of the group and conduct discussions, share experiences, and simply communicate with like-minded people. We believe that electronic social networks can be powerful tool for conducting certain aspects of research;

4) to assess and monitor effectiveness of their own research. Research should be actively discussed in process of its implementation and not only after the publication of the results. The researcher wish to share its own experiences in professional networks is great opportunity to hear feedback about their research. For this purpose you should also use statistics tools offered in most social networks. Received analytical reports will show which publications attract the most attention and approval and from which countries users are interested in your posts and publications [29]. We emphasize that modern scientist should be professional in electronic and academic social networks.

6. Approbation of research results (reports, speeches, webinars, videos, participation in scientific events). Important role in scientist image formation is played by its dialogue with public - both directly during meetings and through the media. It is participation in public, scientific discussions, open round tables, seminars, press conferences, as well as in such image events as Science Days, exhibitions, seminars, festivals, intellectual and scientific games, talk shows on television and others. [27].

Figure 2 presents personal profiles of scientists in various scientometric systems, academic social networks, etc.

We state that today use of digital technologies is relevant and forced measure. General public will be able to get acquainted with scientific results. It will affect scientist image formation and institution image where the researcher studies or works [17]. Also, more and more often scientists image is researched and measured by rating of their scientific publications in various digital open systems in the Science Citation Index system.

It should be emphasized that despite understanding of self-presentation importance of scientists in online social communications. Personalized pages and personal websites of scientists have number of shortcomings in terms of information completeness. Another disadvantage of personal information presenting about scientists on the web is multiplicity of personal pages posted on different sites. The main problem here is need for constant support in current state of many personal pages on various sites [49].

In order to solve this problem there are number of interconnected digital systems, creating personal profiles on them. Scientists can import or export personal data through exchange formats to other scientific information and scientometric systems.

From our own experience and information on the information resources <https://researchgate.net>, <https://www.mendeley.com> we will describe some recommendations for improving personal digital profiles:

- every time of your appearance in search results, your photo and institution name, along with your name, help other researchers to quickly identify you.
- personal photo availability in your profile is also a great way to increase visibility in search engines, because it is proven that profiles with photos are viewed 3 times more than those without author photo;
- institution name where you work must be relevant, because it is displayed next to your name;
- you can help others understand importance of your research, open access to your publications makes you more open to potential colleagues, sponsors and employers;
- indicate your research interests and research areas that you do or that interest you; listing your interests and skills increases your search visibility and helps you find researchers with similar interests;
- provide detailed information on previous jobs and your experience of participating in various studies, grants, projects, etc.;
- specify keywords to summarize current and future areas of research;
- specify your other profiles or export data from different profiles;
- update information in your digital profiles.

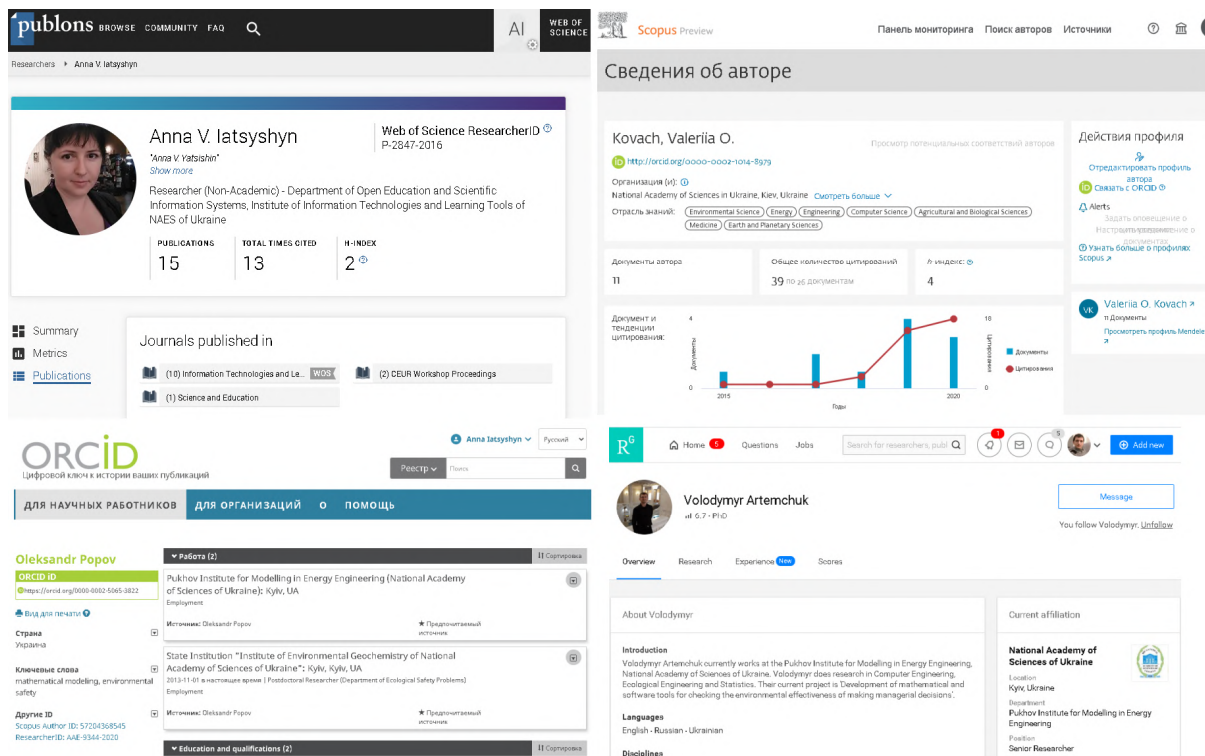


Figure 2. Personal digital profiles of scientists.

6. Conclusions and prospective for further researches

Currently, use of digital technologies is effective for conducting, presenting and implementing results of scientific research in practice. IT market is constantly improved and new digital technologies are developed. Mastering them is important for training scientists, university professors, future PhDs because they are ones who carry out important research for the development of science and education.

We analyzed scientific literature and our own experience. So, we emphasize that development scientist and future PhD image formation is important multifaceted and purposeful process aimed at professional recognition and public activity. Therefore, we recommend use of digital technologies.

Their mastery and use have positive effect on development of personal image and image of institution where scientists work or graduate students.

Authors identified and substantiated directions and means for scientist and future PhD image formation in digital transformation of society. Scientists also given recommendations for their own image formation using digital systems: 1) create an author's digital ID ORCID; 2) create profiles in various international scientometric systems; 3) update personal information on institution website where you work, add hyperlinks to your profiles in scientometric systems and digital ID ORCID; 4) use social networks to interact with colleagues, share experiences, observe colleagues reactions to discussions or information on certain issues, invite colleagues to participate in various scientific events, etc.; 5) present your own scientific results in open access: self-archive scientific publications in electronic libraries; 6) monitor use of their own scientific publications and identify those that are "popular", etc.

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The impact of artificial intelligence on employment before and during pandemic: A comparative analysis

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Abstract. Current trends in scientific research and the development of information technologies cover more and more areas of business. In these conditions, the findings of scientific-technical revolution and the innovations most important factors for the country's economic development and crucial to become a competitive state. The gradual establishment and the scope of use of artificial intelligence on the world innovative technology market increases daily. The purpose of this work is to investigate its impact on business based on the experience of the world and particularly, in Georgia. Accordingly, the study discusses the stages and main trends of artificial intelligence development. Depending on the scale of implementation, Georgia's current trends in job cuts / disappearances along with automation are analysed and future prospects are assessed. The paper discusses the use and increased importance of artificial intelligence 4.0 industry in the context of pandemic restrictions in various sectors of the economy and assessed the role in the post-pandemic period. The paper uses both qualitative and quantitative research methods. Content analysis of the scientific literature, statistical indicators and practical examples of different countries and international organizations is provided. Studies of leading analytical institutions are also included to analyse the current situation and prospects for development.

1. Introduction

Artificial intelligence as a scientific field explores the issues of intellectual programming. Given the wide scope of use in practice, the issue is very relevant. According to data from leading international research organizations, using artificial intelligence than human agents, companies can deliver better customer service (27%) [8]. So, global consumers (73%) are open to the use it and provide to become life easier [9]. As a result, some experts (48%) think that both white- and blue-collar employees will be replaced by robots and digital agents [14]. 54% of jobs are at risk of computerization in the EU member states [12], scientists expects that 9% of new US jobs will be created by robots and automation [13] and artificial intelligence will grow into a \$118.6 billion industry by 2025 [56]. Researchers from Pew Research Center used interviews of US citizens for gathering information and to assess the tendency of public attitudes toward AI. According to a survey, 65% of respondents believe that their work will be replaced by a robot or an intelligent algorithm within 50 years [15]. According to the survey of Boston Consulting Group most respondents (84%) expects AI will enable them to obtain a competitive advantage. They (83%) imagine AI as a strategic priority for their businesses today and state (75%) that AI will allow them to move into new conditions in businesses.



The survey is based on interviews with more than 3,000 business executives, managers, and analysts in 112 countries and 21 industries [17].

Consequently, we need to consider all the positive and negative aspects that accompany these processes – the transformation and impact of the various sectors of the economy in the workplace, both in terms of human resource roboticization and the development of new opportunities. Alongside these processes, as in most of the developed countries: the US [17], Germany [19], Sweden [20], Spain [21] and others, a number of international organizations – the European Union [22], the OECD [24], the OSCE [23] have started to set up appropriate regulatory institutions and set up guidelines. In addition, the main focus is on the need for scientific research and increased funding in these areas ([1], [2], [4], [25]). The paper discusses based on specific cases (such as Korea) the role that artificial intelligence programs have played in adapting to new economic realities for business entities.

Purpose, objectives and subject of the paper: Georgia is gradually involved in the processes of digital economy development and implementation of artificial intelligence in certain sectors of the economy. The purpose of this paper is to analyze the impact of artificial intelligence on the business industry. Also, the scheme of establishment and functioning, advantages and disadvantages, study of the main trends in the use of artificial intelligence in Georgia and its impact on the labor market and its comparison with world experience.

2. Research methods

The paper is based on “task-based” model of the economy ([7], [10]). This model distinguishes jobs as follows: “low-educated workers perform mainly routine cognitive tasks and non-routine manual tasks; middle-educated workers perform mainly routine cognitive tasks; high-educated workers perform mainly non-routine cognitive tasks”.

Consequently, along with technological development, one considers the situation where:

- Middle-educated workers are displaced.
- Middle-educated workers move towards low-education occupations, because high educated workers have a strong comparative advantage over middle-educated workers in performing non-routine cognitive tasks.
- Demand for high-educated workers, who are complemented by the technology that can now perform routine cognitive tasks, increases.

In the UK, Goos and Manning [48] find evidence of job polarisation in the UK between 1975 and 1999 having the following consequences.

To achieve the goals listed above, the following tasks were required:

- Clarifying the essence and regulation of artificial intelligence;
- Institutional analysis and foreign experience research;
- Identifying the risks associated with job cuts as well as analysing qualifications relevant to the new reality;
- Analysing surveys conducted by a leading research organization and summarizing the results.

3. Results and discussion

3.1 Features and uses of artificial intelligence

Artificial intelligence, as a scientific field, was separated from cybernetics in the late 1950s [59]. According to the widespread definition of the term, “Artificial intelligence describes the work processes of machines that would require intelligence if performed by humans.” It also means “investigating intelligent problem-solving behavior and creating intelligent computer systems” [54] and defined “as the process of making intelligent machines” [45] doing “specific task at or above human level capabilities, which has the potential make it more attractive than a human laborer” ([26], [47]).

However, the first who began research on the subject in 1955 and summed up the exact aspects of artificial intelligence learning was John McCarthy ([27], [45]). Also, Allen Newell and Nobel Prize

winner in economics, Herbert Simon [49], believed that “Machines will be capable, within twenty years, of doing any work a man can do”. He argued that many traditional jobs will be abolished by new technologies [28]. Before them, an English computer scientist and mathematician Alan Turing developed a method (named Turing test) of inquiry in artificial intelligence for determining whether or not a computer is capable of thinking like a human being [29].

According to the classification developed by the IBA Global Employment Institute [30], the use of artificial intelligence in economics is divided into the following categories:

- Deep learning – machine learning based on a set of algorithms that attempt to model high-level abstractions in data.
- Robotisation – Robots have been replacing employees because they work more precisely than humans and cost less.
- Dematerialization – because of automatic data recording and data processing, traditional ‘backoffice’ activities are no longer in demand.
- Gig economy – There are more and more independent contractors for individual tasks that companies advertise on online platforms.
- Autonomous driving – Vehicles have the power for self-governance using sensors and navigating without human input. Taxi and truck drivers will become obsolete.

Technological development impact on the employment in two main ways:

- Displacement effect – by displacing workers from tasks they were previously performing.
- Productivity effect – by increasing the demand for labor in industries or jobs that arise or develop due to technological progress [31].

It means that computer system can work constantly in other external circumstances and it is not affected by various factors. As a rule, synchronous work ensures greater productivity and transparency ([6], [32]). In addition, unlike the workforce, the computer system is not affected by fatigue and other factors [34] and sometimes production robot is cheaper than a worker in China is [34]. Therefore, in the Western high-labor cost countries savings with regard to the cost of labor and products caused by automation. For example, the use of a robot costs between €5 and €8 per hour and it is cheaper than one production working more than €40 in German automotive industry [35]. But there is some advantage for employees: on one hand repetitive and monotonous work can be performed by autonomous systems and on the other hand, people have to do less manual or hard work [37]. In conclusion it can be said that rapid technological innovation can threaten and radically changes the structure of employment.

3.2 International experience

John Maynard Keynes [35] postulated that technological change causes loss of jobs and developed his “technological unemployment theory” ([36], [40]). The wave of automation, brought about by the first and second industrial revolutions of the 19th and early 20th centuries, has led to a rapid rise in demand for low or unskilled labor, raising concerns about the growing nature of technological change [38]. Today some researchers think that advances in robotics and artificial intelligence over the next decades could lead to significant job losses or job polarization, and thus expand income and wealth [41]. According to the classification research developed by Oxford University up to 35% of all workers in the United Kingdom, and 47% of those in the United States are at risk of computerization over the next 20 years [42].

The increase in the number of interested groups and lobbyists in this field, as well as the amount of money spent on lobbying, indicates the importance of artificial intelligence. According to The Washington Post, in 2019, the cost of lobbying to influence the federal government by tech companies’ businesses extends into smart home tech, autonomous vehicles and artificial intelligence has reached a colossal amount compared to previous years: Amazon-\$16.1 million, Apple-\$7.35 million, Facebook-\$16.71 million [66].

The European Artificial Intelligence Association, The European AI Alliance, Blockchains and Artificial Intelligence for Business, Economics and Law (BABEL), the European Artificial

Intelligence Association (EurAI) – is a small list of interest groups from The Transparency Register that are actively lobbying. European artificial intelligence policy is in the process of developing. It should be noted that artificial intelligence is considered a field whose implementation strategy, regulatory norms and legal framework are in the process of formation even in developed countries. Consequently, there is great motivation and interest to influence decision makers to achieve the desired result.

Robotics is part of a general overview of business strategies that has become more complex and based on a wide range of variables than simple cost comparisons [43]. The increase in productivity caused by technological change will help expand income and demand [44]. Many researchers think that artificial intelligence has the potential to become another “general purpose technology” that has a wide range of applications in various professions because of its focus on mental rather than physical tasks [46].

According to the report from World Economic Forum [63] AI would create a net total of 58 million new jobs by 2022. The report also remarks that “AI will displace or eliminate 75 million jobs by 2022 and that the net increase will encompass 133 million brand-new roles” [50]. Another report by PwC found that “by 2030 the potential contribution to the economy from AI will be 15.7 trillion dollars and the global GDP could be up to 14% higher as a result of AI” [51].

Autor, Levy and Murane [10] argue that technology can replace human labor in routine tasks, be it manual or cognitive, but it cannot replace human labor in non-routine tasks yet. Goos and Manning [27] estimates that the impact of technology leads to an increase in the relative demand for highly paid skilled jobs and to a relatively high demand for relatively high demand jobs, which typically require non-traditional guiding skills [52]. Acemoglu and Autor [7] believe similar results for the US, while Darvas and Wolff [18] report such developments of EU member states: France, Germany, Italy, Spain, Sweden and the UK. In all these countries, the number of high-education jobs (managers, engineers and health professionals) is growing, while the number of middle-education jobs (clerks, machine operators, assemblers) is declining [53]. Western developed countries will profit because robotic production becomes cheaper than human production in low-labor-cost countries. For this reason, the relocation of the companies’ destroy many routine jobs in the low-labor-cost countries [55].

According to the market research firm Tractica, the global artificial intelligence software market is expected to increase revenues around 118.6 billion by 2025 (figure 1).

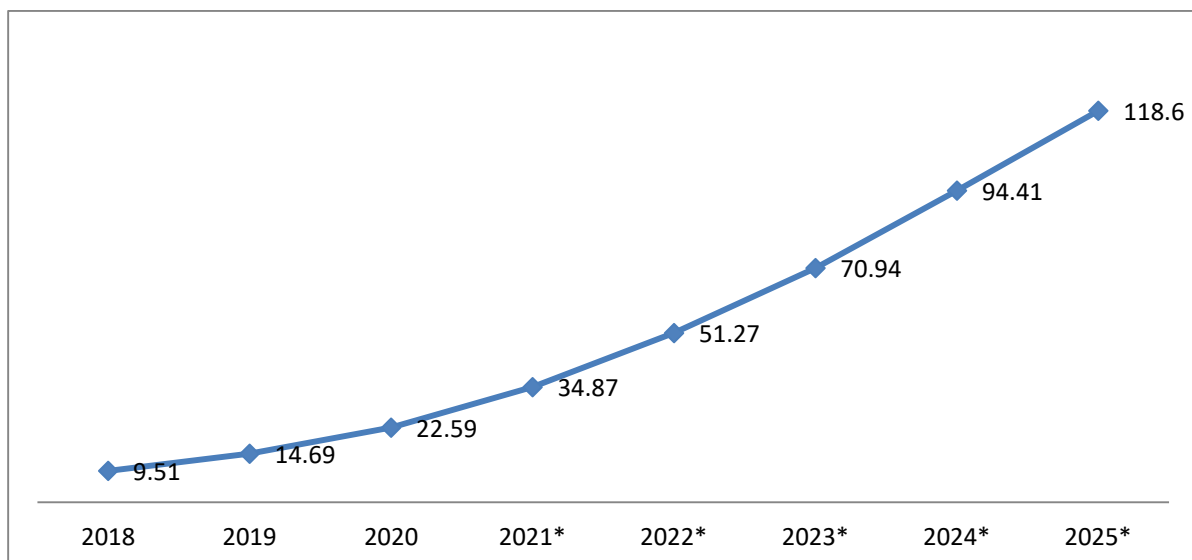


Figure 1. Revenues from the artificial intelligence (AI) software market worldwide from 2018 to 2025 (in billion U.S. dollars) **Source:** authors calculated on the basis of Statista [61]

It should be noted that low-labor-cost countries (China, India, Bangladesh) are still benefiting from their surplus of low-skilled workers, while Western companies are still outsourcing their production to these countries [57]. Ultimately, jobs with low or medium qualifications will be eliminated [60]. Changing human manual labor with robots makes economic sense in countries with low labor costs when the cost of human labor is 15 percent higher than the cost of robotic labor [39]. Chinese companies are already starting to build factories where robots will replace 90 per cent of human workers [11].

The key issue for developing countries is how to integrate large numbers of unskilled producers into the structurally complex labor market, depending on foreign investment. The driving force will probably be international companies that integrate their common systems across all industries in the world. If developing countries are able to provide qualified personnel in the technology sector in this way, developing countries can also benefit from technological change [62].

With big data processing, artificial intelligence, early warning systems, and intensive surveillance, South Korea has managed to get the coronavirus (COVID-19) under control for a short time. The government has created a large database of information on everyone in their territory, including South Koreans and foreign nationals, incorporating all government agencies, clinics, financial services, mobile operators and other services. As soon as a person is diagnosed with COVID-19, every person close to them receives information about their movement trajectory and activities over the past two weeks in the form of mobile alerts. Artificial intelligence ensures the rapid passage of all these stages. Artificial Intelligence provides authorities with information about possible clusters, or risk zones, that facilitate appropriate medical care in a particular area.

It can be said that artificial intelligence, in the course of implementation, gives us different results and challenges in developing and developed countries. In addition, it has various impacts on job creation due to the specific nature of the workplace. As noted at the outset, the use of artificial intelligence along with the structural change in certain sectors of the economy will create new types of jobs and the need for qualified personnel. One example of a newly created job is that of the data scientist [64]. Also crowd working is a symbol of a changing world of work for white-collar workers in the gig economy. They are freelancers who offer their skills via online platforms [65]. Creating one high-tech job will cause to create other jobs such as service jobs, gardeners, home health aides and etc. [33]. In addition, according to research by the IBA Global Employment Institute, with the development of the digital economy, the need for scientists and information technology specialists will grow. There is a greater need for the teaching profession not to be able to organize a professional team, and that includes the benefits of a professional team, the need to spend more money on companies, educate staff, and gain key qualifications for new and existing employees [13]. Also, humans with creative professions such as artists, musicians, actors, authors and etc. will not be replaced by machines in the future either [16].

It is noteworthy that qualified staffing in developing countries with new requirements may lead to an increase in the number of immigrants in developed Western countries [57]. Therefore, understanding the consequences of this distribution is important for many purposes. For example, it allows policymakers to develop appropriate education and skills policies and helps individuals make good choices about what careers they should pursue [62]. According to the World Bank (2016), in developing countries many more jobs are at risk: 69 % in India, 72% in Thailand, 77% in China and a massive 85% in Ethiopia [9]. The United Nations Conference on Trade and Development argues that the historical labor cost advantage of low-income countries might be eroded by robots if they become cheap and easily substitutable for labor [32].

The crisis caused by COVID-19 ([3], [5]) further strengthened the above arguments. In the course of the pandemic, the importance of artificial intelligence has been highlighted in a number of ways: First and foremost, security. Researchers from The Weizmann Institute, The Hebrew University of Jerusalem and Clalit Health Services – and in coordination with the Israeli Health Ministry have developed a strategy based on the questionnaire for identifying and predicting the novel coronavirus's spreading zones in the country [63].

Also, there has been a marked increase in the role of artificial intelligence in customer service services during the pandemic. In applications such as receiving information, healthcare, food and medication delivery and etc. the virtual assistants based on the artificial intelligence programme have significantly helped to regulate the increased flow of users and online referrals. For example, Hyro is a free virtual assistant to support health enterprises and their patients. The artificial intelligence uses a database compiled from the World Health Organization and other reliable sources of information to answer questions [58].

In summary, it should be noted that a business company that has a well-developed information technology management and tries to implement innovative achievements to adapt to unexpected challenges manages more effectively. Consequently, the fourth industrial revolution (Industry 4.0) is especially important in the effective management of enterprises. This includes high-tech and digital transformation of information. Which helps the business entity to easily overcome obstacles and adapt to the changed environment. And continuing the work process without interruption makes it possible to maintain profits, qualified staff and become even more competitive.

3.3. Artificial intelligence – current trends in Georgia

As for the case of Georgia, it is noteworthy that the first Artificial Intelligence Laboratory in Georgia, based on the University of Business and Technology in Georgia provides a research space that will integrate artificial intelligence education and business into various sectors. Creating an educational space includes high-tech laboratories such as workspace, a research center, an electronic library, and resources needed to carry out research projects.

An example of implementing artificial intelligence in business is the Real Estate platform Area.ge, which integrates any real estate transaction into a single electronic space to facilitate communication between stakeholders. With the help of artificial intelligence, inaccuracies are constantly eliminated, as well as rich visual materials and an optimal price tag allow customers to make quick choices.

The Artificial Intelligence Business Association is established in Georgia with the aim of demonstrating the importance of artificial intelligence as a separate field for simplifying and securing business processes. In addition, Artificial Intelligence Digital Mind has been created in Georgia, answering questions orally and in writing: marketing, management and tourism, as it combines over 4,000 books in these three areas. The innovative project also gives blind people access to higher education.

To save time and resources, in partnership with Nova BDO, Nova has introduced the ERP system 1C ERP, which enables optimal production. High-level business process optimization simplifies the control of limits and terms of accounts receivable, customer relationships, fast and seamless inventory.

4. Conclusions and recommendations

Artificial Intelligence can promote economic growth, create new jobs and employment. Destruction mechanism is a replacement effect, new technology will replace old technology and hence changing old technology jobs will inevitably lead to unemployment. Technological advances will reduce costs, make resources more efficient. The saving effect of the innovation process will result in a reduction in labor demand, leading to a high level of unemployment [55]. New technologies create winners and losers in the labor market. They change the relative demands of the professions, even if they improve productivity and standard of living [30].

The global pandemic and the need of physical distance have put on the agenda the development of artificial intelligence that can replace the workforce and increase the efficiency of the productive force. Therefore, in our opinion, the state should pay special attention to the creation and development of educational programs about artificial intelligence. In this regard, financial support for the formation and working process of Technology Parks is also important. All this activities will contribute to the continuous growth and development of the real economic sector of the country. Consequently, given the growing role of artificial intelligence, as a recommendation it can be said that it is important for the rapid economic development of the state.

The study included the research of the formation of artificial intelligence, the stages of development, the main features of its use, the scheme of functioning and the impact on the labor market. This last issue is studied in the paper from the perspective of both individual and organizational - business companies and various economic entities. There has been an increase in the spread of artificial intelligence, which indicates the need for states to develop appropriate regulatory strategies and establish a legal framework. This makes the field particularly attractive for interest groups and lobbyists who are actively working to influence the legislature and achieve their own goals. Also, based on the results of the study, we can conclude that the pandemic caused by Covid-19 has become a factor that has made it even clearer the need to use innovative technologies. In turn, the continuous work of the business sector is the basis for the economic development of the country. Consequently, technological progress and the use of artificial intelligence are a priority for small open economies.

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Modern technologies in the development of professional competence in teachers from professional (vocational) education schools

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Abstract. The article discloses the peculiarities of developing professional competence in professional training teachers. This process mostly involves using traditional pedagogical technologies. The article presents results of the ascertaining experiment and indicates the need for continuing professional development of teachers based on innovative principles. It also suggests using up-to-date pedagogical technologies of distance and project-based learning and production technologies to develop professional competence in actors in the educational process (teachers and students). This refers to the implementation of a competence-based approach in the professional education system. It is reflected in the development of professional competence based on some steps. They include expanding informational and educational space for actors in the educational process and individualizing learning using modern information resources (distance technologies); ensuring the interaction between actors in the educational process, as well as the joint realization of searching, cognitive and research activities (project-based technologies); organizing the educational process under the social partnership, taking into account the timely response of the professional education system to the emergence of innovations in production and the service sector (production technologies).

1. Introduction

The current reforms in professional (vocational) and professional pre-university education lead to some innovative changes. They are aimed at introducing modern pedagogical and production technologies in the educational process and creating effective models and mechanisms for training highly qualified specialists. Given such circumstances, the importance of continuing development of professional competence in professional training teachers (hereinafter “teachers”) increases. It involves introducing a new model of professional education, taking into account the objectives of the strategy for sustainable development of society, state, national economy. Also, it implies providing conditions for developing teachers’ capacity for a comprehensive and interdisciplinary analysis of situations in the labour market and based on the active interaction with actors in the educational process. Finally, it is essential to create an educational and development-oriented environment for managing project activities of future qualified specialists.



2. Theoretical backgrounds

The Law of Ukraine “On Education” states that teachers are to constantly improve their professional and general cultural levels and pedagogical skills [33]; the Concept of Teacher Education Development includes improving the system of teacher education to create facilities for training teachers of a new generation, creating conditions for involving the best specialists in other fields and providing conditions for establishing and developing modern alternative models of teachers’ continuing professional and personal development, which will also become a key prerequisite for implementing the state policy in the reforms of all educational levels [17]; the Law of Ukraine “On Professional (Vocational) Education” [32] and the concept of state policy implementation in the field of professional (vocational) education, titled “Modern Professional (Vocational) Education” for the period up to 2027, indicate that the priority objectives are to improve the system of training teachers in the field of professional (vocational) education through involving highly qualified specialists from production and the service sector in the educational process and introducing motivational mechanisms for stimulating teachers’ professional activities and development [6].

Some Ukrainian scholars (Ihor O. Arkhypov [13], Liudmyla O. Bazyl [3], Valeriy Yu. Bykov [5], Oleksandr V. Didenko [15], Maryna M. Klymenko [4], Vasyl H. Kremen [15], Olena O. Lavrentieva [14], Oksana M. Markova [20], Yevhenii O. Modlo [19], Valentyna O. Radkevych [3], Larysa M. Sergeieva [28], Vasyl V. Yahupov [35] et al.) believe that the enhancement of the quality of future skilled workers’ training depends on a high level of professional competence of teachers. The latter implement certain pedagogical and organizational-and-managerial measures aimed at providing citizens with the knowledge, skills and abilities in the chosen professional area, developing competences and professionalism, cultivating general and professional culture in the system of professional (vocational) education [8].

Today, educational activities of teachers exceed the implementation of syllabi and acquire features of educational multifunctionality. It covers the participation in the realization of strategic objectives in education; the ability to update the content of professional education; the establishment of intersectoral communication; the management of educational projects; the development of integrated models for professional training based on a combination of traditional methods and modern pedagogical technologies in the educational process, copyright protection of educational and methodological products prepared by teachers.

Scholars and practitioners more actively use innovative pedagogical technologies based on a competency-based approach now. In this regard, one should pay particular attention to the systematic development of professional competence in teachers to increase their readiness to employ innovative pedagogical technologies in their pedagogical activity.

The article aims to justify modern technologies for developing professional competence in teachers from professional (vocational) education schools to enhance their readiness to provide professional training to future specialists based on innovative principles.

3. Method

A theoretical analysis of scientific works on the issues of educational philosophy, continuing professional education, adult education; a study of international experience in dealing with this particular problem; a study of regulatory documents in the field of education, an analysis of curricula with the aim of revealing the coverage of the problem under study and determining areas of research); comparison with the aim of studying different scientific views on the problem under study); analysis and synthesis with the aim of determining innovative pedagogical and production technologies for developing professional competence in teachers); systematization and generalization needed to formulate conclusions; pedagogical experiment (the ascertaining stage) required to determine the level of teachers’ and students’ readiness for professional development; statistical methods (frequency analysis, computer tools for statistical processing of experimental data.

4. Results and discussion

Modern education systems gradually start using resources of a competence-based approach to the fullest. In professional education, this approach is the conceptual basis for implementing an innovative system of principles for determining goals, building the content of professional education, organizing the practice-oriented educational process and assessing learning outcomes. The tools for achieving goals of a competence-based approach include innovative technologies (both pedagogical and production). Their effects in professional education depend on the variability of their use at the level of creativity and skills of teachers, their modification based on the characteristics of pedagogical interaction, as well as the changes in educational, technological and social trends.

The teachers' experience of using innovative pedagogical and production technologies in professional training of future specialists is a decisive indicator of their professional skills. At the same time, innovative pedagogical and production technologies serve as a means of teachers' systematic professional development.

4.1. The results of the ascertaining pedagogical experiment

The results obtained from experimental work conducted at the Institute of VET of the NAES of Ukraine within the framework of the topic “*Methodological Principles of Developing Professional Competence in Masters of Vocational Training from Professional (Vocational) Education*” show that teachers demonstrate the need for improving their professional competence systematically.

The questionnaire for identifying the levels of professional competence in masters of vocational training from professional (vocational) education schools (https://docs.google.com/forms/d/128Vn66v8KxnhGs9yEiF4TT4bT7r2gxb_fQvj6DQaNW4/edit#responses) has made it possible to survey 1888 respondents. It takes into account their job functions following the professional standard.

It is found that 60.4 % of them feel the need to develop professional competence. Interestingly, 25.4% of them rather realize that it is necessary to develop their professional competence. The rest of the respondents (14.2%) rarely feel such a need, do not feel it at all or are not sure what to answer (figure 1).

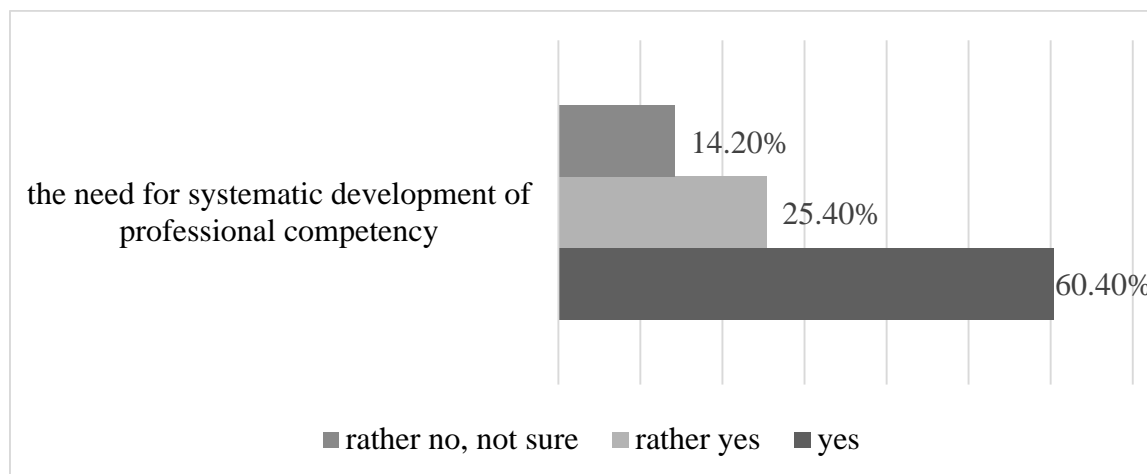


Figure 1. The results of teachers' self-assessment of their need for the systematic development of professional competence.

The results obtained from assessing teachers' readiness to realize the professional development function, correlated with the development of professional competence in terms of the content, show that 48% of respondents are at a high level of readiness for professional development; 47%, 5%, 0% – at sufficient, average and low levels, respectively (figure 2).

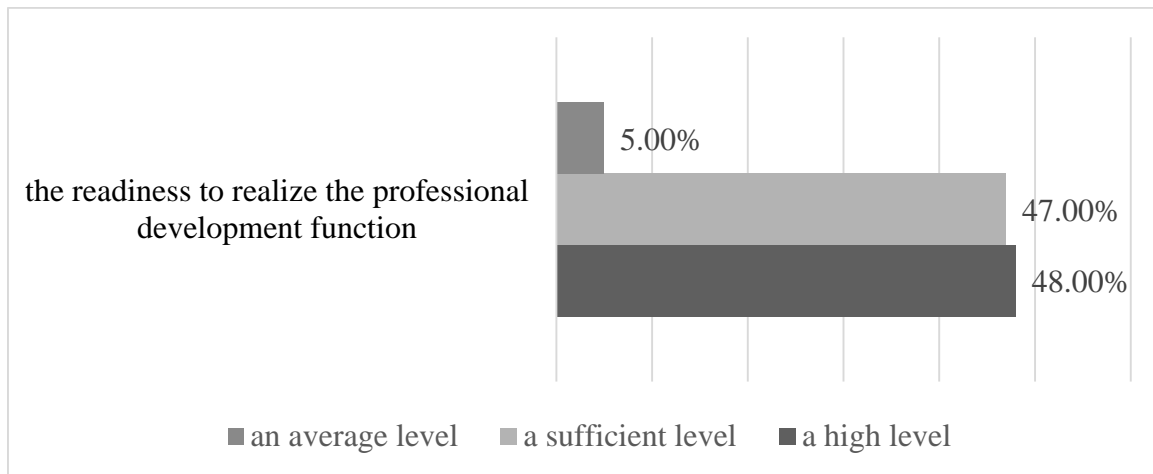


Figure 2. The results of teachers’ self-assessment of their readiness to realize the professional development function.

It must be noted that teachers’ willingness for professional development is extrapolated in the educational process due to the emergence of students’ needs for self-development within a particular profession.

The results of the survey of future hospitality specialists within the framework of the topic “*Developing Professional Competence in Future Restaurant Specialists during Professional-Practical Training*” show that 3.1% of respondents (out of a total of 588 future skilled workers) cannot plan their future profession and systematic professional development and self-development. At the same time, 27.6% of them are at an average level of such ability. Accordingly, 44.9% and 24.5% of them are at sufficient and high levels, respectively (figure 3).

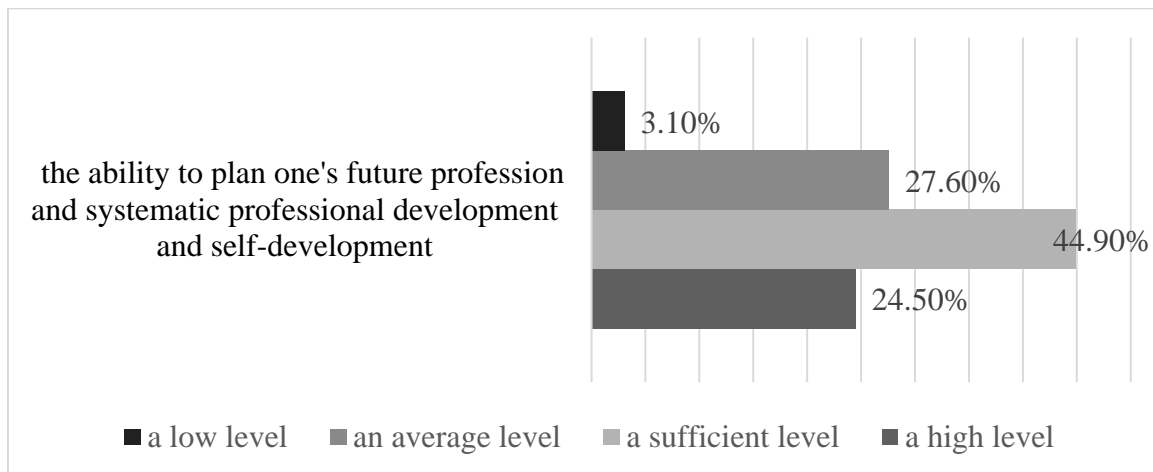


Figure 3. The results of future hospitality specialists’ self-assessment of their ability to plan their future profession and systematic professional development and self-development.

The results of the survey show that the professional development of teachers is correlated with the needs of students in enhancing professional competence. The processes of consolidating teachers’ professional knowledge and skills in a particular field of production, services and developing students’ needs take place within a single practice-oriented educational environment of professional education.

The survey of teachers on clarifying the most optimal factors in the development of their professional competence indicates the priority of their participation in scientific-practical conferences,

methodological seminars, professional competitions, educational exhibitions (27.6%). Also, it points out to the availability of a system of incentives (26.3%) and a system of motivation (23.6%) towards professional and self-study activities. Next, it reveals the realization of the practice-oriented educational process, communication with employers, social partners and the organization of industrial training (23.1%). Finally, it analyzes the functioning of systems of methodical work, advanced training, certification, internships at the enterprises and the study of positive Ukrainian and foreign teaching and industrial placements (20.8%).

As for the possibilities and frequency of using forms of professional development, employees believe that the most commonly used forms are advanced training (studying in educational institutions (87%), internships (57%); retraining (studying in educational institutions (79%), in production (65%) [8].

The development of professional competence is a continuing process. Given the introvert pedagogical system, it is characterized by studying positive practices of teachers; self-study; the participation in the activities of methodical commissions, mentoring schools, novice teachers/masters of vocational training; the exchange of experience, mutual visits, mutual assistance, the organization of methodical seminars.

The open pedagogical system involves integrating the educational process with organizational-and-technological processes of production under the established social partnership between educational institutions and enterprises. It includes studying and applying production technologies, using the resources of public-private partnership and organizing dual training. Besides, it covers enhancing professional and educational qualifications; ensuring internships in production, as well as certification, participation in the national and international competitions of professional skills.

Nowadays, it is admissible that lifelong learning refers to all types of teaching and includes every kind of learning activity undertaken throughout a person's life-time [10].

Therefore, when choosing up-to-date technologies for developing professional competence in professional training teachers, one should focus on those technologies which can ensure the development of professional competence in the practice-oriented environment of professional education schools. In this context, pedagogical technologies of distance and project-based learning, as well as modern production technologies, are the most optimal ones.

4.2. Distance learning technology

The analysis of relevant scientific studies on the implementation of distance learning in higher, professional and adult education institutions proves that the problem of teachers' professional self-development under the introduction of distance learning has originated as a result of the insufficient elaboration of the theory and practice of education informatization in Ukraine. Insufficient use of pedagogical opportunities provided by distance learning and insufficiently high readiness of teachers to introduce distance learning [31] and develop their own digital literacy [9] add to it, too. All this has caused the need for a thorough scientific and methodological support of professional distance learning to use all the opportunities of distance learning fully and effectively [25].

The basing of the educational process on distance learning technologies [29], in particular psycho-pedagogical ones (a system of tools, techniques, steps, whose consistent implementation ensures the accomplishment of tasks), and distance learning on a competence-based approach allows one to ensure learning efficiency. Furthermore, it can increase the practical value of its results in terms of solving specific practical problems with the use of ICT [21].

The Concept of Distance Education Development in Ukraine defines the structure of distance education: organizational and managerial, regulatory and legal, instructional and methodical, informational and communicational, economic and financial components. Teachers should take an active part in the implementation of these components. Indeed, they should update the content of training and methods of teaching and learning, expand the access of students to all its levels, realize the possibility of obtaining professional education by a great number of young people, including those who cannot study in professional education schools under traditional forms, and implement the system of continuing education; ensuring the individualization of learning [16]. Valeriy Yu. Bykov theorizes that

the main problems of creating and implementing distance learning systems are technological, managerial, psycho-pedagogical, financial-economic and regulatory ones [5].

In this regard, it is necessary to model the technology for developing teachers' readiness to implement distance learning and implement its functions, as well as elaborate distance learning courses for professional training of future specialists. The components of teachers' readiness for professional distance learning are motivation and values (a conscious intention of teachers to conduct professional distance learning), cognition (the required amount and level of knowledge, skills and abilities, professional experience in performing specific activities in an electronic environment), operations and activities (ability to conduct professional distance learning technologically well), assessment and reflection (ability to assess the results of professional distance learning on a reflective basis), whose development is possible by implementing organizational, learning-and-cognitive, communicational and diagnostic functions of distance learning [25].

The researchers of the Institute of VET of the NAES of Ukraine have elaborated scientific and methodological support for the comprehensive development of teachers' readiness to implement technologies of distance learning. It includes technologies of professional distance learning [2], methodical recommendations for training teachers from vocational education schools to implement distance learning for skilled workers. Also, they have organized and held educational and methodical measures: the organization of distance learning in professional education schools (https://www.youtube.com/watch?v=3IvSOWaYhkM&feature=emb_title); organizational and pedagogical conditions and a model of professional distance learning (https://www.youtube.com/watch?v=wP4eW1e7joc&feature=emb_logo).

Besides, the Institute has created a distance learning system (e-learning.org.ua), whose users were 1440 teachers (as of 2019). They studied the proposed content of distance learning courses and enhanced their readiness to implement the functions of professional distance learning.

The use of distance learning technologies in the development of professional competence in teachers and the practice of future specialists' training can take place on different platforms and in various organizational forms, including online learning, online courses, online training, online counselling [34], webinars, the use of interactive electronic textbooks [23], electronic virtual laboratories [22], social networks, educational sites [11], blogs [26].

Active development of distance learning technologies and systems is based on theoretical and practical tasks, their designing together with conscious and consistent implementation of methods and tools of project-based management in the practice of professional training.

4.3. Project-based learning technology

The consideration of the sectoral context in professional training of future specialists highlights the importance of using project technologies in the development of professional competence in actors in the educational process. Their popularity is ensured by the possibility of integrating knowledge and applying it to solve specific educational and production problems. Thus, it is a pedagogical technology focused not only on the integration of knowledge but also on its acquisition through self-study activities of educational courses. On the other hand, project technologies involve using a set of different methods and tools of teaching and learning by teachers.

Project technologies aim to create appropriate conditions under which project participants (both teachers and students) can independently gain knowledge from various sources of information. It is also important that they learn the ability to use the acquired knowledge to solve specific cognitive and practical problems, acquire communication skills, develop research skills (identifying specific problems, obtaining feedback, observing, conducting experiments, analyzing them, constructing general and partial hypotheses, summarizing results) and thinking. The essence of project technologies lies in stimulating a cognitive interest in solving certain problems ([1], [7], [24], [30]). This process involves acquiring certain knowledge, implementing it through project activities and applying it in practice by activating reflective (critical) thinking (searching for facts, analyzing, reflecting on their reliability,

constructing the logic of these facts to learn something new, cultivating confidence based on reasoned conclusions) [27].

Project technologies allow organizing joint activities of teachers and students not only based on personal experience but also through developing such personality traits as independence, curiosity, social skills in group interaction, gaining research experience, cultivating creative thinking and intellectual, informational and communication skills. They play a special role in the organization of educational cooperation between students in small groups since all participants need to settle things among themselves, develop a common strategy for solving the problem, distribute responsibilities, provide mutual assistance in its implementation and take responsibility for the results to achieve a common goal. From the standpoint of the student, project activities allow doing something interesting in a group or by oneself, making the most of one's opportunities. It is an activity that allows one to express oneself, test one's strength, apply one's knowledge, be of benefit and present the results to the public. It is aimed at solving a significant problem, formulated by the students themselves in the form of goals and objectives, whereas the result of this activity, that is a way to solve the problem, is characterized by important practical values [36]. Project activities change the role of the teacher, who performs the functions of organizer, mentor, consultant, assistant. He or she helps students to find the necessary sources of information, becomes the very source of information, coordinates the process of working on the project, supports, encourages and provides constant feedback for successful performance.

The main principle of implementing project technologies in the development of professional competence in actors in the educational process is the integration of theoretical and practical components of professional training. It is based on the active and creative use of modern forms, methods and tools of teaching and learning aimed at mastering both knowledge and professional skills for the next transition from training to production activities.

4.4. Production technologies

The technologization of society reinforces the importance of practice-oriented areas of a competence-based approach focused on initial results (competences), which are acquired during dual training, in production centres or the workplace. The authors of the article believe that the process of developing professional competence in actors in the educational process should combine innovative pedagogical and production technologies and bring some practical results. It is reflected in the acquired skills allowing one to perform and update knowledge following new production technologies, have basic computer knowledge, raise problems, think creatively, make original decisions in unusual situations and be active in professional activities and social environment. Today's labour market, however, requires that graduates should have not only practical abilities and skills but also significant personal qualities, which enable them to dynamically change their profession during work activities while developing new production technologies. These are additional skills (key competences, soft skills), including a high level of self-organization, communication skills, creativity, teamwork skills, re-engineering skills, persuasiveness, leadership (being able to take responsibility for proposed and adopted decisions), time-management skills, emotion management skills, capacity for self-development, ability to resolve conflict situations and keep fit [8].

The organization of training with the use of production technologies involves motivational readiness of actors in the educational process to acquire knowledge, skills and abilities and study modern production innovations. Professional training of future specialists based on the use of production technologies optimally ensures the implementation of such principles as links between training and practice, innovations, partnership and cooperation. To this end, Ukraine has launched the creation of training and practice centres for the most popular professions (approximately 150 centres for professional (vocational) education as of 2020). Such centres are equipped with modern resources for workshops. It makes it possible to implement the latest production technologies, update educational and methodological support and increase the level of professional competence in teachers they need to use modern production technologies. Their development is facilitated by the establishment of cooperation

with social partners. It involves organizing joint training and production activities with educational institutions, research institutions, enterprises, production structures, public organizations and other institutions to signal about the changes and innovations in the field of education and science. Besides, it indicates the needs and conditions of a professional environment arising due to the influence of socio-economic factors.

The main areas of cooperation between professional education schools and enterprises and organizations are mentioned in the Concept of Public-Private Partnership. It implies systemic, constructive and mutually beneficial cooperation to ensure high-quality training, attract additional resources for professional education and focus it on modern technical and technological conditions. Also, it includes preparing proposals for updating the professional education system, creating professional and educational standards, providing advisory assistance in dealing with issues of common interest, participating in joint events, developing mechanisms for providing graduates with employment at enterprises and disclosing proposals for joint provision of professional qualifications to graduates by employers and educational institutions. It is essential to encourage large organizations to provide professional education schools with patronage, provide practical training for students and internships for teachers and masters of vocational training at basic enterprises and grant sectoral and nominal scholarships to the best pupils or students by enterprises and organizations. Finally, one should provide assistance to enterprises and organizations in maintaining and developing facilities, introduce financial and moral stimulation of teachers and masters of vocational training by enterprises and organizations, ensure mutual dissemination of information on issues related to the development of professional education, advertising and promotion in the media, web-resources [18].

The participation of teachers and students in all-Ukrainian and regional competitions of professional skills (“World Skills Ukraine”, “The Fair of Professions”, “The Workshop of Professions”, “The Competition of Professional Skills”) is of great importance in the development of professional competence in actors in the educational process.

In the context of the updates in Ukrainian professional education and European integration processes, the process of developing professional competence in actors in the educational process should include some important aspects. They refer to international cooperation (according to tripartite agreements on an industrial placement, masters of vocational training need to organize internships at the leading foreign companies); the participation of teachers and students in international projects and competitions (“BEST Cook FEST Junior – 2016”, “Food Land Bukovina – 2017”, “Best Pastry Chef – 2017”, “Best Cook Fest-Podillia – 2019”); internships abroad (within the Erasmus+ project “Improving teacher education for applied learning in the field of vocational education (ITE-VET)”). The participation of teachers and students in the national and international projects significantly enhances their professional competence, which can be confirmed by the introduction of innovative pedagogical practices and production technologies in the educational process.

In applying production technologies, the following forms of learning are the most expedient ones: professional and practical training (industrial training and industrial placement), dual training, research-based training, extracurricular activities, socially useful work, tour lessons, creative laboratories, workshops, competitions of professional skills, tournaments, as well as methods of analysis and solving of specific industrial and problematic situations, including non-standard ones.

5. Conclusions

Up-to-date technologies for developing professional competence in professional training teachers include distance and project-based learning technologies. One should also add to them production technologies since they aim to increase teachers’ readiness to provide professional training to specialists based on innovative principles.

The development of professional competence in teachers from professional (vocational) education schools should be considered as a purposeful process. Therefore, it should include certain innovative pedagogical and production technologies, modern forms of training future skilled workers, as well as the interaction between actors in the educational process.

Such an assertion relies on the results of the ascertaining experiment. They indicate that teachers do not use e-learning resources systematically. Next, they show a low level of skills in project-based management. Finally, they do not always adjust professional training of future qualified specialists to dynamic technological changes in production.

The use of distance learning technologies in the development of professional competence in actors in the educational process allows integrating the learning system into the global educational field and expanding the space of the national informational and educational environment for actors in the educational process. It can be possible due to using modern methods and information technologies, meeting the personal needs of students in obtaining new knowledge based on the individualization of the educational process and telecommunications and enhancing professional competence in teachers based on mastering programmes of training for introducing professional distance training and doing distance courses.

Project technologies enable the transition from the “knowledge-generative” to the competency-based system of professional education, which lies in interaction, cooperation, partnership, motivation for success, reflective processes. They contribute to the professional development of the individual by independently creating a certain material or intellectual product based on knowledge, personal qualities and personal experience. Finally, they strengthen knowledge and skills and develop professional competence in actors in the educational process due to searching, cognitive and research activities.

In the context of developing professional competence in actors in the educational process, production technologies make it possible to take into account the strategic socio-economic objectives in the development of a particular industry, labour market conditions. Besides, they ensure the organization of the educational process in terms of social partnership and practically implement current scientific innovations in pedagogy and psychology, production and services. Most importantly, they respond to technical and technological changes, structural and content-related innovative production transformations timely and productively.

Further research should aim to justify the conceptual principles of managing the system of professional (vocational) education under today’s transformation. It might be a good idea to analyze theoretical and methodical principles of developing a professional culture in teachers from professional education schools during the course and in-between course periods of advanced training. Besides, it should contribute to disseminate the determined successful experience in its implementation in the system of professional (vocational) education in Ukraine.

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Project-based learning for undergraduate engineering students minoring in textile technology and design

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Abstract. The experience of application of methods of problem-based and project-based learning was described in the training of future engineers for the light industry. Methodological issues are considered, as well as practical recommendations are formulated, for the application of these methods in teaching professionally-oriented disciplines. Examples of project design and their content are given for two specialised disciplines. They are aimed at the development of students' ability to creative thinking and problem-solving when working both independently and in a team. The method effectiveness is illustrated by the formation of students' new competencies, and an increase in their motivation and experience in teamwork. The preferred styles of students' learning were studied for student groups of four different enrolment years. The learning preferences are relatively stable over the four study years. On average, engineering students minoring in textile engineering and design demonstrate a tendency to active, visual, sensing and sequential learning styles. Project-based teaching methods are not universally suitable for students with different learning preferences. Moreover, the success in projecting under the studied conditions correlates with the existing learning preferences of student teams. Student teams succeed in the implementation of projects if they have a balance in the ref-act dimension with a limited preference of the active style. In other words, excessive activity and lack of reflective reflection hindered the successful completion of projects. In the sen-int dimension, the presence of a pronounced sensitive style is also favourable for design and implementation of class projects. Successes in projecting are mostly insensitive to changes in the vis-vrb and seq-glo dimensions. The introduction of the problem and project-based learning methods is useful for engineering students. They acquire new competencies, gain real experience of teamwork, and increase motivation to learn and develop creativity.

1. Introduction

The modern labour market supposes that universities graduate ready to work engineers. The results of a survey of employers, conducted in 2019 and 2020, support such a statement for graduates of Kyiv National University of Technology and Design (KNUTD). About 70% of surveyed companies are mostly satisfied with the professional and social skills of KNUTD bachelor graduates. However, some gaps in the competencies of graduates exist in such areas as the independent acquisition of new knowledge, autonomous work, communication, teamwork and engineering knowledge application to real problem-solving. In this context, the university's role is to provide the best training for future engineers. It can be ensured by the formation of a graduate's adaptive profile that meets the modern requirements of the labour market.



Many factors affect the efficiency and training quality of future engineers. Taking into account the individual characteristics and interests of students is often called among the essential factors ([9], [10], [23]). Several approaches can be used to reckon with these conditions. Attention to the integrated characteristics of students, such as their learning styles, is considered as the correct approach [8].

The learning student preferences for technical specialities are sufficiently studied ([8], [7]). The researcher's data are generally coherent. They allow ones to choose the methods, forms, and means of teaching for the training of a typical engineering student that are the best to meet his requirements. It is generally accepted that problem-based learning (PBL) is the best suited for the training of future engineers ([16], [32]). However, such an approach gained limited application in Ukrainian higher education institutions. The PBL method is mainly used during the writing of course and diploma projects. In contrast, PBL is not traditionally used in teaching fundamental or professionally-oriented disciplines.

Furthermore, the ability to design and manage projects is among the most critical competencies of an engineer. This competency provides for the ability to participate in various aspects of project design and implementation. They include informational, methodological, material, financial and personnel support. It also involves the ability to manage the strategic development of the team in its professional activity. Therefore, activities aimed at the design and management of projects must become a vital component of future engineers training.

However, a contradiction exists between the desired and applied training methods. On the one hand, research methods are based on a student-centred approach. Students learn about a subject by collaborating in teams to solve open-ended problems. Such methods are desirable to meet students' requirements and also necessary to form future specialist competencies. On the other hand, research methods are in limited use, while traditional training methods are mostly used in reality.

Analysis of recent publications shows the growing popularity of problem-based approaches to learning activities ([6], [12], [13], [21], [28]). Researches related to the organisation of learning using a problem-based approach can be divided into two parts. In the first case, learning is based on problem-solving, and this approach is known as PBL. Studies related to PBL are primarily devoted to theoretical and methodological aspects. Their authors mostly specialise in the field of pedagogy ([25], [26], [28]). In the second case, specific examples of the application of the mentioned training technologies are studied in various subject areas for the organisation of project-based learning. This approach is usually called "project-based learning" (PjBL). The researchers are mainly teachers of specialised disciplines in the relevant fields (computer engineering, technology, design, etc.) ([5], [12], [14], [19], [20], [22], [24], [34]).

Both approaches, namely PjBL and PBL, are similar in the involvement of students in solving real-world problems; they imply collaboration in teams and simulate the professional environment. However, they are based on two different strategies. In PBL, learning issues are considered as problem situations. In PjBL, a student project is considered as an end product. Such a project results from the study of the discipline ([15], [18], [19]). PjBL is usually considered as the development of PBL.

The paper is aimed at the implementation of PBL and PjBL methods in the training of future light industry engineers. The work purpose was realised by incorporating the methods of projecting into the existing curricula of two professionally-oriented disciplines at KNUTD. Appropriate modules of the discipline content were developed and tested. The offered scheme of the training organisation intends two-step mastering of project-based technologies. In the first step, students learn the PBL and PjBL methods under control and with a teacher's aid. In the second step, students developed their creative projects without assistance as parts of the discipline syllabus.

2. Methods

The experiment was conducted at the Fashion Industry Faculty at KNUTD. Students of different enrolment years from 2014 to 2017 participated in it. The number of students in a group varied from 15 to 25 people. Students studied in two educational programs focused on training of engineering-

pedagogical specialists for the light industry. One part of students minored in textile technology and the other one in textile design.

Student learning preferences were identified by R. Felder – B. Soloman method. The instrument, known as the Index of Learning Style [11], was used. All respondents answered 44 questions. The processing of responses allowed ones to estimate available preferences in four complementary dimensions. Perception of information was studied through the prism of either sensing (sen in short) or intuition (int). The input of information occurred via visual (vis) or verbal (vrb) channels. Either active (act) action or reflexive (ref) reflection determined the data processing type. Understanding of information took place by the use of a sequential (seq) or global (glo) approach. In other words, each of the four dimensions consists of a style and anti-style pair or two contrasting styles. An 11-point scale was used to quantify students' preferences for each dimension.

An individual style was considered as predominant when the calculated score in the person's answers ranged from 6 to 11 points. The preferred learning styles for a student group were assessed in two ways. In the first case, the shares of students that scored either 6 to 11 or 0 to 5 points were calculated. The learning preference was expressed as the percentage of students who scored from 6 to 11 points. Such an approach illustrated the distribution of student preferences between style and anti-style for each dimension.

Nevertheless, the first approach did not reflect the strength of the existing preference within a styling pair. The second method implies the calculation of the average score of learning preferences instead of the relative number of students in a group. The average score reflected not only the relative number of students with individual preferences but also depended on the preference strength.

Based on the individual data of each person, average data for groups were obtained. The groups were considered both formal, divided by enrolment year or educational program, and informal. In the latter case, these were student communities formed during the project activity. In the process of project implementation, students formed groups independently, based on their motives and interests.

The method of problem situation development (PBL) and the technology of project-based method (PjBL) application are described in many papers ([4], [30]). The development of problem situation involved three stages. The first stage includes the selection of issues in the educational material that could be a subject for the creation of a problem situation. The second stage is aimed at the identification of the knowledge array needed to develop a problem situation. It involves determining the necessary factual material and appropriate information resources. A methodological analysis of the emergence and resolution of contradictions was carried out at the final, third stage.

The general scheme of PjBL application in learning consists of five stages. The first is a problem-target stage, and the second includes the development of requirements specification. The third stage is devoted to practical work. The fourth and fifth are the stages of preliminary and final defence of the developed project ([17], [21], [27]).

The effectiveness of the application of PBL and PjBL was studied in the course of teaching two disciplines. The first discipline was used to practice the skills of working on individual elements of the PBL and PjBL methods under teacher guidance. The second one was used for independent creation of student projects by PjBL. Thus, two stages, namely the initial stage of mastering the components of both methods and the final stage of independent project creation, were present in the project activity. Both disciplines were taught during the seventh and eighth semesters and consisted of two modules.

The first discipline is named "Creative learning technologies". It has a volume of 180 hours (6 ECTS credits). In-class learning hours include lectures (54 hours) and practical works (76 hours). The discipline syllabus was supplemented with three new lectures and three practical classes to master the main components of PBL and PjBL methods. Students mastered the PBL and PjBL methods, as well as performed a cycle of works focused on the development of creative abilities and creative thinking. Finally, the PjBL method was used for independent development of webinars, which were conducted by students under teacher guidance.

The second discipline is "Fundamentals of engineering and pedagogical creativity". Its volume is 270 hours (9 ECTS credits). In-class learning hours include lectures (44 hours) and practical works (66

hours). The course consists of the following modules: “Fundamentals of engineering and pedagogical creativity” and “Fundamentals of project activities.” Mandatory development of a project was included in the curriculum of the discipline as an individual research task. Students began to develop real projects in the eighth semester and had been making them for eight weeks. Five new lectures and five practical works on project development were introduced into the module “Fundamentals of project activity”. During the practical work in the classroom, students worked in groups. They developed the following elements of projects: “tree of problems”, “tree of solutions”, a logical-structural matrix of the project, etc. During the independent work, students developed the same elements by chosen topics. Subsequently, the developed essential elements were supplemented and combined into a project.

Students independently selected topics of projects. Teachers played mainly advisory roles in the process of project design and implementation. External experts were involved in assessing the significance of the projects. Students participated in evaluating the effectiveness of each member of project teams. Their assessments were constituents of the teacher’s evaluation criteria for the completed project.

In parallel with the project activity, practical classes of the course “Fundamentals of engineering and pedagogical creativity” were given. They were aimed to intensify creative processes and used several standard techniques. In particular, the self-questioning techniques by A.F. Osborne and B. Eberly, known as SCAMPER, were used to expand a view on the problem’s environment and develop solutions [31]. The method of F. Kunze, improved and renamed to Method of Focal Objects (MFO) by C. Whiting, was applied for problem-solving and creative thinking enhancement [35]. This method allows synthesising seemingly non-matching characteristics of different random objects into something new. It serves as a means of entering into a creative state and developing imagination and associative, non-standard thinking. Some components of the Theory of Inventive Problem Solving (TRIZ) by G.S. Altshuller were utilised. They focus on provoking a breakthrough in students’ thinking patterns and the way they approach problem-solving [2]. Besides, some elements of the creative training system CARUS by V.A. Moliako [29] were also used in teaching. They focus on stimulating creative thinking and developing skills to solve new problems in engineering activity.

3. Results

3.1. Preferred learning styles

Figure 1 illustrates the results of the learning preferences study for groups of KNUTD students of different enrolment years. The existing learning preferences remain valid for all studied years. However, some variation is observed in the relative number of students with different preferences for groups of different enrolment years. This variability may be caused by the fact that the number of students in each group was relatively small. Therefore, the impact of individual profiles was more significant for groups with a lower student number. Nevertheless, it can be argued that the contour of the profiles remained unchanged, at least in qualitative terms.

Visual learning style has the most significant advantage over verbal style among all four dimensions. In the vis-vrb dimension, the vis style in different years accounts for 83-89% of students. In comparison, only 11-17% of participants prefer the vrb style. The predominance of styles active and sequential is also convincing in the pairs act-ref and seq-glo, respectively. Indicators of these two predominant styles vary between 65-89% of surveyed students. In dimension sensing – intuitive, about 55-67% of students prefer sen style, while the rest 33-45% have a preferred int style. The students demonstrated a high degree of activity, visuality, sequentiality and sensing. These characteristics are almost independent of their enrolment year. The obtained results well fit with other published data for engineering students ([7], [8], [9]).

Figure 2 illustrates averaged learning profiles separately for students minoring in textile technology and design and for groups of 2014 and 2016 enrolment year. The existing preferences in the profiles of the technologists and designers almost coincide in the dimensions act-ref and seq-glo. However, they

are somewhat different in the other two dimensions. Students-designers differ noticeably in higher visuality (95-100% among designers versus 73-80% among technologists). Besides, designers are characterised by a slightly higher sensitivity rate (56-71% versus 50-55%).

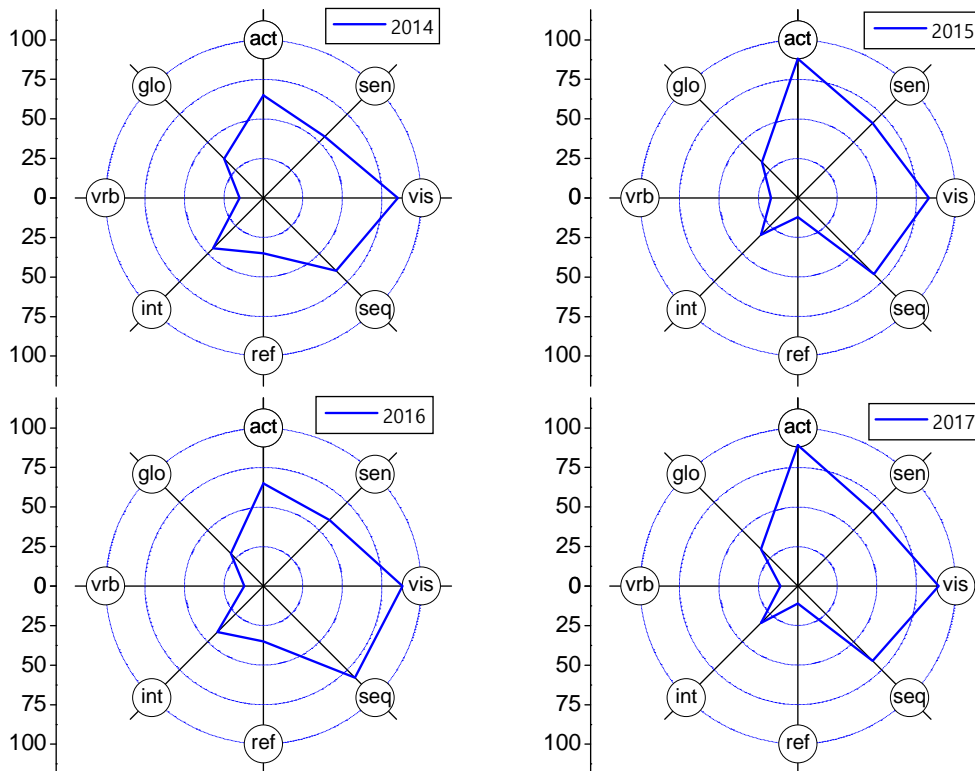


Figure 1. Profiles of learning preferences averaged for all surveyed students depending on the enrolment year.

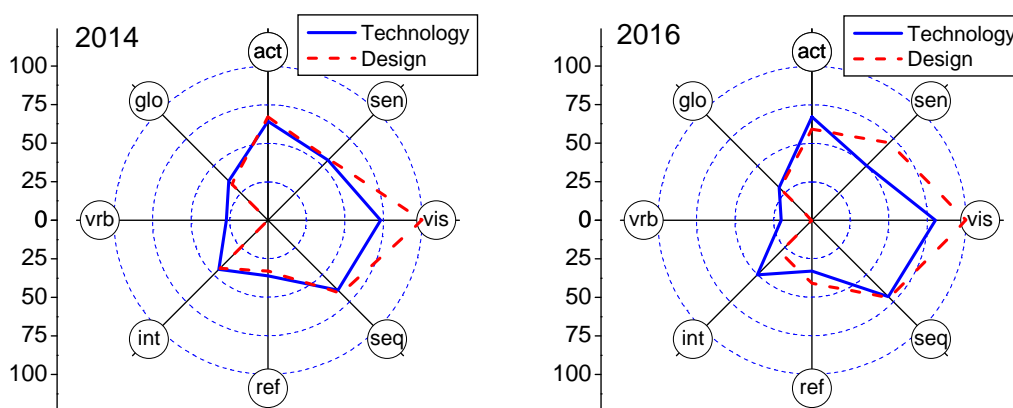


Figure 2. Learning preferences of two student groups minoring in technology and design and for 2014 and 2016 enrolment years.

Thus, the profiles of learning preferences in groups remain qualitatively stable both by enrolment years and specialisation. Such stability allows us to build a specific strategy for students’ training, regardless of an enrolment year but focusing on the integrated characteristics of their learning preferences and time horizon of their changes.

3.2. *Mastering of PBL and PjBL methods*

PBL and PjBL methods were implemented during the study of two professionally-oriented disciplines. Development of students' ability to independent creative and project activities was carried out consistently, from simple to complex. As mentioned above, students first mastered some elements of the PBL and PJBL methods. Then gradually, the tasks became more complicated and ended with the independent development of projects. Teachers encouraged students to ask questions and reveal contradictions in classroom activities to develop a creative approach to problem-solving. The necessary knowledge and skills were gradually developed during the performance of three practical works. The characteristics of corresponding steps are given in table 1.

Table 1. List of activity types which are necessary to master PBL and PjBL methods at the initial stage of the experiment.

Activity type	Description of student activity	Aim
Mastering of PBL		
Identification of issues that could form the subject for problem situation creating.	Students independently formulate a problem that is taken from real life and significant for them. To solve the problem, one needs to use both already acquired knowledge and new ones that have yet to be acquired.	To improve creative activity. Creative comprehension of the material can improve learning and understanding of the subject.
Creation of a knowledge base.	Students analyse what knowledge is needed to solve a problem situation and build a shared knowledge base.	To improve knowledge acquisition. Analysis of the material and the need to make explanations within a team can enhance learning and understanding.
Resolving of contradictions.	Students are responsible for solving the problem situation. They become experts on various topics.	The methodological analysis of contradictions and ways to solve the problem situation.
Mastering of PjBL		
Definition of project problems.	Students work in pairs, acting in turns as a student and teacher. As a student, they describe the problem and formulate a project topic that is important to them. Then they exchange topics and develop project implementation plans as their teachers.	To formulate the topic, goal, tasks and forms of the final product resulted from the project. To determine the range of users, compose the project team and divide responsibilities. To write a short annotation to the project.
Development of a project plan.	Students develop a project plan and describe the main stages of work organisation by PjBL. They try the role of a teacher of professionally-oriented discipline.	To learn planning and align tasks with project goals by highlighting all project aspects (goal, scope, tasks, team, resources, time and results).
Development of a requirement specification and project schedule. Regular written reporting.	Students prepare detailed requirement specification, assess the necessary time and distribute roles among project participants.	To ensure constant feedback from the supervisor and even work distribution between students.
	Students describe their work, explain how participants coordinate their activity and continuously monitor the progress and timing of the work. They select the necessary literature.	To ensure feedback with the head and even work distribution between team members. To master the skills of writing short reports.
Presentation of the report.	Students report on the project results. The report lists all the main paragraphs and briefly explains their most relevant content.	To structure and think over the report content. To write a report.

Several complications were experimentally identified at the beginning of the problem situation development. It was difficult for students to formulate independent ideas. If a student is not accustomed to questions and active communication with a teacher in class, he will not be able to

develop problem situations. Here are the keys to the development of creative activity.

Students were invited to develop a webinar to consolidate the skills of working on the method of projects. The webinars were developed under teacher guidance. Students independently formulated a real-life problem which was significant for them. During the development and conducting the webinar on a selected topic, they consolidated in practice all the stages of projecting. An external audience was involved in the webinar conducting. It included a lecturer, academic group members as experts in the field, as well as all other people wishing to visit webinar.

A report on the achieved results was prepared at the end. Students participated in the assessment of work results. They acted as opponents in the webinar presentation by another group, provided open feedback, and independently assessed the effectiveness of each team member. The use of student's opinions allowed us to increase the objectivity of the teacher's assessment.

The applied approach allowed us to reach 93% of the successful completion of educational tasks. Students learned to plan their work, coordinate tasks with the goal, distribute the work types and load and gained teamwork skills. Students have mastered ways of receiving and processing feedback to improve the resulting quality. The involvement of external experts enforced some pressure to achieve a good final result. As follows from the survey results, students' motivation to study was increased. Their responsibility towards each other was enhanced. Reflection after each stage of projecting, based on students' questions and curiosities, allowed ones to make projects more relevant and students more interested.

3.3. Application of PjBL method

After mastering the basic elements of the PBL and PjBL methods, students began to develop real projects. The activities that students carried out are described in table 2.

Students independently determined topics of their projects. The topic choice depended on the importance of a particular activity area for them. So, topics related to the future field of professional activity dominated among other problems. It can be a response to the demands of potential employers – about 80% of projects referred to this area. Social projects accounted for another 10%. The rest 10% concerned cultural self-identification. Analysis of the typology of developed projects revealed that they mainly belong to short-term mono-projects.

As follows from the analysis of the student activity results, project design improved students' attitudes toward learning and enhanced their creativity. However, only 77% of students were able to complete their projects fully and report the obtained results. The rest 23% of students had difficulties with completing the task. Table 3 illustrates the indices of learning preferences by groups. Students of group 1 successfully developed and completed projects. Students of group 2 were not able to complete all project stages.

The available learning preferences shown in table 3 were assessed in two ways, as was described in Methods. In the first case, the share of students in the group with particular learning preferences was calculated by analogy with figure 1 and figure 2. In the second case, the average indices of learning styles for each dimension were calculated for groups 1 and 2 on the base of individual data. The main difference between students in groups is reduced to two dimensions, namely act-ref and sen-int. For other dimensions, such as vis-ver and seq-glo, students were more visual and sequential regardless of the group.

The most severe difficulties, according to the student survey, occurred in the following types of activity: formulation of the purpose and identification of project tasks; creation of logical framework (logframe) matrix; and budget calculation. Financial calculations were complicated although they were simplified in projecting and included only two budgeting components, namely the team's salary and resource costs. Such difficulty was probably caused by a lack of necessary knowledge in economics. It may indicate the need to move to the implementation of interdisciplinary projects in the future. Such a transition will provide an opportunity to involve teachers of economic disciplines as supervisors or project consultants. All of the above requires finding out the reasons for students' lack of success in designing real projects. Solving this problem will improve the training methods for future

professionals to carry out creative activities.

Table 2. List of activity types while mastering the method PjBL at the final stage of the experiment (independent project development).

Activity type	Description of student activity	Aim
Introduction to classifications and life cycle of projects.	Individual work on information processing — execution of tasks on classification and definition of project stages.	To form the ability to classify projects and specify stages of the project life cycle.
Implementation of methods for project idea generation and their assessment (ranking).	Group work: brainstorming or brainwriting, generating the maximum number of ideas. Individual work as experts: evaluation of other student ideas by specific criteria & ranking.	To promote the development of creative thinking and form a “bank of ideas” for further project development.
Introduction to methods of problem analysis and identification of causal effects (lean-analysis).	Group work: analysis of problem situations, determination of the target audience and project stakeholders, construction of a “problem tree” (causes -problem -consequences).	To develop the ability to establish causal effects in project development.
Definition of the project team, schedule, and purpose and objectives by SMART-criteria.	Individual work: case analysis, construction of “tree of goals” (task-goal-effect), the definition of the goal, tasks, team and project schedule, specification by SMART-criteria.	To develop the ability to identify the project purpose and tasks using SMART-criteria.
Creation of project log frame.	Introduction to the main elements of logframe (general and specific goals, results, actions, milestones, verification, assumptions/risks). Group work: case analysis & development of logframe.	To form the ability to develop a project logframe.
Planning of project results.	Acquaintance with quantitative and qualitative project results, tools of their estimation. Individual work: a study of the algorithm, examples and implementation of SWOT-analysis.	To form the ability to identify quantitative and qualitative indicators of project results and use a SWOT analysis.
Evaluation of project effectiveness. Analysis of the process for project management.	Individual work: analysis of scientific sources, acquaintance with the basic principles and functions of project management, including resource provision and performance monitoring.	To develop the ability to plan project costs and monitor the project flow.
Analysis of successful projects which were realised in Ukraine.	Individual work: search and analysis of five successfully implemented projects, analysis of the results of their applications and implementation.	To motivate students to activities and reduce anxiety about the development of independent projects.
The distinctive design of the project and its presentation.	Individual work of students on project development according to the algorithm with a subsequent presentation to the teacher and the academic group.	To apply the obtained knowledge & skills for the creation and presentation of independent projects.
Finding of grant programs.	Analysis by students of current grant programs that accept applications in certain areas	To give reasons for the realisation of developed projects and further project activity.

Table 3. Average learning preferences of students in groups formed on the base of success in project completion (students of the 2016 enrolment year).

Characteristic	Group	Act	Ref	Sen	Int	Vis	Vrb	Seq	Glo
Share of students in the group, %	Group 1- Project completed	54.5	45.5	63.6	36.4	90.9	9.09	90.9	9.09
Share of students in the group, %	Group 2 - Project uncompleted	83.3	16.7	50.0	50.0	83.3	16.7	66.7	33.3
The average score of the group, points	Group 1 - Project completed	5.64	5.36	7.45	3.55	7.91	3.09	7.00	4.00
The average score of the group, points	Group 2 - Project uncompleted	8.00	3.00	5.33	5.67	7.83	3.17	6.17	4.83

4. Discussion

Figure 3 illustrates a generalised scheme of PBL and PjBL methods implementation in the educational process. The implementation purpose was to develop the ability of future engineers to carry out professional project activities. The existing discipline syllabi have been changed to start the process of integrating PBL and PjBL methods into the educational process at KNUTD. It was done as course parts that the institution chooses at its discretion to meet the requirements of the regional labour market. All changes took place within the framework of credits approved by state education standards. It was considered appropriate to implement PBL and PjBL when students already have enough knowledge to solve professional problems. As a result, the seventh and eighth semesters of bachelor training were used, respectively.

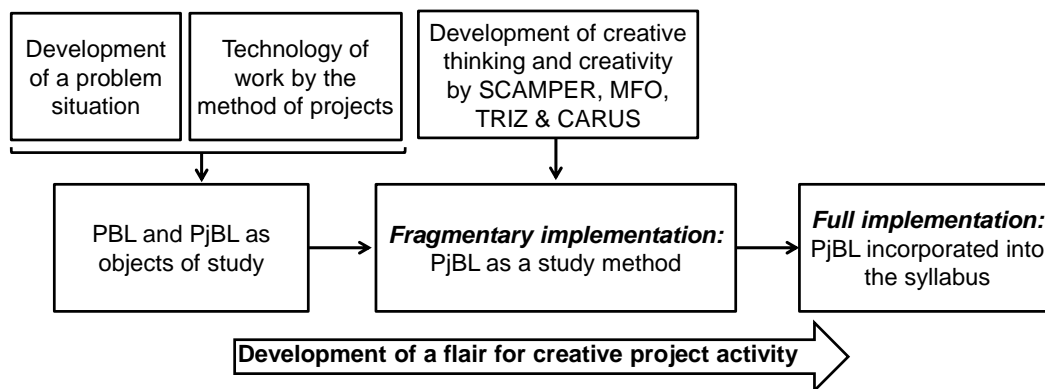


Figure 3. Scheme of PBL and PjBL method implementation in the training process for future technologists and designers.

In general, the proposed implementation scheme can be considered successful. Survey data showed that most students demonstrated a positive attitude towards projecting. According to students, they are more interested in learning using PjBL than in traditional learning. They agree that teaching strategy is an essential factor influencing their interest in the learning process. About 51% of students agreed that project-based learning increases their critical thinking. About 49% firmly agreed that they became more creative when designing their projects. The derived conclusions are supported by the statements in [1], [3], and [33] that PjBL is aimed at involving students in the study of real-life events and the development of personal creativity. Teachers noted that when creating a project, students often exchanged ideas, discussed ideas within a group and learned to find solutions. PjBL increased students’ ability to work in a team.

However, the overall result of the PjBL application is not entirely satisfactory, as 23% of students could not complete all project stages. When they worked on the project entirely under the teacher guidance, the success rate was much higher – 93%. Trying to explain this, we can assume the action of at least two factors. The first factor is the lack of knowledge needed to develop a full-fledged project. In particular, some students recognised a lack of training in economics. The possibility of implementing interdisciplinary projects instead of mono-projects can be considered as a way to improve the projecting in the future. Such interdisciplinary projects involve, if necessary, teachers of related fields (economists, applied mathematicians, computer scientists, mechanics, etc.) as supervisors or consultants. Such involvement can cause additional difficulties in planning the workload of teachers and the distribution of roles in project groups. The solution may be the introduction of a separate discipline. Then, for example, two different departments may be responsible for its implementation with the appropriate load distribution. Tighter fixation of project topic choice by students may be a disadvantage of the new approach. Therefore, this requires additional consideration.

Another factor is related to the characteristics of student learning styles (table 3). Based on the relative number of students, the predominance of the active style is observed in both groups. However, this advantage is much more pronounced for students of group 2. Comparing the average act indices suggests the reasons for this discrepancy. The average score of activity in group 2 is much higher than in group 1 (8 against 5.64 points). In other words, students with a strongly pronounced active style dominate in group 2.

In contrast, students of group 1 are characterised by a moderate advantage of the active over reflective style (table 3). Therefore, according to the obtained results, excessive activity and lack of reflective reflection hindered the successful completion of projects. In the sen-int dimension, students of group 1 exhibit a clear preference for sen style. A relative balance between sen-int styles is observed in group 2.

The results obtained at first glance contain contradictions. Group work and project activities are considered suitable for active students. Our results show that moderate activity contributes to successful project implementation. In contrast, excessive activity hinders its implementation.

It is also common knowledge that invention is natural for students with an intuitive style. Students with a sensitive style learn better about the facts linked to real life. Nevertheless, the results show that students with a predominant sensitive style demonstrate better results in projects that contradict with theoretic considerations. However, this contradiction disappears if we take into account that students independently chose the project topics. Students with a prevailing sensitive style chose projects that had a real connection to real life. Besides, they focused on mono-projects. In other words, they limited the need to work with unknown facts and focused on well-known things ([10], [11]).

The results obtained showed that more than half of the teachers noted the difficulty of using PBL and PjBL methods. The survey of teachers allowed to formulate several major methodological complications when working with the method of projects. They are as follows: uncertainty of some task definitions, inability to use in projecting all the knowledge required by the syllabus, difficulties in the assessment of group performance, and more complex than expected time management and monitoring. However, almost all teachers acknowledged that the project-based methods help to eliminate routine. The advantages of such an approach include higher enthusiasm in work, the interest of students, connection with the profession and real-life, cooperation in work, self-control, and discipline of the group.

Ideally, the involvement of the business sector is needed to formulate the project themes. It can be one of the most challenging stages and also requires methodological development. It is necessary to prove to the business sector that projecting is mainly devoted to a learning process. It is not a free labour force explicitly created for commercial purposes. However, such work can be useful for business, as it has the potential to find real solutions to problems that arise in the business sphere.

5. Conclusions

The learning preferences were investigated for groups of engineering students minoring in textile technology and design. On average, students show a tendency to active, visual, sensing and sequential learning styles. The learning preferences are relatively stable over the studied four enrolment years. Students specialising in the design are more visual than student-technologists. However, the profiles of the groups minoring in design look generally similar to the profiles of students specialising in technology.

The effectiveness of problem-based and project-based learning has been studied experimentally for teaching two professionally-oriented disciplines. Students initially experienced problems when the development of problem situations. However, they moved from simple elements of the studied methods to complex ones under teacher guidance. As a result, both PBL and PjBL methods have been successfully mastered by 93% of all students.

When students formulated and designed projects without teacher assistance, they experienced much more severe problems. The share of completed projects was only 73% against 93% at the previous

stage. Besides, students tended to mono-projects. They lacked some knowledge, for example, in economics, which may have prevented them from doing interdisciplinary projects.

The study showed that successful projects under the studied conditions correlate with the existing student learning preferences. Student groups are successful in the implementation of projects if they have a more obvious advantage of reflective style and simultaneously maintain moderate activity. In the sen-int dimension, the presence of a pronounced sensitive style is also favourable for successful projecting. Successes in project implementation are mainly insensitive to changes in the dimensions of vis-vrb and seq-glo.

Thus, the initial hypothesis about the universality of the project-based methods for students with any learning preferences has not been fully confirmed. Nevertheless, the introduction of PBL and PjBL methods are useful for engineering students. They gain new competencies, obtain real experience in teamwork, increase their motivation to learn and develop creativity. Improving the methods of implementing PjBL is a promising topic for further research.

The problems of PBL and PjBL method application are discussed in terms of teacher training. Most of such problems can be solved by the organisation of specialised training of teachers.

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Students training for numerical control machines programming by means of computer-aided manufacturing tools

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Abstract. The article describes the analysis of computer-aided manufacturing systems introduction for the control program machines preparation with the numerical control into the technical students' educational process. The main stages of teaching students the basics of control machines programming by means of addressing to manual programming and CAM-systems are considered. Recommendations for the control programs testing implementation without a numerical control machine, by means of numerical control machine simulators introduction into the educational process are given.

1. Introduction

Traditionally, studying at a technical higher education institution is related to the development of technical (design and technological) documents in order to manufacture parts, assemblies and products. The development of the documentation is possible only in case of an expert having a developed special reasoning, being experienced in solving positional and metrical problems, being aware of the rules, conventions and simplifications in accordance with the current standards for technical documentation, understanding of applications functioning principles, their classification and application possibilities, being skillful in working with the system [13].

Recently, an indisputable issue is the importance and efficiency of design, manufacture, improvement and modernization of any technological operations and products by using computer systems. Automated computer systems increase efficiency; significantly changing the content of any technological process variety of stages, significantly affect the design methods, technology, manufacturing improvement and its organization. It is especially topical in the field of computer-aided design systems (CAD).

An up-to-date CAD-system is a complex organizational and technical complex, including three main components [12]:

1. Computer-aided design is a technology aiming at applying computer systems in order to facilitate the projects creation, modification, analysis and optimization.
2. Computer-aided manufacturing (CAM) is a technology that lies in applying computer systems with the aim of planning, managing and controlling manufacturing operations through a direct or an indirect interface with the manufacturing resources of the enterprise.



3. Computer-aided engineering (CAE) lies in applying computer systems in order to analyze the geometry of CAD, modeling and studying the product behavior with the aim of its further design improvement and optimization.

Thus, CAD/CAM/CAE technologies are to automate and increase the efficiency of certain stages of the product life cycle. Developing independently, these systems require the integration of design and manufacturing processes. A new computer-integrated manufacturing (CIM) technology was suggested in order to solve the problem. CIM technology presupposes using a computer database to more effectively manage the entire enterprise, including accounting, planning, delivery and other tasks, not just the design and manufacturing covered by CAD, CAM and CAE systems. CIM is often considered to be a business philosophy rather than a computer system as CIM technology performs separate engineering, manufacturing, marketing and support functions of the manufacturing enterprise.

Using the above technologies for preparing bachelor degree students in higher education requires the introduction of new conditions at all stages of learning, from engineering graphics to technological processes of machines with numerical program control (computer numerical control, CNC), because basically young professionals in enterprises, design and technology bureaus are required to have knowledge and practical skills of professionally-oriented information technology implementation in engineering and, especially, skills in CAD/CAM/CAE-systems.

2. Literature review

In the process of science and technology development, man-made technical systems, devices, structures become increasingly complex. At the same time, the requirements for the timing of new products design are increasing, competition on the market of machine-building products is intensifying. Under these conditions, traditional non-automated design methods are ineffective. To reduce the manufacturing and technological cycle of machines duration, the widespread use of application development environment (ADE) system has become an urgent need.

Scientific and methodological aspects of ADE system implementation into the educational process are revealed in the works [2], [4], [7], [11], [16], [17]. They note that to ensure fundamental and special training in the field of computer-aided design, the student must be prepared for the following types of professional activities: design, manufacturing and technological, organizational and managerial, research, operational.

Modern tasks of higher educational institutions can be performed through programmed learning once the continuing computer training is implemented for students, starting with general and technical disciplines of the first year and ending with a diploma project in specialized departments [15].

End-to-end computer training [5], [15] of students of machine-building specialization improves their graphogeometric knowledge and skills, promotes the development of spatial thinking by introducing CAD/CAM-systems into the educational process.

The authors propose a method of production processes integration [8] into the traditional process of preparing students by means of CAD/CAM will let combine the study of different special subjects in a project being a good basis for work in manufacturing sphere [1].

The article is focused on developing the method of improving the quality of technical students' preparation for programming CNC machines by using CAM-systems and emulators of CNC machines in the learning process.

3. Outline of the main idea

Engineering education is mainly tasked to do provide staff with training having both professional knowledge and modern information technology idea. Due to the high scientific intensity of training courses and the simultaneous reduction of teaching hours (basic engineering disciplines), the solution of this problem requires new approaches to teaching methods such as preparing students to design modern CNC machines and work on them using CAM-systems and simulators.

To be able to be highly competitive in the labor market, graduates of technical institutions of higher education must be able to:

- search for information (regulatory, reference, economic, etc.) in databases and on the Internet;
- perform the simplest technical and economic calculations [14];
- carry out design and technological design operations; calculations using CAD/CAM systems;
- know text-processing programs;
- be able to adapt software products to specific design and technological developments.

Modern manufacturing is characterized by the widespread use of machines with numerical program control – a system controlling all the drives of process equipment, including facilities. CNC systems are used in various industries, in particular: metals, wood, plastics processing, sheet blanks cutting, pressure treatment, etc. CAD and CAM-systems are used in the process of technological preparation of manufacturing allowing automate the design of control programs. Users of systems like that must have a thorough computer geometric and graphical knowledge, the foundation of which is in the relevant disciplines related to computer geometric modeling.

Developing a control program for the CNC machine is one of the preparation stages of technological manufacturing, ensuring the manufacturability of the product, design of technological processes and means of technological equipment, calculation of technically sound material and labor standards, the required number of equipment and manufacturing areas, implementation of technological processes and their manufacturing management. These mentioned above are the set of works allowing start manufacturing of a new product in the given volume [3], [10].

Thus, the introduction of CAM-systems into the educational process and the creation of virtual production processes through the use of emulators with CNC machines will significantly improve the quality of student training.

3.1. Methods of preparing students for programming CNC machines by means of CAM

Bachelor students training at Zhytomyr Polytechnic State University in 131 “Applied Mechanics” specialty is firstly possible through studying the following subjects: “Descriptive Geometry, Engineering and Computer Graphics”, “Computer-Aided Design and Modeling”, secondly, on the basis of the acquired knowledge – special design subjects, technology, operation and repair with extensive use of computer technology. In particular, in the process of studying “Technological processes of CNC machines” subject students get acquainted with the structure of modern CNC machines, 3D modeling systems and control program development (CAM).

When programming the machining of parts on modern CNC machines and developing control programs the following methods are used:

- manual programming;
- programming using a CAM system;
- programming on the control panel of the CNC system.

Teaching the basics of programming CNC machines can be divided into the following stages:

1st stage. Study the CNC machines programming and the basics of control programs for machining parts.

During this stage, students get acquainted with the programming language of CNC machines and master the method of manual programming.

A lot of different software are used in the workplace, where different CNC machines perform, but in most cases, all control programs use the same control code – G-code. It is a kind of communication language between the machine equipped with a CNC system, a computer and an operator.

G-code is the language developed in the 1950s, upgraded in February 1980 and standardized as the RS274D standard. The ISO Committee approved the G-code as ISO 6983-1: 2009 [9].

Since then, this standard has been actively used by manufacturers of CNC machines (Siemens, Sinumerik, FANUC, HAAS, HEIDENHAIN, Mazak), extending it at their discretion, but the basic codes and structure of the programs remain unchanged. The reason is that a program written using G-code has a rigid structure. All control commands are grouped into frames – groups consisting of one or more commands. Each command consists of words – the basic elements of the program consisting of a Latin letter’s combination and some numerical value (positive or negative, fractional or integer).

Manual programming is a long-lasting, monotonous lesson. However, all programmer technologists must be aware of the manual programming technique being the basis for further training. There are still a lot of companies in Ukraine using the method of manual programming. Indeed, if the plant has several CNC machines, and it is engaged into the manufacturing of simple parts, then a competent programmer is able to work quite successfully with no addressing to the automation means in his work performance.

Students study the basic G-code commands and reinforce the acquired knowledge through manual programming is the basis for further stages.

2nd stage. Acquaintance with the CAM-systems and their use for the control programs for machining parts manufacturing on CNC machines preparation.

The study of “Technological processes of CNC machines” subject presupposes the student’ acquaintance with the method of manual programming and mastering the basic provisions of ISO 6983-1: 2009; later they proceed to dealing with CAM-systems.

Zhytomyr Polytechnic State University has the following licensed CAM-systems:

- Delcam ArtCAM – CAD/CAM-system for 3D-modeling and manufacturing of art products;
- Delcam PowerMill – an expert solution for programming high-speed and multi-axis machining on CNC machines and robots;
- Delcam FeatureCAM – a system covering all manufacturing stages – from product design to the development of complex control programs for cutting, CNC lathes, as well as EDM process;
- SolidCAM – an integrated CAM system being able to work directly in SOLIDWORKS and Autodesk Inventor systems, including patented iMachining technology, while supporting all the necessary turning and cutting functionality, as well as functionality for programming multifunctional cutting machines, including longitudinal turning machines of the Swiss type.

Students start working with CAM-systems during practical classes, because practical training, as one of the most important forms of the educational process, is the “student – program – electronic model” system matter. In this system, the second element complements and, under certain conditions, for example, in independent working process or distance learning, replaces the teacher.

In the process of performing practical tasks, students get acquainted with the interface of the CAM-system, learn the basic methods of machining trajectories construction, tool selection, as well as optimize machining by visualizing the machining process and making adjustments to a particular trajectory. In the result, they get a ready control program for a specific (depending on the selected postprocessor) CNC machine.

Since the CNC machine implements part of the technological process for the parts manufacturing, the control program must include all the features of machining, in particular:

- know the characteristics of the CNC machine (power of the main drive, the maximum weight of the workpiece that can be installed on the machine, the feed and speed ranges, the number of tools in the store or turret, etc.);
- know the characteristics of the CNC system (programming language, the number of controlled axes and the number of simultaneously operating axes, the of built-in cycles and macrocycles presence, a list of machine functions that can be reprogrammed, etc.);
- know the way to achieve a given accuracy and roughness of treated surfaces;
- know the features of the displacement task and methods of forming individual design and technological elements on the CNC machine;
- know the features of programming a particular machine.

While dealing with the SAM system, students need to use the documentation to CNC machine.

3rd stage. Control programs check-up on CNC machines.

In the process of this stage implementation there occur difficulties associated with the lack of modern machines with higher CNC in higher education institutions, in particular at Zhytomyr Polytechnic State University, because of these machines being costly.

The analysis of the modern CNC machines market showed that their cost can reach several tens of thousands of dollars, for example:

- HAAS Super Mini Mill 2 – € 35000;
- DMG MORI CMX1100V – € 73000;
- Vm3020 Education CNC Cutting Machine – \$ 13000;
- Xh7118 Education Mini CNC Vertical Cutting Machine – \$ 7000.

The presence of a modern CNC machine in a higher education institution solves the problem just partially, because in addition to the machine itself, you need to have the base of the cutting tool, its fastening elements and special devices, which, as a rule, the machine is not equipped with. That is, for laboratory (practical) classes on programming cutting; there must be appropriate sets of cutters, drills, boring heads, etc. in the laboratory. Accordingly, sets of cutters, holders, etc. are required for programming turning process.

3.2. Analysis of integration of production processes in learning

One of the problem solutions to the lack of modern CNC machines in higher education institutions is the conclusion of contracts for practical training at enterprises in the region having the appropriate equipment in their store.

The second solution is to use simulators of modern CNC machines in the study process, because learning directly on the machines is a very important and mandatory component of the study process, but also dangerous because incorrectly designed control program or incorrectly entered settings on the machine control panel can lead to catastrophic consequences.

The task of the simulator is to identify potential programming errors while working offline, before the control program is generated and transferred to the machine. Recently, simulators have become so successful in detecting errors that small and large industrial enterprises using them call simulation a vital factor in maintaining profitability.

There exist two types of simulators: a simulator in the form of a physical machine control panel, and in the form of a program.

CNC machines (FANUC, HAAS, etc.) manufacturers offer simulators of their machine control systems in the form of a full control panel with a basic set of functions corresponding to the CNC equipment of a real machine.

CNC systems simulators in the form of programs have a number of advantages in comparison with those offered by machine tool manufacturers, such as:

- lower license cost for a workplace;
- a large number of machines that are simulated in one program.

The existing on the market software simulators of CNC machines are the following:

SSCN control Simulator (figures 1, 2) (<http://www.swansc.com/en/products/SSCNcontrol.html>) – software simulator for CPN control machines from Nanjing Swan Software Technology Company, including 21 types, 76 systems and 163 control panels, including: FANUC, SIEMENS (SINUMERIK), MITSUBISHI, FAGOR, HAAS, PA, Romi, GSK, HNC, KND, DASEN, WA, GREAT, SANYING, RENHE, SKY, JNC, Decekel, GTC2E, NCT & Mazak.

This simulator for educational institutions is offered in the form of a package “CNC Smart Class” with a lifetime license and a free upgrade to new versions. The cost of a license for one workplace is determined individually.

With the help of “CNC Smart Class” based on SSCN control Simulator it is possible to conduct both theoretical and practical parts of learning directly on classroom computers, significantly saving time and increasing the efficiency of classes, because visual learning is much better perceived by students.

In SSCNC control Simulator, you can control the machine using the virtual control panel, enter control programs, perform machine debugging, set the workpiece dimensions of the workpiece, or load the workpiece geometry as a 3D model. In addition, it is possible to perform a complete simulation of the machining process on a three-dimensional model of the machine.

This simulator for educational institutions is offered in the form of a package “CNC Smart Class” with a lifetime license and a free upgrade to new versions. The cost of a license for one workplace is determined individually.

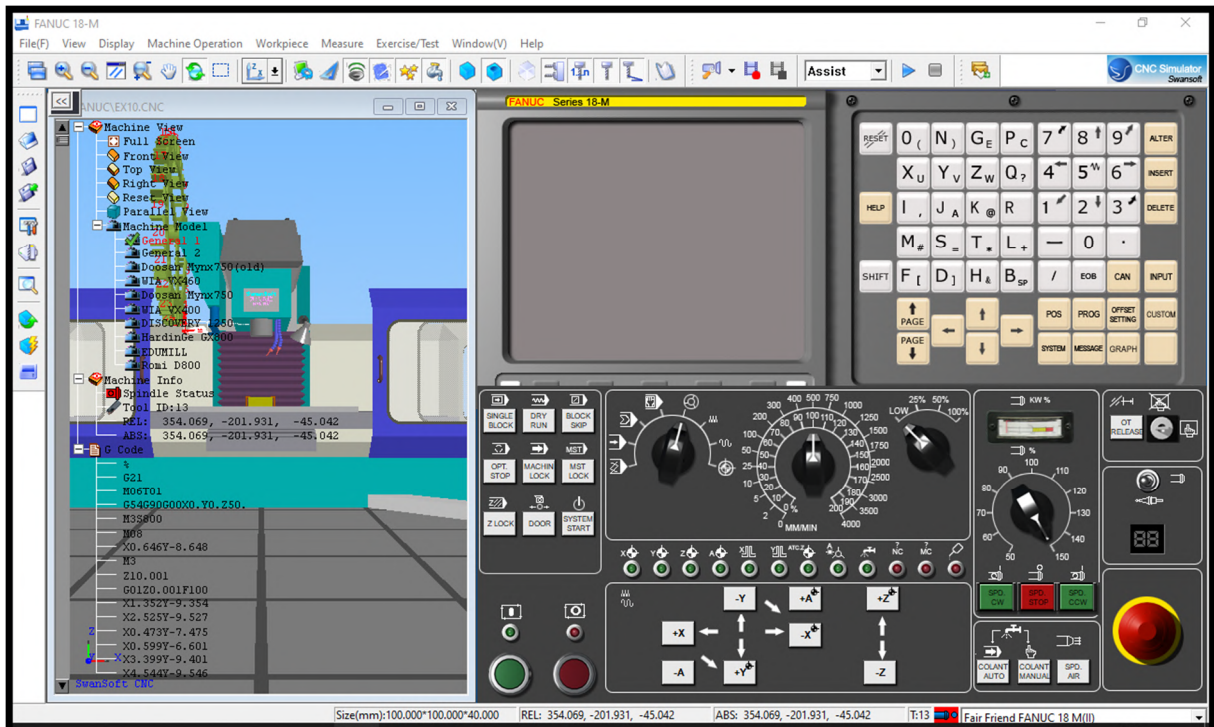


Figure 1. Simulation of a vertical cutting CNC machine in SSCN control Simulator program.

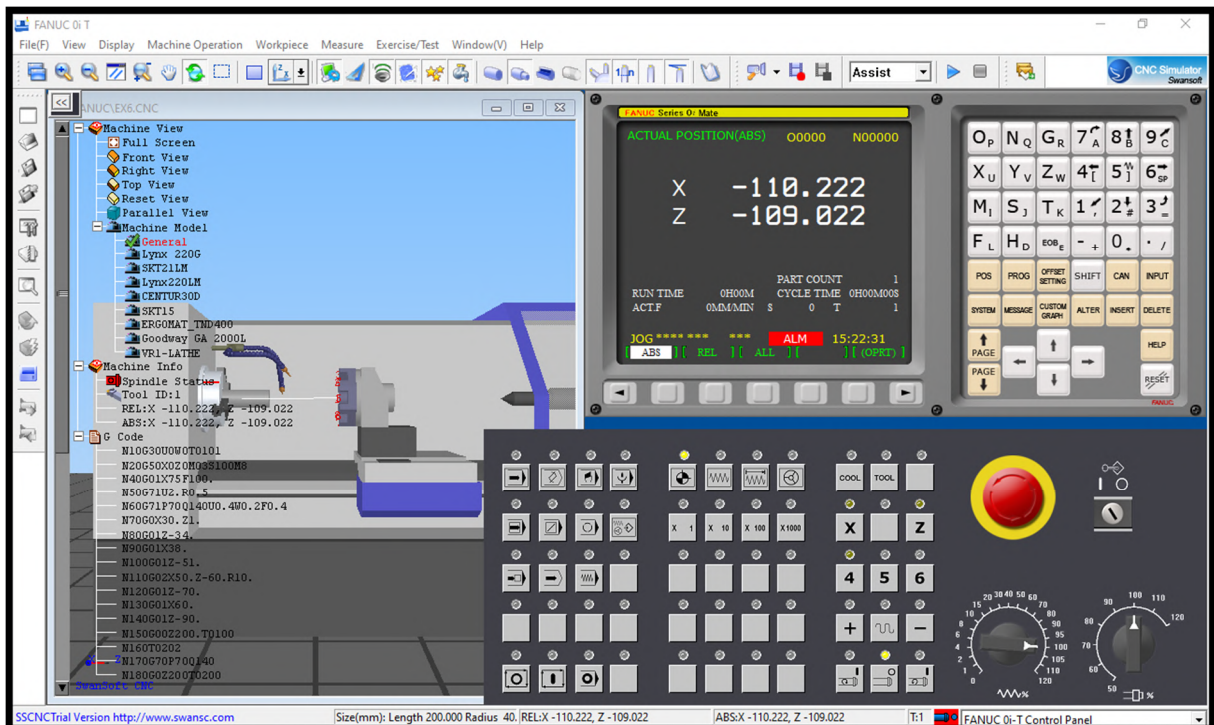


Figure 2. Simulation of a lathe screw-cutting CNC machine in SSCN control Simulator program.

As soon as “CNC Smart Class” is installed in the local network, the teacher gets access to control the simulator on students' computers, allowing the following:

- perform general management of the computer class;

- upload practical classes to the program server;
- broadcast the teacher's computer screen to students' computers in real time;
- perform testing of students within the system with automatic sorting of results;
- manage test data, testing process and results.

By means of “CNcontrol Smart Class” based on SSCN control Simulator it is possible to conduct both theoretical and practical parts of learning directly on classroom computers, significantly saving time and increasing the efficiency of classes, because visual learning is much better perceived by students.

CNcontrolSimulator (figures 3, 4) (<https://cncontrolsimulator.info/>) – includes not just a simulator of CNC machines, but also a CAD/CAM-system SimCam, a tool for cutting 3D-models 3D Maker, a tool for gears Gear Maker gear, as well as a host of other tools and features with the annual subscription for 12 jobs costing \$ 360.

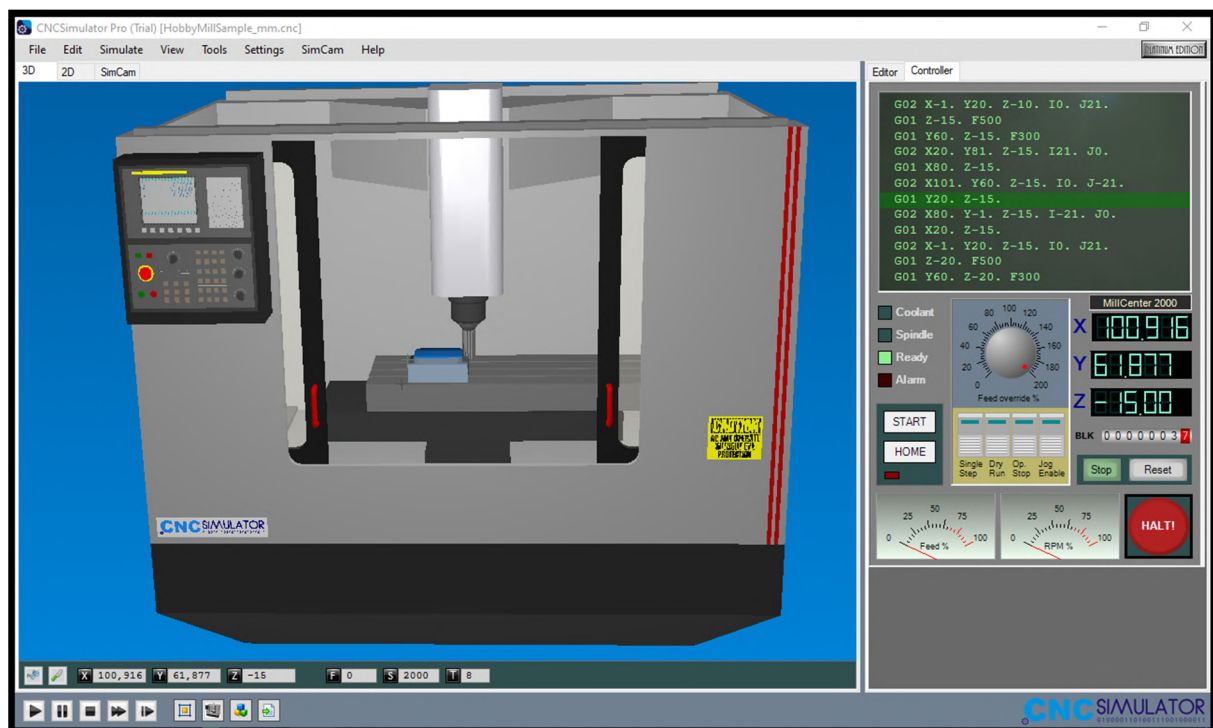


Figure 3. Simulation of vertical lathe CNC machine in CNcontrolSimulator program.

CNC Simulator allows you visualize the following CNC systems: FANUC, SIEMENS (SINUMERIK), MITSUBISHI EZMotion-NC, HAAS, FAGOR, GREAT, RENHE, etc.

In addition, it is possible to visualize a range of control panels of CPN control machines, in particular: KND operation panel, DASEN operation panel, GSK series standard panel, BAOJI machine operation panel, etc.

SSCN control Simulator and CNcontrolSimulator have some of the same functionality such as:

- 3D processing visualization;
- standard sets of preparatory functions (G-codes) support;
- standard sets of M-codes support;
- polar programming, spiral and cylindrical interpolation for FANUC and SIEMENS systems support;
- full animation of the workpiece, tool, stroke of the caliper;
- vertical and horizontal CPN control machines simulation;

- software and manual control;
- machining with cooling, metal processing sound effects;
- base of measuring instrument: templates, micrometers, calipers, etc.;
- a large database of processing tools, operating parameters and management;
- the ability to create and configure custom databases;
- three-dimensional design of products upon the manufacturing cycle.

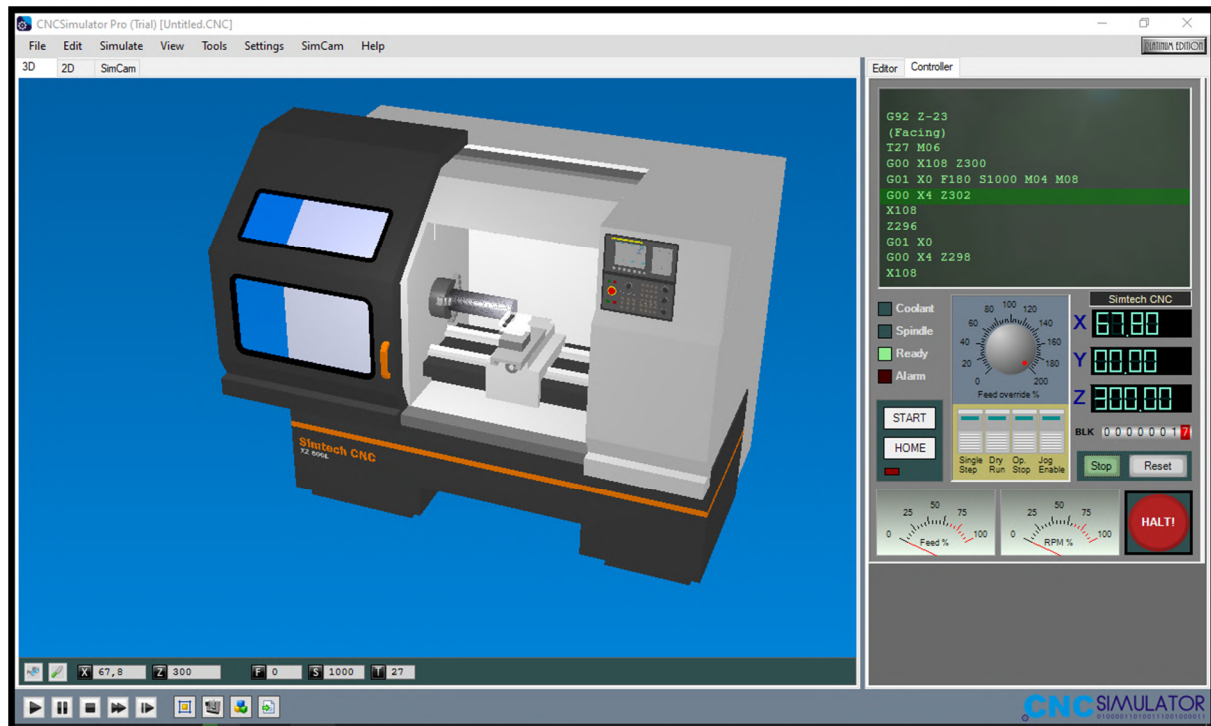


Figure 4. Simulation of vertical screw-cutting CNC machine in CNcontrolSimulator program.

Unlike SSCN control Simulator, CNcontrolSimulator does not implement the network control of the study process. But the availability of additional modules allows effectively perform student training.

4. Expected results

Integrating CNC machines simulators into the educational process results in:

- the learning process intensification through repeated development of control programs without any risks for students or machines;
- reducing the cost of training equipment by emulating different combinations of CNC machines and tools while developing a control program for a specific part;
- the ability to simultaneously teach more students both in the computer classroom and by means of the Internet, providing access to the software of the CNC machine simulator;
- simulation of the CNC machines working process, including tools and special equipment;
- students' performance with different types of CNC machines and their control panels;
- control program errors correction right in the workplace;
- students' opportunity to receive both individual and group consultation of the teacher, as an important component of the educational process is the student's independent work with different types of CNC systems to solve specific problems in the process of further study.

5. Discussion

The method of CAM-system simulators and CNC machines introduction into the educational process was discussed at a round table meeting, attended by scientists and teachers of Zhytomyr Polytechnic State University and representatives of leading Zhytomyr region industrial enterprises. As a result, it was agreed that the proposed method will significantly affect the adaptation speed of a higher education institution graduate on the workplace and reduce the time of his preparation for work on specific technical CNC equipment.

6. Conclusion

The simulators integration into the educational process is more cost-effective comparing to the purchase of full-featured CNC machines. Besides, while working on simulators, students will not be afraid to get the costly machine, instrument or tool out of order. Having processed the part on the machine simulator, it can be then transferred to a real machine with CNC. Eventually, comprehensive solutions – training students in CAM-systems and CNC machine simulators will provide them with the latest knowledge, as well as increase their competitiveness on today's labor market.

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Using interactive scribe-presentations when teaching Ukrainian

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Abstract. The article is devoted to the urgent topic of using new modern information technologies in lessons in general and in the Ukrainian language lessons in particular. The authors of the article prove that multimedia presentations have become one of the most popular ways of visual accompaniment in the presentation of theoretical material. In the article the authors analyze the results of the external independent evaluation (EIE) of the Ukrainian language and literature from 2015 to 2018 as well as online testing results of students from the Australian, Canadian and Polish diasporas on the level of Ukrainian language proficiency. According to this analysis it is determined that the level of knowledge on this subject deteriorates every year. Relying on these statistics, scientists have proved the need to improve the quality of knowledge using multimedia presentations, which provide more effective perception of educational information by helping students to visualize it. The researchers have proved the effectiveness of using the PowToon service in teaching philological disciplines in the educational process. This article is a practical step-by-step assistant for teachers and academic staff in creating a scribe-presentation. The authors have analyzed in detail the peculiarities of the methodological approaches that are worth using for effective implementation of PowToon and PowerPoint in the educational process (competence (the ability to actualize available knowledge, skills, experience to solve the difficult tasks in professional activities), systemic (forms the relationship in the study of philology disciplines, systematizes and structures complex information, using them in teaching), informative (use of information and communication technologies in the study of philology disciplines). The effectiveness of using online (PowToon) and offline (PowerPoint) services to create multimedia presentations has been compared. The key stages of the scribe and the advantages of the scribe-presentation have been considered. Taking into account that information is absorbed and reproduced better when it is visualized, that is, through visual perception, therefore, it is proved that use of PowToon service is accompanied by positive emotions and high indicators in the students' learning outcomes. It is confirmed by a reflection questionnaire at the end of the lesson. The questionnaire consists of five questions and is evaluated on a 10-point scale. After analyzing the responses to the questionnaire the authors have come to the conclusion that the use of the script-presentations has a better influence on the perception of new visual information; increases the motivation for learning, interest in a subject that prompts subjects of the educational process to develop their creative projects and use their knowledge in everyday life; saves teachers' time while preparing for a lesson; inspires teachers and academic staff to give unusual lessons and provide new interesting teaching ideas, as well as create integrated lessons.



1. Introduction

1.1. Problem statement

In the connection with the global technical process, particularly the constant use of smartphones, laptops, tablets in everyday life, the enthusiasm and interest in paper editions and their use in the process of education decrease. As a result, literacy, the ability to formulate and express thoughts correctly has been declining since school years.

Later on, each student has to pass an external independent evaluation (EIE), the results of which influence on admission to higher educational institutions.

Having analysed the level of the results of EIE on the Ukrainian language and literature, we can conclude that each year more and more students do not gain the minimum number of points to participate in the competition for the future profession. So, in 2015, the percentage of participants who did not score the lowest passing score was 8.4 %, in 2016 – 9%, in 2017 – 7.55 %, in 2018 – 14.5%, and in 2019 it increased to 16 % (see figure 1) [25].

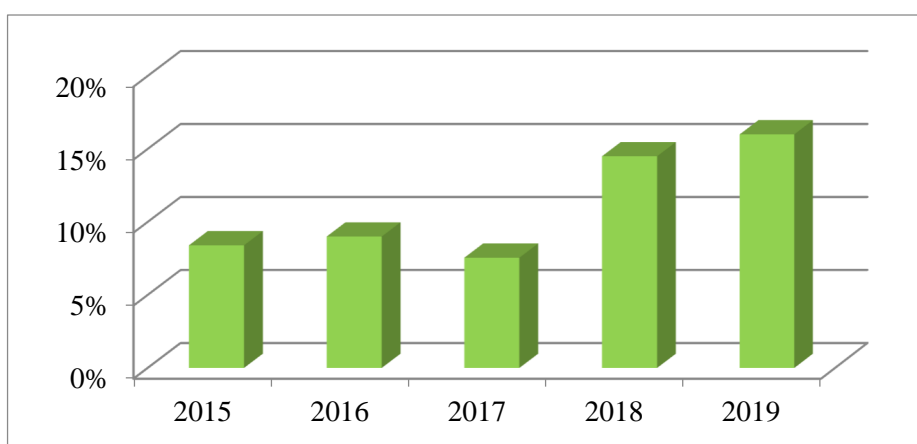


Figure 1. Percentage of participants who have not crossed the limit “pass / fail” on the subject the Ukrainian language and literature.

Moreover, 276 students in the Australian, Canadian and Polish diasporas took online tests on their level of proficiency in the Ukrainian language (see figure 2).

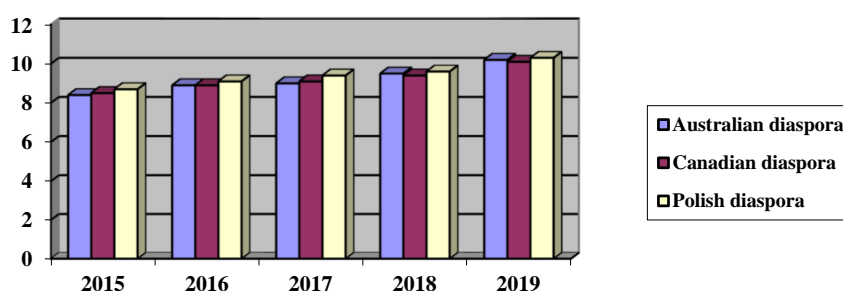


Figure 2. Percentage of students in Australian, Canadian and Polish diasporas who have not scored a minimum on the test.

The testing was conducted from 2015 to 2019 and included checking the level of knowledge in spelling, phonetics, vocabulary, morphology, etc. As the diagram shows, the percentage of students who did not score the minimum number of points increases every year. Subject teachers admit that students’

interest in learning has recently decreased, it is difficult to stimulate them to study and to acquire new theoretical knowledge.

Consequently, teachers and academic staff should use more ideas to motivate their students to study their subjects and stimulate their own level of knowledge. That's why it is necessary to create such activities and lessons that will encourage children to study the subject in depth. These activities can include lessons in the format of trips, quests, excursions, conferences, researches, disputes, etc. While carrying out such lessons it is necessary to apply technologies to visualize educational materials. Such classes can have various aims: from presenting new information to checking knowledge or revision. Smartboards, tablets, smartphones and other modern technologies are worth using to visualize information during the classes [19].

The rapid development of information technologies is a priority direction of the state policy of the developed countries. Computer communications, along with modern learning technologies, can significantly influence on the formation of a new content of education and the modification of organizational forms and teaching methods. Nowadays new educational technologies and modern conditions for the social development require significant changes in the training future teachers as specialists in pedagogical area, raising the requirements for the quality of the educational process can be observed, which certainly influences on the formation of professional training and students' information competence.

The solution of the problem of forming the information competence of the future teacher, his/her readiness for work on the grounds of a deep understanding of modern pedagogical, informational and communication technologies is of absolute practical significance [22]. The creation of alternative type schools, the recognition of the right of every school to have their own unique image and work on authorial programs, require teachers with innovative thinking capable of consciously assuming responsibility for themselves constantly developing personalities and the responsibility for the development of the school as a system, which needs improvement too.

To work more effectively during the lesson the teacher and academic staff needs not only to present the new material, but also to visualize it in an unusual format in order to attract the attention of each student, i.e., to use new educational technologies, for example scribe-presentations. Thus, nowadays taking into account all the aforementioned promising directions we consider it topical to study scribe-technologies to visualize educational material and consequently increase the quality of knowledge and raise the interest in the educational process.

The **purpose of the article** is to analyse the expediency of using PowToon and PowerPoint services while teaching philological disciplines, to consider the peculiarities of their use on the example of the Ukrainian lessons in the 6th form and to prove the topicality of using scribe-presentations.

1.2. Analysis of recent research and publications

Today, high-quality teaching of disciplines is very important in our lives as availability of new educational technologies calls for changing the quality and content of the educational material. The use of the tools and opportunities provided by computer technologies and the Internet helps to achieve high goals.

The problems of using ICT in the educational process and the use of information visualization services in teaching philological disciplines have been researched by Andrii I. Abdula [1], Sara Abou Afach [2], Olga V. Bondarenko [3], Siti Cholifah Fimbriani [6], Olha V. Chorna [4], Elena H. Fedorenko [5], Beth Fuchs [7], Halyna I. Ivanova [8], Yuliya M. Kazhan [9], Alla A. Kharkivska [10], Arnold E. Kiv [12], Olha V. Korotun [13], Svetlana I. Kovpik [14], Tetiana H. Kramarenko [15], Olena O. Lavrentieva [16], Ffion Lindsay [17], Pavlo V. Merzlykin [18], Iryna S. Mintii [20], Yevhenii O. Modlo [21], Pavlo P. Nechypurenko [23], Kateryna P. Osadcha [24], Victoria V. Pererva [26], Halyna F. Ponomarova [11], Natalya V. Rashevskaya [27], Nina Sarkar [28], Serhiy O. Semerikov [29], Vladimir N. Soloviev [30], Rostyslav O. Tarasenko [31], Viktoriia V. Tkachuk [32], Anastasiia V. Tokarieva [33], Viktoriia O. Ustinova [34], Tetiana A. Vakaliuk [35], Inna V. Vidiborenko [36], Kateryna V. Vlasenko [37], Maryna M. Volikova [38], Tracy Weber [39], Snizhana O. Zelinska [40] and others.

In the research “Using Rowtoon and Rrezi Online Services in History Lessons” Vidiborenko uses a variety of online services for the modern information presentation in history lessons [36].

According to Abou Afach, Kiwan and Semaan, the usage of technology in education, including video presentation tools, helps students to be more motivated, to feel comfortable in the classroom, and read clearer concepts. Today, the growth of technology is inevitable, and it plays a major role in education. Its impact includes a creative learning environment that gives teachers more control over their learning choices, thus improving learning outcomes [2].

Sarkar, Ford and Manzo believe that the application of technological tools to involve students into school classes and out-of-school activities promotes better information perception [28].

Fimbriani proves that implementing scribe-presentations (video presentations) had a positive influence on improving the quality of writing. Students’ grades were gradually getting higher. In general, students were more interested in the information presented with PowToon and were more active in class [6].

In the context of our research Fuchs’ work is worth mentioning as it indicates that PowToon as a free resource for animated presentations was used to create “an animated” story similar to a cartoon in order to emphasize students’ learning outcomes [7].

Weber claims that it is possible to use PowToon in any subject. It can be applied during English lessons to dramatize Romeo and Juliette from students’ point of view; in a Culture lesson to demonstrate how to fix an engine or how fertilize the crops/plans correctly, and even during Industrial Art lessons in order to demonstrate welding methods [39].

Thus, after analysing the results of the external independent evaluation, scientific researches of the leading scientists, methodological, scientific and pedagogical literature, we have not found any methodological tutorials, recommendations, guidelines, which reveal the expediency of using scribe-presentations to visualize educational material with the help of the service PowToon. It accounts for the relevance of this research.

2. Theoretical basis of the study

The research is based on the following approaches: competence (the ability to refresh available knowledge, skills, experience to solve the difficult tasks in professional activities), systemic (forms the relationship in the study of philology disciplines, systematizes and structures complex information, its usage in teaching), information (use of information and communication technologies during philology disciplines studying).

In the epoch of ICT multimedia presentations created in PowerPoint, Prezi, GoAnimate, PowToon and others are often used for visualization. Let’s take a closer look at the most popular PowerPoint presentations and lesser-known online services for creating a PowToon scribe-presentation.

PowerPoint is a Microsoft Office application, it is intended to accompany a report where the material is displayed in the form of charts, diagrams and graphic objects that can be displayed as slides through an interactive whiteboard or other device. This support is called a presentation.

PowToon is a cloud service designed to create scribe-presentations. That is, creating animated presentations using ready-made templates to visualize the report. Ready works can be uploaded to YouTube. The continuous development of the information support system in connection with technical support ensures high quality of the educational process. Thanks to this service you can also improve knowledge of English.

In order to create a scribe-presentation for a philology lesson, we used the PowToon service for the topic “Nouns as the Notional Part of Speech”, subject “Ukrainian language” for the 6th form of secondary educational institution.

At first, you need to login to <https://www.powtoon.com> and sign up for this service. To do this, you will be offered several options (see figures 3 and 4). One of the options is to enter your own data or sign up with the help of social services.

Next, you will be redirected to PowToon homepage, where you will be prompted to select a blank slide or one of the templates to create your own presentation (see figure 5). A blank template can be

used if you are familiar with ICT. With a readymade template it's easier to work, even if you do not know how to work with your computer at all or you are bad at it.

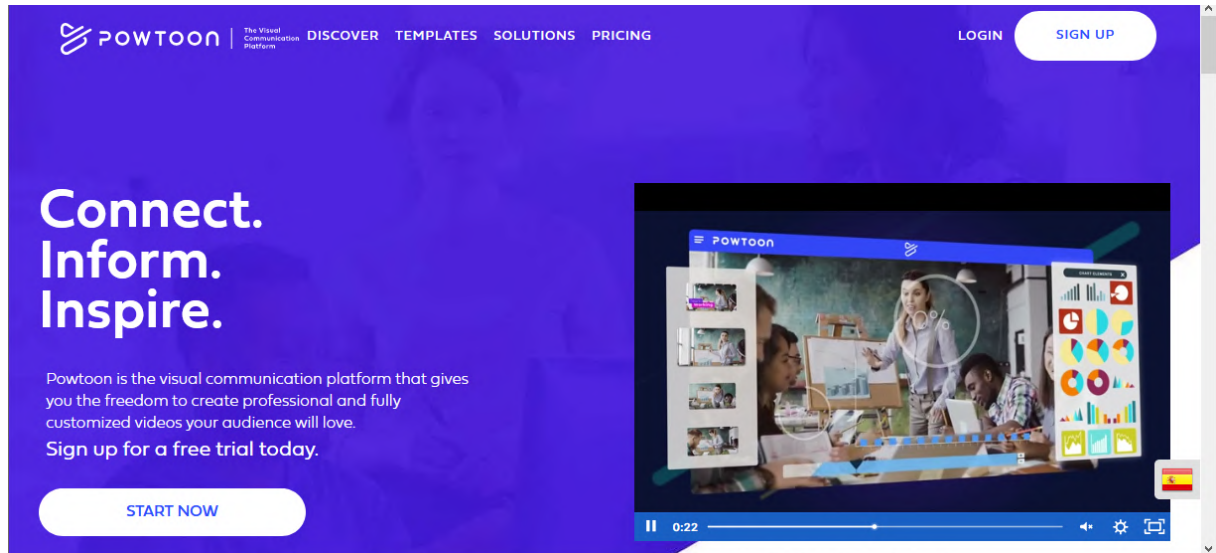


Figure 3. PowToon homepage.

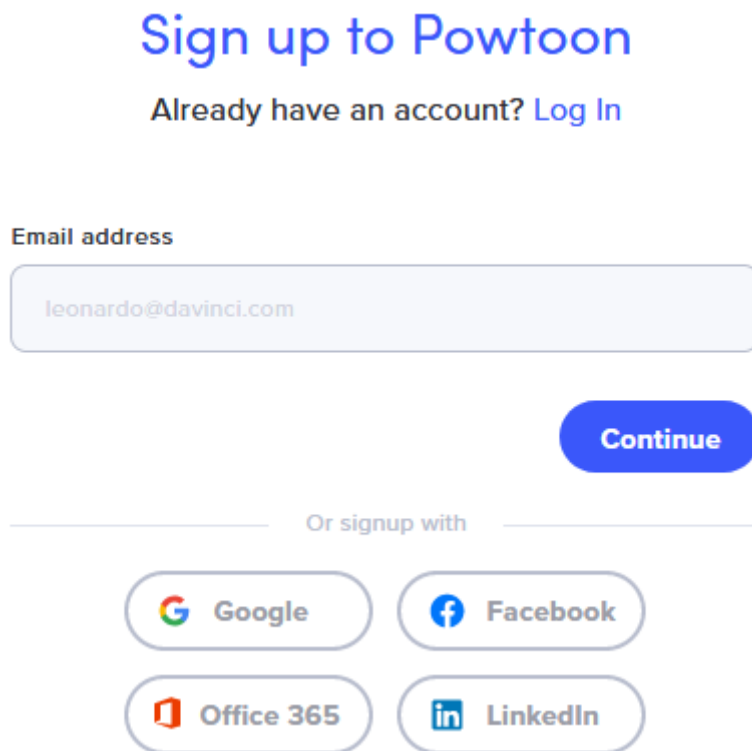


Fig. 4. Site registration page.

We have chosen a ready-made template for our lesson. Next, we will adjust it to our topic (see figure 6).

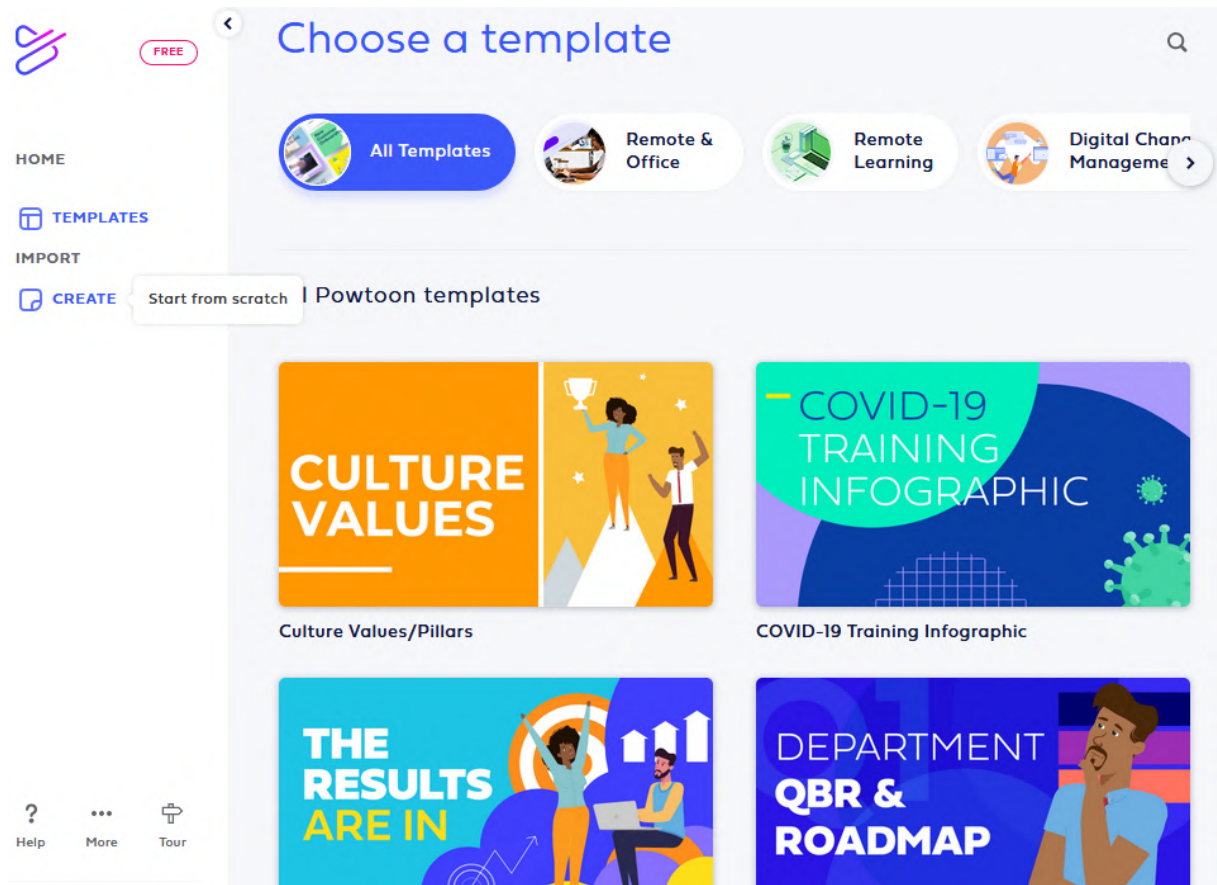


Figure 5. The page to select a template.

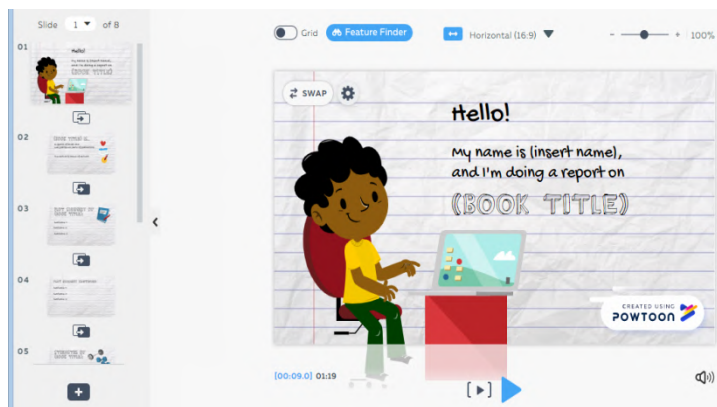


Figure 6. A ready-made template chosen.

Another important point is that you will first need to switch from edit mode to create mode. To do this, click on the Edit Mode button, and then select Create Mode. After that, you will see additional options on the right side for editing your presentation. With this additional menu you can change the scene that is to change one slide to another ready-made one (see figure 7).

Next you can change, choose a new one, simply choose a colour, or download your presentation background. Since we have already chosen a template, we leave it (see figure 8).

The next step is to work with the text, particularly how to create or edit it. To do this, you will be prompted to add Title, Subtitle or Body Text, or use ready-made templates for the text in the Text Tab (see figure 9).

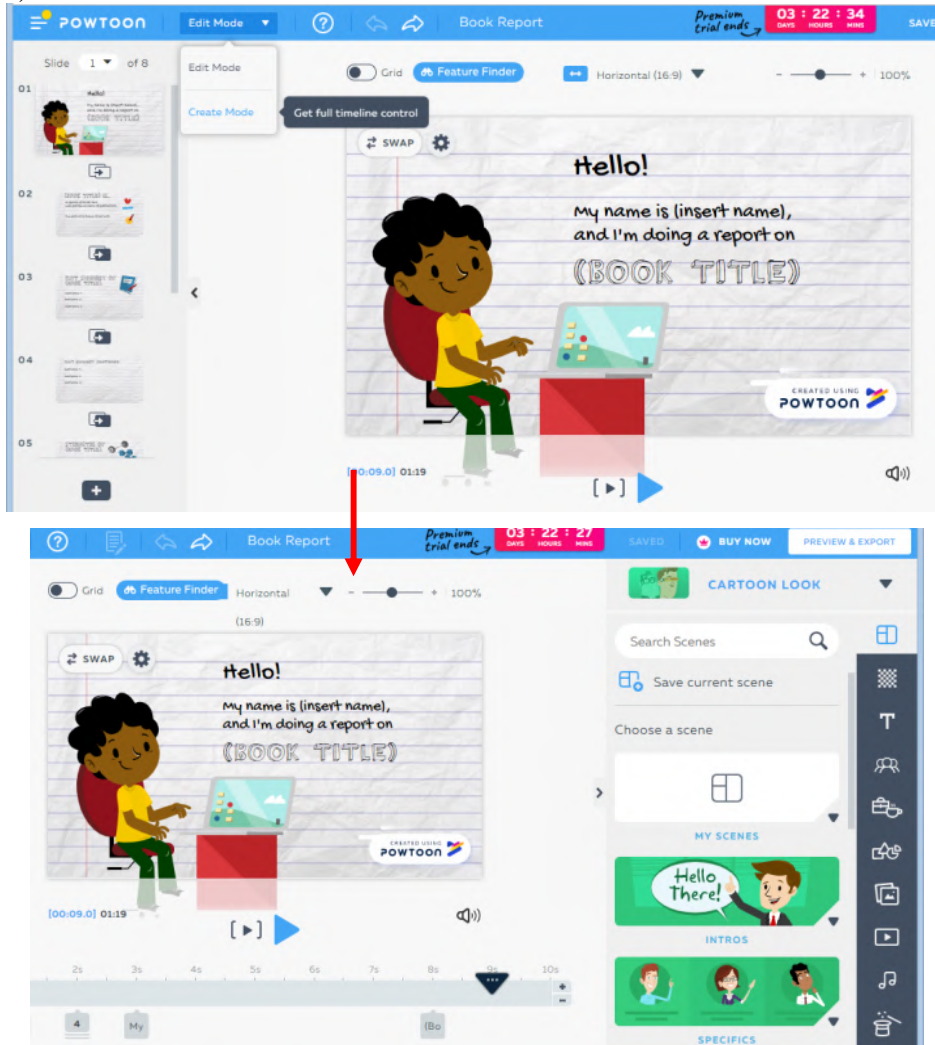


Figure 7. Switch from editing mode to creation mode.

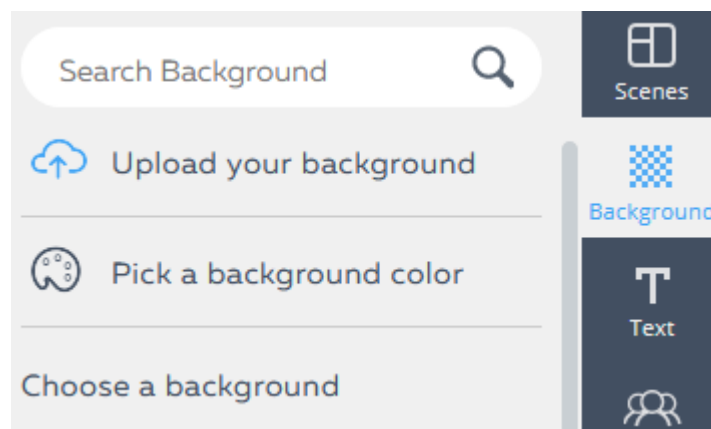


Figure 8. Select the background of the presentation.

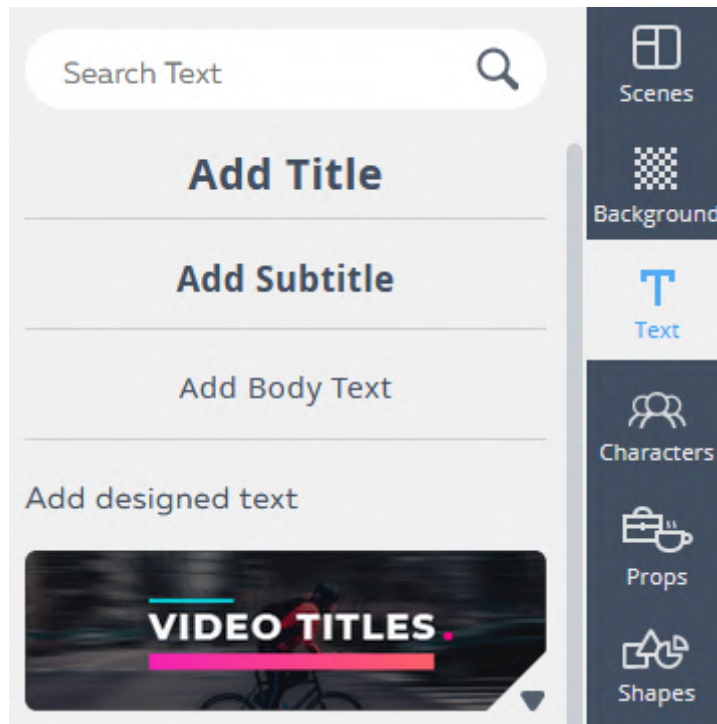


Figure 9. Button for creating or editing text.

In our case, we don't need the text "My name is (insert name), and I'm doing a report on ...", so it's deleted and we write our own. To do this, you must first click on the figure with the text so that it is encircled with a dashed line and press the Delete button or right-click on the selected text and find the Delete (see figure 10).

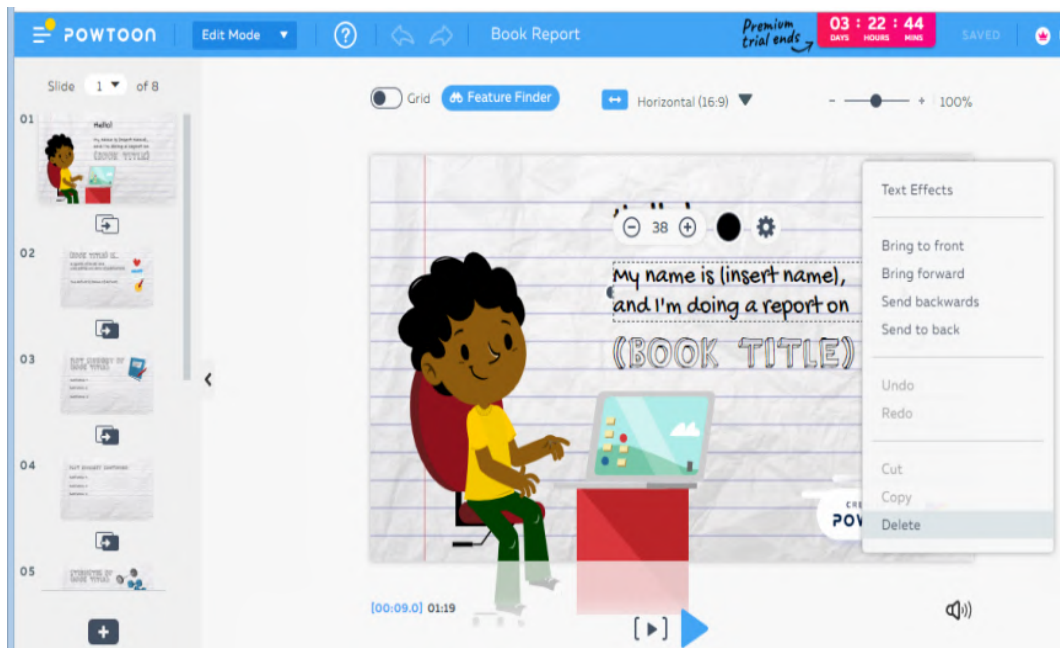


Figure 10. Deleting the text.

To write a new text, we chose a Text Cloud from the Text Elements as if our hero was expressing his/her thoughts (see figure 11).

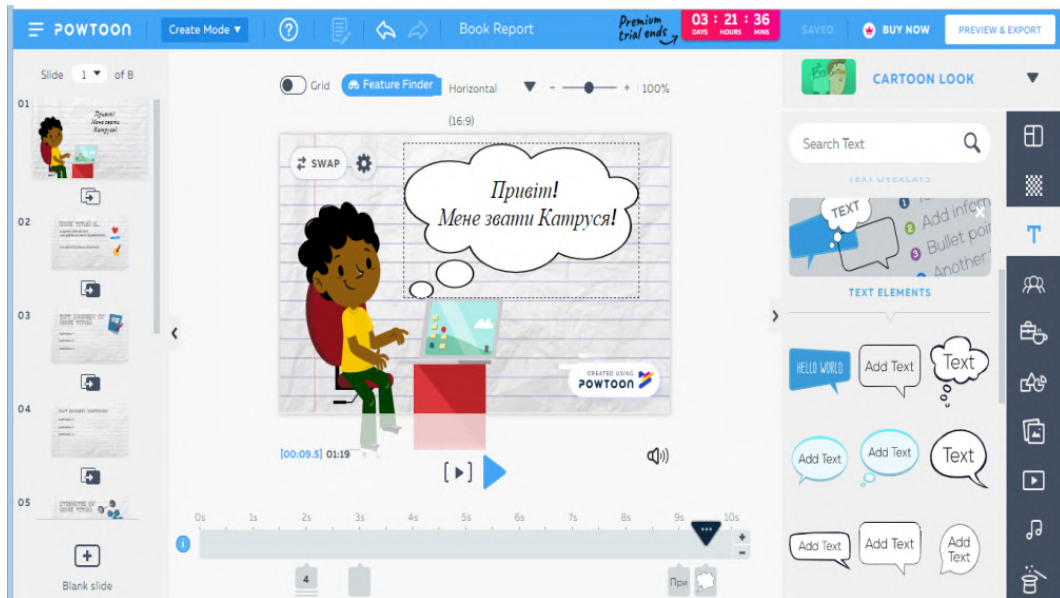
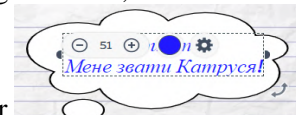


Figure 11. Selecting the text design.

If you click on the text in the cloud, a dialog box will appear to change the font, colour and size. If



you want to change the colour of the font, click the circle with title Colour and the colour palette opens. In order to save the selected colour, you need to click on a circle with a plus, as shown in the figure below (see figure 12). After that, the selected colour will be saved at the bottom of the tab to find it sooner.

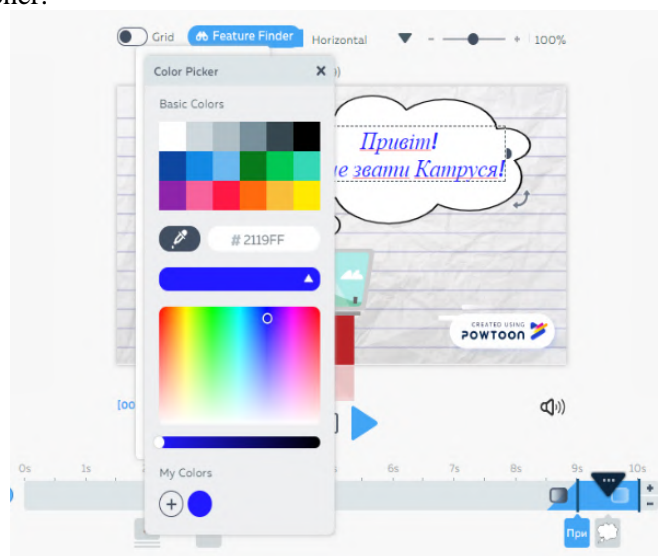


Figure 12. Fixing the selected colour.



Next, if you click on the Settings button, you will have another dialog box for editing text, where you can choose the style of writing, landmark, text transparency, and the most interesting how the text will be reproduced on the slide. To do this, select Effects in the dialog box and you will be prompted to select the effect of the text output (see figure 13).

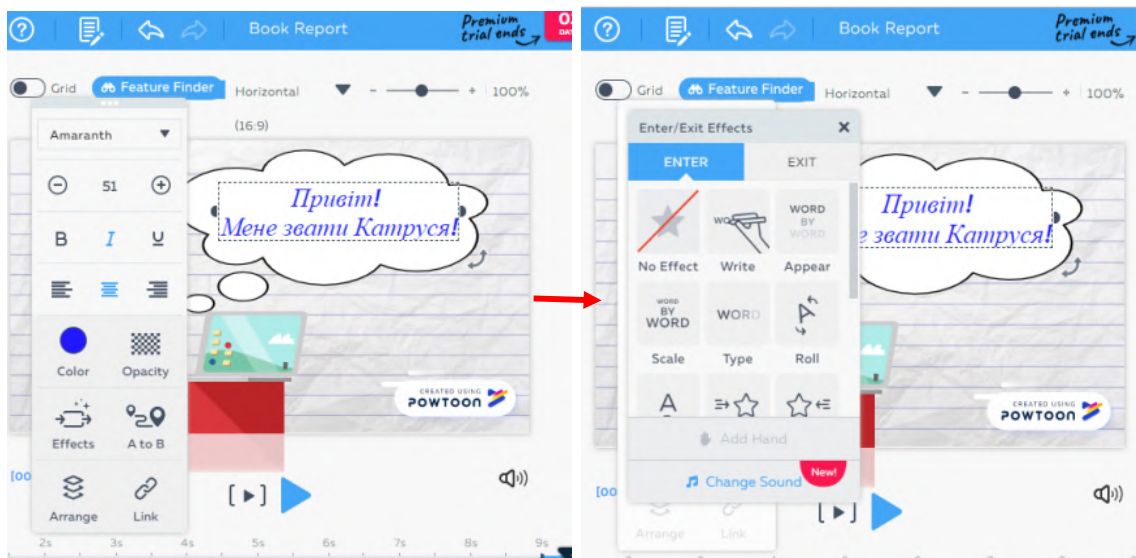


Figure 13. Selecting the effect for text output.

Next we'll need to change the character. This can be done using the tab with different categories, which is located on the right side of the page (see figure 14). Or, as in our case, click on a character and a menu will appear above it (see figure 15).

You can also change the body position and the character's emotions using the additional menu. For example, if on the first slide, the girl greets us, waving her hand, on the next we can choose her being happy or having some good idea, or she' can be upset, or thoughtful, etc. (see figure 16).

One of the main points is the Time Scale. With the help of it, we choose how long one object should act on the slide and the sequence according to which everything will happen (see figure 17). If you added a new object and it is not where it was planned, it can easily be moved from one scale point to another, you only need to select the desired object with the left mouse button and drag it to the right place, without releasing the button.

Next, if there is not enough time on the slide to demonstrate all the information or there is some spare time, you can prolong or shorten it with the help of the additional buttons that are at the end of the time scale (see figure 18).

After you put everything on the slide you can see how a complete picture everything looks. This can be done with the help of two buttons that are above the time scale. Using the triangle, in grey brackets, you can view the entire slide, and the blue triangle will give you the opportunity to view any part on the slide (see figure 19).

The next step is to switch to another slide. It can also be very interesting and exciting, which will attract students' attention. To do this, on the left side of the screen, you see a list of slides and there is a small button between them, which allows you to change the transition from slide to slide. When you click on it, a dialog box opens to work with the transitions (see figure 20).

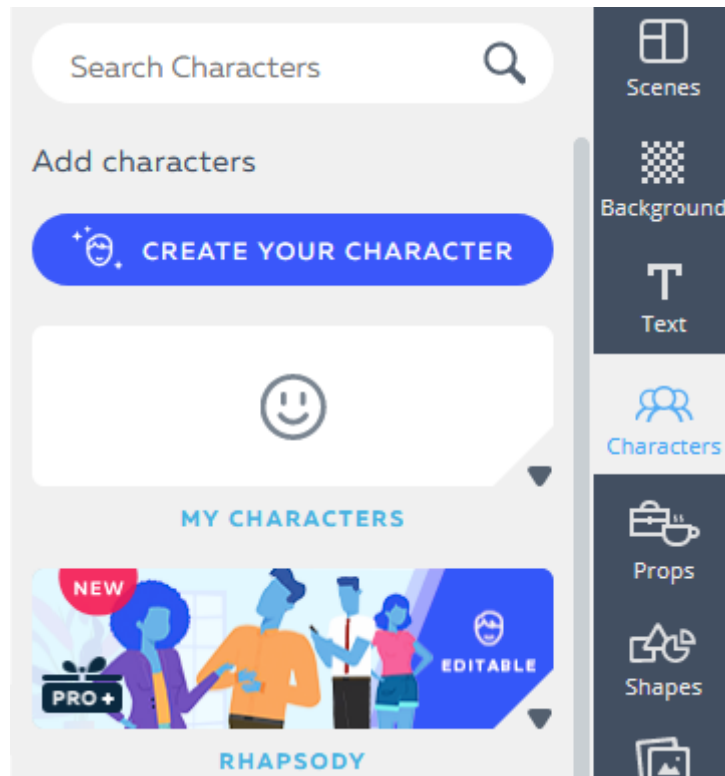


Figure 14. Changing the character using the additional menu on the right.

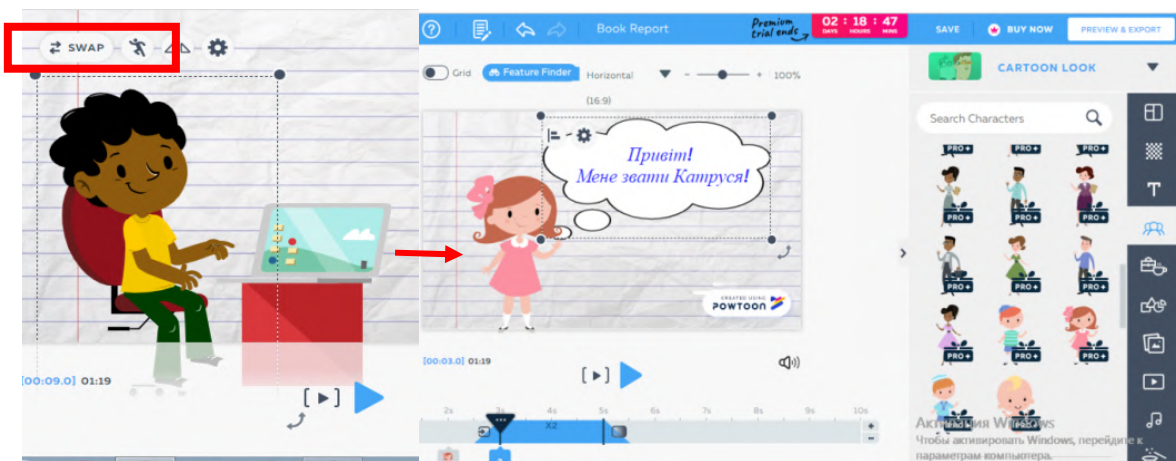


Figure 15. Swap Character menu.

Additionally, to create a bright and exciting presentation, you can use the standard props and shapes that are in the tab on the right. There are many categories in which there are animated and non-animated objects (see figures 21 and 22).

You can also add standard pictures or upload your own. To do this, you need to click on the image icon on the tab on the right and click + Add image (see figure 23). Then a dialog box appears asking you to upload a new image from your computer or from any other service. And then it will appear on your slide (see figure 24).

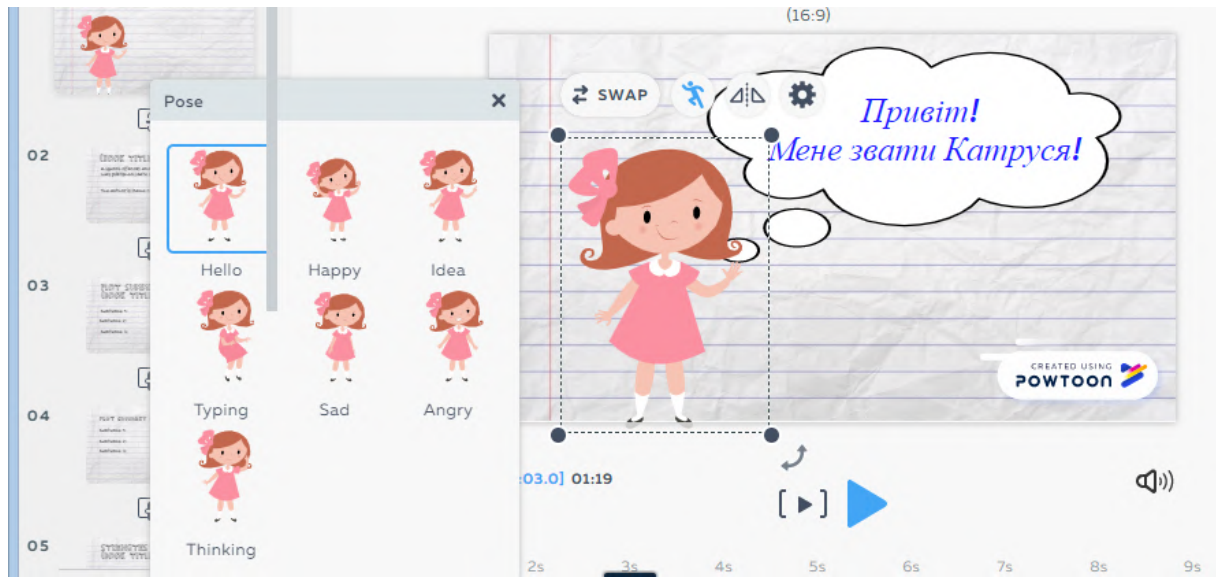


Figure 16. Menu for changing body position.

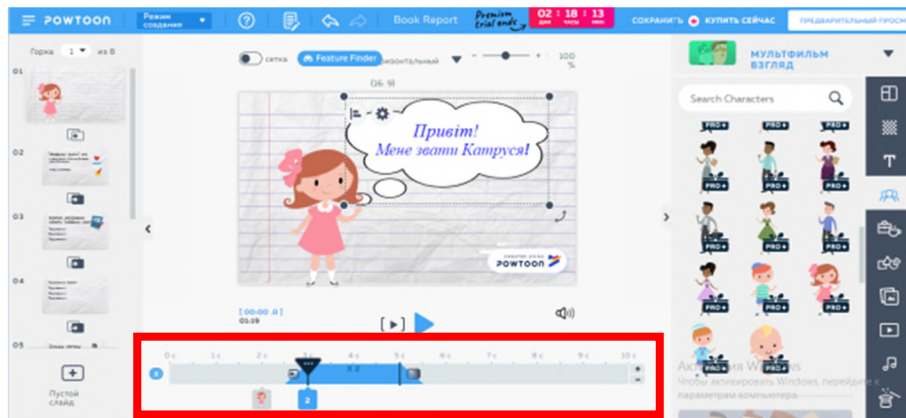


Figure 17. Time Scale.

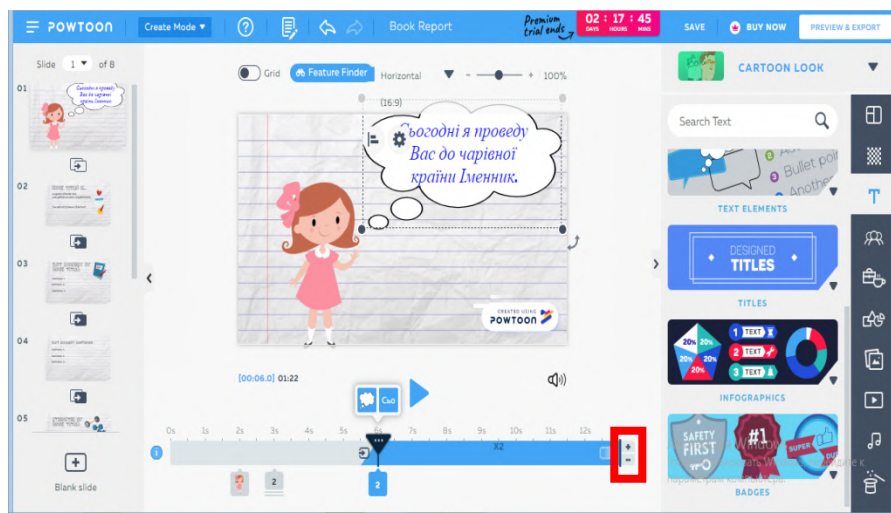


Figure 18. Buttons to prolong or shorten the time on the slide.



Figure 19. Buttons for viewing a slide or a part of it.

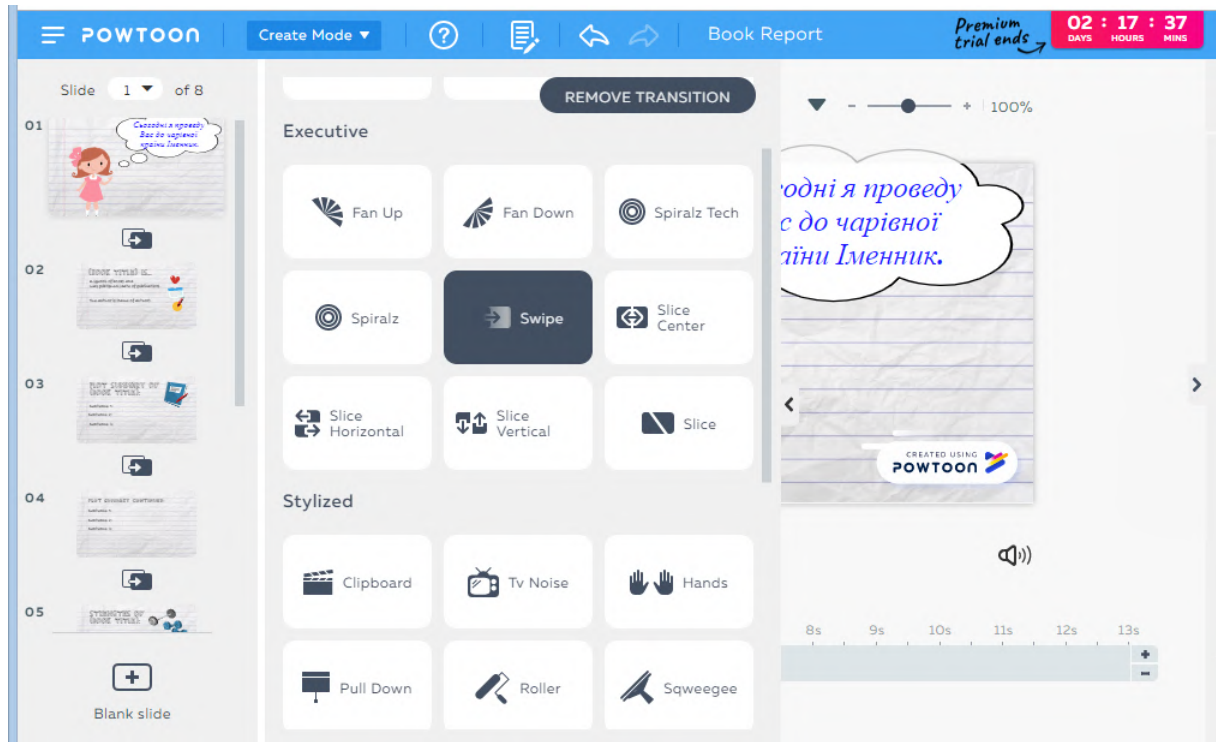


Figure 20. Examples of transitions between slides.

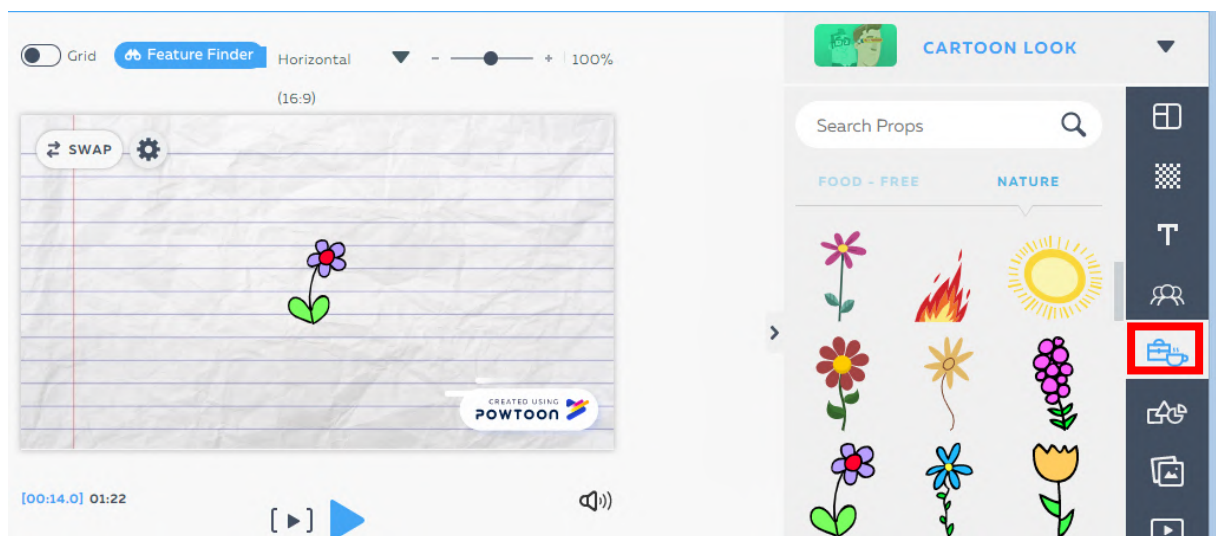


Figure 21. Examples of props.

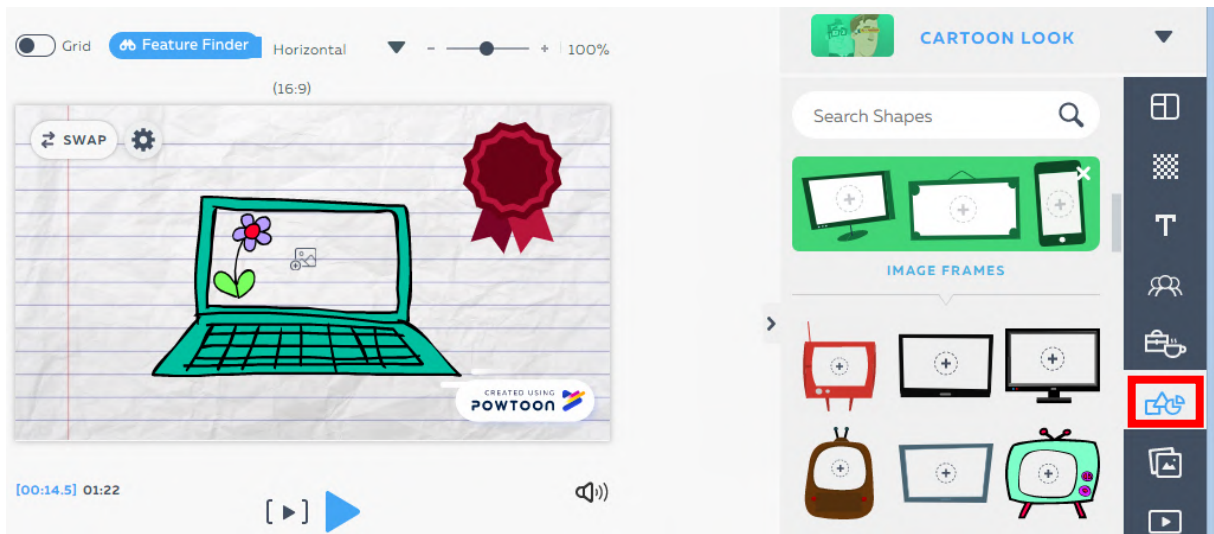


Figure 22. Examples of shapes.

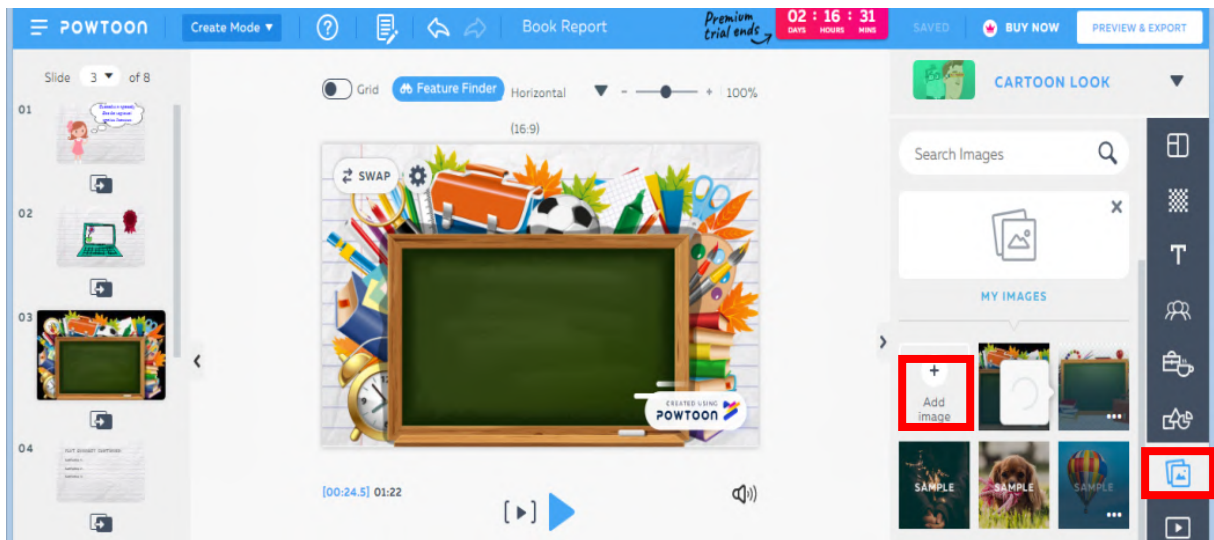


Figure 23. Uploading your own picture.

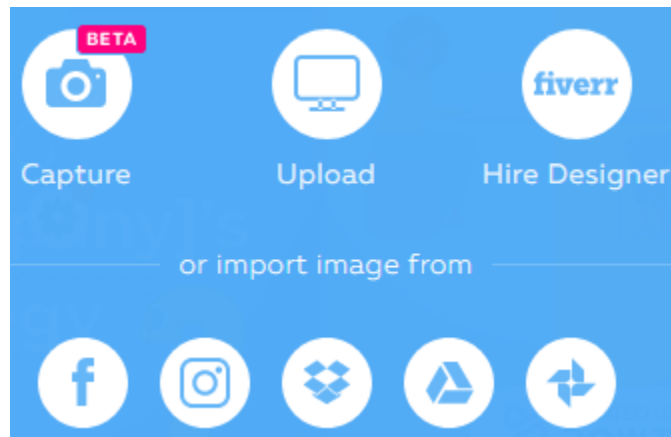


Figure 24. Dialog Box to choose the source for uploading the picture.

Another effective element of presenting information is the addition of a video. You can also choose from here or upload your own. We used the Video Tale about the Noun, which was also created in PowToon and uploaded it to our presentation. In our case, all the video did not fit on one slide, so the program split into several slides automatically (see figure 25).

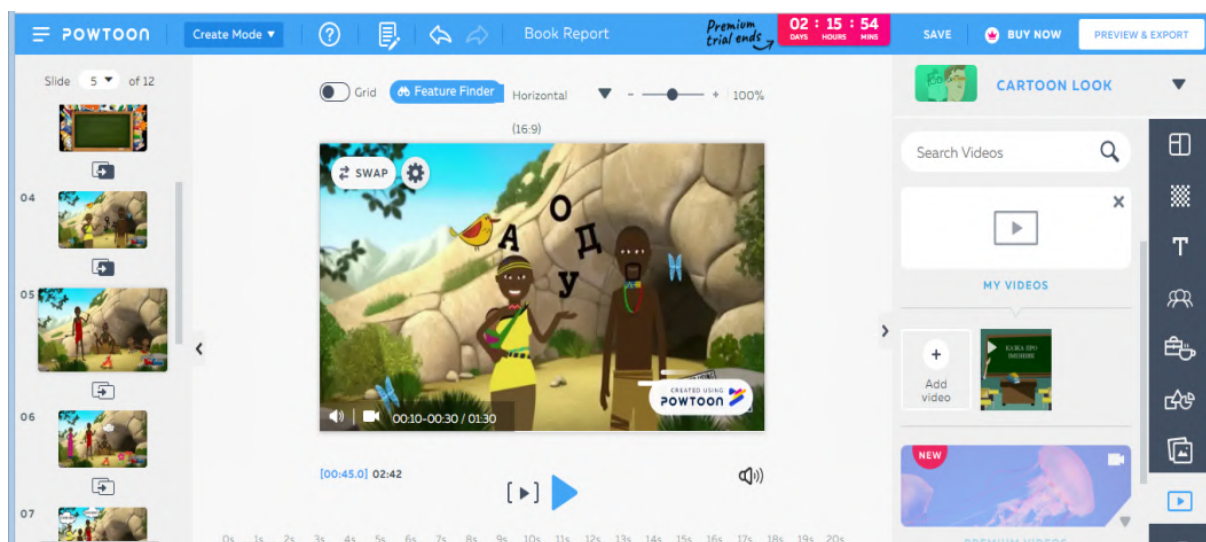


Figure 25. A fragment of the video tale about the Noun.

And at the end, to give the presentation a brighter impression, you can add music and special effects (see figure 26).

After you have created the presentation, you can download it. To do this, click the Preview & Export button and you will see a window for previewing and saving the presentation. There will also be two options either as a slideshow or a video. Then you should press Export and you will be asked what way you want to save it (see figure 27).

3. Results of the study

On the grounds of the developed presentations, lessons were conducted in two groups of 6th form. The first group, consisting of 18 students, learned with the presentation created in PowToon, and the second group, consisting of 17 students, worked with PowerPoint. The experiment identified the effectiveness of PowToon and PowerPoint services their influence on information perception by the students. During the lessons, the group working with the PowToon presentation appeared to be more active and interested. It was explained by original template and attractive design of the presentation. Unlike PowerPoint, where the presentation looks more business-like, PowToon is complemented by animated characters, ready-made vivid patterns, a variety of ideas and special effects to create a spectacular presentation. The animations help the teacher and academic staff to interest the students in studying the material and focus their attention on the educational process.

At the end of the lesson, a reflection questionnaire was conducted in each of the groups. It included five questions asking students to express their opinion using a 10-point scale. The first question 'Have you been interested in acquiring new material?' got 88% of positive answers in the first group and 82% in the second one. The question 'How comfortable emotionally did you feel at class?' the maximum points were given by 83% and 76% respectively. 88% and 65% of students awarded 10 points to the question 'Have all the new rules and practical tasks been clear to you?'. The next questions 'Have you been excited by presenting the material in this way?' and 'Would you like to have such lessons as often as possible?' were positively answered by 95% and 88%, 95% and 88% respectively (see table 1)

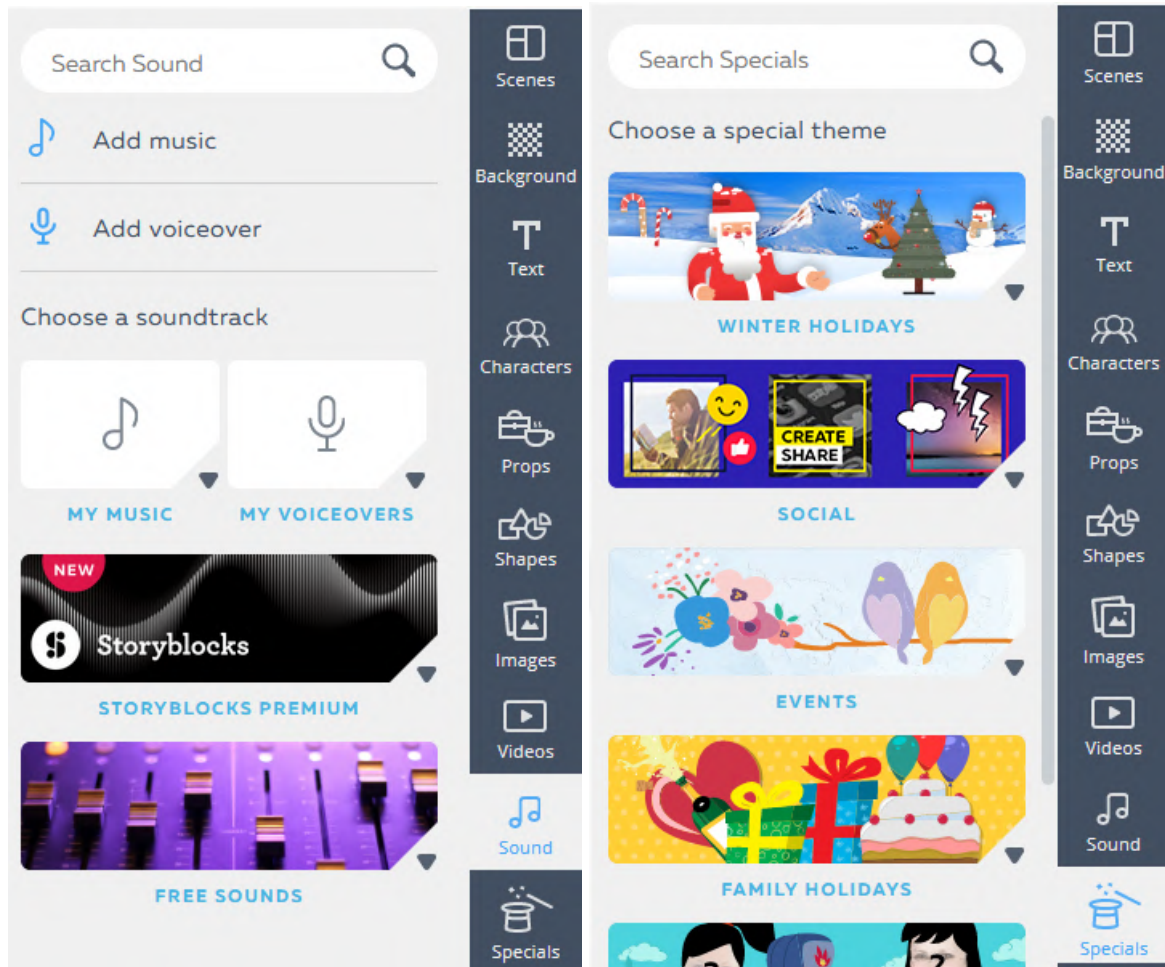


Figure 26. Buttons for uploading music and special effects.

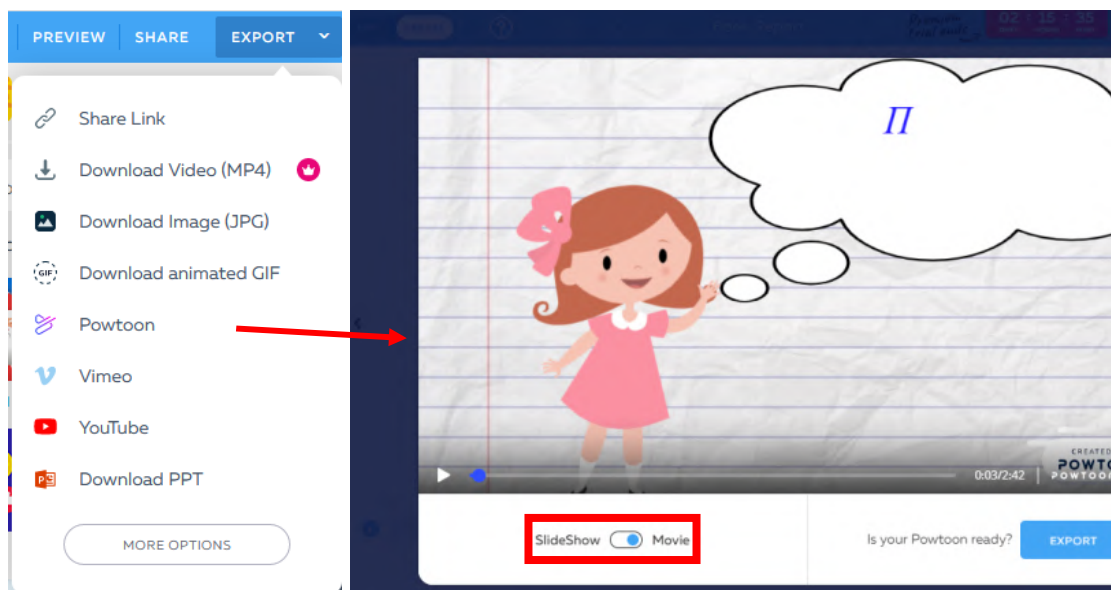


Figure 27. Steps and ways for saving the scribe-presentation.

Table 1. Student’s answers.

Questions	The first group (18 students)		The second group (17 students)	
	students	%	students	%
Have you been interested in acquiring new material?	16	88	14	82
How comfortable emotionally did you feel at class?	15	83	13	76
Have all the new rules and practical tasks been clear to you?	16	88	11	65
Have you been excited by presenting the material in this way?	17	95	15	88
Would you like to have such lessons as often as possible?	17	95	15	88

The results of this questionnaire are presented in the diagram below (see figure 28).

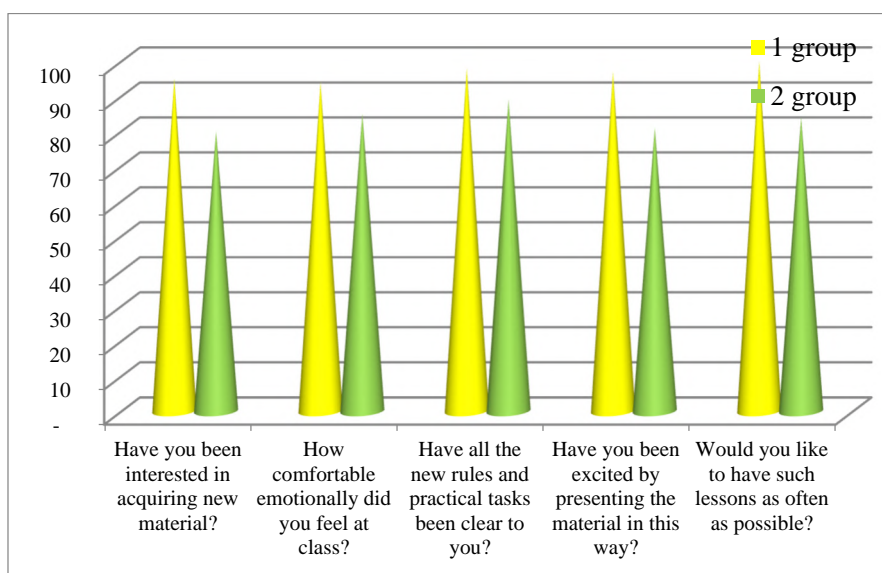


Figure 28. Comparative diagram of the reflection questionnaire of two groups.

The pedagogical experiment also involved 95 students. The experimental group consisted of 44 participants and the control group of 55 participants. During their pedagogical practice the students of the experimental group used the presentations developed in PowToon while the students of the control group used PowerPoint.

Prior to the pedagogical practice we hypothesized that the quality of learning and pupils’ interest in the Ukrainian language and literature would significantly increase if to apply competence, system, information and methodological approaches and to provide visualization of the educational material.

We also determined the criteria to assess the level of professional competence of future teachers - information-cognitive (involves the quality of presentation and information acquisition (information competence), personal-motivational (to determine the level of students’ abilities to learn ways, techniques, methods aimed at the formation of interest to teaching a particular subject).

Therefore, we made one more assumption that the material presented with the help of PowToon service would appeal to pupils more than the usage of the ordinary PowerPoint presentations.

To evaluate the probability of the results obtained during the experimental work, not percentage but quantitative data were used (table 2). The hypothesis of the research was tested with the Pearson T -criterion: $T = 11,3 > T_{crit} = 9,21$ ($\alpha = 0,01$, $v = 2$).

Table 2. Complex evaluation of the effectiveness of using PowToon and PowerPoint in the educational process (comparative analysis).

Level of formation	Experimental group (E1) (44)		Control group (C1) (51)	
	Initial data	Control check	Initial data	Control check
High	10	25	12	14
Medium	28	17	33	33
Low	6	2	6	5

Thus, having analyzed the obtained data, we can conclude that the use of both services contributes to the visualization of the educational process. However, the pupils while studying the Ukrainian language and literature as well as the students while getting ready for classes appeared to be more interested in PowToon service, because its use promotes creativity, imagination, spatial and critical thinking, encourages participants of the educational process to search for new ways to solve the problems they faced, etc.

4. Conclusions and perspectives for further studies

Summarizing all of the abovementioned and taking into account our own experience of work, it is proved that application of scribing technologies (scribe-presentations) provides for the visualization of the educational material and as a result pupils perceive information better as it is directed to different channels. Presented visual training material increases the quality of knowledge, raises students' cognitive activity, their interest in the educational process, promotes comprehensive development, creative approach in learning, critical thinking, creativity, etc.

The hypothesis of the research was proved by the conducted pedagogical experiment. Namely, the use of scribe-presentation as a kind of visual presentation is better suited for training, idea presentations, project creation and ensures higher quality of learning.

In our opinion, the advantages of scribing are: efficiency – having spent less time on preparation, it is possible to explain the material perfectly and convey the idea originally in a more accessible form; creativity in theoretical material visualization; transformability – complex information becomes more comprehensible with the help of scribe; interconnection – communication with the audience throughout the lesson, etc.

The use of scribe-presentations helps to memorize educational material more effectively, it promotes creativity, and also corresponds to the principles of comprehensive learning. Application of scribe technologies in the Ukrainian language lessons often triggers positive emotions, love for the motherland, respect for the achievements of the Ukrainian people and the language characteristics of the students, as well as contributes to raising the quality of knowledge and motivates to learning.

The promising area of further researches is a wider range of PowToon application, as well as the expedient use of other modern scribe-presentations in the Ukrainian language lessons, different projects, in order to increase students' motivation to learn the Ukrainian language.

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Constructing personal learning environments through ICT-mediated foreign language instruction

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Abstract. The article deals with the concept of student-centred Personal Learning Environment (PLE) in the context of higher education, which is used as a means of transforming foreign language learning and teaching practices. It aims to reveal the opportunities for creating PLEs through incorporating Information and Communication Technology (ICT) in the process of foreign language education. The study focuses on the roles of teachers and students of non-language University majors in designing efficient learning environments highly adapted to changing objectives and student personal needs. The authors reveal the unlimited potential of ICT in constructing PLEs for both in-class activities and informal learning, providing a scope of practical student activities, which imply their active engagement both in and outside the classroom, as well as constructing a flexible, personalized, time and space independent learning environment. Students, teachers, ICT, which is a set of resources based on the use of educational technology tools thoroughly selected and organised in order to manage the content, applying relevant methods of teaching and learning strategies, as well as a learning process, are all regarded as constituents of PLEs aimed at mastering four foreign language skills when taking the course “Foreign Language for Specific Purposes”: reading, listening, writing and speaking within personal, academic, and field-related contexts.

1. Introduction

There is widespread recognition in modern Information Age that skills and human capital have become the backbone of modern progress and economic welfare of a country. In the *Feasibility Study Report on the Assessment of Higher Education Learning Outcomes* performed by Organisation for Economic Co-operation and Development, it is stated that “in contemporary knowledge-intensive economies and societies”, individual and societal prosperity is retained by “developing and sustaining a skilled workforce, maintaining a globally competitive research base, and improving the dissemination of knowledge for the benefit of society at large” [33]. In addition, advances in technology and all-round digitalization in recent years “have changed the learning behaviours and reshaped teaching methods” [22]. As a result, higher education is regarded as a critical factor in human capital development that demands constant transformations in its performance, quality indicators, and integrated use of communication and educational technologies. Foreign language instruction in non-language institutions of higher education is not an exception and calls for substantial changes in the paradigm of learning and teaching under “heavy digital technological influence” [23].

In this context, it is of ultimate importance to achieve quality education in compliance with modern global trends regarding extensive use of digital media, relevant learning content, “innovative pedagogy, learning by doing and constructing knowledge” [30], which may become the solutions to meet the



modern challenges in foreign language instruction. The need for designing highly engaging activities for students to increase their motivation, proliferation of the Internet, Web 2.0 tools and services, smart applications, social networks, and freely accessible educational resources substantiated the need to consider foreign language learning from these perspectives. Whalley argues that pedagogy must change from “institution-centred to a student-tutor-device focus” that is best done via active learning and incorporating cognitive awareness [35]. The changing understanding of the whole system of knowledge transfer has already established in people’s mind, where ICTs play a leading role. They accumulate novel data and information, disseminate them, serve as a means of knowledge transfer, and thus, perform the function of both tools and objects of knowledge. Learning from and learning with technology infers an active student participation, can take various forms and provide interactive environments. It offers unique opportunities to customize learning environments to individual learners [12]. In addition, the principles of user-centred learning approach formed the basis for initiating the idea of constructing personalized active learning environments, which are highly adaptable and responsive to changing needs and facilitate cognitive processes [1].

Thus, the purpose of the article is to further develop and elaborate the existing approaches and ideas for constructing PLEs and the effect of ICT instructional techniques on increasing student progress in foreign language acquisition when balancing teacher control and increased student autonomy.

2. PLEs in foreign language education

Educators agree that “formal education no longer comprises the majority of our learning” because learning occurs in modern age “in a variety of ways – through communities of practice, personal networks, and through completion of work-related tasks” [29]. Barab and Roth claim that it is necessary for the learners to be involved in rich learning situations where learning is characterized by direct functional value rather than the exchange value [2]. In the context of foreign language learning, greater emphasis is placed on the development of learning strategies, drawing structured connections for the most appropriate resources selected and organized by a student, and constructing learning environments in which foreign language acquisition occurs in the context of its use and is highly customized to student’s personal needs and abilities.

Personal learning suggests students’ autonomy and increased responsibility with their active participation “in learning process by making decisions about how to search, where to search” and the content necessary to meet learning objectives [12]. It is believed that the key ability required from future professionals is related to searching for information, its evaluating and managing, as well as constructing knowledge in foreign language medium. Another requirement to arranging such environments is to provide students’ access enabling them to track their individual data and measure progress. All these encourage students to become active agents in organizing their own learning process, in which they are “capable of acquiring and building upon their knowledge” through technology-supported learning environments [3].

In UNESCO Research on Learning Environments, the complete physical, social and pedagogical context in which learning is intended to occur in any designated place as well as distance learning contexts convey the meaning of the term “learning environment” [34]. Gros claims that digital technology has promoted a new vision of learning environments with the need to orchestrate the different locations in which a person learns combining formal and informal situations [17]. The *2020 EDUCAUSE Horizon Report, Teaching and Learning Edition* identifies personalized learning as a “general teaching and learning practice that seeks to more finely tune the course experience to the individual needs of the learners” viewing technology as a “major addition to the set of educational technology tools serving the broader educational practice of personalized learning” [5]. The information and communication support systems accommodating individual learning style and needs are regarded as learning environments contributing to the concept of PLEs. They can be considered as a potential means of achieving personalization in learning [23]. The EDUCAUSE defines PLEs as the “tools, communities, and services that constitute the individual educational platforms that learners use to direct their own learning and pursue educational goals” [13]. Wilson, Liber, Johnson, Beauvoir, Sharples and

Milligan demonstrate consistency of PLE with a competence-oriented approach and describe it as an environment “enabling a wide range of contexts”, integrating experiences and collecting resources to support the goals of the user [36].

Such learning environments represent a set of resources based on the use of educational technology tools, appropriately selected and organised with the aim to manage both content and the process of learning [2], [7], [28]. The process of modelling and shaping learning activities performs a valuable educational function in case “the individual develops personal control of different types of (intentional) learning activity (formal or not)” [16]. In this learning activity, the acquisition of the course content is done not through its transmitting but because of student personal activity directed at defining, working out and solving the tasks, conducting self-analysis, self-control and self-assessment of their own learning process, going beyond the boundaries of the classroom and adding to student autonomy. The massive use of technology has become an integral part of foreign language teaching and learning. Technology-enhanced language learning is regarded as an effective approach that enhances student motivation and improves learning outcomes enabling access to constantly updated authentic foreign language materials, online environments and social media, smart language learning tools [9]. Educators also stress the potential of implementing technology-supported learning environment in foreign language for specific purposes teaching that promotes self-regulated learning competency and ICT literacy [38]. Therefore, it can be viewed as an efficient way to not only achieving learning objectives but also sustainable foreign language competency development when equipping “students for tomorrow’s workforce and a world in which lifelong learning” is a must [3].

Educators agree that PLEs can be viewed as a solution to self-directed learning in which students manage their learning process [18], a key to personalized learning by adjusting to the educational needs of individuals [37]; they are believed to contribute to developing higher order thinking and student satisfaction [14]. Kompen, Edirisingha, Canaletta, Alsina and Monguet claims that using a PLE, learner can choose and mix from several alternatives for “capturing, storing, classifying, analysing, creating, sharing, disseminating and processing information, thus creating knowledge” [23]. Creating efficient and viable PLEs produces the required teaching results and enriches teaching environments “as a part of a self-oriented feedback systems with the assistance of the teacher” [11]. In addition, it enables students to perform quality control of the large-scale educational data [37]. Thus, we agree with Castañeda, Dabbagh and Torres-Kompen that PLEs have direct implications on such learning models and processes as adaptive learning, learning analytics, Massive Open Online Courses (MOOCs), all having personalisation at their core [8]. They rely on analytics to support adaptive learning using such components and processes as a language learner’s profile and user modelling, collecting and configuring digital e-learning content, aggregating content and tracking progress [8].

In foreign language instruction, learner profiling is greatly facilitated by the Common European Framework of Reference for Languages (CEFR) describing language ability on a six-level scale and providing descriptors specifying progressive mastery of each skill graded on the scale [10]. The CEFR also proposes a self-assessment orientation tool intended to help learners to profile their main language skills in four language activities, i.e., listening, reading, spoken interaction and/or spoken production, and writing activities. Hence, a lot of e-learning resources can both provide the learner with instant online test to determine the level of language proficiency and become a tool for practicing one of the language activities. However, besides forming foreign language competence, students are required to achieve specific learning outcomes within the university course. Thus, there is a challenge of preserving the balance between personalised learning and institutional requirements.

Tochon, Karaman and Ökten claim that with new approaches to instruction it is now possible to go beyond the boundaries of the classroom thanks to PLEs [31]. Within personal e-learning domain, effective and efficient integration of formal and informal learning becomes possible, allowing unlimited opportunities to create a continuous learning process, in which a student may decide on his or her learning style and pace. PLEs can support deep language and culture learning, provide extensive use of infinite authentic resources and up-to-date context. Tochon, Karaman and Ökten identified crucial aspects of organising PLEs, among which a special focus for language acquisition is on social

involvement that we consider to be the key to language awareness [31], which Carter refers to the development of enhanced consciousness of and sensitivity to the language forms and functions [6]. Among the values of PLEs, there are cognitive advantages reflecting upon the target language and language learning process. In PLEs, learners make use of high rate of personalisation with the support and data of community members, ownership of their data and aggregation of multiple resources. They can also facilitate text-based and task-based approaches, which develop experiential responses to the language and allows time and space to contextual meanings, language features and text structures [6]. Another advantage is to provide a learner with the ability to see connections between fields, ideas, and concepts, and make decisions about updating the learning process according to the alterations in incoming information [29]. Constructing PLE is of undeniable value in the context of Foreign Language for Specific Purposes instruction due to its benefits of constant information updating and “situating learners in real-world scenarios” [17].

However, in order to connect a range of available resources and create an efficient learning system within a personally managed space, it is to be organised by both a student and a teacher who is capable of guiding students in incorporating Web 2.0 tools and services in their learning. Such tandem can help support the search and supply of relevant material, coordinate learning process, consult in solving problems and seeking for solutions, as well as assess student progress and achieving objectives. What is more, it is likely to become a key factor in constructing positive foreign language learning environment and create strong motivation based on real or imagined expectations and potential or actual rewards for the efforts.

The results of the 2020 Horizon surveys of applying technology-integrated approach, presented in the report, verified the gains in the rates of student success resulting from combination and integration of the technology and active-learning engagements. At the same time, it is stated that technology is necessary but not sufficient to enable student success. It rather demands the leverage of online, blended, adaptive, and active learning throughout the course program [5]. A good example of such a combination may be provided using a system of acquiring knowledge according to Bloom’s taxonomy. The experience of some universities testified the ratio of using adaptive technology by students at the two bottom layers of the taxonomy (remembering and understanding). Then, on the remaining four levels (applying, analysing, evaluating, and creating), the use of flipped model proved to be effective, when the instructor organizes activities, based on active learning, to be done in class [5]. Thus, foreign language acquisition may require a tandem of active classroom activities and wide use of ICT-mediated instruction in open, dynamic, efficiently-structured and personally adjusted PLEs.

To provide efficient support for students in designing PLEs, it is the responsibility of a teacher to give students an overview about how ICT can be used effectively to enhance both formal and non-formal learning process [7], help them incorporate Web 2.0 tools and services for formal studies, guide students in their learning to use Web 2.0 for lifelong learning and preparing higher education students for future employment [24]. In order to achieve learning objectives, students can get help from their language teachers when building an initial catalogue of tools, which can be used to practice four language skills: e.g., reading, writing, listening and speaking. Online encyclopaedias and dictionaries, open language learning resources from British Council and Cambridge English, National Geographic, engVid etc. (for the English language), Goethe-Institute, Deutsche Welle (for the German language) can become powerful smart tools for creating authentic environment to improve vocabulary, reading and listening comprehension. Social networks, forums, videoconferences, blogging and video presentations are helpful to practice such productive skills as speaking and writing. A more detailed approach to the use of ICTs in the Foreign Language for Specific Purposes university course will be presented in Chapter 3.

3. Foreign language acquisition through ICT-mediated instruction

The modern educational world, according to Torres and Castro, encompasses the following features:

- Today’s students are social. They like to get in touch with peers and therefore have preference to do group activities.
- Students are inclined to discover, explore, experiment and analyse critically.

- Modern learners are inclined more to “do” than to “listen”.
- Learning must be student-centred.
- Work must be interdisciplinary and project-based.
- Learning must be linked with reality.
- There are multiple intelligences and different learning styles.
- Learning should be comprehensive, permanent and meaningful [32].

These features entail that classroom activities may be replaced or enriched by online learning experiences, which have increasingly been penetrated into the university life and foreign language classroom, allowing varying degrees of interaction or just time alone in independent study and learning activities, reshaping higher education through Internet-based content delivery and various forms of interaction.

Among a variety of terms describing the notion of applying technology in classroom, and foreign language learning in particular, we stick to the term “ICT-mediated instruction” introduced by Blurton [4], which implies delivering knowledge “via a technological channel such as television, radio, or a computer and network” [4].

Houcine lists the following advantages of ICT impacts on learners:

- ICT increases learners’ motivation and thus enhances personal commitment and engagement;
- ICT improves independent learning;
- Learners’ collaboration and communication are more important;
- Learners’ attainment and outcomes are improved [19].

Taking into account these advantages, we can assume that ICT hugely influences students’ foreign language learning acquisition, modifies their learning environment, and shapes their foreign language learning outcomes. The learning environment, both formal and informal, is thus enriched with new means, forms, modes and methods of learning, as well as an extended language- and field-related content. Teachers and learners are confronted with a huge amount of authentic materials in the target language. These materials can be used both at the class preparatory stage and during the class. The potential of ICT lies in the fact that learners can construct the learning process for themselves and eliminate the difficulties by using the media they are familiar with. Besides, ICT is very helpful when the classes are conducted outside the country of the target language as it brings the foreign language world into the seminar room. Although our students belong to the “digital generation” or “generation 2.0”, these technologies are not *per se* relevant and motivating; and teachers have thus to apply such methods of teaching and such content that would make students feel interested in and find themselves engaged in online and offline foreign language learning activities.

Foreign language is a constituent of study programs in all major fields of study in higher school, which is beneficial for students, on the one hand. On the other hand, the insufficient volume of class hours, particularly for non-language students, makes foreign language university teachers find themselves at a crossroad, and thus, makes them think of what and how to teach and look for the ways of improving their teaching. The foreign language teacher faces a range of rapidly appearing new ICTs as online materials challenge them didactically and they are responsible both for the process of learning and interaction.

In order to start the learning process it is not enough only to introduce the learners to new media. Planning a class, the teacher has to consider the following:

- tasks have to be developed in such a way that the ICT introduction fosters solving the tasks set;
- it is advisable to choose such tools in classroom that match the target audience, incl. their chosen future professional field;
- the introduction of tools has to be organized in such a way that they support the cooperative learning and enable students to construct a flexible, personalized, time and space independent learning; this can lead to the self-led expansion of personal learning experience, i.e. students can develop their foreign language skills outside the classroom, expanding their PLEs.

In order to construct an effective foreign language learning environment, we share the Gros’ opinion that the learning environment must provide personalized assignments and/or formative feedback, and should include pedagogical strategies that support:

1. Conversation: the learning environment can engage the learner in a dialogue or facilitate a group dialogue on a relevant topic or problem;
2. Reflection: the learning environment can generate self-assessment based on students’ progress and performance, preferably suggesting activities and attributes in the learning environment that can be adjusted to improve overall effectiveness;
3. Innovation: the learning environment uses new emerging technologies and leverages innovative technologies in creative ways to support learning and instruction;
4. Self-organisation: the learning environment can rearrange resources and control mechanisms to improve its performance over time based on data that are automatically collected and used to refine how the environment interacts with learners in various circumstances [17].

Concerning the issue of the efficiency of digital tools to be used in constructing highly efficient PLEs, there are four constituent factors presented in figure 1 to name:

- students and teachers as participating actors;
- ICT;
- learning processes.

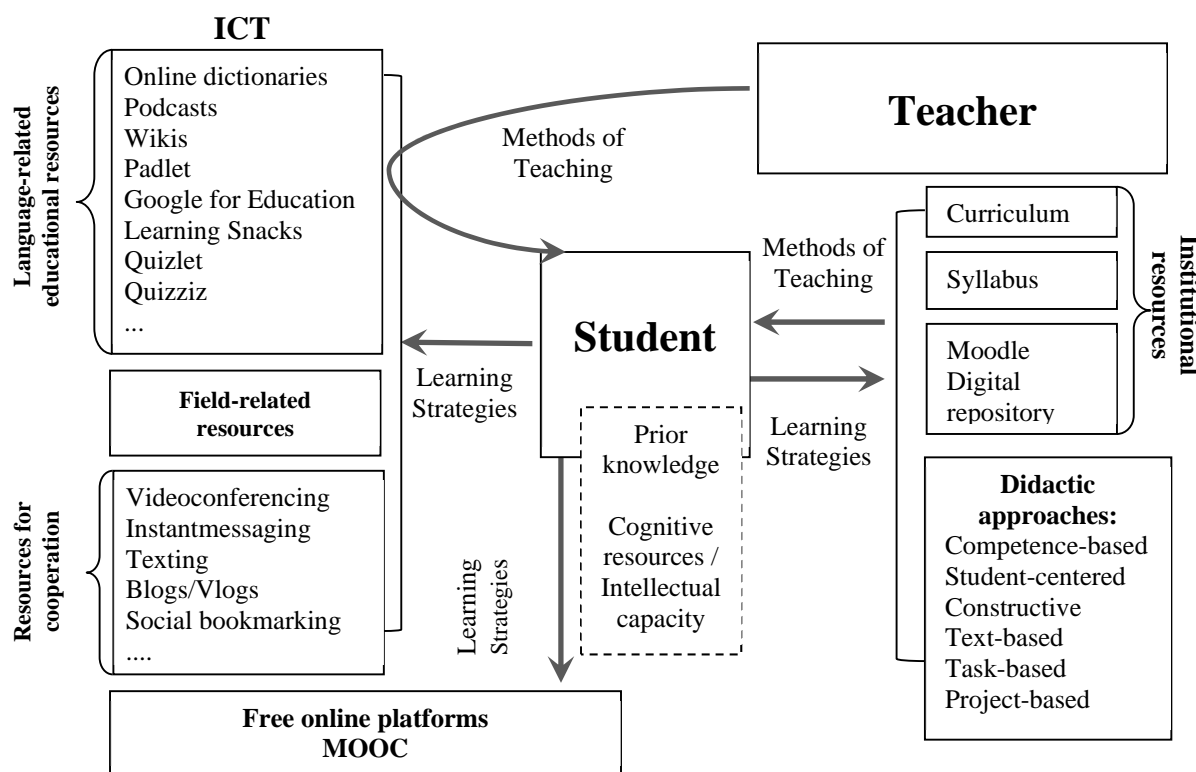


Figure 1. Model of Personal Learning Environment for foreign language acquisition.

The authors’ own experience underlay the model proposed in figure 1. It depicts the process of modelling PLEs of non-language university students within the Foreign Language for Specific Purposes course, where the foreign language teacher acts as a facilitator coordinating the resources, using the appropriate didactic approaches and teaching methods. Judging from experience, it helps in choosing one of the conceptual framework approaches to improving individual learning process in a formal educational environment. It becomes helpful guidance for users to maintain coherence between higher

rate of personalisation and the need to achieve learning outcomes defined in the course syllabus, to balance formal and informal contexts alongside with creating the necessary skills for lifelong language learning. Students build their PLEs basing on their prior knowledge and using their cognitive resources. They apply learning strategies needed to acquire or improve foreign language skills and achieve the learning outcomes identified in the syllabus while working on institutional platforms such as Moodle and using the Digital Repository as a source of the content to be studied. Teachers, on the other hand, act as facilitators in the educational process. Basing on the syllabus and filling the Moodle platform and digital repository with the appropriate and course-relevant educational materials, so that they are “available at all times and are accessible from any device” [17], teachers improve and adapt the process of foreign language acquisition via various ICT tools, which can be divided into language-, field-related and resources for cooperation. Applying them, it is necessary for teaching staff to look for the teaching methods that mostly suit the needs of students and help develop their foreign language skills by means of ICT. Teachers are also challenged nowadays by a great variety of free online platforms offering various foreign language courses, which students can choose from and which can be acknowledged by a higher educational establishment within the volume of hours stated in the certificate obtained in case the course was successfully completed.

Students can be identified by specific characteristics and features, e.g., their subject-specific or interdisciplinary prior knowledge, their cognitive resources or intellectual capacities, their values and attitudes, which form a complex of learning strategies to be applied by acquiring a new piece of foreign language knowledge. Thus, one of the main attributes of effective PLE is a learner profile portraying “the individual characteristics of each learner’s strength, preferences, motivations, etc.” [26], tools to continuously measure individual performance and evaluate progress.

Teacher is characterized by being knowledgeable about didactics and has to be ICT-didactic competent, has specific understanding of the profession, the values and attitudes, which influence the design of teaching-learning situations in different ways. ICT allows teachers to optimise instruction strategies and methods by analysing students’ performance data, by sorting out educational resources according to the matching degree from high to low, and by providing personalised adaptive learning services that can be well compatible and integrated with differentiated instruction, adaptive learning and life-long learning [25].

ICT can be described by different peculiarities and features, which are important both separately and in combination with each other. Media offer is marked with specific content, objectives, forms of presentation, process and navigation structures, interactivity properties, coding types, addressed sensory modalities, design techniques or learning theoretical implications. Depending on the offer, some of these properties can have greater or less importance, e.g., it would become a digital medium having the character of a tool (e.g., a word processor or a video editing tool), no content component or specific objectives, so that these aspects would not come into play. On the other hand, the process or interaction, its structures or the forms of presentation are relevant to a learning programme. New ICTs give the student and teacher the ability to control, manipulate and contribute to the information environment. On the lowest and least valuable level, this may simply mean the student controls the pace and order of a presentation. But much more is possible. Using ICT, students may not only make choices about the pace and order of a presentation, but may choose topics; take notes; answer questions; explore virtual landscapes; enter, draw or chart data; run simulated experiments; create and manipulate images; make their own multimedia presentations, communicate with others, etc.

Learning process can also be done through various constitutive characteristics for which, e.g., teaching goals, contents, the didactic structures of the process, social forms, and teaching methods on the part of a teacher, as well as learning strategies applied by a student, have to be considered. Blurton describes these constructivist methods of learning as “self-paced, self-directed problem-based ... learning processes” [4].

In such learning process, students gain responsibility for finding information, setting goals, deciding on appropriate learning paths and iterations, monitoring and evaluating their progress that help them develop self-regulated learning skills. Another defining factor is highly motivating context that can

strongly influence academic performance. Thus, it is of critical importance to pay special attention to developing the necessary self-regulated learning skills and strategies. Apart from obtaining language, speech and socio-cultural knowledge in a target language, formation of language and speech strategies, which help choose an appropriate learning path in order to achieve the best result within the shortest time period, is another constituent of foreign language content. In foreign language learning, there are some crucial aspects for language acquisition: self-awareness (being aware of one’s learning style); language awareness (conscious language perception); self-regulation, planning and monitoring one’s learning process. They are mostly referred to cognitive and metacognitive strategies, which can be best developed in motivating constructivist environment such as PLE. The effective role of these strategies is claimed to be conspicuous to language acquisition and self-regulation mastering the four language activities: e.g., oral communication, oral comprehension, reading comprehension and writing [26].

Lim and Newby mentions students’ familiarity with using Web 2.0 tools and their positive attitude toward using these tools and services for learning, but at the same time he notes that students reference challenges with using Web 2.0 in a carefully designed and structured manner [24]. No doubt that Web 2.0 tools can provide students with extra opportunities to do meaningful language learning tasks from the comforts of their own homes or local libraries. However, Web 2.0 tools work best when students are asked to develop, create, and share their work online [20]. That is why, to take advantage of all these facilities and suggest the most effective ways of incorporating ICT for developing four language skills: speaking, reading, writing and listening in formal contexts, a plethora of ICT can be used. Table 1 offers a range of ICT tools actively used by authors along with a possible student activity.

Table 1. Foreign language Personal Learning Environment toolset.

Language skill	ICT tool		Student activity
Reading	Online dictionary	https://dictionary.cambridge.org	Find the xxx word in the dictionary.
		https://www.duden.de/	Find out its meaning/s. Read the examples given.
	Wiki	https://en.wikipedia.org	Search the Wikipedia on the topic given.
	Blog / professional blog	http://edublogs.org/	Subscribe to the blogs of other students of the group. Follow these blogs and post personal comments.
		https://www.blogger.com	
		https://wordpress.com/	
	Social bookmarking	https://www.reddit.com/	Upvote, downvote or comment one story a day you find interesting during a week. Go back through your account at the end of the week. Choose one of the bookmarked books for reading.
		https://digg.com/	
	Social bookmarking	https://stumbleupon.com/	Bookmark interested things on the topic given each day during a week. Go back through your account at the end of the week. Read the bookmarked stuff.
		https://twitter.com/explore	
	https://twitter.com/	Read posts on the topic given.	
	https://www.facebook.com/		

Language skill	ICT tool		Student activity
	Social networking site / SNS	https://www.instagram.com	
	SNS	https://web.telegram.org/	Subscribe to a foreign language learning channel.
	Learning Snacks	https://www.learningsnacks.de/	Read a piece of information shared by other students on the topic given.
	Games	https://www.gamestolearnenglish.com	Read the description and click on the matching image.
Listening	Podcasts	https://www.bbc.co.uk/podcasts	Search an ICT tool for podcasts related to the topic. Subscribe to at least two podcasts.
		https://www.iheart.com/podcast/	
		https://www.podcastsinenglish.com/	
		https://learnenglish.britishcouncil.org/general-english/podcasts	
	You Tube as audio/video sharing library	https://www.youtube.com/	Search for an interesting film in a target language. Watch this film. Recommend this film to your group mate.
	Video-conferencing	https://zoom.us/	Attend a conference. Listen to the speakers.
		https://www.skype.com	
https://www.microsoft.com/en-us/microsoft-365/microsoft-teams			
https://www.adobe.com/products/adobeconnect.html			
SNS	https://www.tiktok.com/en/	Find a short video on the topic given. Watch this video.	
Games	https://www.gamestolearnenglish.com	Listen to the words/numbers and click on the matching images.	
Writing	Blog	https://www.blogger.com	Create your own blog. Post a personal reflection on the given topic every day.
		https://wordpress.com/	
	Online journal	https://penzu.com/	Create your online journal (on the topic you desire). Write an entry to your online journal.
Quizlet	https://quizlet.com/ru	Write/Type a definition to the word you see. Type the term that goes with the definition before it reaches the bottom of the screen.	

Language skill	ICT tool		Student activity
Language skill	Learning Snacks	https://www.learningsnacks.de/	Write a piece of information you want to share on the topic given.
	Padlet	https://padlet.com/	Fill in your own portfolio Padlet board.
	Games	https://www.gamestolearnenglish.com	Guess letters to spell out a hidden word.
	SNS	https://www.whatsapp.com/	Text your friends (group mates) in a target language. Respond to the instant messages received from your friends (group mates) in a target language. Create a photo blog. Invent metaphors within chosen photos. Make up and document some context to photos. Practice xxx grammatical structures on photos.
		https://www.messenger.com/	
		https://www.viber.com/	
		https://www.instagram.com/	
	SNS	https://web.telegram.org/	Write posts on the topic given in a target language.
		https://twitter.com/	
		https://www.facebook.com/ https://www.instagram.com/	
Speaking	Video-conferencing	https://zoom.us/	Attend a conference.
		https://www.skype.com	Present the results of your research to other conference participants. Respond to the questions asked. Put your own questions to other conference speakers.
		https://www.microsoft.com/en-us/microsoft-365/microsoft-teams	
		https://www.adobe.com/products/adobeconnect.html	
	Webinar	https://meet.google.com/	Attend a webinar.
		https://zoom.us/ https://www.microsoft.com/en-us/microsoft-365/microsoft-teams	Voice your own point of view on the topic discussed. Put questions to other webinar participants. Agree vs. disagree with other webinar participants.
	SNS	https://www.tiktok.com	Shoot your own short video on the topic given. Upload the video on the SNS.
	Games	https://www.gamestolearnenglish.com	Guess xxx by forming questions.

The table offers a range of options available to students, among which they can choose the applications that can better suit their needs and abilities, interests and learning styles. Student activities within each language skill presented in the table correspond to the hierarchical structure of learning content according to Bloom’s taxonomy. This structure is based on working with educational content at different

levels (materials for learning – materials for practices – materials for creation) making students apply different levels of language cognition (remembering to creating) and forcing teachers to choose student-relevant instructional methods. As the skills specific to foreign language learning do not form a hierarchy, but are interrelated and dependent on each other, the highest level of language learning (creation) depends on the lower levels of the structure, namely understanding, analysing, evaluating and applying knowledge. Thus, the student activities for reading and listening skills formation mostly correspond to the lower levels of language learning, whereas the activities for writing and speaking skills are based on the previous ones and require student's ability to use information in a new way, to break it down into its essential parts, to judge and criticize information, to establish cause-and-effect relations, and to create something new from different elements of information.

Although the fact to be acknowledged is that these resources are constantly changing, are being updated and added with new functions, this preliminary toolset can be of great value forming the users' ability to learn new tools through the learning curve having some previous experience.

Learners acquire knowledge in both informal and formal contexts, doing so in informal contexts, especially with and via the media. This means that university-based learning processes and informal learning processes have to be related to each other much more strongly. ICTs play an important role as a means of learning processes and as a means in the process of constructing foreign language personal learning environment. In addition, teachers have to be aware of the fact that foreign languages can be learnt by students in informal contexts, i.e., in massive open online courses (MOOC) on different free online platforms, like Coursera, Prometheus, etc., which allow online learners "to learn asynchronously, synchronously or autonomously" [15].

Moreover, the use of apps contributes to the enhancement of the learner's cognitive capacity, the student motivation to study in both formal and informal settings, the learner autonomy and confidence, as well as the promotion of personalized learning, helping low-achieving students to reach their study goals. However, to achieve the effectiveness of these apps, it is desirable to design, plan and implement them with caution, according to students' needs, and to deliver multiple language skills in authentic learning environments [21]. To augment the traditional foreign language learning, the application of ICT is preferable, but their meticulous choice has to be done according to what ICT devices are at hand or could be available for students in class or at home to meet the needs of each student and allow them to create a comfortable learning environment. To choose interesting, motivating and affordably challenging educational content, the English teachers can make use of the following websites: Ted Talks, British Council, ESL Brain, etc., blogs: English Outside the Blog, English with Adriana, etc., providing free educational materials for all language learning levels according to the Common European Reference for Languages. Some practical applications of ICT can also be presented via learning vocabulary on a range of platforms which allow teachers to diversify and visualise the classroom activities and make students concentrate on the topic vocabulary, allow them to extend and network their knowledge for themselves. These learning by doing activities include mindmaps, own associations, crossword puzzles, Bingo, gapped texts, quizzes, cards, Trimino, etc., which can be practised on Padlet, Learning Snacks, Quizlet, Quizizz, etc.

Internet remains a very important source to find the audio-visual materials by facilitating a transversal use of language in different contexts. In foreign language teaching, ICT is of an added value because we have a fast access without time limit to different types of texts (text, audio, video), which can be used directly or indirectly through the learning process. We can manipulate digital data in whichever text (text, image, and video) and so we can create new resources.

SNS technologies, as it is seen from the table, are not to be underestimated as well, and thus, have been investigated by many researchers in the field of foreign language acquisition since the time of their emergence. SNSs are regarded as a type of social media that foreground personal profile and network activity; they are open, dynamic and offer collaboration options. As people need socializing with others, information sharing and joint activities, education practitioners and researchers have realized their potential and have been trying to integrate these means for communicative practice into teaching, creating not face-to-face authentic communication with native speakers. Another benefit is gathering

feedback for in-class activities through anonymous polls and questionnaires possible to be conducted on e.g., Telegram. Blogs, short for weblogs, which are recognized as ideal spaces for culture learning and intercultural exchange and continue to hold potential for language learning. A framework of blog types can be offered for educational application: tutor blogs as instructor-maintained collections of class references and resources, learner blogs as online journals or portfolios for individual students, and class blogs as spaces for collaboration and interaction.

In recent years, an increasing interest from educators is accrued by digital games characterised by interactivity, multimodality, and immersion creating extremely popular environment. Educators agree on “positive effects of game play on motivation, willingness to communicate, language socialisation” [27]. These games foster target language vocabulary output, active and volunteer engagement in the target language interaction, improve fluency and discourse management practice [27] as well as develop cognitive and metacognitive strategies for language learning. Another advantage is authenticity of gaming environment with both language learners and native speakers as participants.

ICT-mediated instruction leads to students’ increased autonomy, as they can choose the format (text, audio, video) of authentic foreign language learning material and tailor it to their needs, both personal and professional going for synchronous or asynchronous mode of learning. Thus students build up their own pathways in foreign language learning in a self-directed manner, piling up their own experiences from a constructivist perspective in effectively tailored PLE.

Nevertheless, various learning experiences are synthesised, can complement each other, be planned or orchestrated to run in parallel, thus creating the environments, learning in which enables increasing students’ motivation and gain ratio.

4. Conclusions

PLE is considered today to be a surrounding that enhances student motivation, improves learning outcomes, and favours student progress in learning, including foreign languages. Because of different pace of learning, different attitudes, background and abilities, students find themselves at different levels of foreign language knowledge in higher educational establishments. In order to succeed, students need to create personal learning environment basing on their prior knowledge and cognitive resources through using the tools, forms, and materials that match every student. As ICT is unavoidable today, and young people are best equipped with it and are familiar with its usage, teachers cannot but apply them in their teaching processes, making them closer and more appropriate to help students immerse in the world of authentic foreign language material that is extensively offered by the Internet. Using different ICTs accessible for students and the content that can be constantly updated enhances student motivation to become a life-long foreign language learner, on the one hand, and to enrich the traditional teaching practice, on the other.

A range of approaches (competence-based, student-centred, constructive, task-, text-, and project-based) favour the application of ICT in everyday teaching and learning practice. The model developed by the authors visualises that ICT is applied by teachers after thorough consideration of what and how to teach. Mobile devices, laptops, tablets, etc. as tools and SNS, blogs as a means are used to construct flexible, personalized, time and space independent learning, to expand personal learning experience through not face-to face authentic communication and authentic material. Google services and other videoconference platforms allow reaching students outside the classroom and conduct both foreign language classes outside the classroom and for students to perform tasks in teams. ICT helps a student, who becomes more and more autonomous, define what learning strategies can be applied by learning different content from both printed and online sources, which are placed on institutional (University) and non-institutional (free online) platforms. Thus, a student is free to choose what, where and when to learn, expanding their foreign language learning experience to outside the classroom. A range of online resources for both teachers and learners are offered to be used in mastering four foreign language skills: reading, listening, writing and speaking, together with the proposed activities.

Further studies have to be based on quantitative research methods to investigate age and gender differences in using ICT, the extent of autonomous application of ICT for language learning, as well as

on the application of adaptive learning environments in tertiary foreign language education in non-language universities.

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Exploring the experience of integrated teaching of the management core courses in a foreign language based on ICT use

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Abstract. The authors search the solution to the practical tasks of the contemporary education characterized by the increasing role of individual work in implementation of ICT at the lessons and in the independent work, the development of new principles, strategies and methods of teaching within the framework of integrated learning. These novelties can be applied when teaching professional subjects and foreign language and will provide the effective learning process aimed at acquiring the necessary competencies. The research discusses the process of integrated teaching using ICT and defines the organizational and educational conditions of integrated building of professional and foreign language competences using ICT. The authors generalize the experience of implementation of contemporary innovative technologies in integrated teaching of the professional subjects and foreign languages and analyze the ways of the effective ICT use in the integrated teaching of the management core courses in a foreign language. The content analysis performed in the research provides the basis for classification of both positive and negative aspects accompanying ICT use in education.

1. Introduction

Ukraine is going through the process of reforming the national system of higher education. This process is accompanied with radical changes in pedagogical theory and practice of the educational process. Modern society is becoming increasingly dependent on all forms of technology for daily functioning. The unification of the system of higher education in Europe and the development of education programs that meet the requirements of the international standards put forward the task of the professional training of specialists with the level of the foreign language competence that corresponds to the world standards and provides the opportunity to use a foreign language in their further professional activity for creating business contacts and building cooperation with specialists in the related spheres.

2. Actual scientific researches and issues analysis and the research objective

Modern researchers dwell upon multiple aspects of ICT implementation in education: E-learning tools and technologies (Clark, Mayer [6]; Fu, [9]; Modlo et al, [18]; Rösler, [23]; Symonenko et al [26]; Triakina et al [27]), communicative characteristics of informational media of communication



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(Lawrence, [15]; Hernandez, [10]), didactic opportunities of network technologies (Bondarenko et al, [3]; El Mansour, Mupinga, [7]; Fong, [8]; Katz, [11]; Kazhan et al, [12]; Kiv et al, [13]; Merzlykin et al, [16]; Nickerson, [19]). The Ukrainian researchers (Chorna et al, [4]; Pavlenko et al [22]; Symonenko et al, [25]) have studied the methodological grounds of ICT using for building the foreign language communicative competence in different types of speech activity. The Ukrainian psychologists and educators consider that the influence of informational technologies on personal development is impossible to classify as definitely positive or negative (Konovalenko, Nadolska, [14]; Shmygol et al [24]; Yudina et al [28]).

The current situation in the field under consideration puts forward the following contradictions:

- between the tendency of the swift growth of the role of ICT in the educational process stipulated by the development of the informational society and the upgrade of the system of higher education on the one hand and some unsolved aspects of the general problem of ICT use in efficient management of the educational process on the other hand;

- between the radical change of the educational approaches, transition from separate pedagogical functions to the systematic ones, from the standard techniques to the innovative, creative and personality oriented ones on the one hand and the ambiguity of the researches in terms of the influence of ICT on the student's personal development on the other hand.

Our research is directed at resolving the above stated contradictions. The aim of the research is to analyze the experience of ICT using in the integrated teaching of the subjects “Corporate Social Responsibility” (in English) and “English for Professional Purposes” and to evaluate experimentally the efficiency of ICT for integrated building of professional and foreign language communicative competences.

The aim is to be achieved through the fulfilment of the following tasks:

- to generalize the experience of implementation of contemporary innovative technologies in integrated teaching of the professional subjects and foreign languages;

- to define the organizational and educational conditions of integrated building of professional and foreign language competences using ICT;

- to analyze the didactic opportunities of ICT in integrated education programs in English;

- to develop the model of the education programs of the disciplines “Corporate Social Responsibility”, “English for Professional Purposes” using ICT;

- to verify through the experiment the effectiveness of the developed model of the education program and to use the qualitative and quantitative analyses;

- to analyze the results of experimental teaching in terms of positive and negative effect on building professional and foreign language communicative competences and personal development of students;

- to determine the effective and ergonomic approaches to ICT using and to develop the recommendations as to its using in the integrated teaching of professional subjects and foreign languages to future managers.

The following theoretical and empiric methods have been used in the research: critical analysis of resources, current programs, education regulations, manuals; method of observation, questioning of students and professors to reveal their attitude to different aspects of ICT using in higher school; simulation method to develop the education model within the standard amount of ECTS credits; education experiment and statistical processing of data, obtained in the experiment to check the effectiveness of ICT using in education, content analysis of teachers' answers to open-ended questions describing their experience with ICT use in educational process..

3. Organization of educational m-learning environment using ICT

The implementation of ICT in educational process requires the creation of m-learning environment that depends on different factors – technical, psychological, methodological. Technical factors are predetermined by the infrastructure of a certain educational institution and PDAs used by students and professors [17]. The great choice of available ICT tools for different purposes determines their insignificant influence on the character of m-learning environment. The factors that we consider more

important are teaching and learning competences of the participants of the educational process as well as their psychological readiness to accept the novelties.

The negative factors of ICT implementation and m-learning environment should not be underestimated. The researchers note rigid schedule (El Mansour, Mupinga, [7]), technology-supported cheating opportunities and communications-related distractions (Nworie, Haughton, [21]), lack of engagement (Zhu, Kaplan, [29]).

Putting an accent on didactic and methodological advantages of ICT use in the process of integrated building of professional and foreign language communicative competence we agree with the opinion of the scholars (Nikolayeva, Mayer, Chernysh, [20]) who accept the existence of disadvantages in the use of the Internet technologies:

- the possibility to obtain the outdated or unprofessional information;
- the author's bias as to the issues presented in hypertexts;
- the limited amount of professional editions in open access.

There is no doubt that the model of the integrated teaching of core disciplines and foreign languages is to consider the drawbacks of ICT use in order to minimize its negative influence on the process of building of the professional foreign language communication competence. The solution of the practical tasks of the contemporary education is connected with the implementation of modern innovative educational technologies, development of new principles, strategies and methods of teaching within the framework of integrated learning.

The use of m-learning environment along with other IC technologies is used for the organization of educational process that does not depend on certain place and time. PDAs allow students to access educational resources, to connect with other students, to create educational content in class and outside the University. It is undisputable that technologies provide new learning opportunities to students, namely, increasing the information flow, speeding up its processing and memorizing, compensating the absence of natural foreign language environment, following the principles of visualization, interactivity, feedback.

For example, the use of Podcasts in the educational process allowed the use, spread, revision and listening to audio and video materials in the Internet. Due to their didactic qualities – audio nature, multimedia characteristics, interactivity, efficient space and time organization convenience of use and availability – podcasts increased the educational opportunities of both teachers and students. The use of podcasts helped the development of listening and speaking skills, but its influence on reading and writing skills is relatively insignificant. This resource was very useful for improvement of the aural perception of the English speech. During listening the students performed the tasks directed at developing media literacy, learning autonomy and creative abilities.

Chats were used mostly for the development of reading and writing. Chats allow the organization of fast communication among students and professors, discussions of resources and common projects. Social networks were used by professors and students to create educationally oriented groups. This tool was used not only for communication but also for educational purposes; this allowed the improvement of reading and writing skills as well as the ability of working in a group. The Viber application for smartphones on platforms Android, iOS was useful for the improvement of all types of speech skills as well as for the development of professional competence.

Project technology, web-quests, case technology, facilitation, professionally oriented business games were used in the integrated teaching of core disciplines and the English language. These technologies are efficient tools for the organization of individual and class work; they allowed the improvement of the foreign language competence in all types of speech activity as well as professional competence, the development of logical thinking, ability of reasoning and persuading counteragents. One of the elements of professionally oriented tasks was solving professional problem cases based on the analytical research using informational resources, creating multimedia presentation, organizing business game.

The results of web-quests were realized through a multimedia presentation the aim of which is to present the students' research activity. Participation in web-quests developed the ability to think independently, to solve professionally important problems, to forecast the results and possible consequences of different scenarios, to determine cause – effect relations. Through the use of the

multimedia resources students met their specific needs and participated in collaborative projects that promote communication with peers in both their classrooms and throughout the global community.

The following professional students' skills have been developed: information search, key words highlighting, topic / problem definition, extraction of the main information, presenting and summarize the obtained information.

The researches in the problem of the provision of interactivity of educational means based on ICT define the following indicators of interactivity: non-linear access to educational information; efficiency of feedback in both directions; communication among the subjects of educational process; adaptation of the education system to student' individual needs; implementation of the educational strategies in the individual activity.

Special attention in the process of organization of independent learning should be paid to web technology / the Internet technology, especially its different communication opportunities that can be used for control organization, joint project performance, and information exchange. M-learning environment involved in the model includes both university and personal learning environment for professors as well as for students. Since the proposed integrated model was to realize complex and competence approaches to the educational process and involves both class and individual out-of-class work, the exclusion of ICT technologies from variant B was impossible.

4. Implementation of the integrated teaching system

The courses in our experiment "Corporate Social Responsibility" and "English for Professional Purposes" are part of the curriculum of bachelor degree program in management. The main goal of the experiment was to define the level of influence of ICT on the quality of learning and to determine the most efficient integrated educational model with the use of ICT.

The hypothesis of the experiment: to achieve a high level of professional foreign language communicative competence in the process of professional education of future managers is possible through the integrated teaching of a foreign language and core disciplines in a foreign language using ICT in the class and during out-of-class learning activities guided by the teacher having chosen the most efficient educational model.

Our investigation was held in the third and in the fourth semesters of two consecutive academic years (2016-2017, 2017-2018). The total amount of students, that took part in the experiment – 52 students. The questionnaire that was held among the students revealed some of the strongest stimuli (from the students' point of view) for the development and implementation of ICT into the educational process. Having prioritized these stimuli, we obtained the following list: building of professional independence; wider opportunities to successfully finish the course; development of competitiveness; academic mobility; knowledge acquisition; adaptation of new forms of activity; changing of communication mode between the subjects of the process.

Variability of the experiment is presented through the models of integrated teaching using ICT. Invariables of the experiment are the groups (EG1, EG2, EG3, EG4) composition: number of participants (13 students in each group) and their knowledge level; program content and study material; the control content before and after the experiment; time and duration of the experimental learning; criteria of checking of professional and foreign language competences in all groups; teachers in each group.

The choice of control group without ICT is not considered since the important element of the educational process is students' individual out-of-class work that is based on active use of different informational resources and technologies. The object of the experimental check within the discipline "English for professional purposes" was the determination of the level of professional foreign language competence in the four types of speech activity. The use of ICT in development speech skills are presented in table 1. The series of tests determined by the control purpose and the speech skills nature was performed.

The evaluation of speaking skills was carried out according to the following criteria:

1. The degree of relevance to a certain topic or situation (relevance to a topic, realization of communication intention).
2. The completeness of the covered topic, situation (topic interpretation, topic coverage).

3. The level and the characteristics of improvisation in utterances.
4. Adequate use of vocabulary and grammar (correct use of language means).
5. The correspondence of the volume to the task.
6. The speed of speech.
7. Correct understanding of the questions and the speed of response.

Table 1. ICT use in development of speech skills.

Types of Speech Activity	Information and communication technologies										
	Information education resources	Podcasts	Multimedia resources	Chats	Social networking	Viber	Project technology, web-quests	Case technology	Facilitation, professionally oriented business games	LMS Moodle	
Speaking		+				+	+	+	+		
Writing				+	+	+	+	+	+	+	
Listening	+	+	+			+	+	+	+	+	
Reading	+		+	+	+	+	+	+	+	+	

The following criteria were developed for the evaluation of writing:

1. The relevance of the tasks to the topic (the relevance of communication intention).
2. The completeness of the coverage of the topic or situation.
3. Lexical and grammar correctness.
4. Logic connection of utterances.

Reading and listening were evaluated according to the following criteria:

1. Understanding of the texts in general.
2. Understanding of the details.
3. Critical understanding of the information contained in the text.

Information communication resources allowed deepening of professional knowledge and building professional competence. Search engines, the Internet catalogues were used by students as sources of materials like video, audio and multimedia files for their presentations, projects and other educational tasks. Different types of electronic reference media provided the students with the up-to-date professional information and news (data, facts, diagrams, etc.).

5. The verification of the effectiveness of using ICT in education

The competence level control before and after the experiment has proved the increase of the level of professional and foreign language competences due to the implementation of the proposed teaching methods (tables 2, figures 1–4). The fulfilment of the tasks connected with problem solving using ICT (project technology, web-quests, case technology, facilitation, professionally oriented business games), different teaching methods (group work in pairs, in small groups, in teams, participation in simulation and business games) stimulated the level of speaking skills.

All students participating in the experiment got more than 90% grades for the tasks of the first part of the test on writing. Most of the students demonstrated twice as good results in the second part of the test – to write an e-mail.

The systematic work with podcasts and audio texts has allowed developing the mechanisms of listening, improving forecasting, widening the range of understanding different phonetic realizations.

Table 2. ICT use in development professional competence.

Professional competence	Information education resources	Podcasts	Multimedia resources	Chats	Social networking	Viber	Project technology, web-quests	Case technology	Facilitation, professionally oriented business games	LMS Moodle
Ability to work in team				+	+	+	+	+	+	+
Ability to perform professional responsibilities according to adopted norms and regulations		+	+	+	+		+	+	+	+
Ability to evaluate different factors of external environment	+	+	+	+	+		+	+	+	+
Ability to mobilize management resources	+	+	+	+	+	+		+	+	+
Ability to systematize and distribute information in management system	+	+	+	+	+	+	+	+	+	+

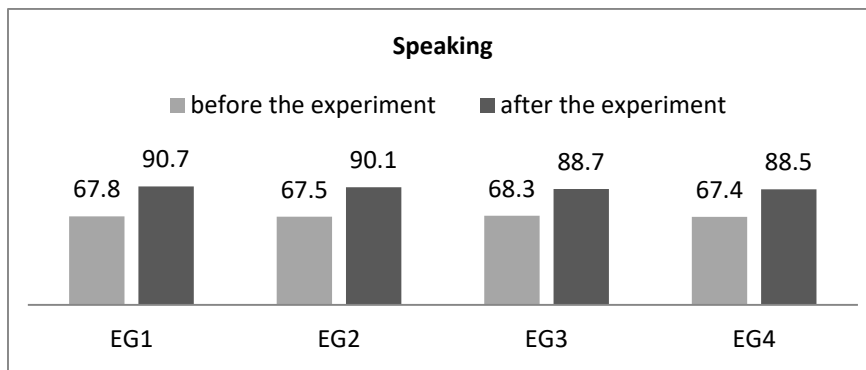


Figure 1. The results of the evaluation of speaking skills before and after the experiment.

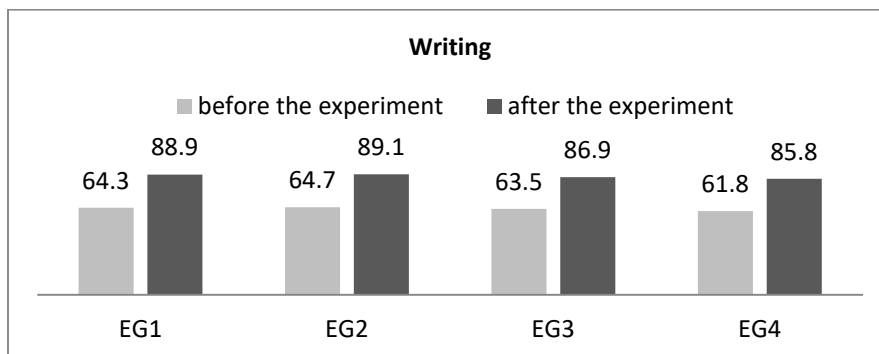


Figure 2. The results of the evaluation of writing skills before and after the experiment.

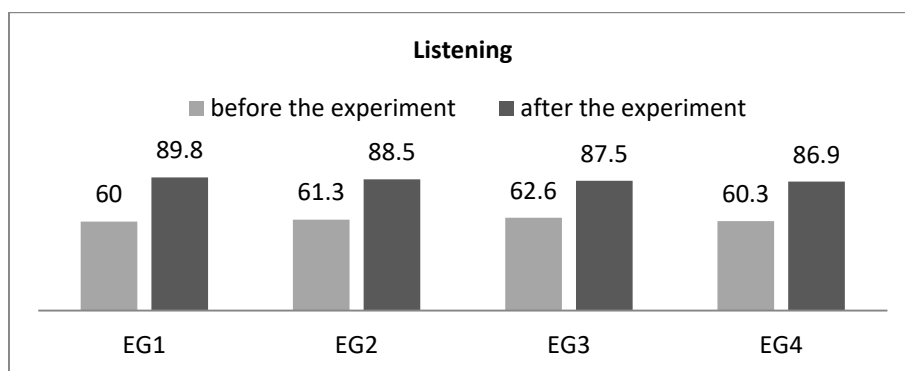


Figure 3. The results of the evaluation of listening skills before and after the experiment.

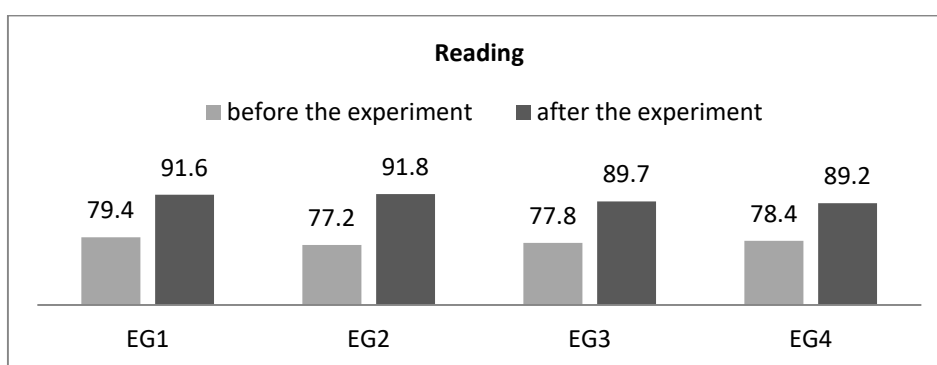


Figure 4. The results of the evaluation of reading skills before and after the experiment.

Student involvement into independent and out-of-class activities using information communication resources and the Internet technologies has allowed the intensification of the work on building reading competence, stimulated the development of learning skills and independence.

According to the results of the evaluation of skills before and after the experiment, obtained data showed the following result after verification of the statistical hypotheses using Student's t-test. The calculated value before the experiment $t \approx 0.11$ was lower than the critical table value $|t| < t_{50;0.05}$ ($0.11 < 2.00$). This proves the absence of deviations of mean values before the experiment. After the experiment the calculated value ($t \approx 3.2$) exceeded the critical table value $|t| > t_{50;0.05}$ ($|3.2| > 2.00$). Since the calculated value t exceeds the critical table value, we can conclude that the experimental teaching of the students of experimental groups on the basis of integrated model using ICT has influenced the expected level of professional and foreign language competences. The use of F-test allowed the confirmation of the fact that after the experiment the level of dispersion of the results of building the professional and foreign language communicative competences among the students of experimental groups has significantly decreased. This fact proves the stable competence level and consequently supports the statement about positive influence of the developed model of teaching using ICT. The dispersion of the random variables X and Y prove that the results in groups EG1 and EG2 are better compared to the results of groups EG3 and EG 4. The detailed statistical analysis of the obtained data was earlier presented by the authors (Yudina et al [28]).

Although the positive influence of ICT use in educational process has been proved experimentally and it is difficult to overestimate them, the negative sides are to be given careful consideration. The project of our integrated model presupposes the profound research of both advantages and drawbacks of ICT use in educational process with the help of the content analysis. The topic of negative influence of ICT has been covered in many researches (Al-Ansi et al, [1]; Alhumaid, [2]; Chusavitina et al, [5] and others), but it is mostly fragmentary and has not got a profound systematic analysis. The authors suggest that the analysis of the educators' opinion on this issue would be a good starting point for its deeper consideration.

The open-ended questions have been chosen as the instrument to investigate the professors' opinion as to positive influence of ICT use as well as the negative one and the methods of its minimization. The advantage of this instrument is the absence of the preliminary developed research scheme based on the researcher's bias. The answers to open-ended questions allow revealing the genuine interests and preferences of respondents. The two questions were asked in the cause of our experiment: What are the positive results of ICT use in education based on your teaching experience? What are negative results of ICT use in education based on your teaching experience? In the cause of our experiment we have analyzed 63 answers using the classification scheme mentioned above. This analysis allowed us to identify narrower categories and build more detailed classification scheme. Table 3 represents the results of the analysis of the answers provided by the professors engaged in our research. The units were gradually added to the related category in the cause of the analysis.

Table 3. The results of the analysis of the answers to open-ended questions.

Categories and units of the analysis	Evaluation of results	
	Positive	Negative
The factors that have only negative evaluations		
Literacy and numeracy issues		
Inability to write a complete sentence		52
Spelling problems		49
Inability to work with simple formulae		42
Work with information		
Inability to find correct information / selectivity in the work with information		37
Inability of critical thinking		34
Inability to create cognitive support		36
Inability to create presentation support		29
Digital divide		18
Student's distraction during classes		23
Low motivation of students due to lack of computer skills		13
Technical problems arising during classes		8
Teacher's incompetence in ICT		3
The factors that have only positive evaluations		
Feedback tools		
Knowledge of results	59	
Knowledge of correct results	56	
Elaborated feedback (additional information, explanations, etc)	54	
Immediate feedback	45	
Support of lectures		
Cognitive support	42	
Presentation support	46	
Combined support	36	
The factors that have both negative and positive evaluations		
Assessment tools		
Peer assessment	26	29
Teacher assessment	38	15
Feedback tools		
Delayed feedback	18	32
Communication in the educational process		
Communication with peers	29	31
Communication with the teacher	42	18

Although the results obtained in the analysis of these answers are not comprehensive, they provide the preliminary list of positive and negative effects that accompany the use of ICT methods in education.

6. Conclusions

The examination of scientific researches and personal pedagogical experience gained by future managers at high school allowed us to systematize the didactical and methodological grounds for building foreign language professionally-oriented communicative competence based on ICT which are the following:

- the availability of a wide range of authentic sources of professional information and a large selection of virtual educational facilities (dictionaries, encyclopedias, search engines, E-platforms in the distance learning system, multimedia-based courses, public services and foreign-language learning facilities);
- the interactive character of most virtual educational facilities, which intensifies the learning process, expands learning environment, facilitates the access to information sources;
- creation of natural environment in the framework of joint linguistic projects; increase of students' motivation and interest due to exchange of information, ideas and plans, use of authentic situations, connected with cooperation, search and delivery of professional information in foreign language;
- use of different forms of in-class and out-of-class training: individual, pair and group work aimed at searching the information on the Internet and analyzing it allows organizing the joint research, prompt information exchanging and building of communication competence;
- enabling favorable conditions for individual learning, obtaining information and its prompt renewal promote efficient organization of informational environment, development of learning autonomy, self-organization, self-control and creativity;
- interactivity, fast feedback and control over students' performance allow objective evaluation of students' progress, placement and fulfilment of on-line tests, prompt grading and following own progress in learning and developing professional communication skills;
- free and fast access to theoretical and reference resources, archiving, storing, exchange and spreading of professional information provide multiple repeating of learning material and self-control of educational activity.

The analysis proves that most educators engaged in the research consider both positive and negative results of using ICT. The main negative effects are referred to the sphere of basic competences. The use of gadgets in educational process requires completely new methodological approaches to teaching such basic skills as writing correctly (spelling), using proper style (avoiding the style of messages), counting. The second big methodological issue is to build the competence of critical processing of big volume of the information available from the Internet. Less important but still considered by many participants of the research is dealing with students' distraction during classes. Digital divide has been also mentioned by some professors, but it is not crucial and its overcoming is beyond the sphere of development of new teaching methods.

The big amount of answers included the factors that were considered as positive by some educators and negative by others. This fact shows that some teachers are able to successfully overcome the challenges brought forward by using ICT in educational process due to new teaching methods applied by them, whereas others fail trying to combine old methods with new technologies. This list is to become the basis of the classification scheme for the profound content analysis which is under development at this point and to be performed later in our research.

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The formation of educational environment in foreign language training of energy engineering students by means of project technology

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Abstract. The article deals with the results of experimental work concerning the educational environment formation that is focused on the foreign language training of future energy engineering students. Project learning technology is chosen as the means of formation. A model of the educational environment for the metalanguage studying of the speciality of energy engineering students has been developed. In the educational process, educational projects with elements of professional orientation were implemented in accordance with the subject of the discipline “Business Foreign Language”, and the language abilities and internal potential of students were taken into account. The preparedness of energy engineering students to integrate knowledge of professionally oriented disciplines into a foreign language environment for solving project tasks of communicative nature has been determined. According to the results of the pedagogical experiment, it was established that in the process of project activity the mastering level of lexical and speech competences as the components of foreign language competence of students has significantly increased. The developed educational environment is characterized by differentiation, individuality, independence, autonomy, informativeness, creativity, which allows to create the necessary conditions for successful learning of foreign language, development of creative thinking, communicative skills of energy engineering students, formation of foreign, communicative, professional, informational, project, research competencies.

1. Introduction

International integration activities, scientific and technological developments and the latest technologies in the field of modern energy, employment opportunities or advanced training in a foreign-language environment, etc. – all these processes extend the range of the professional range of new generation engineers of energy. Accordingly, new requirements are set for technical educational institutions for the



training of students for higher education in the speciality 141 “Electric power engineering, electrical engineering and electromechanics”.

The energy labour market needs the competent professionals who are able to solve the engineering problems innovatively and creatively. The future energy engineering students must be ready to develop and improve professional knowledge by foreign languages for the purpose of self-realization in today’s conditions, the future challenges of scientific and technological progress. All this actualizes the problem of mastering the foreign language knowledge at such level that would allow them to use them spontaneously during engineering activities. The possible solution to this problem is by making adjustments to the organization of the educational environment, which provides training for future professionals in the energy sector. It is necessary to form an individual space for the disclosure and development of students’ speech abilities, the formation of foreign language professional competence by educational technologies. In the process of their selection, we should take into account the specific activity sphere of specialists in the energy sectors.

Project technologies are effective for acquiring and expanding foreign language knowledge independently, close to design as a type of engineering activity ([9], [25], [34]).

The problem of implementation the project technologies into the process of foreign language training has attracted the attention of many researchers and found a partial solution in the following aspects:

- teaching English to students of technical college on the basis of modular design methodology ([6], [14], [32], [39], [40]);
- English-language training of future programmers according to the design methodology in combination with information technologies ([36], [37], [38]);
- creation of professionally oriented projects by postgraduate students on the basis of German-language texts ([12]);
- project methods of learning a foreign language in the context of modern pedagogical technologies ([15], [17], [43], [47]);
- typology of projects in foreign language teaching ([26]);
- features of the project methodology in the process of forming the foreign language communication skills ([13]).

The scientific works of these scientists outline the problem in general. We believe that it is necessary to specify the feasibility of using the project technologies in the educational process and on their basis the possibility of forming the foreign environment for studying the metalanguage of the speciality 141 “Electric power engineering, electrical engineering and electromechanics”.

Viacheslav M. Oleksenko stresses that for the training of future students in engineering specialties should be created a “development technology based on the scientific concept of learning, which would educate the individual in activities combining individual, group and frontal forms of work, contribute to improving the quality of the pedagogical process, be aligned with the main provisions of the Bologna Declaration” ([24], p. 5). The innovative pedagogical technology developed by the scientist is called student-based and, in our opinion, is related to the project technology, as it focuses on the personality of the applicant for higher education and the ability to acquire relevant knowledge in self-independent activity. We believe that the project technologies can ensure the acquisition of up-to-date knowledge for future activities, despite of the individual or collective character of execution. These technologies are considered as pedagogical technologies of the 21st century. Because learning through them enables the formation of an individual, who won’t be lost in the circumstances of a rapidly changing society ([26], p. 58) and the design methodology combines “the best achievements of communicative and problem methods of foreign language teaching, creates optimal conditions for effective foreign-language communicative and cognitive activity of students” ([12], p. 4).

2. Experimental methods

The pedagogical experiment of the educational environment formation for foreign language training of future power engineers by means of design technology was carried out on the basis of a Separated Subdivision of the National University of Life and Environmental Sciences of Ukraine (SS NULES of

Ukraine) “Berezhany Agrotechnical Institute”. The study was conducted in the first semester of academic year 2018-2019. It was attended by two groups of undergraduates in the first year of speciality 141 “Electric power engineering, electrical engineering and electromechanics”. The research was conducted in the practical classes and extracurricular activities of students in the discipline “Business German”. The study of the topics of content modules was based on the use of design and ICT. Forms of evaluation of acquired knowledge were also project-oriented. Such actions are due to the need of creating an effective educational environment for intensive and deep study of metalanguage lasting one semester.

The experimental work consisted of 5 stages, in the process of which a number of methods of scientific research were used (analysis, synthesis, observation, survey, comparison, modeling, pedagogical experiment, methods of mathematical statistics). We offer a description of the stages of experimental research.

The first stage was theoretical. Its purpose was to study the state of foreign language training of energy students and to determine the conditions created in the SS NULES of Ukraine “Berezhany Agrotechnical Institute” for competent mastery of metalanguage. It is established that the process of professional training of future energy engineering students involves the study of a professional foreign oriented language of as a compulsory educational component.

The formation of practical foreign skills and ability in the metalanguage acquisition of future speciality ensures the study of the academic discipline “Business foreign language”, which includes 4 credits. Foreign competence, as the final result of the acquisition of foreign language curriculum, belongs to the general competences, which must be mastered by the students Master’s degree of the speciality 141 “Electric power engineering, electrical engineering and electromechanics” [31]. However, the foreign-language training of students is not limited to the program requirements, but extends beyond it. It should be noted that the influence of a foreign language is multifaceted and extends to the study of vocational subjects. Foreign-language elements are present in all fields of educational process of students’ preparation of speciality “Electric power engineering, electrical engineering and electromechanics”, in particular:

- international activity of SS NUBIP of Ukraine “Berezhany Agricultural Technical Institute” (cooperation with Vienna University of Natural Resources and Natural Sciences, the Wieselburg Research Centre for the Production and Use of renewable Energy, internships in Switzerland on the enterprises, which are automated by modern electrical equipment, short-term studies at Berne University of Applied Sciences according to Agrimpuls programme, meetings with foreign delegations, etc.);

- library collections (scientific and technical literature, professional journals, encyclopaedias and energy directories of foreign-language publishers);

- asubstantive content of disciplines of general and vocational training with a relevant information from the foreign sources;

- visual aids (information panels using foreign abbreviations, posters showing the technical characteristics of European energy facilities, catalogues of electrical equipment of international firms);

- material and technical infrastructure (modernized laboratory workplaces with modern electrotechnical and electromechanical equipment, electrical apparatuses of foreign manufacture) etc.

Foreign-language means, combined with ICT, project and interactive technologies, and practical methods, problem-based and inverted-learning techniques, make it possible to achieve the unity of all educational objectives: training, developmental practical, educational. Binary classes in foreign language and vocational training disciplines are favourable pedagogical condition for implementation of interdisciplinary integration of foreign and professional (vocational) knowledge of future energy engineering students. The creation of educational projects, writing the course papers and master’s degree works are accompanied by processing of foreign materials for the disclosure and substantiation of research topics with up-to-date information. Active participation in scientific and practical seminars, international conferences and energy forums is possible thanks to the ability of energy engineering students to use scientific and technical literature in a foreign language to prepare reports on subject of the study, the ability to present the results of scientific work in a foreign environment. Knowledge of

the metalanguage of the speciality expands the range of possibilities of practical training, allows an internship at power establishments abroad, thus, it contributes to the acquisition of European experience in the field of power engineering and to the assessment of the level of professional foreign knowledge.

Thus, a foreign language is an auxiliary mean of organizing and conducting lectures, practical and laboratory exercises by professors and a way of carrying out educational, scientific, research, industrial, cultural and educational work by students.

The basis for metalanguage acquisition is formed on the basis of the academic discipline “Foreign language in vocational training”, which is studied by the students of Bachelor’s degree at the first year of study. The postgraduate students learn “Business foreign language”, the subject of which is also vocational. These subjects are complementary and interdependent. Without knowledge of one subject, learning another one is problematic, but it is possible. Therefore, the metalanguage of the baccalaureate specialty is a peculiar tool for acquiring foreign skills and business communication skills in Master’s degree. There is a large gap between the two subjects, which has a significant impact on the gaining and acquisition of new foreign knowledge. Therefore, the second stage of the experimental work was diagnostic and evaluative. On-line testing was conducted to determine the level of formation of lexical and grammatical competencies of the students of Master degree. Test tasks are available at <https://onlinetestpad.co/ua/test92000-test-z-nimeckoi-movi>. According to the results of the test control it is established that the vocabulary in 76% of students is passive, practical skills are manual, grammatical material needs to be revised. The average level of residual knowledge is observed in 20% of postgraduate students. Only 4% of future energy engineering students are able to acquire a foreign language at a higher level. Such quantitative indicators indicate the need in leveling and improving the students’ knowledge.

The third stage of experimental work was based on the observation of the activity of undergraduates in practical classes, their productivity in all types of speech activity. On the basis of observation, the positive aspects of students' project work were established, in particular, increasing motivation in foreign language training, interest in performing professionally-oriented tasks. Also, the problems were found during the process of creating thematic projects by the future energy engineering students. These include: confusion in a foreign language information environment and passivity in teamwork due to the insufficient vocabulary, practical skills of foreign language proficiency. The main focus was on the use of design and information and communication technologies. These technologies are able to provide activation of processes: repetition, generalization, studying, acquisition, and systematization, application of foreign knowledge during practical lessons, and extracurricular work. To implement these processes effectively, teaching materials (<https://www.youtube.com/watch?v=QdpAJcuYX18>) was used in German with English subtitles. The video watching contributed to the training and improvement of listening and speaking skills. The ability to carry out the educational projects creatively, the ability to understand them by audio-visual tools and the presentation them to the audience are depended from the level of their skills formation.

Concerning the information above, a research hypothesis has been formulated: the educational environment for foreign language training of future energy engineering students will be effective if its molding tool is a project-based learning technology. This process based on the implementation of project activities by postgraduate students, it provides conditions for acquiring a range of personal competences: foreign, communicative, informational, professional, project, research. To confirm the correctness of the hypothesis at the fourth stage of research, a model of the educational environment for foreign language training of energy students was developed and a pedagogical experiment was conducted to test it.

The purpose of the pedagogical experiment was to determine the effectiveness of project the educational environment for foreign language training of future energy engineers by means of design technology. For conducting the pedagogical experiment two groups were created: experimental and control. Each group consists of 25 students. Undergraduates of the experimental group studied “Business German” according to the project methodology, students of the control group – according to traditional teaching methods: communicative, grammar-translation, audiolingual, situational. Although the process

of acquiring foreign language knowledge took place in different ways, the end result was aimed at achieving a single goal – mastering the metalanguage of the speciality, the formation of readiness to solve professional problems by means of a foreign language.

The disadvantage of the pedagogical experiment was the limited duration. This is due to the requirement programs, according to which “Business Foreign Language” is studied only one semester. Nevertheless, within the framework of the experiment it was possible to form foreign language project skills and skills of undergraduates, to develop a number of professionally oriented educational projects in a foreign language.

The final stage of the experimental work involved the implementation of control and evaluation measures. They allowed to reveal the level of formation of foreign language knowledge of future energy engineering students in the created educational environment by means of project technology. Using the comparison method, the data of the control and experimental groups were compared.

Based on the data obtained as a result of pedagogical research, we offer a description of the educational environment for foreign language training of future energy engineers.

3. Results

Project technology is chosen as a mean of creating an educational environment, and project activity is chosen as a way of carrying out the foreign language training. The position of the Roman M. Horbatiuk is taken as the basis, who approves that “project technologies are one of the most promising and effective innovative technologies, allowing to develop a wide range of competences in subjects of study” ([7], p. 35).

In addition to the researcher’s opinion, it should be noted that such competences in future energy engineering students are linguistic, lexical [10], phonetic, speech, pragmatic, sociocultural. They are components of foreign competence, which means the integral character of the individual, who possesses a complex of foreign language knowledge, practical skills and ability whose level of formation is determined by the ability to decide educational, social and professional tasks by means of a foreign language in all types of speech activity of a receptive and productive nature, as well as readiness to implement of professional mobility by means of a foreign language ([8], p. 274). The focus on project technologies is due to the following factors:

1) the orientation of pedagogical technology towards the personality of student, his/her natural abilities and interest in learning a foreign language, and his or her internal potential to carry out the defined tasks, both constructive and creative;

2) it is desirable to develop project skills necessary not only for the creation of foreign language product in the course of training, but also for the acquisition of practical project skills during the implementation of professional engineering duties in the future, for example the project of models of electrical or electromechanical equipment, etc. Project technologies bring together two processes: the development of knowledge, skills and abilities and their practical use in future professional activities. For project work as a form of solving foreign tasks by students and a variety of engineering activities as a way of performing professional duties in the energy industry, are characterized by common features:

- motivational and personal – interest, initiative, creativity and ingenuity in solving the problems;
- effective – individual, collective, work in pairs;
- organizational and executive – planning, implementation and presentation;
- resulting – project as a result of students’ educational work and a product of constructive activity of energy engineering students.

3) the autonomy of the training which is necessary for the students of Master degree, who study according to the individual plan in connection with employment. Project technologies offer students the freedom of educational activities, starting from the choice of research topic, information sources, the way of implementation and presentation of project work. There are no instructions for tasks of a project nature – and there are no clear limitations in their solution. During the implementation of the project, students are able to manage the learning process independently, which is characterized by self-regulation, reflectivity and consciousness, motivation, cooperation, use of convenient learning strategies

([41], pp. 94–97). This approach to the study of a foreign language is characterized by accessibility, autonomy, initiative, motivation, productivity and intensity, because it occurs through the students’ personal activities, taking into account individual interests, internal motives, level of foreign-language knowledge, etc.

3.1. Implementation of problem-based learning and developed projects

Taking into account the factors that were substantiated above and own experience the model of the educational environment for foreign language training of future energy engineering students is developed. In figure 1 shows its visual image.

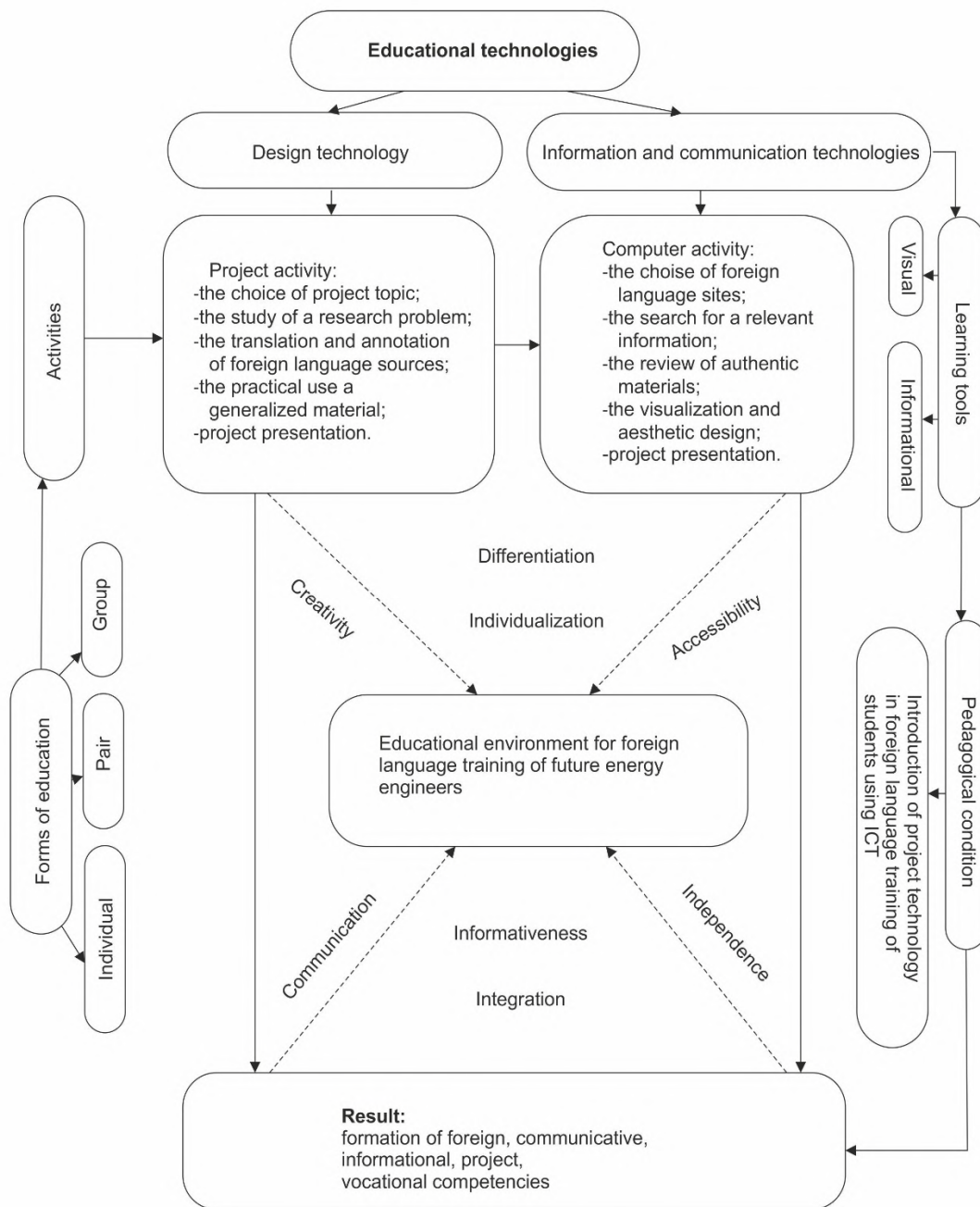


Figure 1. The educational environment model for foreign language training of future energy engineering students.

The definitional characteristics of the developed model are differentiation, individualization, accessibility, autonomy, integration, informativeness, communication, and creativity. Project and computer activities, individual work, work in pairs and groups on a thematic project; informational and visual teaching tools belong to the structural elements of the model. It is based on the pedagogical condition of implementation of project technology into the foreign-language training of students using ICT. These technologies provide for the substantive and linguistic integrated training of future energy engineering students: acquisition of general language and vocational knowledge. In our research, the informational and communication technologies are considered from the following points:

1) Moodle platform for mastering the program requirements of the discipline “Business German” (<https://www.nipbati.nubip.edu.ua/mod/page/view.php?id=11621>) and foreign language training by levels (<https://www.dw.com/de/deutsch-lernen/deutschkurse/s2068>, https://www.deutsch-lernen.com/virtual/e_test_kurz_leitung.php);

2) foreign professional sites (<https://www.absolventa.de/jobs//channelietechnik/ma/beruf>, <https://www.ernerbare-energien.de/EE/Navigation/DE/Home/home.html>);

3) electronic dictionaries (<https://www.duden.de/woerterbuch>, <https://www.linguee.de/>);

4) test tools (<https://www.goethe.de/spren//kup/tsd.html>, <https://www.sprcaf.fede/spracht-deutsch.htm>).

The above positions, selected taking into account the scientific approaches of researchers to the issues of communicative and integrated foreign language learning ([3], [5], [16], [18], [33]), the use of ICT ([2], [4], [11], [23], [28], [44], [45], [46]), e.g. Moodle ([1], [19], [20], [21], [22], [27], [29], [30], [35], [42]).

We offer a description of the project activities of energy engineering students of SS NULES of Ukraine “Berezhany Agrotechnical Institute” in the discipline “Business German” and a description of the developed projects in the metalanguage speciality 141 “Electric power engineering, electrical engineering and electromechanics”.

It should be noted, that the course and end result of the students’ project activity depends primarily on the ability to acquire the vocabulary practically and use it actively in non-standard tasks of vocational and communicative nature. Knowledge of foreign language is based on foreign language vocabulary. The vocabulary minimum of future energy engineering students is formed by commonly-used vocabulary, professionalism, technical terms and abbreviations of energy objects, electrical and electromechanical equipment, electrical apparatuses and appliances. From our own experience, learning foreign words is very problematic for energy students. According to the results of the survey, 66% of postgraduate students use the new words; 24% of students remember lexical units, associating them with the names of objects, phenomena, processes, etc., whose foreign meaning has already been learned; 10% of students learn vocabulary by adding them into phrases, sentences, mini-dialogues. This enrichment of students’ vocabulary is typical of the traditional methods of foreign language learning. The project technology expands the ability to form the vocabulary of future energy engineering students and allow not only add it with new words, but also update the learned lexical material in memory, repeat the passive vocabulary. During the search for the necessary information, independent work on foreign-language sources, students find additional lexical units, which are not the key to the project’s topics disclosure, but important for the general vocabulary. The presentation of the result of project activities allows activating the words that were learned in practice.

In order to test the effectiveness of the project technology as a means of forming lexical competence of future energy engineering students, the training project “Thematic mini-dictionary of technical terms” has been implemented in educational process of the technical terms. Masters of the control group were studying the foreign words according to traditional methods (translation, recitative-reproductive, productive-communicative exercises), and experimental – in the form of independent research work on authentic materials of scientific and technical nature.

The students’ task of the testing group was to learn the selected vocabulary, which is the key for the themes learning “Alternative energy sources”, “Energy saving technologies”. The postgraduate students

of experimental group were asked to work out the vocational articles independently, write the most commonly used technical terms, find their Ukrainian equivalents and sort them by subject.

You can find practical application of learned vocabulary in receptive and productive types of speech activity during the implementation of the thematic project “Energy saving technologies based on alternative sources”, which covered two stages: class and extracurricular work. The class work included the formation of three mini-projects based on the training material of the informative module “Professional activity of future energy engineering students”, which is the obligatory component of the subject “Business foreign language”. For activation of thematic thesaurus, practical skills of audition, speaking, reading, writing mini-projects on the theme has created: “Business card”, “At energy enterprise”, “Contract for purchase and sale of solar panels”. The work on the project ensured the interdisciplinary integration of students' vocational and foreign knowledge. We offer fragments of training projects, which were worked on by postgraduate students of “Electric power engineering, electrical engineering and electromechanics” speciality.

Mini-project “Business Card” (figure 2) was aimed at forming communicative abilities of students, vocational and business qualities, practical skills of conducting a meaningful, grammatically correct monologue with transition to spontaneous dialogue.

Mini-project “Business Card”

Objective: The aim is to teach foreign-language knowledge in practice and develop skills in group work.

Implementation condition: Check out the business card of the head of “Centre of Bioenergy”. Working in pairs, describe the energy specialist on the basis of the data specified in the business card. Create a personal business card, indicating surname, first name, position, place of work, address of the institution, contact details. Presenting yourself to future colleagues.



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Figure 2. Mini-project fragment “Business Card”.

The execution of the mini-project “At the Power factory” was carried out in two stages: 1) viewing of foreign-language material followed by communication (figure 3); 2) creating an interactive online presentation in Google Slide using the information presented on www.buergergergiebodensee.de (figure 4). The main objective of the first phase of the project was to develop foreign language video skills with full understanding and subsequent communication. The second phase of the project was carried out in compliance with the following requirements:

- learning the thematic headings and their distribution among the project participants for further justification;
- individual search of up-to-date information on foreign site;
- limitation of test content filling, focus on key concepts;

- preference for visual representation;
- presentation of the results of the work in a monological form with open discussion.

Step 1.

Mini-project “At the Energy Enterprise”

Objective: The aim is to teach to comprehend the foreign information and to increase its use in foreign communication situations.

Implementation condition: See video link:
<https://www.youtube.com/watch?v=TaIzGjoRzPo>

Take notes of what you hear. On the basis of the video, discuss the theme “Energy-saving technologies. Solar panels: types and range of applications”.

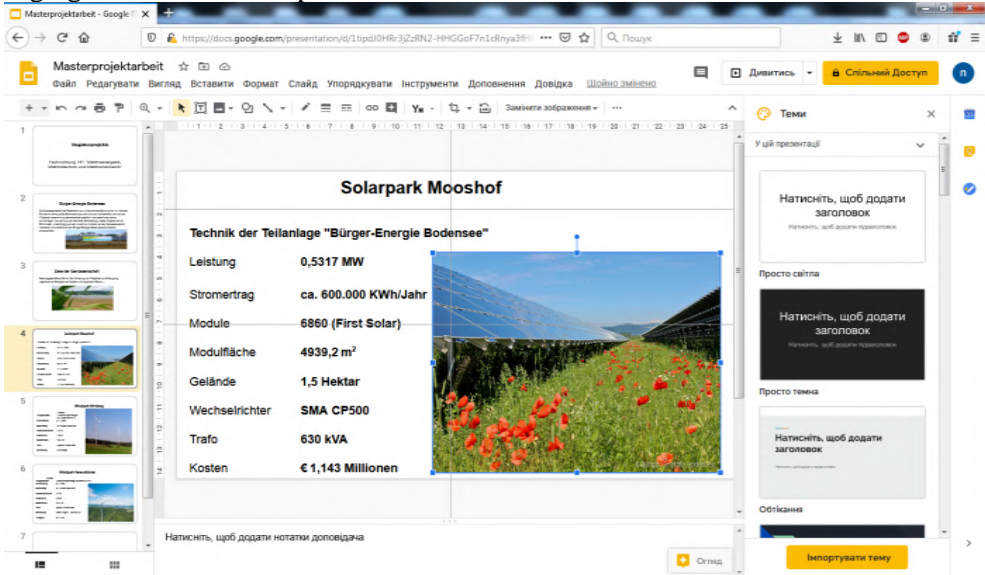
Figure 3. Mini-project fragment “At the energy enterprise”.

Step 2.

Mini-project “At the Energy Enterprise”

Objective: The aim is to develop the practical skills in working with authentic foreign material, to operate vocational vocabulary in a foreign communicative environment.

Implementation condition: create an online presentation using foreign sites, for example www.buergergiebodenseede and present it in front of the audience.



The screenshot shows a Google Slides presentation with the following technical specifications for the 'Bürger-Energie Bodensee' plant:

Technik der Teilanlage "Bürger-Energie Bodensee"	
Leistung	0,5317 MW
Stromertrag	ca. 600.000 kWh/Jahr
Module	6860 (First Solar)
Modulfläche	4939,2 m ²
Gelände	1,5 Hektar
Wechselrichter	SMA CP500
Trafo	630 kVA
Kosten	€ 1,143 Millionen

The slide also features a photograph of solar panels installed in a field with red poppies in the foreground.

Figure 4. Mini-project fragment “At the energy enterprise”.

Following the algorithm of the sequence of actions with the requirements consideration gave us the opportunity to determine the students’ skills to orientate in foreign informational environment, to extract the main material, the ability to reproduce a text, the level of formation of all types of speech activity of future energy engineering students, the readiness to conduct the spoken communication successfully on the basis of independently studied unadapted foreign materials without prior study, to discuss with classmates spontaneously, to express personal opinions easily. On the basis of the results of the presented projects in the form of monologues with transition to polylog, the postgraduate students evaluated their knowledge and practical skills independently, determined the level of proficiency in foreign language acquisition in the group, identified the drawbacks that needed to be eliminate in the foreign language training process.

The mini-project “Contract for purchase and sale of solar panels” was carried out with the aim of forming business documentation skills of future energy engineering students, writing skills (figure 5).

The students’ work in groups and work in pairs during the practical classes concerning the creation of the above-mentioned mini-projects ensured the formation of practical skills and abilities which are necessary for realization of individual project “Energy saving technologies on the basis of alternative sources” during the extracurricular work. The postgraduate students substantiated and disclosed the research topic in the training projects, the names of which are: “Energy saving technologies at enterprise”, “Energy saving technologies of individual and general consumption”, “Electric energy saving as a way of energy saving”, “Alternative energy sources” and others. The creation of individual projects and their presentation ensured the formation of foreign, communicative, informational, project and vocational competences of postgraduate students as integral components of professional competence of energy engineering students.

Mini-project “Contract for purchase and sale of solar panels”	
<i>Objective:</i> The aim is to teach students to orientate in a foreign text during the process of first reading and to find the necessary information, to develop reproductive and creative abilities.	
<i>Implementation condition:</i>	
1. Read the agreement.	
Agreement of sale	
We are the persons, who the signed below,	
On the one hand, the head of the Bürger-Energie Bodensee eG company Andreas Klatt, whose name is “Supplier”, and on the other hand the head of the company “Ökoenergie” – Victor Kondratenko, whose name is “Receiver” concluded a contract for the purchase and sale of solar panels. The supplier will undertake to deliver the delivery after he receives the money. After the receiver gets the account, he has to pay for the goods ordered in three days.	
Date of signature	Date of signature
Signature	Signature
Andreas Klatt	Victor Kondratenko
2. Make your own agreement text yourself, pay attention to the model.	

Figure 5. Fragment of the mini-project “Contract for purchase and sale of solar panels”.

3.2. The effectiveness of the proposed approach

Checking the feasibility and effectiveness of the use of design technology in foreign language training of future energy engineers were control measures.

To determine the level of proficiency in lexical and speech competences as a part of foreign competence such diagnostic forms were used: word dictation that required not only the translation of learned words, but also the words writing which are associated with the theme and their introduction to the phrase. Monologue and dialogue speech was conducted according to the project theme. Based on the checking results of written works and the control of oral speech, it is determined that the level of thematic vocabulary learning and its practical application in communication among the students of the experimental group is higher than in the postgraduate students of the testing group (table 1 and 2).

Table 1. Formation levels of lexical competence of future engineers.

Category of groups	Number of future engineers (N)	Levels of formation					
		High		Medium		Low	
		N	%	N	%	N	%
Control group	25	6	24	12	48	7	28
Experimental group	25	8	32	14	56	3	12

The data presented in the tables show that in the conditions of the innovation environment, foreign

language training of future energy engineers was successful.

Table 2. Levels of formation of speech competence of future engineers.

Category of groups	Number of future engineers (N)	Levels of formation					
		High		Medium		Low	
		N	%	N	%	N	%
Control group	25	4	16	12	48	9	36
Experimental group	25	7	28	14	56	4	16

Due to the introduction of the developed model in the educational process in the levels of lexical and speech competence of future energy engineers there were positive changes due to the use of project and information and communication technologies. The technology data provided motivation to learn a foreign language, independent work, access to relevant information sources, individualization and differentiation of project tasks, formation of personal and professional qualities and a range of basic competencies. In particular, the number of future energy engineers with a high level of command of foreign language vocabulary increased from 24% to 32%. The number of undergraduates with an average level of knowledge of foreign words increased from 48% to 56%. There is a decrease in the number of students with a low level of vocabulary from 7% to 3%. 28% of future energy engineers are able to perform foreign language professionally-oriented communication at a high level. At the average level, 56% of students can speak a foreign language. Low level of oral speech is typical for 16%. Compared with the control group, the number of undergraduates with a high level of speech competence increased by 12%, with a medium level – 8%, with a low level – 5%.

The results of the pedagogical experiment prove the effectiveness of the created educational environment for studying the metalanguage of the speciality. Additionally, the skills acquired by undergraduates in the process of foreign language training were revealed. The level of their formation is determined on the basis of objective self-assessment of students (Table 3).

Table 3. Quantitative indicators of self-assessment of formed skills in the process of foreign language training.

Competence	“My Success” Questionnaire					
	Project learning technology			Traditional teaching methods		
	High level	Medium level	Low level	High level	Medium level	Low level
Free to navigate in a foreign language information space	64 %	32 %	4 %	44 %	48 %	8 %
Work independently with foreign electronic resources	64 %	32 %	4 %	44 %	48 %	8 %
Understand authentic professional materials	56 %	36 %	8 %	36 %	48 %	16 %
Annotate the content of foreign language professional texts	56 %	36 %	8 %	36 %	48 %	16 %
Practically use the obtained information	56 %	36 %	8 %	36 %	48 %	16 %
Perform non-standard tasks	72 %	20 %	8 %	28 %	44 %	28 %
Think creatively	64 %	24 %	12 %	56 %	36 %	8 %
Communicate spontaneously without prior preparation	28 %	56 %	16 %	16 %	48 %	36 %

The data presented in the table show that project technology provides a higher level of practical skills of undergraduates compared to traditional methods of teaching a foreign language, which are necessary

to master foreign language, communication, information, design, professional competencies of students.

4. Conclusions

According to the results of experimental work, it has been established that for the successful acquisition of foreign language knowledge, a special educational environment should be functioned. This need is caused by the following factors: the specifics of a foreign language as a discipline; features of theoretical mastering and practical application of foreign language knowledge; priority position of “Business Foreign Language” among professionally-oriented subjects; personal potential of energy students. The pedagogical experiment in studying the “Business German”, which was based on the use of project technology in combination with information and communication technologies, gave the positive results. In particular, the number of future energy engineering students who are able to actively operate with vocabulary and skillfully use lexical items, depending on the context, increased to 16%. The number of undergraduates who can communicate using foreign language for a professionally oriented topic in non-standard and unpredictable communicative situations has increased to 20%. Thematic projects which were presented by undergraduates to the audience: “Business card”, “At the energy company”, “Contract for purchase and sale of solar panels”, “Energy-saving technologies in production”, “Energy-saving technologies for individual and general consumption”, “Energy saving as a way of energy”, “Alternative energy sources”, testify to the positive dynamics in foreign language training of future energy engineering students and the correct choice of design technology for learning a foreign language. During the project activity, the level of foreign language acquisition competence of undergraduates significantly increased, skills of independent work with authentic foreign language information were formed, the ability to operate it practically in receptive and productive types of speech activity was intensified.

The research hypothesis is confirmed and the efficiency of the developed model of formation of the educational environment for foreign language training of future energy engineering students by means of project technology is proved. The developed educational environment by means of project technology allows: to reveal and comprehensively develop language abilities, communicative abilities and skills of each applicant of higher education in speciality 141 “Electric power engineering, electrical engineering and electromechanics”; to intensify the educational and cognitive activities of students and expand their motivational sphere; to provide differentiation and individualization of acquisition of foreign language knowledge.

Without taking into account the processes above and the use of active learning technologies, achieving positive results in foreign language training is problematic.

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Application of ICT tools in teaching American English for computer science students in the context of global challenges

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Abstract. The article deals with the urgent issue of American English learning for IT-professionals under challenging conditions of the changeable economic situation in the world. Some statistical data on global education trends and its analysis are given to confirm the topicality of the problem. State-of-the-art trends in foreign language teaching in the context of global challenges are presented. It is stated that informal education environments, distant learning platforms, virtual reality environments, artificial intelligence applications and collaboration platforms are to be mastered by Ukrainian undergraduates. Certain peculiarities of choosing and studying British and American English course by students of IT-specialities at three Ukrainian universities are given: the course choice procedure, the reasons for course preference, and the syllabus content. The best technologies, applications and tools for classroom activities and independent learning are substantiated, specific examples of their application for British and American English course learning are presented. The transferability of the skills inculcated in the course participants through implementation of the certain tools is founded.

1. Introduction

The interdependency of global changes and education advance has always been the reason for scientific, social and economic progression: educational level of population ensures its citizen awareness and determination; on the other hand, shifts in collective consciousness caused by any wide-ranging triggers (both positive and negative events) influence education vectors and methods. Nowadays, namely this congruence globally determines the headway in most public spheres.

In Ukraine which had the reputation of a rather conservative country in the field of teaching and training, education (and higher education specifically) had had a stable paradigm of its functioning for decades. Nowadays, dramatic changes have been introduced in accordance with European tendencies of the student-oriented approach, the choice of a student training trajectory, skill transferability and the lifelong learning concept. The Osvita Nova educational portal presents the most relevant concepts which have come to the fore due to current social challenges.

The key concept is lifelong learning since “speed and diversity of changes increase” [2]. The other important notions included into the list are the equal access to learning for everyone, personalization



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of the learning process, dissolution of the border between learning and work, appearance of new educational environments.

The National Institute of Strategic Research [12] emphasizes development of the lifelong learning system along with further export capacity building of Ukrainian higher education as crucial factors of obtaining economic outcomes and accelerating education modernization and empowerment of the positive image of the country globally.

According to the Organisation for Economic Cooperation and Development [22] to develop individuals as persons, citizens and professionals is the ultimate goal of education in order to continue to deliver on its mission. That is why education itself must continuously evolve on the ground of economic, social and technology changes. This “requires the reorganization of formal and informal learning environments, and reimagining education content and delivery”. The mentioned above concept correlates both with compulsory education and lifelong learning.

Tom Vander Ark in [3] has considered trends in education in terms of aims, strategies, measures and supports. The author has outlined four mega trends, four emerging trends and four adjacent trends impacting education. The mega trends include new goals, active learning, competency and integrated services. The emerging trends list interrelated items are: contribution, immersive learning, success skills, and thoughtful guidance. The adjacent trends comprise inclusion and equity, lifelong learning, quantified life and mindfulness.

Lynda Gratton and Andrew Scott, professors at the London Business School, insist that the traditional model of education (education-work-retirement) has not been relevant, and the multistage model consisting of education, exploration, transition, employment in an organization, self-employment, portfolio in the sense of mixing paid and unpaid work, and retirement is to be more applicable [10]. The stages in the multistage model can be carried in different orders; they can overlap and be repeated.

The Valamis consumer-grade learning platform designed to provide digitalization of learning outlines numerous long-term benefits of lifelong learning for adults: renewed self-motivation, recognition of personal interests and goals, improvement in other personal and professional skills, and improved self-confidence [37]. The listed above benefits include only those connected to personal learner advantages without taking into account business, industrial and even national and international aspects.

The Government Office for Science, UK provides the list of possible returns of lifelong learning concerning individuals, employers and society [9]: benefits to the individual (increases in incomes, career promotion, physical and mental health and independence, etc.); benefits to the employer (performance of higher-level tasks, increasing productivity, acquiring occupational- or sectoral-specific new skills); health benefits (improvements in life satisfaction, slowing cognitive decline); welfare and exchequer benefits; social and civic benefits (reducing racism, and increasing civic participation and voting, greater participation in sport).

In their turn, businesses and organizations are to encourage their employees who “(1) anticipate learning requirements, by, for instance, identifying areas for future job requirements and implications for needed skill updates, (2) set development goals that reflect needed knowledge and skill structures, (3) participate in learning activities, (4) ask for feedback to test goal relevance, and (5) track progress” [17] to make it possible to continue their learning.

In spite of the overall tendency of the last decade to prolong seniors’ professional engagement, the implementation of lifelong learning is not uniform across the countries of the world. As Anja P. Jakobi stated in 2012 the implementation was based on similar principles and values “without sufficiently taking into account the specifics of the national context” [13]. The current trend in lifelong learning in some countries is replacing of integrated approaches with disintegrated ones “focusing on certain life phases, modalities of learning and topics”, while other countries develop lifelong learning systems which integrate all levels of education, ages and learning modalities [35]. The advantage of the disintegrated approach has been explained by Mohanbir Sawhney on the example of IT-specialist training. He proposes to organize lifelong learning using “learning objects” instead of courses. These

learning modules can be sequenced and combined, the range of modules for every student can be chosen by the AI-algorithm according to their learning objectives [24].

TeachThought (a brand dedicated to innovation in education) has made an attempt to determine the most popular trends in education [33]. To identify them the organization has applied four objective aspects and one subjective one. The objective aspects have been popular search engine data, TeachThought search data, traffic and search trends within and across popular education websites, and social media metrics. The subjective aspect of identification has been TeachThought editorial impression. As a result of the research the list of 30 most popular education trends has been obtained with growth mindset, maker learning, Bloom's taxonomy, digital citizenship/literacy and personalized learning as the top-5 trends with the highest scores.

Brain-based learning, adaptive learning algorithms [23], game-based learning [34] and mobile learning [14] are surprisingly found at the bottom of the list. Rustam Shadiey, Taoying Liu and Wu-Yuin Hwang [13] also reveal in their research that in the field of task-based learning and communicative language teaching (pedagogical approaches) mobile-assisted language learning (MALL) is nowadays of great demand especially in terms of language learning and cognitive load (as to affordances of authentic environments). For instance, there has been a significant switch from desktop learning to mobile learning within ICT application in undergraduate training due to recent overcoming lags in technology in Ukraine (introduction of 3G and 4G, tablet and smartphone availability to young users) [19]. On the other hand, ICT literacy of Ukrainian educators has been increased and resulted in their abilities to create and operate mobile versions of websites, distant courses and applications [15].

2. State-of-the-art trends in foreign language teaching in the context of global challenges

Language teaching is nowadays exposed to challenges on the part of global educational trends of switching to ICT on a large scale; on the other hand, it is impossible to ensure training live communication and spontaneity in verbal reaction without taking into consideration the human factor (like confused articulation, humour, sarcasm, the set of language varieties which is native to certain territory, for instance, American English). As the result, two prospects have occurred: 1) developing software and 2) tools for exclusively teaching languages and accommodating the available ICT projects for teaching foreign languages. In practice, adapting the cutting edge technology and tools has been quite resulting globally: in their study, Ruofei Zhang and Di Zou [40] emphasize the benefits of the state-of-the-art technologies integrated into various aspects of language teaching and learning through "promoting practices, delivering instructional content, facilitating interactions, and restructuring teaching approaches". The specifically designed tools are of great assistance for foreign language teachers, they ensure student pronunciation correctness, unprejudiced assessment and language learner motivation increase. Nevertheless, high-priced ICT achievements are rarely affordable for public educational establishments. Oleg Tarnopolsky, Nataliia Volkova and Svitlana Kozhushko [32] accentuate the lack of adequate modern equipment (such as computer laboratories specifically designed for language teaching) in Ukrainian non-linguistic higher schools. Especially for this reason only free and the most efficient ICT products are implemented into foreign language courses at Ukrainian universities: they are previously scrutinized by language instructors, then implemented into learning programs as a minor part of experimental activities with study groups and after the necessary volume and timing modification of application prospects are introduced to students as a compulsory course aspect.

The future and implementation prospects of the mentioned above educational trends are still uncertain because modern large-scale challenges like the Covid-19 pandemic demand lots from professionals all over the world, but in the first line flexibility is wanted ([11], [26]). In crisis situations education is one of the most well-founded spheres, since teachers are predictably loyal to their students and persistent enough to educate under most unusual circumstances. Teaching and managing staff is the most valuable asset, the source of sensible crisis solutions and unexpected ideas. With reference to what has been noted above the survey among the training staff of Dmytro Motorny

Tavria State Agrotechnological University, Bogdan Khmelnytsky Melitopol State Pedagogical University and Classic Private University has been conducted. 50 teachers who educate future computer science specialists have been asked about the most influential educational concepts of the next decade for Ukrainian universities.

The opinion poll has revealed that to majoring in ICT students the inevitability of inculcation in their educational background the following concepts for their competitiveness (ranging from the crucial to important) should be explained:

- 1) lifelong learning (competitive capacity, knowledge update ability, transferable skills);
- 2) collaboration ability (professional adaptability, fast forming new skills, extensive professional engagement);
- 3) personal adaptability (communication competence, multiculturalism);
- 4) academic globalization receptiveness (exchange programs and academic grant application);
- 5) professional globalization receptiveness (claiming to job overseas, freelance working for international employers);
- 6) intellectual flexibility (broad mental outlook, progressiveness);
- 7) personal globalization receptiveness (tolerance, ethical and sustainable thinking).

Within English courses a collaboration ability, intellectual flexibility, personal adaptability and globalization receptiveness are developed since they underlie both the communicative approach and educational resources of prominent publishers whose English and Business English coursebooks (and sets with video and resource bank materials, with links to interactive tasks and mobile course duplicates) are used to teach future IT-specialists. Lifelong learning concept is, on the contrary, new to most undergraduates and needs to be introduced through appropriate resource usage and appealing toolkits.

In order to inculcate the mentioned above key concepts in Ukrainian undergraduates within the university study they should be undoubtedly engaged in mastering the following learning resources:

- 1) informal educational environments (like communicating with course participants and instructors via social networks, messengers and chatbots, using cloud-based video conferencing services for distant communication);
- 2) distant learning platforms (like Moodle, Canvas LMS or LearnDash used by both universities and corporate professional coaching for training and controlling student educational activity);
- 3) virtual reality environments (like Mondly, Jigspace VR, Samsung VR);
- 4) artificial intelligence applications (like ELSA (the English language proficiency app), Socratic by Google, Glossika);
- 5) collaboration platforms (Confluence, Podio, Common Data Environment, Unified Communications, GoSoapBox, Ryver) and more sophisticated project management tools (Bitrix24, Planfix Worksection).

Foreign language knowledge and competence are of the utmost importance for successful careers of specialists in different fields ([4], [20], [29], [31]). Lifelong learning is crucial in language acquisition since languages change and evolve enormously [30]. English has expanded as a global language and at the same time it has undergone the great influence of American culture and as the result American English is nowadays as much demanded by learners as British English. Verbal communication principles, intercultural communication etiquette and netiquette rules have been exposed to the focus shift from averaged depersonalized behaviour to personal space, needs and choices. Therefore it is important to teach students not only to make the most of ICT tools for actual communication [16], but to familiarize them with strategies of independent learning, to improve their command of language themselves, to adapt their skills for changing professional environment and rising labour market demands, to employ wide application ICT tools for a specific goal.

Supporting the concept of person-oriented and student-oriented approaches to training undergraduates at Dmytro Motornyi Tavria State Agrotechnological University, Bogdan Khmelnytsky Melitopol State Pedagogical University and Classic Private University, the teachers of the department of foreign languages have developed for future computer science specialists a range of thematic study

groups, which could be chosen by students to be implemented into extra curricula activities in the academic year 2019-2020. All the topics are relevant for students whose aim is enhancing their English proficiency and who are determined to collaborate on international projects in the nearest future. The results of student choice (at the first stage two most demanded leads of study were selected, among them the one was opted for in the second stage of the survey) are represented in figure 1.

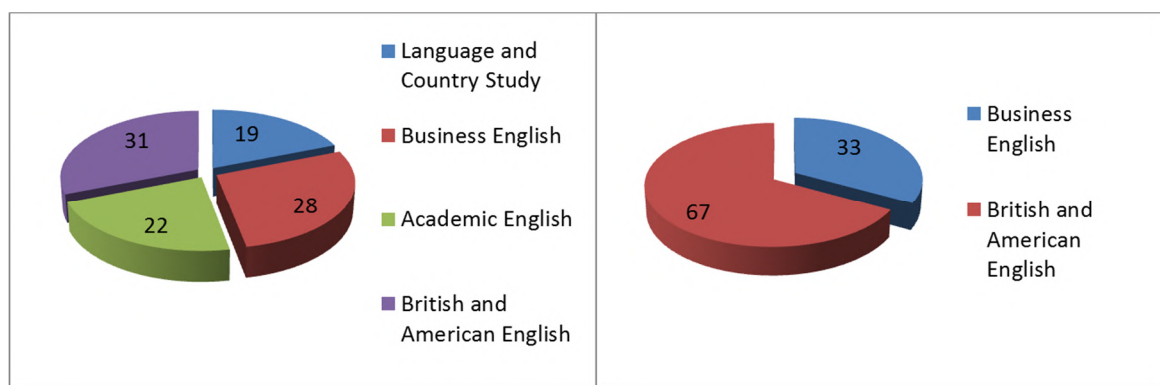


Figure1. Results of student choice

85 students participated in the survey and their reasons for choosing or rejecting the study groups are the following:

1) Language and country study – most students referred to the current ESP and general English courses, present in their curriculum and considered the knowledge gained within the courses sufficient for their current academic study and prospective professional situation.

2) Business English – the students expect having this discipline to be included into their Master course curricula, and nowadays they already have basic skills in Business communication – writing a CV, an application letter and an inquiry letter.

3) Academic English – the students, deeply interested in scientific researches and further study have already been active participants of study groups which goal is maintaining and enhancing undergraduate academic proficiency and are managed by their regular teachers, providing them with assistance in reporting and presenting, narrative writing, supervising them writing theses, and applying for study and internship abroad.

4) British and American English – the aspects of differentiation between two languages have not at once been perceived by the majority of the surveyed students as important or beneficial for their personal and professional development. Still, the students having professional experience in collaborating with foreign employers have noted the prevalence of American English in verbal and especially written communication. These students have convinced their groupmates of advantage of an ability to correspond in American English and to produce American English content for the websites they could possibly create and administrate.

The necessity of being proficient in American English is also founded by the tempo of its expansion combined with globalization tendency. It is stated, that estimating the speed at which Americanisms have been assimilated in British English, by 2120 American English will have absorbed the British version entirely [1]. It has recently been the mass media, tourism and sales spheres that have demonstrated the massive usage of double forms – for example, the ESP textbooks have purposefully introduced both lexemes in American and in British English for the same concept or action. Nowadays, it is difficult to highlight the spheres not influenced by American English. As to IT-sphere, the USA has been the leader in its development for years. The country has still maintained this position: American products and services are in good request around the world, the giant IT-companies are concentrated in its territory, and main IT-startups are originated. The demand for

experienced and highly-qualified computer specialists in the USA is being increased nowadays; moreover, there is a lack of IT-specialists in the country. Thus, there are apparent opportunities for individuals with good professional and communication skills from all over the world to be employed.

Therefore, it is sensible to teach undergraduates, who are oriented for international cooperation abroad or within Ukraine American English in spite of minor academic load of the 'Foreign language' discipline in the curricula. The solution to provide a study group on American English chosen by students this year is going to be carefully considered and in case of successful training and increased motivation a selective discipline 'American English' is going to be offered for students' opting for the academic year 2020-2021.

The current study group syllabus includes the following aspects:

1) differences in vocabulary between American and British English (*elevator / lift, railroad / railway*);

2) grammar topics: affixation – *advisor / adviser*; irregular verb forms – the verb *to get* has past participle form *gotten* in American English and past participle form *got* in British English; tense usage – *I just wrote* vs. *I have just written*; word order – *Hudson River* (AE) vs. *River Thames* (BE); the usage of prepositions – *live on a street / live in a street, chat with / chat to*; data indicating: *the year begins January 1st. / the year begins on January 1st., March the Fourteenth, 2021* (AE) / *the Fourteenth of March, 2021* (BE); *Monday, September 6, 2020 / Monday the 6th of September, 2020*; simplified grammar constructions in American English – *Do you have a pencil?* (in AE) *Have you (got) a pencil?* (in BE);

3) spelling – *organize / organise, center / centre, color / colour*;

4) pronunciation, accents and intonation: differences in stress in such words as advertisement, brochure; differences in pronouncing words ending in -ile like mobile, hostile; some letters are pronounced differently – 'a' in such commonly used words as class, chance, ask, after, can't, example or 'r' in the words hard, were, pure, more, the letter 'i' in the -ization ending in words like organization, authorization, globalization and many others. Moreover, the letter 't' in the middle of a word (better, writing, bottom, native, artificial, notice) can be pronounced in American English like a fast sound 'd'.

The British intonation tendency is to use high falling intonation, hitting the main stress high and then dropping down. In American English rising tones are more common. A speaker usually goes up from the main stress demonstrating the rising intonation on statements.

All of the mentioned above aspects are to be introduced to students using the most effective techniques and tools, successive rigorous training is demanded and various control forms are to be applied in order to exclude the possibility of students' confusion between forms and rules of British and American English. This is the obvious reason for creating a learning environment providing both training and controlling resources.

3. ICT application for development of American English language skills of computer science students

According to the aspect (vocabulary, spelling etc.) it is important to select the most appropriate tool both for class activities and independent learning. It is essential to take into account personal demands and individual language proficiency in order to create suitable course average with relation to and prospect of each participant proactive involvement. The chosen tool should be captivating and improvable in accordance with education and information technology advance in order to ensure that students will not quit as soon as they do the entire study group course but will gain strategies and skills for lifelong self-development.

The example of such a tool is the Moodle open source platform widely used at universities all over the world [18]. It was launched in 2001 and since then has been developed: more than 1700 plugins are offered for downloading and maintained, new capabilities, controls and integrations have been added, improvements and support enhanced, communication and collaboration options as well as privacy settings modified [21]. Moodle is the most productive tool for training and successive control

of spelling, word-building, word order and vocabulary usage skills [36]. Moreover, it is going to expand, since it becomes gradually more learner oriented and offers focus on vertical and horizontal interaction within any educational process and collaborative construction of content, and it is in continual evolution.

The most productive instruments for developing verbal communication skills and training such aspects as pronunciation, intonation and word order in spontaneous speech are virtual reality applications. They provide individual approach, self-determined tempo of progressing within an opted course and they also support comfortable virtual environment formed by situation, scenery and interlocutor on your choice [31]. The innovative Virtual Reality application Mondly [25] offers its users American English as one of 30 available languages. The American English course is equally meticulously designed as British English and is as captivating.

Mondly is the application using augmented reality with the chatbot technology and speech recognition. Mondly comprises listening, reading, writing and speaking activities providing verbal communication with virtual characters on the given topic in real-life situations and giving feedback on their pronunciation. The study group participants from Dmytro Motornyi Tavria State Agrotechnological University cooperated with computer science students from Bogdan Khmelnytsky Melitopol State Pedagogical University using the facilities of the informatics and cybernetics department. At the Pedagogical University computer science students hosted their colleagues at the virtual laboratory where they shared their impressions on differences in American and British English presented in Mondly and trained their ability to distinguish between accents. The study group participants noted the colourfulness and vividness of the virtual environment. They are provided by the characters who are young adults with corresponding national and geographical background which is relevant for improving command of American English. The study group participants have also appreciated the conversational chatbot replying with a human voice. The instructors have noted the specified motivating students to self-reliant error correction. In case of the incorrect pronunciation or spelling a student is politely asked to correct the mistake without pointing it out. The skills of confident VR use are crucial for IT-professionals in the 21 century [27], therefore presenting well-founded analysis of VR environment abilities and faults should be trained in university study.

The prospective way for a teacher to most congenially be included into the communication process which is habitual for students is to create groups in social networks. The attractiveness of social networks for young adults as personal communication means is nowadays transformed into the professional related communication tool. This statement is confirmed by including different types of accounts/profiles on social networks and in messengers into cloud based managing systems. Social networks are effective means of fostering communication for professionals, including foreign language learners, as they bring together people of different ages and social backgrounds located in different parts of the world, but united by common motives and interests (mastering a foreign language or improving their professional level). Students, as members of virtual communities, have access to a wide range of resources and distribute self-created materials. Interaction and communication within virtual communities help students develop all the necessary communication skills (reading, speaking, listening, writing) and professional skills, because community members use knowledge and participate in the formation of new knowledge and new products. Successful functioning of virtual communities requires a modern content, a constant increase of interest and motivation of participants, and their active interaction. On the other hand, English speaking social network communities always reflect the most innovative language trends, use loan words, and introduce abbreviations and professional expressions which often confuse Ukrainian undergraduates and need to be studied.

Some of the social networks preferred by Ukrainian students are Facebook and Instagram. Within next decades their necessity tends to grow, since face to face socialization (both personal and professional) has receded in the 21 century because of the global communication principle alteration. Facebook allows its members to look through numerous pages, share audio, video, and text information with other members, participate in industry-related groups. To provide opportunities for communication with IT-professionals and software engineering professionals about their academic

issues and work routine in English we have created a “Communication for IT Specialists & Software Engineers” group on Facebook. Some interesting news about the industry, videos, infographic are posted, different surveys and polls are organized, problematic questions requiring helpful tips are put (figure 2). The mentioned above positive aspects of participating in the Facebook group are reinforced by American English speakers who can be appealed to via Facebook with questions on linguistics (most students inquire about IT abbreviations and slang lexemes), on country study, on current events and professional issues.

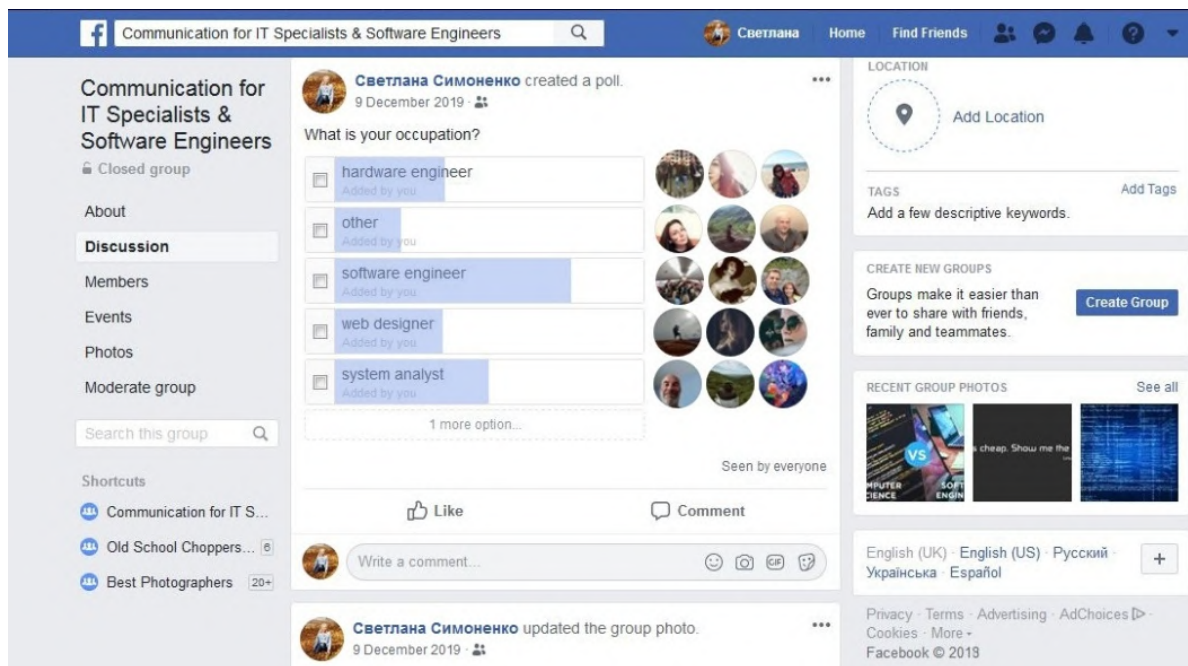


Figure 2. Example of the survey in the Facebook group

Artificial intelligence implementation is one of the most prospective trends in foreign language learning [38]. Self-study applications achieve popularity because of learner-tailored proficiency level and tasks promised by their designers. Glossika [7] is the AI-guided language study application. AI within this technology helps the user to estimate their own proficiency level and to focus on building basic ‘fluency’ which means manipulating sentence structures learned through listening, reading and typing ready-made phrases. The benefits of Glossika are tailored learning material, choosing the material volume and pace, the access from both desktops or smartphones. Using the application reveals that Glossika is intended for individual self-learning and paired with traditional learning methods (like collaboration in a class and the communicative approach) can ensure a fast foreign language vocabulary increase.

The ELSA application has been introduced as a Personal Virtual Pronunciation Coach, it uses the AI speech recognition technology ranked third in the Top 5 artificial intelligence apps of 2019 composed by the influential Analytics Insight platform [6]. ELSA is positively assessed by more than 6 mln learners eager to improve their American English accent. The application offers 1,600 lessons covering all English sounds and over 40 topics aiming at helping to gain proficiency in American English language pronunciation and presents user advancement reports. The learning progress in real-time is accessible from the organization dashboard.

Extra curricula activities can also be organised for a study group with focus on individual attention towards needs and preferences of every participant. A cloud based suite of communication, social collaboration and management tools for a team of business people or individual workgroups aimed at

a particular project, including CRM, file sharing, project management, calendars, and more can be equally applicable for student groups.

One of the most demanded collaboration platforms is Google Suite for Education [8]: it includes an expansive suite of tools and apps which let teachers collaborate one-on-one with a student or instruct the whole class. G suite allows to create classes with Google Classroom, co-edit documents and presentations within Google Docs and Google Slides, distribute assignments and send feedback in real time [5]. As a suite part, Google Meet enables for online learning and teaching with video capabilities supporting virtual classrooms and meetings. Its rivals in educational sphere are Zoom (a video-conferencing product) and GoSoapBox (a web-based classroom response system), created at the beginning of the 2010's but both having their raising due to Covid-19 lockdowns.

The examples of more complex project and activity managing services are Bitrix24, Planfix and Ukrainian Worksection service which operate under the similar principle of task division and control having been typical for most professional structures for decades. Still, taking into consideration changes in fair employment practices law, communication rules modification and novelties in Business etiquette, Worksection [39] is a system of accounting and control of project management which systemizes the data about tasks and time frames along with discussions and provides a complete suite of communication, social collaboration and management tools including file sharing, project management and more. It is sought-after by entrepreneurs and IT sphere CEOs, but this system is also applicable to learning facilitating. In the Worksection application a language instructor can split the affairs into projects, tasks and subtasks, it is easy to create timelines and define priorities. Through prioritizing and deadline setting for the study group members American English vocabulary is learned simultaneously with spelling rules, which is the most effective strategy, the grammar content is split into units and proficiency levels linked to the B1 / B2 / C1 level verbal communication tasks, and American English pronunciation is trained in selected pairs and mini-groups that coordinate their training timing on their own directly through Worksection facilities. The learning pace of each subtask is person-oriented and the time amounts for every task performed are recorded and can be corrected accordingly to the group average. Tasks and sub-tasks contain statuses, terms, priorities, tags, files and a communication panel where 12 different correspondence reactions are provided to save executives' time. The calendar and Gantt chart are of great assistance for planning through visual control.

Cloud based suites are indispensable in organising creative activities and involving individual participants in creative competitions, writing and essay contests, calls for papers etc. Writing in American English, composing short stories and making up lines for dialogues using American English vocabulary can be examples of creative tasks for the mentioned above study groups and appealing to each student individually.

Managing and supervising the study group member activities and submitted by them documents and papers is time effective and beneficial: undergraduates get used to operate cloud based services and to correctly communicate within while being students, not employees. The mentioned above services are also prospective in the view of lifelong learning because managing professional and personal activities (both group and individual projects) is highly demanded assistance and one of preconditions for highly qualified specialist accuracy.

Study group participants have been given a task to present a SWOT analysis of the Worksection services wide-ranging implementation into the educational process (table 1).

The results have demonstrated numerous prospects and appreciation of motivated students but also have reflected their concern about teachers' unwillingness to get involved into learning how to manage this management tool as an educational means and about unmotivated student failure.

Most of the analysed above ICT tools are applicable to all academic disciplines. ELSA and VR Mondly applications are the most preferred tools highly estimated by study group participants for their unusualness and direct accordance with the student learning goal – to master American English. Nevertheless, all the items (Worksection, Google Meet, Moodle, and social network options) have been appreciated for their English interface and facilities: on the one hand, the students have enhanced their American English communication skills and have improved definite foreign language aspects, on

the other hand, the undergraduates have developed their profession-related skills of applying ICT tools in their future employment.

Table 1. SWOT analysis of Worksection implementation into the educational process.

<p>Strengths Appeal Unusualness Effectiveness Collaboration encouragement Communication enhancing</p>	<p>Weaknesses Account and role setting inflexibility High level complexity for average users Demand for intense concentration and accuracy (especially from administrators)</p>
<p>Opportunities Involving large number of participants with various educational background Shifting a part of educational assignments into the Worksection service Developing separate projects for specific academic spheres</p>	<p>Threats Time consuming setting and routine administrating Unmotivated students' disregard ruining planned activities of the whole group Price rising</p>

The skills inculcated in the students and participants of the study group within training operating and using Mondly, Moodle, AI, Worksection and social networks with English and American English interface are transferable and will definitely be of great value in the future when more sophisticated and advanced derivatives of the learning environments, communication tools and management platforms occur. The lifelong and collaboration concepts will underlie every new ability of the young people who are currently capable to master the broad spectrum of the mentioned above ICT applications and training tools.

4. Conclusions

Education development trends are nowadays important for every specialist in order to match the rising labour market requirements, but it is urgent for IT-professionals (whose skill and competence half-life continually shortens), especially for the ones determined to collaborate internationally. Since most employees need periodic or even urgent retraining in response to global economic, environmental and social changes, reskilling and upskilling postgraduate holders should demonstrate the independent learning habit which must be fostered in undergraduates within curricula or study groups. ICT tools for learning English like online courses, AI, virtual reality applications, systems of project management control and social network facilities are popular with students since using them provides the individual approach, a self-determined pace and combines foreign language acquisition and mastering software application facilities and settings, both applicable in IT-professionals future employment. The use of the mentioned above technologies and tools for study and further on for work ensures forming transferrable skills underlying for the life ability to withstand the challenges of the future.

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E-learning in the present-day context: from the experience of foreign languages department, PSACEA

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Abstract. In the present context of COVID-19 lockdown, when pedagogies had to turn from in-person to virtual instructions, computer-mediated communication (CMC), including distance learning and e-learning, has come to the foreground to maintain the barrier-free educational environment. The three-dimensional model of the e-learning, which includes the principles of knowledge acquisition at ‘any place’, at ‘any time’, at ‘any speed’ is incomplete without the organisational culture component. To analyse what e-learning modes are used in a particular institution, to measure the efficiency of distance courses and, further, to suggest the most effective model and the ways of e-learning integration into a particular HEI according to its needs’ analysis was set up as the aim of this article. To achieve this aim, a complex of qualitative and quantitative research methods was applied. Therefore, in the first phase of our inquiry, a literature review was conducted in which we analysed the definitions of ‘distance learning’ and ‘e-learning’, traced the history of the question, and collected the main characteristics, quality parameters, and models of the distance and e-learning. On the later phases, we introduced the form ‘Analysis of the Distance Learning Tools Preferences’, disseminated among the teachers; a questionnaire ‘Distance Learning Mode of Work Satisfaction/Dissatisfaction’, disseminated among students, and ‘The Instructional Materials Motivation (IMMS)’ online survey by J.M. Keller to measure the efficiency of the distance learning courses design, also disseminated among students. The empirical data was collected at Prydniprovsk State Academy of Civil Engineering and Architecture (PSACEA), the Department of Foreign Languages during March-May, 2020. Thirty instructors from the Department of Foreign Languages and twenty-three students from the first-third years of Foreign Languages studies who regularly participated in online lessons took part in the experiment. Based on the theoretical and empirical data, we got a picture of the e-learning state (in its first approximation) in our HEI, proved that the forms and questionnaires used in the experiment may serve as informative tools of quantitative measurement, drafted the format for further improvement of the e-learning in our organisation.

1. Introduction

A present-day need to find ways of future specialists’ training efficiency increase in Higher Educational Institutions (HEIs) dictates further development of approaches and techniques to computer-mediated communication (CMC), including distance learning and e-learning as its variations. Therefore, the discussions around educational digitalisation and CMC’s implementation into various educational contexts continue to gather momentum and are reflected in many contemporary foreign and national scholarly works. For example, the scientific inquiry of A. A. Andreev [2] and L. M. Petrenko [25] is



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connected with distance learning, while V. Ye. Velychko analyses the questions of informatisation in HEIs [11]. W. Bramble and S. Panda in [8] present various distance and online learning models. N. Dabbagh [19], B. Bannan-Ritland [4] focus on online learning's concepts, strategies, and application. R. M. Palloff and K. Pratt [24] describe effective strategies for an online classroom. V. P. Bepalko [6], D. H. Jonassen [9], A. E. Kiv [17], O. O. Lavrentieva [19], W. Lewoniewski [7], Y. Masuda [22], L. M. Rybalko [20], A. M. Striuk [28] – 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 [3].

The recent situation with COVID-19 in the world in general, and in Ukraine in particular [27], when in-classroom work has become unavailable, when pedagogies had to turn from in-person to virtual instructions, when the initiatives to maintain the barrier-free educational environment have become paramount [12] – prompted the research topic for this article, which is summarised by us as 'E-learning in the present-day context: from the experience of foreign languages department, PSACEA'. Given this, the purpose of the article is to analyse what means of computer-mediated communication were used for e-learning in time of the quarantine by the faculty at the Department of Foreign Languages, Prydniprovskaya State Academy of Civil Engineering and Architecture (PSACEA); to discuss the advantageous and the weak aspects of the CMCs' tools used; to test the instruments to evaluate the efficiency of the courses built on e-learning and distance learning platforms; to suggest strategies for the distance digital format of teaching and learning improvement.

2. Research methods

To address the purpose of the article, a complex of qualitative as well as quantitative research methods was applied. For this reason, in the first phase of our inquiry we conducted a literature review, and analysed the definitions of 'distance learning' and 'e-learning', traced the history of the question and collected the main characteristics, quality parameters, and models of the distance and e-learning.

On the later phases, to get statistical data, we introduced the form 'Analysis of the Distance Learning Tools Preferences', disseminated among the teachers; a questionnaire 'Distance Learning Mode of Work Satisfaction/Dissatisfaction', disseminated among students, and 'The Instructional Materials Motivation (IMMS)' online survey by J. M. Keller to measure the efficiency of the distance learning courses design, also disseminated among students.

The empirical data were collected at Prydniprovskaya State Academy of Civil Engineering and Architecture, the Department of Foreign Languages during March-May, 2020. Thirty instructors from the Department of Foreign Languages and twenty-three students from the first-third years of Foreign Languages studies who regularly participated in online lessons took part in the experiment.

3. Results and discussion

It should be noted that at the moment there are many definitions of the term 'distance learning' that reflect the diversity of approaches to its understanding. In the works of A. Andreev, we could find the following definitions of the phenomenon collected by the scientist:

- 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 [2].

Having analysed different definitions of distance learning, R. Palloff and K. Pratt distinguish three main characteristics of it: 1) learning 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 [23].

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. radio courses 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 [8].

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 [14].

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 [5].

According to the method of interaction, the following modes of e-learning are 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 utterance. 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 [1].

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 component of educational instruction. At the same time, we maintain that the e-learning model, which is based on the dimensions 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 [26]. This, in turn, implies the need to understand what e-learning modes are used by an organisation, measure their effectivity, and suggest the most efficient model and the ways of e-learning integration into a particular HEI according to its needs' analysis.

In the time of the quarantine, at the Department of Foreign Languages, Prydniprovsk State Academy of Civil Engineering and Architecture, the instructors have been using such distance learning platforms and tools as Google Classroom, Zoom, Hangouts, Edmodo, Skype, Telegram, Viber, Discord, Web room, WebEx; online resources Edpuzzle, Quizlet, Cambridge English, Lexical Lab, TED Educational (the English Language); AUF, BNEUF, Le Point du FLE, TV5MONDE, Francaisfacile.com (the French Language); Deutsche Welle, Easy German, Learn German with Anja, etc. [15] (the German Language).

To understand what the most preferred platforms and tools for the foreign languages teaching and learning are, we disseminated the form 'Analysis of the Distance Learning Tools Preferences' to be answered by the teaching staff of the department, that contained (among others) the following graphs: 'Specify what online platforms you use for your online classes (ZOOM, Skype, Meet, etc.); 'other

platforms and digital tools you use to organise e-learning, e.g. ‘Google Classroom’; ‘use of e-mails, social networking sites or messengers’; ‘others’.

According to the statistics, obtained after the completed forms’ analysis (30 teachers were asked), we received the following results:

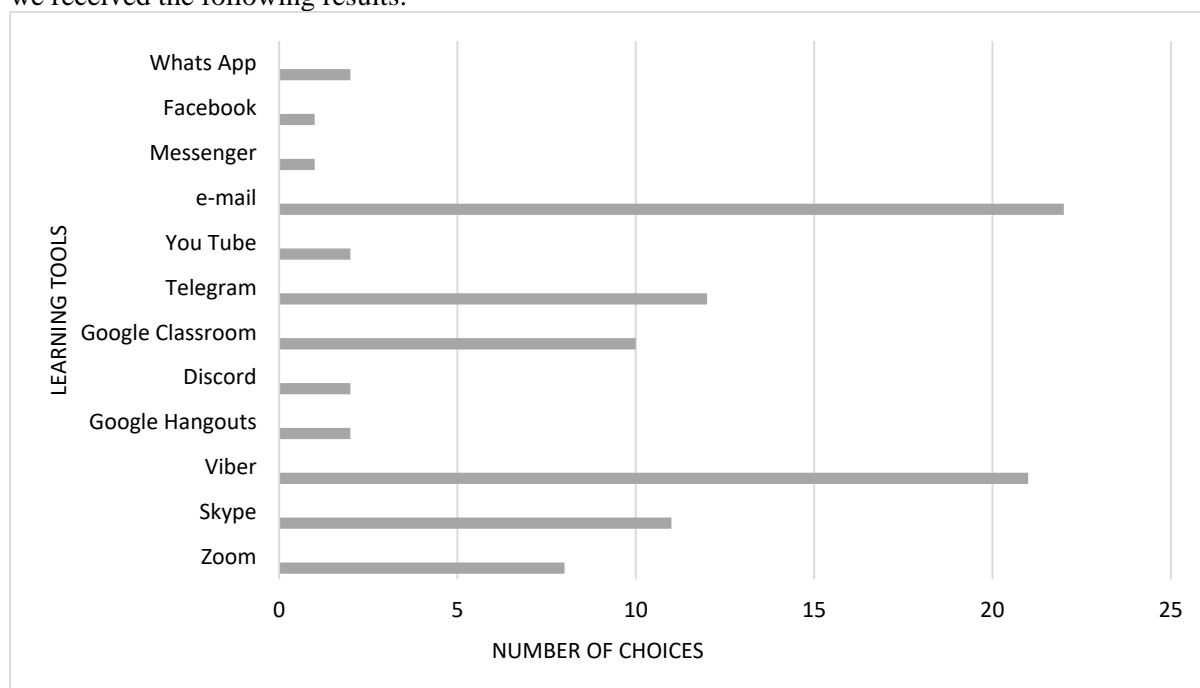


Figure 1. Distance learning tools preferences.

In line with the data received, the most popular video-conferencing platforms chosen by teachers of the department were Skype (11 choices) and Zoom (8 choices), while Google Hangouts (2) and Discord (2) with video-conferencing features were found less popular. The popularity of Viber (21) is also explained by its video-conferencing function. Social networking apps that were actively used by the faculty were Telegram (12) and Viber (21). E-mail (22) service was also chosen for the asynchronous correspondence with students. Google Classroom (10) was applied by instructors to exchange texts, audio, video, and hyperlinked material.

Our experience has also ‘fed in’ some 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, 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).

A separate part of our discussion should be given to 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 to this is provided by Tanya Joosten, a senior scientist, and director of digital-

learning research and development at the University of Wisconsin at Milwaukee. 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', – that may mean that we spend more energy on monitoring our non-verbal communication than we do in person [29]. What we also experienced was a shift towards teacher-centricity and one-way communication.

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 distance 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.

We also wanted to understand the quality of the e-courses offered in the time of the quarantine. Therefore, in the final phase of our experiment, we organised an online survey based on the IMMS instrument.

There are a number of 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' (Institute of

Higher Education Policy ‘Quality on the Line: Benchmarks for Success in Internet-Based Distance Learning’ Project, 2000); T. Volery and D. Lord’s ‘Critical Success Factors in Online Education’, 2000). A model developed by the European Commission (The BENVIC Project by the European Commission, 2002). The second category includes A. Chickering and Z. Gamson’s model ‘Seven Principles for Good Practice’, 1987; K. Barker’s model ‘Quality Guidelines for Technology-Assisted Distance Education’, 1999; S. Marshall and G. Mitchell model ‘The E-learning Maturity Model’, 2000 [21].

There is one more scientist whose works have been directed at measuring the quality of a course (including distance-learning). J.M. Keller has developed and tested a model to measure learners’ motivation to improve a course design or to adapt a course to learners’ motivational needs [16].

As a result, he came up with 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, by 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 job 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. According to the scientists’ conclusions if all these conditions are met, then students are likely to have a high level of motivation as well as build a continuous motivation to learn [16].

The model and the inventory (that is an integral part of it) were successfully applied to different educational settings and proved to be informative as an instrument for the efficiency of a course measurement ([10], [13]).

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 the examples of questions for each of the subscales.

Examples for ‘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 ‘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 ‘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 ‘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’ [13].

The data we obtained after analysing the received answers (IMMS) is presented in the table 1.

Table 1. Motivation level range.

Motivation Level	Scores	Number of Participants (<i>N</i> =23)	Percentage
High Level	4.00 – 5.00	<i>N</i> =2	8.7%
Upper Medium Level	3.50 – 3.99	<i>N</i> =5	21.7%
Medium Level	3.00 – 3.49	<i>N</i> =12	52.2%
Low Level	< 3.00	<i>N</i> =4	17.4%

In our research out of 23 students 12 (52.2%) demonstrated medium motivation levels, 5 (21.7%) had upper-medium motivation levels, only 2 (8.7%) had high levels of motivation, and 4 (17.4%) – low motivation levels. The data results may be interpreted as ‘satisfactory disposition’ to the e-learning courses of students who participated in them. It should be noted that the respondents took different courses with different instructors and different syllabus. Consequently, what we got is an overall picture of e-learning courses efficiency.

4. Conclusions and prospects for further research

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 HEI, reveals several challenges and needs, helps layout further strategies to support fluid, holistic, seamless, pervasive, personalised education optimised by technology.

To sum up the data received, the most popular video-conferencing platforms and tools chosen by the teachers of the department 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 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. 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.

As for the inventory used by us in the experiment, the form that we introduced among teachers ‘Analysis of the Distance Learning Tools Preferences’ proved to bring informative data to understand what distance learning tools are chosen in our organisation (which gives the understanding of what technological means and technical skills our faculty possess). Not less informative was an online questionnaire ‘Distance Learning Mode of Work Satisfaction/Dissatisfaction’ disseminated among students.

Regarding the efficiency of the courses offered by our department, the majority of students who participated in online classes regularly demonstrated the medium level of courses’ design satisfaction that may be attributed to the short period these courses had to be structured and moved online; 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 course 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’ ICT and digital literacies.

All of the above brings up the issue of a Digital Learning Unit creation as an indispensable part of a contemporary Ukrainian Higher Educational Institution and the need for the extensive digitalisation’s

implementation initiatives that should be rooted in management and the cohesive institutional strategies, which was discussed in our previous work [30].

Unit of Digital Learning, Royal Institute of Technology (KTH), Stockholm, Sweden can serve as an example of such an organisation. The main objective of it is to examine how technology can support education and learning. It is the place where educational digital platforms, online courses, and video are designed. At the unit, research and development (R&D), education and supervision are carried out. The unit is organised into four groups: E-Learning, Media Production, MOOC (Massive Online Open Courses), and Resource Centre for Online Education [18].

The E-learning group maintains and develops the digital learning environment at KTH. It is responsible for investigations and evaluations of the digital learning process, as well as education and support to KTH's teachers (i.e. it conducts the activities to investigate what digital learning environment KTH should have, as well as evaluates whether the current environment meets the needs of teachers and students).

Media Production group provides guidance, development and support in video production for KTH's teachers. Resource Centre for Online Education group has the task of organising and supporting online teaching and developing networking skills. It works for students who want to study online courses and for institutions that want to offer online courses.

Besides these groups, there are Flipped Classrooms, KTH play – a media portal and a recording tool that helps to record, store and share video and audio material, Lecture theatres with recording, Lunch 'n' Learn seminars (aimed at those who are interested in e-learning and want to know more about KTH's digital learning environment).

In conclusion, we would like to summarise that the e-learning that expands educational process by giving access to knowledge from anywhere, at any time, at any speed and is backed up by the latest multimedia technologies and the Internet should be applied with the organisational culture's preliminarily conducted needs' analysis. In this article, we tried to describe our experience of such kind of an analysis based on the data obtained during the distance work (March-May 2020) at Prydniprovsk State Academy of Civil Engineering and Architecture. The research we undertook gave us a picture of the e-learning state (in its first approximation), proved that the forms and questionnaires used in the experiment may serve as informative tools of measurement, gave grounds to draft the format for further improvement of the e-learning in our organisation.

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Assessing online education during the COVID-19 pandemic: a survey of lecturers in Ukraine

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Abstract. The winter and spring of 2020 was a challenging time worldwide. The COVID-19 pandemic seriously affected all spheres of life: from an industrial decline to educational transformations. In order to continue the 2019/2020 academic year, higher educational institutions had to adjust in-class learning to online. This paper aims at assessing the satisfaction and acceptance rate of Ukrainian lecturers with online education, as well as indicating problems and benefits they had singled out. The technical side of online education was also of interest. Therefore, the study employed an online survey to investigate technical support and tools used during the quarantine, advantages and disadvantages of online teaching, the level of satisfaction and acceptance. The findings from the study suggest that lecturers got different levels of technical support and used an assortment of tools to organise online education. The study revealed that the main advantage was time efficiency, while internet connection and technical problems were the most commonplace problems. Other findings of the survey are that lecturers were partially satisfied with online education but showed low acceptance of online education.

1. Introduction

The educational sector in Ukraine has been facing tremendous changes for over two decades. They are about content, methods, assessment, etc. On introducing the Bologna system, higher education has switched to ECTS. At the same time, the powerful impact of ICT and smartphone advancements in education worldwide have shifted the modern focus on digitalisation.

In 2013, the Taras Shevchenko National University of Kyiv launched the first massive open online course (MOOC) in Ukraine. About 9,000 students completed the course on Marketing and were awarded a certificate. One year later, three more courses were introduced on History of Ukraine, Programming and Financial Management. They were developed in partnership with Taras Shevchenko National University of Kyiv, Kyiv Polytechnic University, Kyiv-Mohyla Business School and posted at educational platform Prometheus which was a milestone of developing MOOCs in Ukraine [19]. Now it offers more than 100 courses, 80% of them are made from scratch, with the remaining 20% from top universities translated into Ukrainian.

The use of MOOCs was furthered with the program initiated by the Massachusetts Institute of Technology in 2008. It piloted a project combining short videos and in-class teaching. Larson and Murray used the term the Teaching Duet for this phenomenon when there are several segments which involve passing the teaching baton between the video and live face-to-face learning segments. Thus, Blended Learning Open Source Science or Math Studies (BLOSSOMS) were pioneered and the approach became a framework for blended learning [7].



Following suit of MIT, numerous universities and colleges piloted BLOSSOMS programs in the US and around the world, e.g. Universiti Teknologi Malaysia (Malaysia), AUC (Egypt), etc.

Sener defines blended learning in higher education as “courses and programs which combine online and classroom delivery modes”. The threshold for materials delivered online varies in different definitions, i.e. 20-79% in the annual Sloan Survey of Online Learning and 50% in the Southern Association of Colleges and Universities as well as the Commission for Higher Education [18].

A growing interest in blended learning (not only developed around MOOCs) in higher education [5] has initiated ample researches. To be exact, the pilot at San José State University based on an EdX course demonstrated a 35% increase success rate of the final exam (from 55% to 90%) [9], while another pilot at Vanderbilt University embedding a Coursera course received positive feedback from students who chose self-paced learning as the main advantage [6]. There are projects which highlight both benefits (personalized learning environments, focus on key skills, cost efficiency, etc.) and obstacles (student engagement and retention, low computer literacy and technology acceptance of students and teachers, etc.).

In 2016, the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, the Ivan Franko National University of Lviv, the Lviv Polytechnic National University and the Ukrainian Catholic University piloted projects on the blended learning technology where MOOCs available at Prometheus were combined with face-to-face learning [19].

Currently, the digitalisation trend in Ukraine is stimulating the introduction of more blended learning courses in higher educational institutions. However, in the spring of 2020 there was a clear shift to online learning when schools, colleges, and universities were closed [11], [16]. With an increasing need of social distancing when in-person schooling posed a threat, students were forced to learn and later take tests online as an emergency response. Concentrating fully on online learning only was a first on the state level for many countries and Ukraine was no exception.

On February 3, 2020, the official letter was sent to higher education institutions with recommendations to organise “distance learning for students from the People's Republic of China and Southeast Asia countries, who are not currently in Ukraine and/or who cannot arrive in Ukraine due to the spread of coronavirus” [14].

As the epidemiological situation worsened, the letter of the Ministry of Education and Science of Ukraine from March 11, 2020, No 1/9-154 announced a three-week quarantine for all types of educational establishments in order to prevent the spread of COVID-19. The letter also recommended using ICT to set distance learning [13]. Later, the quarantine was prolonged and most students didn't even return to higher education institutions to sit exams as there were held online.

It is necessary to point out a variety of terms used worldwide for the same phenomenon as an education response to COVID-19, including e-learning [15], remote learning (UNESCO), digitally-based distance learning (the UN), digital learning, online learning, etc. However, Guri-Rosenblit argues that e-learning and distance learning are not the same. She defines three aspects as a basis of distance learning: 1) remoteness, 2) cost, 3) target audience having a number of social, economic, working and other barriers [10].

Taking into account that ICT, cloud and mobile technologies enabled learning during the pandemic when social distancing was key, the term ‘online education’ is used in the study.

Rising to educational needs and health- and life-saving measures of COVID-19, several online education solutions were available in Ukraine. School students were offered lessons broadcast on numerous TV channels, which were also added to the official YouTube channel of the Ministry of Education and Science of Ukraine. However, university students were not offered any universal courses because of curricula differences. As a result, digital solutions of higher education varied greatly.

2. Literature review

The quarantine resulted in emergency e-learning in Ukraine. Murphy [15] finds the phenomenon of emergency e-learning (eLearning) programs appropriate crisis-response measures. In the US, the policies were declared in the period of March 6-13, 2020 at all higher educational institutions, mostly

by university Presidents (72%). They stressed that “emergency eLearning is the security measure proposed to protect the community”.

Emergency eLearning was first turned to in 2009. In the US, Allen and Seaman stated that 67% of contingency plans under threat of H1N1 had online classes as a substitution for face-to-face classes. 20% had no available online alternatives but were ready to develop them [1]. According to the earlier reports on online education (2005-2009), 60% of administrators agreed it was strategic in the long run and over 10% disagreed, while about 30% remained neutral. Moreover, institutions offering courses and full programs rated learning outcomes as the same as face-to-face (over 60%) and somewhat superior to face-to-face (20%). By contrast, institutions with no online offerings were more pessimistic with the highest result of inferior (about 33%) and almost equal for somewhat inferior and the same as face-to-face (about 30%).

In the 2013 report, Allen and Seaman [2] proved that the number of institutions with complete online programs almost doubled from 34.5% in 2002 and totalled 62.4% in 2012.

Sener argues that online education will attain full scale as it is to become fully integrated into mainstream education. Moreover, the author believes that disasters both natural and manmade (unpredictable sources) are wildcards that have a potential to spread online education [18].

John Katzman, the CEO of Noodle, a Californian company that helps colleges transfer academic programs online, says that the new model creates agility and makes programs available both under normal circumstances and in emergencies [4].

Despite the ongoing growth, academic leaders are reported to estimate that for faculty members teaching on online courses requires more time and effort as compared to corresponding face-to-face ones. It should be noted that in 2006 there were 40.7% supporting the belief, while in 2012 the number increased to 44.6%. This may explain lasting resistance among many faculty members towards online education reported by Allen and Seaman [2]. When analysing the level of value and legitimacy acceptance with the starting point in 2002, it has no steady positive tendency. A slow growth was 6% in 2007 which was followed by a slight drop and another increase resulting in the 2004 level as of 2012. Therefore, the lack of acceptance was rated as important (41.2%) and very important (25.6%) problem of online education adoption in 2012.

Moreover, there are a number of researchers arguing that it takes much planning and investment to develop entirely online courses [3], [8]. Yang and Li support the idea that online teaching training is necessary both for students and instructors [20].

Although some discussions in the literature relate to using MOOCs and blended learning in Ukraine [12], empirical evidence to demonstrate faculty attitude, problems and gains is lacking.

This study reports on research into online education conducted over the quarantine. The research has focused on the faculty satisfaction, pros and cons of online education. The emphasis on faculty experience with e-learning is relevant for further development of e-segment for both entirely online and blended learning programs. Understanding the issues faced, the insights gained as well as perspectives considered helps to strengthen weak points in order to increase the acceptance of online education and satisfaction of instructors.

The researchers developed a multi-item survey to assess satisfaction and acceptance rate of lecturers. First, they were asked whether they got technical support when developing an online learning pattern and tools they used. Next, they were asked whether the general experience was satisfactory, what benefits and problems they had, whether online education was critical in the long run.

3. Research questions

The study had three main focuses:

1. Technical support and tools
2. Advantages and disadvantages
3. Acceptance and satisfaction with online education.

Accordingly, the questions asked were as follows:

1. Did you get technical support/recommendations when organising online teaching of your course (from the university, tech support, tech department, etc.)?
2. What software were you using to hold classes online?
3. What resource did you ask your students to send assignments to?
4. What problems did you face when organising and holding online classes?
5. What benefits of online learning are there for you?
6. Do you find online education satisfactory?
7. Would you like to teach a part of your course online?
8. Do you find online learning critical in the long run?

4. Method

The researchers created a survey for lecturers who had taught online courses during the quarantine. Google Forms were used. Various types of questions were used, including multiple-choice, check-boxes and open-ended questions.

The survey took place from early May to early June. The link to the survey was posted at Facebook. In total, there were 60 responses. The participants responded to the survey anonymously. The respondents were asked to provide demographic information. The responses were tabulated in Google spreadsheets.

Responses to the questions on the respondents' problems (1) and benefits of online education (2) were grouped according to keywords in order to make categories. The categories of issues (1) were: internet connection, technical problems, lack of face-to-face interaction, technical knowledge, students' work, motivation, efficiency, support from universities, workload and stress, other. "Technical problems" included problems with both software and hardware. "Student work" included quality of work and assignments, readiness to learn online, cheating. The benefits (2) had the following categories: none, mobility, time efficiency, flexible hours, learning tools, clear control, inviting experts, self-development, special education. "Other" was used to include responses that did not fall into any of the stated categories.

5. Results

The study confirmed some commonly held beliefs about online education, refuted others, and provided predictions about the future of online education. The questions on software were with check-boxes, while those one advantages and disadvantages were open-ended.

5.1. Demographics of respondents

A large majority (96.6%) of the survey respondents held teaching positions, while only 3.4% were administrators. Only four respondents said their institutions offer online courses (3.4%) and only one had taught online courses. Mostly, the respondents were from Kharkiv region (86.7%) with only 6.7% from Kyiv, 5% from Ternopil and 1.7% from Poltava regions.

5.2. Technical support and tools

Deciding on digital tools and platforms was up to lecturers mostly, as there were no official recommendations from the Ministry of Education and Science of Ukraine. However, 60% of respondents indicated that they got technical support/recommendations when organising online courses (from the university, tech support, tech department, etc.), while 38.3 got none and only one participant chose the option "Other" to add partial technical support (see figure 1).

As for the software to hold online classes, it is universal worldwide. At Yale, Peter Salovey in the update speech on the first confirmed Yale COVID-19 case mentions holding "classes online using Zoom, Canvas, and other digital tools" [17].

When responding to the check-box question "What software were you using to hold classes online?", the most popular turned out to be Zoom (57 respondents) and communication tools (Viber and Skype were chosen accordingly by 46 and 30 participants). Such video conferencing software as Google Meet,

Canvas, Jitsi Meet and Microsoft Teams were ticked by correspondingly 11, 2, 1 and 1 those surveyed (see table 1).

Did you get technical support/recommendations when organising online teaching of your course?

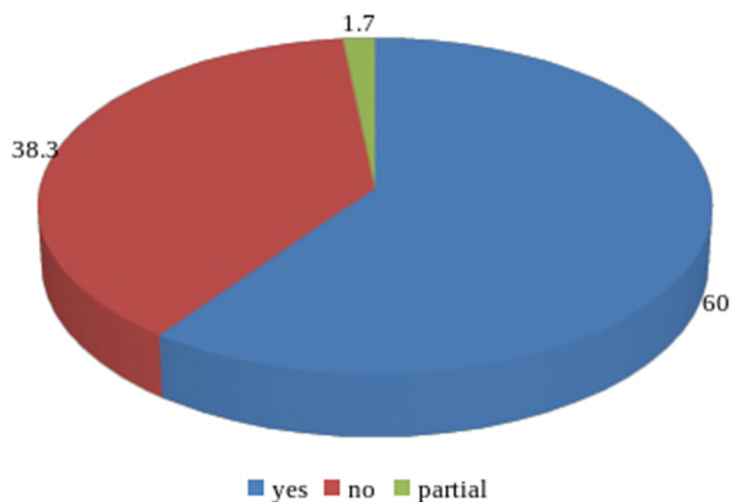


Figure 1. The response rate of getting technical support from universities.

Table 1. Analysing software to hold online classes

No	Response option	The number of response options	Response rate
1.	Zoom	57	38.5
2.	Viber	46	31.1
3.	Skype	30	20.2
4.	Google Meet	11	7.4
5.	Canvas	2	1.4
6.	Jitsi Meet	1	0.7
7.	Microsoft Teams	1	0.7
	Total	148	100

Similarly, there was a variety of software to which students were asked to send assignments. 47 respondents checked the box of E-mail and 45 communication tools (Viber, Telegram, Skype). Much fewer used Google Classroom (37) and Moodle (7). Only one respondent had the Padlet board to gather student work. Some respondents ticked not one but several boxes when answering the questions on software (see table 2).

Table 2. Analysing software for students' assignments sorted by the respondents' answers

№	Response option	The number of response options	Response rate
1.	E-mail	47	34.4
2.	Viber, Telegram, Skype	45	32.8
3.	Google Classroom	37	27.0
4.	Moodle	7	5.1
5.	Padlet	1	0.7
	Total	137	100

5.3. Advantages and disadvantages

When analysing the problems online instructors had, all open-end answers were grouped into nine categories based on keywords (see table 3).

Table 3. Analysing the problems online instructors experienced.

No	Response option	The number of response options	Response rate
1.	Internet connection	31	41.9
2.	Technical problems	10	13.6
3.	Student work	8	10.9
4.	Lack of face-to-face interaction	6	8.1
5.	Computer competency	4	5.4
6.	Lack of support from universities	4	5.4
7.	Workload and stress	3	4
8.	Motivation	3	4
9.	Other	3	4
10.	Efficiency	2	2.7
	Total	74	100

Number one problem was low quality or no internet connection. Online instructors complained that students who don't live in the city missed online classes because of poor internet connection. As a result, instructors had to work extra hours when students were online. Besides, some courses require close contact. An instructor noted that because of bad connection, there was audio latency and it was impossible to perceive a timbre (course specifics matter).

The second most often problem was about software and hardware. Two online instructors regretted that Ukraine wasn't among the countries where Zoom lifted the 40-minute session restriction. As for hardware, it wasn't powerful enough and one instructor even mentioned that a laptop had broken down.

Student work was the third most mentioned problem. Online instructors argued that there was a drop of assignment and work quality as well as some cheating. Moreover, several reported that students were not ready for online learning. Over 8% of respondents missed face-to-face interaction and instant feedback.

Although computer and digital competency is considered commonplace, respondents expressed the lack of it. 5.4% also noted that they had got no support from universities and it would have helped a lot. 4.1% of survey participants reported an increased workload and stress as online work was draining. The same number indicated that students lacked motivation to pursue online education.

After highlighting the problems, the respondents were asked to focus on the benefits they experienced. As open-end answers, they were grouped into ten categories according to keywords (see table 4). Unlike problems when most respondents indicated several challenges, only one respondent expressed two benefits.

Almost a quarter of respondents specified time efficiency (24.6%). Most of the responses showed that working from home saved a lot of time as instructors didn't have to go to higher educational institutions and could have instant access to classes and assignments. 13.1% of respondents mentioned flexible hours, self-development and an assortment of learning tools. Instructors pointed out using time-saving testing services and a lot of new interactive multimedia resources to make learning more engaging, i.e. Mentimeter, Wizer.me, Padlet, etc. Mobility was a benefit of online education for 11.4 participants. Clear control of student work available at digital learning services was appreciated by 8.2%. 3.3% of survey participants enjoyed individualisation of online education, as well as advantages for students who have special educational needs. The same number considered inviting experts to online classes. To be exact, native speakers were mentioned in two responses. However, four respondents (6.6%) chose no benefits adding that online education during the quarantine was time and energy consuming.

Table 4. Analysing the benefits online instructors experienced.

N ^o	Response option	The number of responses	Response rate
1.	Time efficiency	15	24.6
2.	Flexible hours	8	13.1
3.	Self-development	8	13.1
4.	Learning tools	8	13.1
5.	Mobility	7	11.4
6.	Clear control	5	8.2
7.	None	4	6.6
8.	Individualisation	2	3.3
9.	Special education	2	3.3
10.	Inviting experts	2	3.3
	Total	61	100

5.4. Acceptance and satisfaction with online education

Do you find online education satisfactory?

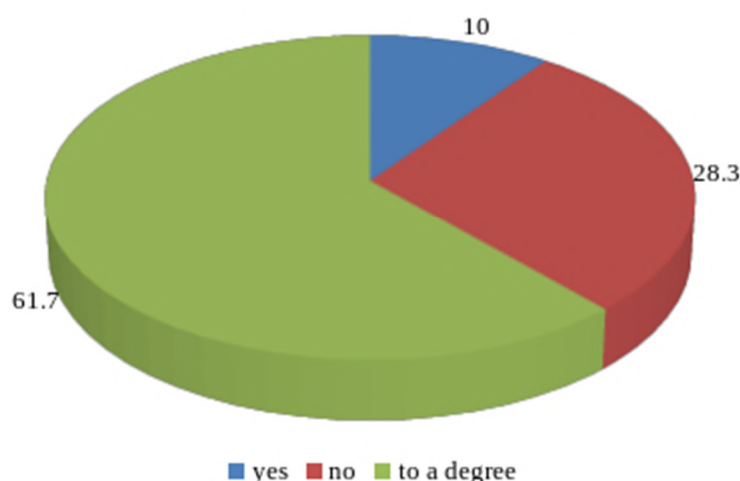


Figure 2. The response rate of satisfaction with online education.

At the final part of the survey, those participated were asked to consider their satisfaction with online education and general acceptance. More than half (61.7%) chose the option “To a degree”. About a quarter of respondents found online education not satisfactory. Only 10% indicated their satisfaction (see figure 2).

When asked about an intention of teaching a part of a course online, almost half (48.3%) expressed their unacceptance of online education and answered they wouldn't like to teach online. One instructor in the “Other field” added “Despite the fact that I would not like to teach a part or the whole course online, it looks like I’ll still have to.” At the same, almost a quarter of respondents (23.3%) considered the possibility and 20 respondents have already integrated online learning in the courses. 10% of surveyed instructors stated they had already made their course 100% online (see figure 3).

The final question was “Do you find online learning critical in the long run?” and almost half of respondents answered negatively (see figure 4). One instructor indicated a low quality of online education. Two instructors stated that it is an emergency only when online education can be used. Eight respondents considered blended learning emphasising the importance of in-person interaction. Twenty respondents believed online education to be critical in the long run.

Would you like to teach a part of your course online?

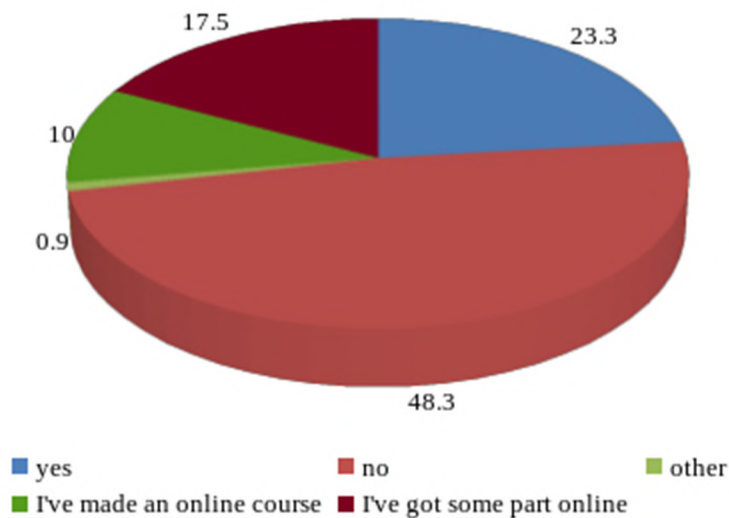


Figure 3. The response rate of lecturers' intention of teaching a course online.

Do you find online learning critical in the long run?

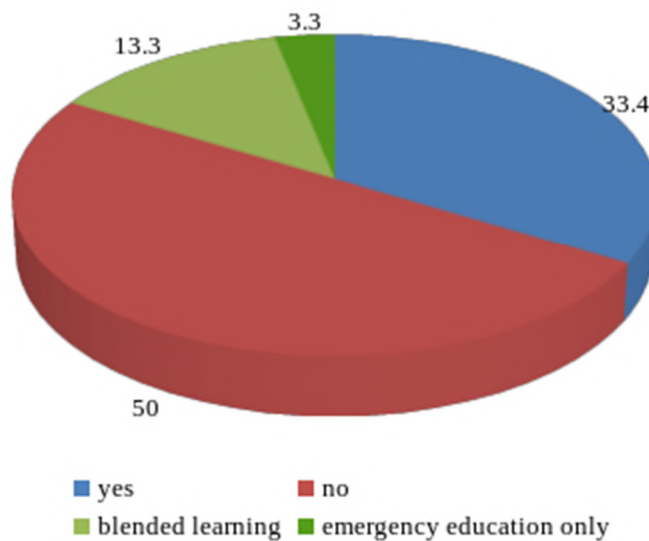


Figure 4. The response rate of online education importance in the long run.

6. Conclusions

The 2019/2020 academic year was challenging in many aspects, most of them triggered by the COVID-19 quarantine. In Ukraine, online learning at higher educational institutions was chosen as an emergency measure. Unfortunately, most institutions had had no previous experience, ready tools or trained faculty. However, there have been discussions about advantages and disadvantages of online education for some years now, under normal circumstances and in emergencies, for example by Allen and Segman [2], Blumenstyk [4] etc. Taking into account a still lasting pandemic and a growing number of online courses worldwide, it was of relevance to examine the general situation of online education, trends and attitudes of lecturers in Ukraine. This study was primarily motivated by the need to investigate and assess the satisfaction and acceptance of Ukrainian higher education teachers. Also it was aimed at distinguishing

problems and benefits of online education. The survey was created to study faculty feedback and insights.

Despite the fact that emergency eLearning was unprecedented in Ukraine, some countries have already had such experience. Allen and Segman analysed that under threat of H1N1, two thirds of US contingency plans accepted online classes as a substitution for face-to-face teaching [1]. Thus taking into an unexpected turn to online education for most Ukrainian lecturers and a limit use of blended learning (otherwise the authors argue that the shift to online education in March 2020 would have been smoother and faster as some survey respondents noted that it took a lot of time to get used to the online paradigm of teaching), those surveyed mostly indicated partial satisfaction with online education. Allen and Segman stress that higher acceptance of online education demonstrated participants which had previous experience of teaching online courses (colleges and universities had online offerings) [1].

The findings of the study revealed the main problems teachers faced and the benefits they experienced. Thus, among main problems the following are indicated: low quality or no Internet connection, software and hardware, a drop of assignment and quality of student work, and computer and digital competency. At the same time there were highlighted main benefits of online education experience: time efficiency, mobility, clear control of student work, and individualisation.

However, there is certain resistance among instructors of online education as a majority of respondents didn't plan to integrate online segments in courses and didn't recognise its importance in the long run. In this aspect the findings of Allen and Segman are noteworthy: the lack of acceptance of online education by faculty is considered either an important or very important barrier to the widespread adoption of the online paradigm [2].

Taking into consideration a gap in computer competency and lack of technical support from universities, the authors argue that it is necessary for faculty and administration to steam-work on developing a pattern on teaching online with strong methodical background and support, namely to hold trainings on online education, to plan and develop internal university platforms, as well as provide support services. This way, lecturers will have a basic set of tools and skills to use them expertly.

The authors report certain limitations of the study. One of the most relevant is a lack of data and prior research studies on online education at higher educational institutions, including blended learning. Moreover, increasing the sample size can be beneficial. In the current survey, 60 respondents participated.

In the post pandemic world of COVID-19, education is likely to face further changes and lecturers should be ready to provide high-quality relevant teaching.

Thus, the perspectives for further research can be such aspects of the problem as professional development of higher education teachers in online education context, preparing lecturers for online or blended teaching, online education impact on student achievements, etc.

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Features of distance learning of cloud technologies for the organization 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 smart maps; means of creating sites; cloud-based learning management systems (for example, Google Classroom). 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.

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-pedagogical workers”, one of the approved forms of professional development is remote [9]. 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



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the development of digital competence [9].

Therefore, it was decided to modify the developed course ([43], [48]) 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 [38], which was developed within the accredited 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 of such scholars as D.S. Antonuik [49], O.V. Bondarenko [3], O.Yu. Burov [34], V.Yu. Bykov ([6], [7]), O.V. Chorna [10], O.G. Glazunova [13], A.M. Gurzhiy [8], A.V. Iatsyshyn ([20], [16]), A.E. Kiv [19], V.V. Kovalenko [20], O.O. Lavrentieva [23], S.H. Lytvynova [37], O.M. Markova [29], I.S. Mintii [47], Ye.O. Modlo [27], P.P. Nechypurenko [28], V.P. Oleksiuk [30], V.V. Oliynyk [31], L.M. Rybalko [24], M.P. Shyshkina [36], V.N. Soloviev [12], A.M. Striuk [44], N.P. Volkova [46], V.I. Zaselskiy [22], M.I. Zhaldak [51] etc.

At the same time, I.A. Getman [45], L.H. Havrilova [15], H.M. Kravtsov [21], L.M. Petrenko [33], S.V. Shokaliuk [41], V.V. Yahupov [50] and others pay attention to distance learning in their research.

In particular, I.S. Mintiy, N.A. Kharadzhan and S.V. Shokaliuk in their joint work 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” [26].

V.V. Osadchyi and K.P. Osadcha investigated the possibilities of distance learning in the study of technical disciplines [32].

A.V. Bukach offered a distance learning program “Google Apps for Education” [5], which aimed to familiarize participants with the possibilities of Google Classroom for the organization of the educational process.

Later, the team of authors Yu.M. Bogachkov, A.V. Bukach, and P.S. Uhan proposed another approach – 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. [1].

Regarding foreign authors, that M. Britto considered cloud computing in higher education [4], C. Dzikite, Y. Nsubuga and V. Nkonki studied lecturers’ competencies in information and communication technology for effective implementation of ICT-integrated teaching and learning in textiles and clothing degree programs [11], D. Hanson-Baldauf and S. Hughes Hassell studied the problem of the information and communication technology competencies of students enrolled in school library media certification programs [14].

M. Jalgaonkar and A. Kanojia analyzed the possibilities of adoption of cloud computing in distance learning [18], M. Simonson, S. Smaldino, M. Albrighth and S. Zvacek studied the problem of teaching and learning at a distance [42]. But the researchers ignored the question of the effectiveness of organizing such courses in a remote form.

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” [39].

This course has been modified by improving the course “Cloud Technologies in Education” [3] 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” [3] 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 [25];
- 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 [17];
- tools for creating sites [35];
- cloud-based learning management systems (for example, Google Classroom [2]).

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 smart 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.

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 – see figures 1-2), 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 (see figure 3). 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 figures 4 and 5 in the form of diagrams.

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.

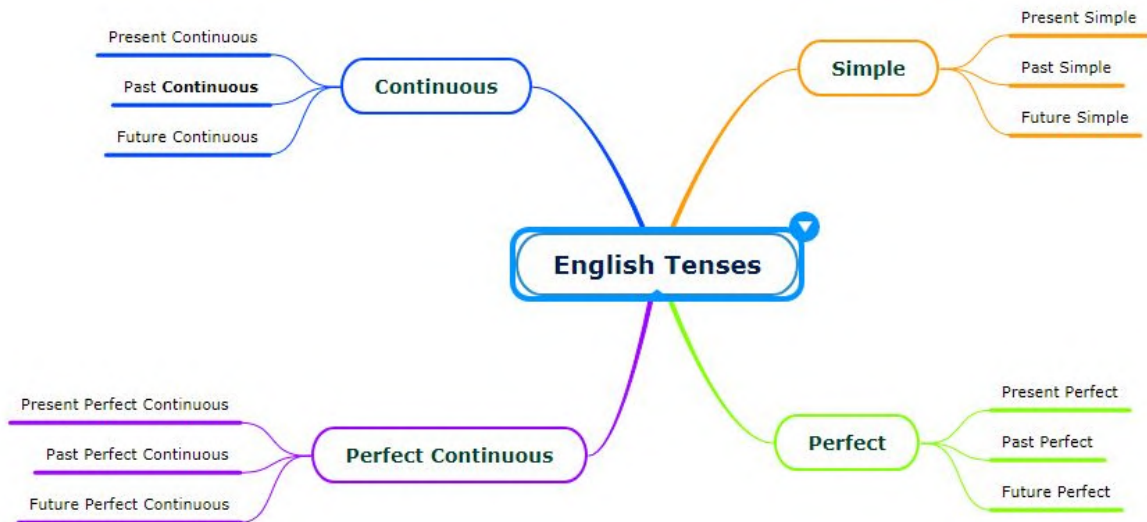


Figure 1. An example of a mind map for learning foreign languages, created by students during a distance learning course.

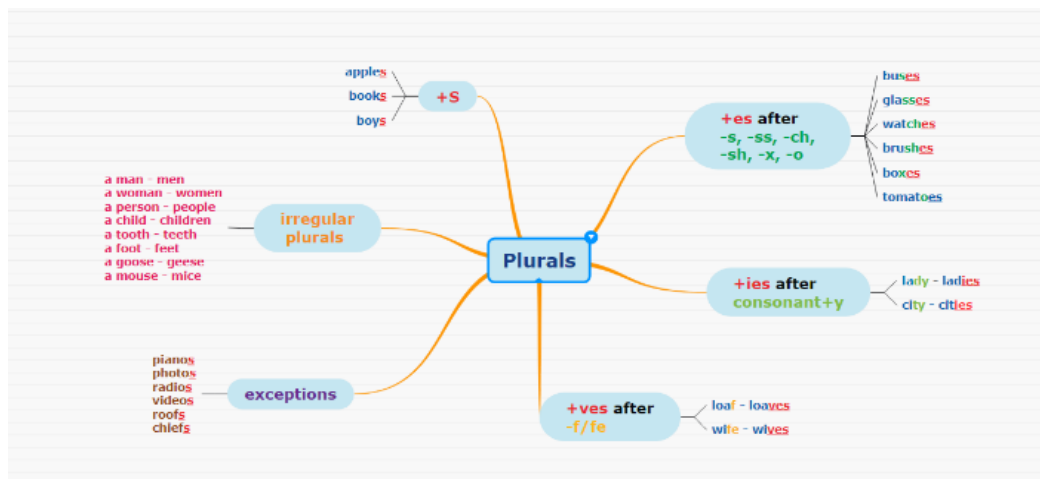


Figure 2. An example of an intellectual map for learning foreign languages, created by students during a distance learning course.

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 6.

Employees of 40 higher education institutions became students of the developed distance course. The most active were the employees of the following free economic zones: Zhytomyr Polytechnic State University, Pavlo Tychyna Uman State Pedagogical University, the National University of Life

and Environmental Sciences of Ukraine, the National M.P. Drahomanov Pedagogical University, Uzhhorod National University.



Figure 3. Example of a presentation created by students during a distance learning course.

Table 1. Statistics of participants on waves.

	1 wave	2 wave	3 wave	Together
A total of registered	500	600	400	1500
Joined the course	367	381	281	1029
Completed the course	296	274	246	816



Figure 4. Statistics of course participants in general.

If we consider the statistics of participants about the regions of Ukraine, there were representatives of all regions of Ukraine (see figure 7).

4. Conclusions

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.

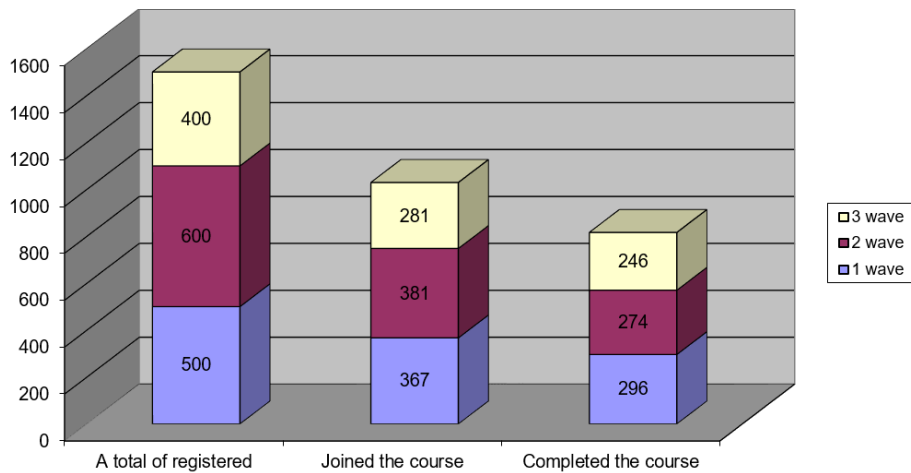


Figure 5. Data on the participants of the course on the waves.

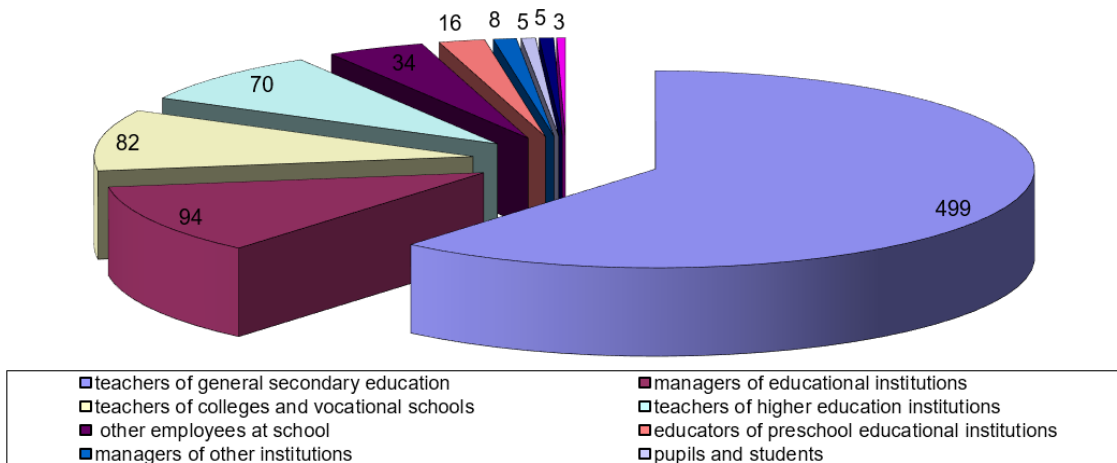


Figure 6. Percentage of participants at the place of work.

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 courses were organized and conducted in a convenient format. All participants of the courses expressed a desire to take part in further similar events.

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.



Figure 7. Statistics of course participants by regions of Ukraine.

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Developing digital competence of teachers of Humanitarian disciplines in the conditions of COVID-19 quarantine measures

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Abstract. The relevance of the research is explained by the necessity of developing digital competence of teachers of Humanitarian disciplines at the higher education institutions (HEIs) in the conditions of the quarantine measures to prevent the spread of COVID-19. It is particularly challenging for teachers of Humanitarian disciplines, who are not specialists in the digital sphere as their profession is focused on humans. The purpose of the paper is to define the influence of the quarantine on the work of teachers at HEIs, revealing the level of the development, challenges and peculiarities of enhancing the digital competence of teachers of Humanitarian disciplines, their needs in education and giving recommendations how to arrange education and make administrative decisions. The methods of the research are survey, theoretical analysis, others. The results are to define the peculiarities of the influence of the quarantine on the arrangement of distance learning, the peculiarities of developing digital competence of teachers during the quarantine, their needs in education, the challenges in conducting mass distance learning, the determined complex of scientific approaches to developing digital competence. The practical significance of the research refers to developing three internship programs, based on the results of diagnosing teachers' digital competence.

1. Introduction

Coronavirus pandemic and quarantine measures turn to be challenging for the work of many specialists in different spheres. The digital education using digital technologies (DTs) becomes the basis for higher education institutions (HEIs). At the same time, there is no theory of digital education (DE) at HEIs for mass distance learning (DL) in pedagogy that makes it difficult for both teachers and administrative staff to arrange DL and to make conditions for students' learning and teachers' work. It is the most difficult issue for the teachers of Humanitarian disciplines, as its full implementation during the



quarantine is challenging, a lot of problems arise, people learn while working. The reasons for this are the following:

1. The teachers of Humanitarian disciplines at higher education institutions aren't the specialists in DE and DL. Humanitarian disciplines are aimed at studying humans, their cultural, creative, and spiritual activities [26]. In Ukraine, the subject area "Humanities" includes such specialities as religious studies, history, archeology, philosophy, culture studies, and philology [28]. Teachers of Humanitarian disciplines provide the general humanitarian component of curricular of training future specialists of different professions. Their main work tool is a word, not a digit. And the professional focus of teachers of Humanitarian disciplines is on a human, but not on nature, a digit, technics, etc. That is why to quickly master the professional activities based on technics and digits tools to change and reorient a personality's professional focus. This does not happen all at once, DTs are new for them. So, the problem of developing digital competence of teachers of Humanitarian disciplines in the sphere of using DTs in education arises.

2. There are persons among the teachers of education institutions who are of different ages and have different levels of training – computer devices were different in different years and different generations were taught differently. HEIs didn't arrange the systematic further training of teachers for improving teachers' digital competence (TDC [21]), as the practice put the different tasks – transition to the competence-based approach in higher education, entering the EU, the new requirements of HEIs accreditation, etc. Currently, this problem is urgent and massive. There is a need to improve teachers' qualifications in the sphere of DE and DL, in particular, it concerns teachers of Humanitarian disciplines. But these needs are different, taking into account teachers' professional training. Their training should be conducted differently. So, scientists should define what and how to study them.

3. Teachers of Humanitarian disciplines should have not only digital literacy but also digital competence for solving professional problems in the conditions of the quarantine and mass DL. This requires defining the essence of the influence of the quarantine measures on DL, digital technologies, and professional activities of teachers of Humanitarian disciplines.

4. In the system of distance education, there is a bigger number of learning process participants. They are A) Student; B) Tutor (teacher); C) Organizer; D) Administrator. In education using DT, all the subjects should learn how to interact with one another and share time and duties. They are new conditions for the realization of the educational process for teachers and students, all the participants should be trained to be ready for it. This is a scientific problem of the informatisation of education and the implementation of digital technologies for arranging mass distance learning at HEIs. Its solution contributes to the improvement of higher education quality and the development of a sustainable society in Ukraine.

We have analysed the regulatory documents of the Ministry of Education and Science of Ukraine on distance education and digital education, the experience of Ukraine and EU in the issue, as well theoretical researches: 1. Regulatory documents of the Ministry of Education and Science of Ukraine, the Laws of Ukraine on Higher Education concerning DE (the Law of Ukraine "On Higher Education", the Law of Ukraine "On National Program of Informatization", the Order of the Ministry of Education and Science of Ukraine "On Approval of the Provisions for Distance Learning", the Order of the Ministry of Education and Science of Ukraine "Requirements for Institutions of Higher Education and Institutions for Postgraduate Education, Scientific, Academic Institutions Providing Educational Services in the Distance Form of Education on Training and Professional Development on the Accredited Fields and Specialties". They legitimize distance education and present the tools in recommendations. Before the quarantine, distance education at higher education institutions was considered to be "an opportunity to study and get necessary knowledge remotely from an education institution at any convenient time" [14]. At the same time "The Regulations on Distance Learning" and "The Concept of Distance Learning Development in Ukraine" regulate the rights and obligations of learning process participants. "Learning process must be built on the use of different communication tools" [13]. In these Regulations on Distance Learning, they say that "individualized process of getting knowledge, skills, abilities, and ways of human cognitive activity which occurs mainly by indirect

interaction of distant learning process which functionates based on modern psychological-pedagogical and information-communication technologies” [13]. Learning is a component of education that is why psychological-pedagogical and information-communication technologies are also necessary for distance education. It’s a new direction of further training of HEIs teachers that has not been developed for teachers of Humanitarian disciplines before. It’s about distance technologies in education which are certain platforms and services for organizing and conducting distance learning (for example, Moodle [18], Google Workspace [2], etc. [37]) that allow students and teachers to communicate and realize the learning process with all its phases. These distance technologies, depending on the countries, universities, and academic disciplines, can be integrated at any stage of academic course. This means that mass DL in Ukraine can be introduced at any time in the middle of the academic year because of the quarantine measures. Distance education is a form of education that is equal to full-time, evening, part-time education and externship which is mainly realized due to distance learning technologies. Thus, DL has a legal framework for functioning, including the quarantine period, and allows students to get the diploma. It is only necessary to correctly arrange the learning process in the quarantine conditions when digital learning becomes the basis for distance one [14]. This brings up the question about teachers’ readiness to use DL in quarantine conditions. We should emphasise that The first distance education course in the modern sense was provided by Sir Isaac Pitman in the 1840s, who taught a system of shorthand by mailing texts transcribed into shorthand on postcards and receiving transcriptions from his students in return for correction [43]. In 1856 Charles Toussaint and Gustav Langenscheidt started teaching language in the extramural form in Germany [9]. The advantage of distance learning is its accessibility for people all over the world.

During the quarantine, the Ministry of Education and Science of Ukraine has organized several events to help to implement the distance education in HEIs. We list them and analyse their content:

– At the site of the Ministry of Education and Science of Ukraine, there is a list of HEIs which gave the opportunity to study remotely before the quarantine, had the right to do it, and gained certain experience in such a type of education [14]. These HEIs provide educational services in a distance form and can share their experience. Also, they have an experience of implementing the distance technologies in the educational process (blended learning, “Face-to-face Driver”), which allows to combine in-class and electronic learning and to introduce the supplements for in-class learning and students’ independent activities [36]. They can be preconditions of DL but they cannot continue to the same extent in the conditions of the quarantine. There is a necessity to arrange the mass DL at HEIs.

– The Ministry of Education and Science of Ukraine and the Committee on Digital Transformation in Ukraine have given the list of services for arranging distance learning only for secondary school teachers [30]. But their content doesn’t regard to the teachers of Humanitarian disciplines at HEIs. However, some digital tools for carrying out DL can be useful. In May 2020, Ukraine became one of the first of three countries where there is the global learning online-platform (UNICEF, Microsoft, and Cambridge University). It offers access to learning and didactic resources, developed for the learning process participants in conditions of COVID-19 pandemic [16].

– The Ministry of Education and Science of Ukraine created a site “Teach and Learn in the Quarantine: Changes in Education System”. But this site doesn’t give instructions for HEIs teachers how to arrange DL. It foresees that HEIs teachers have a certain level of digital competence development. At the same time, HEIs in Ukraine have academic autonomy in the issues of what platforms and Internet-resources to use for implementing distance learning, but every student has to complete an individual curriculum for this academic year [17]. The Ministry of Education and Science of Ukraine published the recommendations “On organizing current, semester control and certification of students with the use of distance technologies” [15], according to which the same tool for control should be used. The question arises on how to do it if there is no high-quality Internet connection in small towns and villages in Ukraine, students and teachers have no devices for DL. So, there is a need to use different platforms, tools and communication means for DL.

Thus, in Ukraine the first opportunities are created and the state informational and organizational support for HEIs is given for implementing of digital technologies during the quarantine. And the

theories and methods of implementing digital education with the use of DT, which includes all the stages of learning process and takes into account peculiarities of activities of teachers of different specialities, including teachers of Humanitarian disciplines, haven't not been developed in Ukraine and the world yet, this is the issue of autonomous HEIs. The administrative staff of the HEIs should provide conditions for training teachers to work in distance education in the conditions of quarantine measures for realization of the right for students to get higher education. This is a new issue that requires defining the needs of teachers in education, in particular, teachers of Humanitarian disciplines. This is what prompted us to this study. Also, the Ministry of Education and Science of Ukraine doesn't instruct university teachers how to use DT. At the same time EU are solving this problem. The foreign learning platforms are iLearn, Coursera, Coursera for Campus and others. Famous world universities have given the free access to their courses. All the universities have given the access to their libraries and platforms, some platforms for distance education are developed in certain countries and even at universities [29]. However, it's important to know the foreign language to use them. So, in France HEIs "turn to more intensive use of their shared digital environment, make them available to students where the course materials are materialized" [25]. Poland has turned all HEIs to distance education, whose main feature is the compulsory dialogue between a teacher and students. At Adam Mickiewicz University the free course "The use of information and communication technologies in teachers' work" has been developed for distance learning in the quarantine conditions. At Tallinn University there is a series of seminars "Expert on the air" [29]. Thus, HEIs teachers in the quarantine conditions need technical support, technical devices, and digital tools in digital education, teacher training how to use them, pedagogical dialogue communication for better learning of the material by students, combining the efforts and creating various conditions for distance education.

In Ukraine there is also a certain experience in training teachers of Humanitarian disciplines at HEIs, using distance technologies. All the HEIs have trained teachers how to develop materials for distance learning, to work with different digital services and platforms, and to conduct an examination in a distance form. So, at Ternopil Volodymyr Hnatiuk National Pedagogical University the center of digital education is functioning which develops and implements learning courses, devoted to the methods of developing an electronic course in the system Moodle, revealing the basis of developing electronic courses for the system of managing the learning resources Moodle, using communication tools, and distance learning technologies etc. Three online seminars have been carried out for teachers: "Using activity-based components in distance learning and online communication of Moodle system". The second online seminar has continued the topic with such issues: 1. Control of knowledge using tests in Moodle (Recourse Test). Editing, developing, and uploading test tasks in Moodle system. 2. Digital tools for communication in the process of distance learning (interactive online boards, Google documents, a platform for conducting online classes). The third seminar has the topic "Tools of the service BigBlueButton for conducting online classes" (the seminar is for those who are planning to use the software BigBlueButton in distance learning). We should emphasise that the events with such content have been carried out in many universities with about the same number. During the quarantine the workers of the distance education center give the online assistance to teachers, groups at social networking sites have been created: the group of Distance Education Center of Ternopil Volodymyr Hnatiuk National Pedagogical University is functioning in the messenger Viber whose participants are the university teachers. Similar groups are also created at the university faculties and departments. All of them are aimed at direct work of the university teachers in the quarantine conditions ([38], [39]). However, the peculiarities of the training and activities of teachers of Humanitarian disciplines haven't taken into consideration yet, the training and instructions are the same for teachers of different specialities. It influences the quality of education process.

Thus, we can reveal the presence of the following contradictions in the theory and practice of education: between new requirements to carry out the mass distance learning and teachers' experience in this work; between the present information resources in the world and in the country and the lack of development of teachers' digital competence for using them in DL; the necessity to train teachers to arrange DL and the lack of researches in the conditions of the quarantine that concern the arrangement

of this learning. The basis for solving these contradictions is thought to be teachers' digital competence which is complex and unstudied for making administrative decisions on the ways of its mass development. Especially it concerns teachers of Humanitarian disciplines whose professional focus is on a human but not on technics.

Taking into account what is said above, the chosen theme of the research is considered to be relevant for improving the quality of education and ensuring its continuity in the conditions of quarantine and pandemic using DTs. DTs are considered to be a new sphere for teachers that involves their implementation in the conditions of the quarantine without having previous systematic training.

It concerns all the university teachers of Humanitarian disciplines at HEIs of Ukraine. The purpose of the paper is to define the impact of the quarantine on the implementation of distance learning in the work of teachers of Humanitarian disciplines at HEIs, the level of their digital competence and to give recommendations on how to improve its level. The studied issue concerns all the teachers of Humanitarian disciplines at HEIs of Ukraine, who work in the same conditions during the quarantine. Thus, the purpose of the paper is to define the impact of the quarantine on the implementation of distance learning in teachers' activities at HEIs, as well as the level, challenges, and peculiarities of the development of digital competence of teachers of Humanitarian disciplines, their needs in education, and to give recommendations on how to improve the level of digital competence.

2. Methodology

The methodology includes the defining of theoretical research framework, the choice of methods of studying teachers' digital competence, and research basis. Distance education is a certain type of education that is carried out using distance technologies. In 2014, as a part of the strategy Education and Training (ET) 2020 European Commission introduced a wider term – “digital and online education” (DOE). Respectively digital education is the form of teaching and learning by the use of ICT that has a lot of formats and hybrid methods, including the use of locally set up software. Online education is a prevailing form of distance learning, being realized mainly via the Internet, and implying the use of social networking sites and services Web 2.0 for shared and personalized learning using desktop computers or mobile devices at any time and from anywhere in the world. Open learning resources can also be used in it [5]. That means the terms “digital and online education”, “electronic education” and “digital education” are used as synonyms. The research of arranging the digital learning in the quarantine conditions due to a coronavirus pandemic becomes important for us ([4], [8], [10], [19], [20]), as it reveals the effective digital tools, means, and technologies of the work with students, the opportunities of Moodle platform for implementing the competence-based approach in future engineers' training (this platform is the basis for Ukrainian HEIs in the quarantine conditions), it has been revealed that the following facts are important for distance learning in the quarantine conditions: 1) modern distance education at HEIs should be electronic with the elements of electronic education which is a kind of distance education; 2) mobile learning [10]. Mobile learning is defined as a type of distance learning and electronic learning, this is an educational technology, which is based on the intensive use of modern mobile devices and technologies, gives new opportunities for teaching those students who live in isolation or in remote places or has learning difficulties [36]. Nowadays there is no unified theory of distance education in the world that is essential for developing TDC and the successful use of these tools in education. For effective distance education, the digital literacy of population and the digital competence of a specialist of the certain sphere are necessary. This is discussed in the European Framework for the Digital Competence of Educators, which contains 22 digital competences, grouped into 6 blocks. We take them into consideration in our research as a modern framework for arranging distance education, using distance technologies ([3], [4]). That is why it is necessary to know the level of teachers' digital competence and methods of its measuring. Thus, it is essential to know the essence of the term “teachers' digital competence”, its possible level of the development, and methods of measuring. Analysing the term “teachers' digital competence”, we take into account its various definitions. So, Nataliia V. Morze et al. [22] assert that “educators' digital competence is a complex dynamic holistic integrative formation of a personality that is his/her multilevel professional and

personal characteristic in the sphere of digital technologies and experience to use them, which is caused by needs and requirements of digital society, as well as by the emergence of digital learning environment that changes educational interaction of all the participants of learning process and is characterised by the wide use of the Internet, digital systems of data storing, initial data systematization, and automated digital analytical systems (based on neural networks and artificial intelligence), as well as it allows to do professional activities and requires (perhaps, stimulates or needs) constant professional self-development" [22]. This definition takes into consideration the modern experience of the EU and orientation on teachers' constant professional self-development that are important for arranging DL in the conditions of the quarantine. There is the single definition of digital competence for secondary school teachers and HEIs teachers that considers "it as the system of applied knowledge, skills, and targets which give an opportunity to arrange all the stages of educational activities and to improve the education quality, based on the opportunities that are given by digital technologies (individualization of learning, technical solution of creative tasks, interactive project work, etc.)" [1]. The same for all the definitions is direction of all the teachers to arranging the learning based on the digital framework and using digital technologies. These definitions can be supplemented by the understanding of teachers' digital competence given by Garry Falloon [6]. According to his definition, teachers' digital competence must include skills which are necessary for productive, safe, and ethical functioning in various digital environment. Thus, teachers' digital competence is described as a list of skills and their functions in modern digital educational process that must correspond to the problems of digital and human society, educational needs of teachers and students. We focus on defining what teachers of Humanitarian disciplines need in the conditions of quarantine measures for preventing the spread of COVID-19. That is why the list of skills, included in teachers' digital competence, which is described in detail in the literary sources mentioned above, becomes the basis for our research. These skills are the same for teachers of all disciplines and we don't focus on finding out the frequency of their use by teachers of different disciplines. We use it for teachers of Humanitarian disciplines.

The methods in our research are the following: survey of the teachers of Humanitarian disciplines using questionnaires, theoretical analysis of the sources, observation, conversations with teachers, and methods of mathematical statistics. We have defined the level of the development of TDC and the reasons which influence the implementation of DE in the quarantine conditions. The written survey was developed for HEIs teachers. The survey questions are based on the competence-based, andragogic, pragmatic, and activity-based approaches to distance education, as they reflect the features of teaching activities in the quarantine conditions. 222 teachers of Humanitarian disciplines took part in the survey, 61 teachers of them were from H. S. Skovoroda Kharkiv National Pedagogical University (SKhNPU), 66 teachers were from Khmelnytskyi Institute of Social Technologies of Higher Education Institution "Open International University of Human Development "Ukraine" (KhIST), and 95 teachers were from Donbass State Pedagogical University (DSPU). These HEIs were chosen as Khmelnytsky Institute of Social Technologies was the best university according to the level of distance education in the system of universities "Ukraine". This was the HEI that started the first the distance education with the students with special needs. DSPU was the HEI that was situated near the zone of the military conflict in the east of Ukraine. At this university there were the students who did not live in Ukraine, so they needed distance learning. SKhNPU was chosen as the national pedagogical university in Ukraine that was situated in a peaceful area and had the opportunities to implement all the innovations and provides quality education using distance technologies. All the teachers of Humanitarian disciplines at these HEIs were proposed to anonymously take part in the survey, 77 – 89% of all the teachers who worked at these HEIs answered the survey questions. The purpose of the survey was to find out who of the teachers of Humanitarian disciplines needed the further training for carrying out the professional activities using distance technologies, what the disadvantages were, and what should be involved into the content of their learning. The survey had the monitoring nature for improving the quality of learning process and was developed in accordance with the regulations on inner monitoring of education quality (as required by National Agency of Higher Education Quality to the accreditation of HEI, the Law on Higher Education), which had the same content in three higher education institutions. The survey had 2 blocks.

The first block was about the training and the work of teachers during the quarantine. This survey included closed and semi-closed questions; in some questions several answers should be chosen. As this wasn't the survey for studying the personal qualities and psychological characteristics of teachers, it didn't contain the lie scale. The second part of the survey included questions of the ready-made survey, tested in the Russian Federation within the EU project on defining the digital competence of HEI teachers [1].

We developed and asked such questions of the first block in the survey for the teachers of Humanitarian disciplines at HEI:

1. What is the higher education institution where you work?
2. Did you have the experience in online teaching and digital teaching of the students before the quarantine?
3. Could you conduct online and digital education before the quarantine? Yes; no; to a limited extent.
4. Have you been trained in digital and online education before? Yes; no.
5. How did you master digital competence essential for online and digital education before the quarantine? The course of further training; self-education via the Internet; consultations with colleagues; online webinars; private lessons; I didn't concern about it before the quarantine; others.
6. What or who encouraged and motivated you for mastering digital competence? The leadership of educational institution motivated financially; the leadership of educational institution motivated morally and psychologically; self-motivation and self-stimulation; it was interesting to learn and use something new in the work; I want to catch up with students; shared work with colleagues; the desire to be a modern teacher etc.
7. How did you master digital competences during the quarantine? Self-development via the Internet; consultation with colleagues; online webinars; online courses of further training; there was no need; others.
8. What difficulties did you face up to while organizing online and digital training? The lack of time; the lack of economic and material resources at home; the lack of technical facilities at home; the lack of teachers' digital competences; the lack of students' digital competence; no desire to work in digital education; there are no conditions and place to work at home; the absence of conditions in the country for developing digital education.
9. Which online forms/ways do you use for communicating with your students and colleagues?

Before the quarantine (BQ)	During the quarantine (DQ)
Telephone calls	Telephone calls
Calls and chats via messengers	Calls and chats via messengers
Online consultations	Online consultations
Online lectures	Online lectures
Online seminars	Online seminars
Online department meeting	Online department meeting
Online journal	Online journal
Online rectorate, online faculty meeting, online department meeting	Online rectorate, online faculty meeting, online department meeting
Online defense of course works	Online defense of course works
Online academic council meeting	Online academic council meeting
Online examinations, credits	Online examinations, credits
Others	Others
10. Which other digital tools have you used in your pedagogical activities? (you can choose some of them):

Before the quarantine	During the quarantine
Presentations	Presentations
Watching video/ Listening to the audio	Watching video/ Listening to the audio
Computer tests/ quizzes	Computer tests/ quizzes

Digital posters	Digital posters
Mind maps	Mind maps
Blogs and wiki	Blogs and wiki
Interactive tables	Interactive tables
Interactive posters	Interactive posters
Virtual tours	Virtual tours
Virtual laboratories	Virtual laboratories
Others	Others
I haven't used any digital tools yet	I haven't used any digital tools yet
11. How much time have you spent to prepare for classes?	
Before the quarantine	During the quarantine
Less than 1 hour on a lecture	Less than 1 hour on a lecture
Less than 0.5 hour on a seminar	Less than 0.5 hour on a seminar
More than 1 hour on a lecture	More than 1 hour on a lecture
More than 0.5 hour on a seminar	More than 0.5 hour on a seminar

The analysis of various methods of measuring the level of digital competence has revealed that Galina U. Soldatova's method [33], who first developed it, is the most interesting and modern, but it is applicable to schoolchildren. That is why we measured the index of ICT competence – the integrative indicator that describes the teachers' readiness to actively use ICT in educational process [1]. The index of teachers' digital competence was studied, based on six levels which were defined in the research in the Russian Federation. All the survey questions were developed on the basis of European Digital Competence Framework 2.0 for educators (DigCompEdu [4], [40]) and adapted by Analytical Center applied in education system of the Russian Federation [1]: A1 – Newcomer, A2 – Explorer, B1 – Integrator, B2 – Expert, C1 – Leader, C2 – Pioneer. The index of ICT and the index of teachers' digital competence were considered as synonymous definitions. As the basis for the survey was European Framework, we used it for conducting the survey of teachers of Humanitarian disciplines for defining their level of digital competence in the context of Ukrainian orientation to European integration, the reformation of the education system, and the common roots of education in Ukraine and the Russian Federation [1]. So, we describe them:

A1 Newcomer. Teachers should develop their skills to use digital technologies in educational process. It is necessary to improve educational process, to support these improvements in a new term and to gradually increase the competence level in the field of digital technology.

A2 Explorer. Teachers are aware of the fact that digital technologies have a high potential and want to master them for using in their professional activities. They start occasionally using digital technologies in classes.

B1 Integrator. Teachers try using digital technologies in different contexts and for different purposes, implementing them in their teaching practice. They use DTs creatively, trying to improve their professional skills and to expand the scope of digital technologies.

B2 Expert. Teachers use a great number of digital technologies confidently, creatively, and critically in their professional activities. They select digital technologies purposefully and try to comprehend the advantages and disadvantages of different digital strategies. They are open to new ideas and understand there are digital technologies which they haven't applied yet and which they can implement in their teaching practice. Trying, they upgrade, structure, and improve their set of strategies.

C1 Leader. Teachers develop consistent and complex approach to using digital technologies in teaching practice. They have a certain number of digital strategies and are knowledgeable about the most suitable strategy for the certain situation. Teachers always think about enhancing their practical skills. They always know about innovations as they share experience with experts and are always ready to help colleagues – to teach them to use digital technologies in educational process and to explain them what the benefits of digital technologies in educational process are.

C2 Pioneer. Teachers question the adequacy of modern teaching practice, using both innovative decisions and traditional methods. They think about restrictions and disadvantages of modern educational process and try to improve it. Teachers-innovators try using highly innovative and challenging digital technologies and develop new pedagogical approaches. They are also guides to innovations and role models for other educators [1].

The methods include assigning points on the scale. Taking into account the points assigned, each respondent was assigned to one of 6 groups [1].

3. Research results and discussion

We conducted the survey among the teachers of Humanitarian disciplines at three higher education institutions: SKhNPU, KhIST, and DSPU. Its results are presented in tables 1, 2, 3. Tables 2, 3 BQ indicate the data before quarantine, and DQ has data during quarantine.

Table 1. The results of the survey of the teachers on implementing distance education in the quarantine conditions.

	SKhNPU	KhIST	DSPU
2. Your scientific and pedagogical experience			
3-10 years	53%	18,2%	2,6%
10-20 years	26,7%	63,6%	7,9%
more than 20 years	20,3 %	18,2 %	89,5 %
3. Your age			
under 30	33,3%	0 %	18,4%
30-39	26,7%	63,6%	51,8%
40-49	26,7%	36,4%	14,9%
50-59	6,7%	0 %	12,3%
60 and over	6,7%	0 %	2,6 %
4. Did you have the experience of online and digital education before the quarantine?			
Yes	60%	91%	84,2%
No	40%	9%	15,8%
5. Could you implement online and digital education before the quarantine?			
To limited extend	60%	27,3%	32,5%
No	13,3%	0 %	5,3%
Yes	26,7%	72,7%	62,3%
6. Have you been trained in online and digital education before?			
Yes	73,3%	72,7%	68,4%
No	26,7%	27,3%	31,6%
7. How did you master digital competences during the quarantine?			
Online webinars	6,7%	45,5%	22,8%
Self-education via the Internet	80%	81,8%	46,5%
Courses of further training	26,7%	18,2%	22,8%
Consultations with colleagues	46,7%	90,9%	42,9%
Private lessons	6,7%	0%	0%
Studying the subject, distance education	6,7%	0%	0%
8. What or who encouraged and motivated you for mastering digital competence? (you can choose some answers)			
self-motivation and self-stimulation	80%	63,6%	21%
it was interesting to learn and use something new in the work	60%	36,4%	5,3%
the leadership of educational institution motivated morally and psychologically	13,3%	54,5%	51%
the leadership of educational institution motivated financially	0 %	18,2 %	2%
The conditions of the accreditation	0,8%	1,5 %	1,8%
9. How did you master digital competences during the quarantine?			
Self-education via the Internet	100 %	81,8 %	60,5%
Consultation with colleagues	66,7 %	72,7 %	37,7%
Online webinars	33,3 %	36,4 %	24,6%

	SKhNPU	KhIST	DSPU			
Private lessons	6,7 %	0 %	0%			
There was no need	0	18,2 %	5,3%			
10. What difficulties did you face up to while organizing online and digital training?						
The lack of time	53 %	27,3 %	31,6%			
The lack of economic and material resources at home	26,7 %	0%	15,8%			
The lack of technical facilities at home	20 %	18,2 %	15,8%			
The imperfection of teachers' digital competences	33,3%	0%	11,4%			
The imperfection of students' digital competence	13,3 %	45,5%	15,5%			
There are no conditions and place to work at home	40%	18,2%	3,5%			
The absence of conditions in the country for developing digital education	20,3 %	9%	8,8%			
No desire to work in digital education	0 %	0%	4,8 %			
11. Which online forms/ways do you use for communicating with your students and colleagues?						
	BQ	DQ	BQ	BQ	DQ	
Telephone calls	73%	46,7 %	91%	72,7%	74,6%	74,6%
Calls via messengers	66,7%	53,3%	81,8 %	91%	77%	77%
Online consultations	26,7%	80%	54,5 %	100%	3,5%	85,1%
Online lectures	60,7%	100%	27,3%	100%	12,3%	70,2%
Online seminars	60,7%	100%	18,2 %	100 %	3,5%	100%
Online department meetings, exams, and course works	60,7%	100%	18,2 %	91 %	3,5%	100%
12. Which other digital tools have you used in your pedagogical activities? (you can choose some of them)						
	BQ	DQ	BQ	DQ	BQ	DQ
Presentations	80%	46,7%	90,9%	81,8%	66,7%	53,5%
Audio/video	60%	60%	63,6%	100%	53,5%	53,5%
Computer tests	40%	73%	81,8%	100%	54,4%	57,9%
Mind maps	53%	53%	45,5%	63,6%	6,1%	26,3%
Blogs	40%	67%	45,5%	72,7%	25,8%	57,8%
Interactive posters	40%	67%	27,3%	81,8%	9,6%	50%
Virtual tours	33%	73%	45,5%	72,7%	9,6%	50%
Virtual laboratories	13,3%	93%	45,5%	81,8%	9,6%	0%
Haven't used yet	80%	20%	36,4%	72,7%	0%	0%
Others	33%	73%	81,8%	27,3%	0%	0%
13. How much time have you spent to prepare for classes?						
	BQ	DQ	BQ	DQ	BQ	DQ
Less than 1 hour on a lecture	40%	33,3 %	45,5%	27,3%	38,6%	57%
More than 1 hour on a lecture	60%	66,7%	54,5%	72,7%	61,4%	43 %
More than 0,5 hour on a seminar	40%	60%	45,5%	45,5%	26,3%	18,4%
Less than 0,5 hour on a seminar	60%	40%	54,5%	54,5%	73,7%	81,6%

Table 2. Calculations of the index of digital competence of teachers of Humanitarian disciplines (methods [22]).

	SKhNPU (61)	KhIST (66)	DSPU (95)
0–19 group A1 Newcomer	0%	0%	0%
20–33 group A2 Explorer	23,5%	14%	9,0 %
34–49 group B1 Integrator	23,5%	14%	54,5%
50–65 group B2 Expert	53 %	33%	18,2%
66–80 group C1 Leader	0%	0%	18,3%
81–88 group C2 Pioneer	0%	0%	0%

The analysis of the results (table 1) has revealed that the same number of teachers at SKhNPU and KhIST have work experience more than 20 years (20,3% and 18,2%), whereas at DSPU the number of teachers who have work experience more than 20 years is 89,5%. KhIST takes the first place, where the

number of teachers with work experience between 10 and 20 years is 63,3%, SKhNPU takes the second place (26,7%), DSPU takes the third one (7,9%). The number of teachers with work experience less than 10 years is the biggest at SKhNPU (53%), at KhIST (18,2%), at DSPU 2,6%. These figures correlate with the age of teachers of Humanitarian disciplines. The biggest number of teachers who are under 30 is at SKhNPU (33,3%), at KhIST (18,4%), at DSPU 0%. The teachers of Humanitarian disciplines who are between 30 and 39 most work at KhIST (63,6%), at DSPU (51,8%), SKhNPU (26,7%). The teachers of KhIST (36,4%), SKhNPU (26,7%), and DSPU (14,9%) are between 40 and 49. The teachers between 50 and 60 work at DSPU (12,3%), SKhNPU (6,7%), KhIST (0%). The teachers of Humanitarian disciplines at SKhNPU and DSPU (6,7% and 2,6%) are over 60, KhIST has no teachers of this age group. These figures prove that DSPU and SKhNPU have teachers of Humanitarian disciplines who are older than those at KhIST. This proves that they learned at school and university without studying computer sciences which developed skills to conduct lifelong self-education and digital competences, to find information on the Internet. Whereas KhIST has a staff of mostly young teachers, who are energetic and since the childhood have been learning, using different gadgets, and learn systematically computer sciences; they used the knowledge gained in everyday life. So, they have certain digital literacy. There are many young teachers who have work experience at SKhNPU. They also have an opportunity to more easily take up online digital education in the quarantine conditions. At KhIST the teachers work who are mostly between 30 and 50. They have a significant difference in previous training that concerns digital competences which depends upon the development of the Internet and learning gadgets. Thus, Humanitarian disciplines are mainly taught by young teachers at SKhNPU and by experienced teachers at DSPU and KhIST. At the same time, before the quarantine 91% of teachers at KhIST, 84,2% of teachers at DSPU, and 60% at SKhNPU had the experience of teaching in online and digital environment.

It was found out that the age isn't defining condition to master digital competences. The work experience has also an influence on it. At the same time 72,7% of teachers of KhIST, 62,3% of DSPU, 26,7% of SKhNPU can implement distance education and confidently say 'yes'. The young teachers are unconfident in their TDC. However, the distance education was implemented mainly at KhIST, where a lot of students with special needs and military workers study who cannot always be physically present at classes. We also can assert that the young age and skills to work with gadgets do not include all the components of TDC, they need not only digital literacy, but also teachers' digital competence. We have studied if the teachers have been trained how to teach in distance education before (tables 1 and 3). So, 73,3 % – SKhNPU, 72,7 % – KhIST, 68,4% – DSPU were trained in distance education before the quarantine. If we look at such a training in accordance with the teachers' age (table 3), we can see that 100% of teachers at SKhNPU, who are under 30, between 50 and 59, and over 60, 50% of the teachers, who are between 30 and 39, and 60% of teachers, who are between 40 and 49, were trained (before the quarantine) in digital and online education. That means that young teachers are taught digital competences, but there is an urgent need to develop pedagogical digital competences for successful distance education. So, at SKhNPU the teachers who are between 30 and 50 are less taught, but more than half of them have such a special training. DSPU and KhIST haven't established such a training for young teachers who are under 30, relying on their digital literacy, at KhIST there isn't any training for teachers who are over 50 and 60. Special attention at KhIST is paid to the teachers who are between 30 and 39 (85,7%), between 40 and 49 (50%). More than half of the teachers at DSPU who are between 30 and 60 have passed themselves such training, this mainly concerns the persons who are older than 40. These teachers have well-developed professional competences, work experience, but they lack teacher digital competences (TDC).

Questions 7 and 9 explain how the teachers of Humanitarian disciplines have mastered TDC before the quarantine and during it. It's interesting that before the quarantine the teachers improved their professional level of TDC through the self-educating activities on the Internet (80% of teachers at SKhNPU, 81,8% of teachers at KhIST, 46,5% of teachers at DSPU). The second place takes consultations with colleagues – 90,9% at KhIST, 46,7% at SKhNPU, 42,9% at DSPU. So, the teachers didn't need specially organized training for their work, they successfully dealt with those competences

they had before. 45,5% of teachers at KhIST, 22,8% at DSPU improve their level of TDC via online webinars. Less than quarter of teachers at all the HEIs need the courses of further training: 26,7% of teachers at SKhNPU, 18,2% of teachers at KhIST, 22,8% of teachers at DSPU. They are mainly persons who are over 40. That means that they are aware of the lack of their TDC and consciously continued studying. The rest of the ways of improving the level of TDC get equally about 6,7%. They are private lessons and distance education. So, before the mass transition to distance education, the teachers worked, having such a level of the competence that they had, that was sufficient to do their everyday teaching activities. The teachers who are over 40 need specially organized training. Thus, the age and the previous ICT training influence the development of TDC of teachers of Humanitarian disciplines. They have an opportunity to improve their level of TDC via different forms of further training, including formal, informal and non-formal education. However, it is the most difficult to work in distance education for young teachers who are under 30 who don't have pedagogical professional competence. Teachers who are over 40 need the further training in developing TDC if they have pedagogical competences. We look into other reasons that affect the successful development of distance education at HEI. The answers to question 8 reveal them. The greatest work to motivate its staff has been done by the leadership of KhIST, there are all possible types of motivation and stimulation and the teachers are also very aware. The teachers of SKhNPU appear to be the most aware of self-education (80%) who are little stimulated psychologically and morally and who aren't financially stimulated at all. At DSPU the leadership's moral and psychological stimulation (51%) has the greatest influence, some of the teachers (21%) have self-motivation and self-stimulation, however, they are not interested in every issue for using it in their professional activities (5,3%), but they are sure they need them in everyday life. Whereas the teacher of Humanitarian disciplines at SKhNPU (60%) and KhIST (36,4%) have an interest and ability to use something new in their work. This can be explained by their young age, not long work experience, and the habit of working with gadgets. Thus, financial, moral, and psychological stimulations have an influence on the development of TDC, as well as self-motivation and self-stimulation do. The total quarantine in the world and in Ukraine because of coronavirus pandemic and transition of Ukrainian HEIs to the distance education causes the necessity to master TDC by the teachers of Humanitarian disciplines. All the teachers understand that it is the only way of preserving the workplace and salary. There are no persons who don't want to master TDC in all HEIs that are crucial for conducting professional activities. We also revealed the difficulties in mastering TDC during the quarantine learning according to their age (question 10). The similar answer of all the teachers is that they lack time. The preparation to the exams takes more time (question 1). But teachers at KhIST, SKhNPU and DSPU spend less time on getting ready to the seminars. Whereas the teachers at DSPU spend less time on lectures. If we consider the influence of the age on the preparing for lectures, we can see that the teachers who are over 40 and 50 spend more time on preparation for lectures than in other age groups, excluding young teachers who are under 30 and read little. It proves the necessity to master new forms of distance education and new tools by teachers, as well as to have time for doing this. At the same time according to the rate of difficulties of mastering TDC for implementing distance education in the quarantine conditions, the absence of place and conditions to study at home (especially in Kharkiv) takes the next place, the further difficulty is the lack of economic and material resources. They not always have a free computer when the children are learning at home. Not everyone has high speed Internet connection, a free room where a teacher can give lectures and communicate with students for hours. The teachers of all the HEIs which take part in the survey complain about the absence of the conditions in the country for implementing distance education. Some students are not registered in Moodle, some of them don't have Internet connection as they live in villages and small towns. The low level of the development of TDC is a challenge for the teachers of SKhNPU, to a lesser extent for the teachers at DSPU. At the same time the teachers of DSPU, SKhNPU and KhIST pay attention to the fact that the students' digital competence is insufficiently developed and foreign students don't have access to distance education because of their countries (China, Turkmenistan). That is why it is impossible to implement distance education with them. We compare difficulties in distance education: imperfection of TDC and imperfection of students' digital competence (figure 1, figure 2).

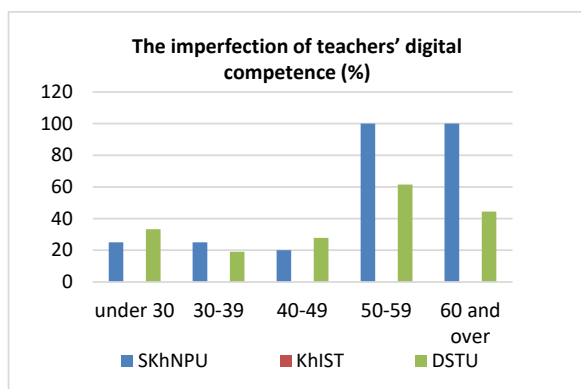


Figure 1. The imperfection of teachers' digital competence (%).

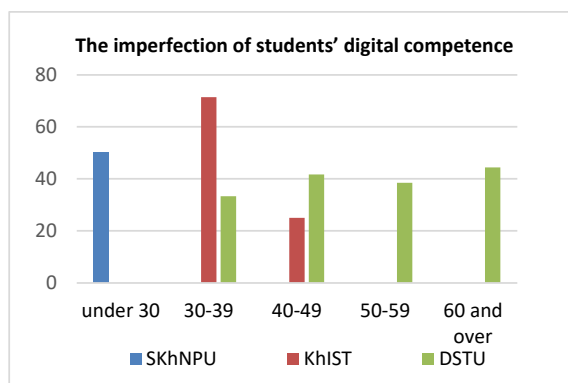


Figure 2. The imperfection of students' digital competence (%).

This imperfection is claimed mostly by the teachers of SKhNPU and DSPU (between 44% and 100%), aged between 40 and 60, it isn't claimed by teachers of KhIST of all age groups (0%). About the quarter of teachers at SKhNPU and DSPU are not satisfied with the development of their TDC. Almost all teachers are dissatisfied with the students' level of digital competence, excluding young and older generation of KhIST (0%) that is proved by the fact, for example at SKhNPU, that there is no certain discipline, aimed at developing students' digital competence, in curricula

The teacher training, focused on developing TDC during the quarantine, has changed, as well as its forms have. We can consider which forms appear to be the most effective and preferred by teachers (table 3).

Table 3. The ways of developing teachers' digital competence.

	SKhNPU		KhIST		DSPU	
	BQ	DQ	BQ	DQ	BQ	DQ
Course of further training	23,9	4,8	18,2	9,1	22,1	9,5
Self-education via the Internet	95,2	100	81,8	81,8	100	100
Consultations with colleagues	57,1	71,4	63,7	72,7	82,1	77,9
Online webinars	38,1	47,6	45,5	36,4	25,3	54,7
Private lessons	0	0	0	0	1,1	2,1
There is no need	0	0	0	9,1	0	0
Others	0	9,5	0	0	1,1	8,4

Most teachers are trained by conducting self-education activities, courses of further training at all HEIs, which are mostly realized via webinars. However, the situation is different at different HEIs, depending on the teachers' age. So, self-education via the Internet for teachers, aged under 30, appears to be effective at SKhNPU and DSPU (100%), at SKhNPU the consultations with colleagues take the second place (75%), short online webinars – 5%.

Long courses of further training are not suitable for young generation of teachers. But at DSPU this age group has the different answers – 33% for both consultations with colleagues and short online webinars, the courses of further training under the condition of 100% self-education via the Internet. At KhIST the teachers of this age group don't master TDC in such a way, they use different ways and means, as they have higher level of training as the condition of conducting their professional activities even before the quarantine. At the end of 2019 Moodle at KhIST was developed by 78%, during the quarantine – 98%. This means that self-education and consultations with colleagues for teachers, aged under 30, turn to be the most effective form for developing TDC. This can be explained by their digital literacy and incomprehension of the necessity to master TDC. The courses of further education (100%) appear to be the most interesting for teachers at SKhNPU, aged between 30 and 39, 50% – for both self-

education via the Internet and online webinars. For the teachers of this age at KhIST self-education via the Internet (85,7%) and consultations with colleagues (85,7%) are the most suitable, but there are those teachers who are interested in the courses of further training (14,3%) and short online webinars (42,8%). Thus, they have already had the conscious need to develop TDC. The teachers of DSPU the least choose the courses of further training (19,4%) and the most – self-education via the Internet (66,7%), the consultations with colleagues (57,0%) and short webinars are also helpful for them. At the same time the courses of further training at DSPU have been essential for developing TDC, the teachers were stimulated to work in Moodle, but when the problem arose, they became interested in how to solve this problem, so they chose short online webinars and consultations with colleagues. The age between 40 and 49 is characterized by other answers. The courses of further training (100%) are helpful for improving teachers' qualification, 40% are influenced by self-education via the Internet and consultations with the colleagues. So, it is necessary to have thorough long-term education and additional sources. This can be explained by new requirements to distance education, for example, how to take state and qualification exams, to hold a session and to check students' assignments. At KhIST, the consultations with colleagues (75%) and self-education via the Internet (75%), online seminars (50%) are helpful the teachers, some of them need the courses of further training. The teachers at DSPU give similar answers to KhIST about self-education via the Internet and consultations with colleagues, but they less need online webinars (50%) and more need the courses of further training (36%) than at KhIST. This can be explained by the fact that the teachers at DSPU are older than at KhIST. The teachers, aged over 50, equally use all the ways of developing TDC at SKhNPU (all the ways get 50%), at KhIST there are not many teachers of this age group that is why they are not trained, at DSPU they study more, however, there are much more teachers of this age group than at SKhNPU and KhIST. They use all the ways, but the courses of further training are preferable (more than 77%). The teachers, who are over 60, also improve their qualification, but to different extent and by different ways. So, at SKhNPU they mainly study through the self-education via the Internet and consultations with colleagues, but they don't use the courses of further training and online webinars. At KhIST there are no teachers of this age that is why they don't improve their qualification. There are many teachers of this age at DSPU and they use mainly the same ways as the teachers at SKhNPU, and they use online webinars (36,4%), too.

We have studied how the use of different forms/ways of communicating of teachers with students and colleagues in distance education have changed during the quarantine (Question 11). It is found out that telephone connection, which was the priority way of communicating at all the HEIs, is also used, but the frequency of its use has slightly decreased among the teachers of all HEIs, excluding DSPU where it is at the previous level. The calls via the messengers have decreased at SKhNPU, increased at KhIST and been the same at DSPU. The number of online-consultations, online-lectures and online-seminars has significantly increased at all HEIs and reached 100% rate. The number of online department meetings, taking examinations and presenting course works has also increased at all HEIs (100%), excluding KhIST.

This proved the complete transition of these HEIs and their teachers to conducting the learning process in the form of distance education. The changes have occurred in using digital tools by teachers in their professional activities. All the teachers use presentations less, that means that lectures have changed their character. At KhIST audio and video are used more (100%). This is a prospective direction of organization of practices with the analysis of what is seen and doing tasks, based on them. All the teachers use computer tests more, excluding the teachers of DSPU. This can be explained by the fact that the teachers at DSPU hope that students will take examinations at face-to-face meeting. Mind maps are more used at HEIs, excluding SKhNPU where they have been used at rather high level before. They are considered to be reference signals of V. Shatalov as visual means at lectures. Instead of the presentation, which has pages, the mind map is always in front of students' eyes and repeated many times, so it contributes to better assimilation of material. The use of blogs, interactive posters, and virtual tours has increased in all HEIs, whereas the use of virtual laboratories has increased at SKhNPU and KhIST a lot and decreased at DSPU. This can be explained by the fact that the combination of words with visual aids contributes to assimilation of material. Special attention should be paid to the fact that

these visual aids must be interesting and repeatable in different forms. The teachers of SKhNPU use various digital tools, whereas the teachers at DSPU don't use them, at KhIST they reduce the use of other digital tools. This can be explained by the fact that every teacher has academic freedom within the education standard. However, 20% of teachers at SKhNPU and 18,2% of teachers at KhIST haven't used digital tools yet that is a large percentage of teachers. This is caused by the fact that some teachers gave all the lectures and seminars within the academic disciplines before the quarantine started (for example, higher school pedagogy and pedagogy in the third semester). That is why they didn't use any digital tools.

The level of the development of teachers' digital competence is presented in table 2. According to the methods selected [1] it's revealed: there are no newcomers of A1 level at any HEI, all the teachers have the practice and experience of using TDC in education (table 1). Level A2 is the highest at SKhNPU, DSPU takes the second place and it is the lowest at KhIST that proves their high readiness to distance education. The greatest number of teachers who has level B1 is at DSPU and KhIST, the least number is at SKhNPU that says about the insufficient readiness of some teachers of SKhNPU to do their professional activities in distance education. Most teachers of SKhNPU have a level of expert in comparison with the teachers of DSPU and KhIST. No teachers at SKhNPU have Level C1, but some teachers at DSPU and KhIST have it. The teachers of Humanitarian disciplines don't have level C2 that is natural. These data indicate that the level of digital competence of teachers of Humanitarian disciplines is different within one HEI and it differs significantly between different higher education institutions.

The practical significance of the results of our research refers to the fact that the level of digital competence of teachers of Humanitarian disciplines and the results of its analysis make it possible to develop the system of further training and webinars based on diagnosing digital competence of the teachers of Humanitarian disciplines. So, according to the results of the survey of teachers of Humanitarian disciplines at SKhNPU and the analysis of reports of the departments about the arrangement of distance learning during the quarantine, we submitted the proposal about the arrangement of differentiated internships to the administrative staff for developing digital competence of teachers of Humanitarian disciplines. According to Order 64-od of SKhNPU dated April 14, 2020 "On Arrangement of Educational Process during New Academic Year and Planning Teaching Activities of Scientific and Pedagogical Staff During 2020-2021 Academic Year", the individual working plan of each member of scientific and pedagogical staff includes intra-university internship per 8 hours for developing digital competence and implementing the individual development trajectory, taking into account the needs of employees, their level of digital competence development, and objectives of the university on the distance learning platform of SKhNPU according to a certain schedule at the Department of Information Technology. In according to this order at the Department of Information Technologies of the Institution of Informatisation of SKhNPU, the internship programs were developed on the topics [7]: "The implementation of information and communication technologies in the educational process" (Level A), "The implementation of open resources in education" (Level B), "Technology of developing the distance course on the platform Moodle" (Level C). Levels A1-A2, B1-B2, C1-C2 are combined as in practice they are very close to each other. The topics of the program of level A include the familiarization with Google services for developing the personal environment (making personal email, Google Communities, Google Calendar, and Google Disk). In the program of Level B, the participants are proposed to make educational products for distance learning (PowerPoint presentations), video and audio files, infographics (Canva), mind maps (XMind), interactive posters (Thinglink), etc.). The program of level C includes the development and presentation of the distance course on the platform Moodle. After finishing the internship, the participants get certificates, approved by the Academic Council of SKhNPU. This internship is developed for teachers of Humanitarian disciplines, as teachers of technical disciplines have a high level of the development of digital competence. It helps teachers of Humanitarian disciplines arrange distance learning during the quarantine. The purpose of the internship is to improve the digital competence of teachers of pedagogical universities for implementing information and communication technologies in scientific and teaching

activities for different profiles of curricular, for familiarizing with the system of distance learning on the platform Moodle, innovative approaches to implementing DL in HEIs. Special attention is paid to the tools of a safe cyber environment, searching and critical processing of information, multimedia learning resources, and the tools of effective intellectual activity in a personalized learning network. Special attention is paid to the integration of e-resources (video and photo hosting) and mass online open courses (MOOCs), principles of academic integrity, etc. The final result of the internship is the portfolio of digital technologies for improving the process of implementing a certain curriculum and author course-resource on the distance learning platform Moodle [7]. One of three internships is free, but the administrative staff of the university solves the problem of giving an opportunity to the teachers who have level A of the development of digital competence to master the further levels free of charge. We should emphasise that before the internship teachers are proposed to take part in an online survey to define the level of their digital competence development and according to the survey results the teachers can choose the internship program (Levels A, B, C). The internship is practice-based and pragmatic. After it, the further training of teachers is planned to be more systematic, to have a wider scope and longer term. These issues are being developed now and the results of this research are the basis for making administrative decisions about developing digital competence of teachers of Humanitarian disciplines for ensuring the education quality in the conditions of quarantine measures due to the internship and further training of teachers of Humanitarian disciplines.

The data obtained in the research prove that the level of development of digital competence of teachers of Humanitarian disciplines is different within one higher education institution and it is significantly different among HEIs. We should emphasise that the levels of teachers' digital competence are similar to the data of Russian research [1]. However, they don't focus on the specificity of Humanitarian disciplines that is why all the levels of TDC are present. We also compare obtained empirical data with data obtained by Nataliia V. Morze et al. ([22], [23]) about TDC and the motivation of teachers of all the disciplines for its development. When the quarantine wasn't introduced, in usual conditions of pedagogical activities, the factors that influenced the motivation of teachers of different disciplines for mastering TDC were listed: STEAM-education (Science, Technology, Engineering, Art, Mathematics) [34]; the development of competences (subject [11] and key [32] ones); the learning personalization [12]; adaptive learning [27]; practice-based learning, oriented to the certain results [35]; the development of entrepreneurial [44], research [24], and critical [31] thinking; gamification – learning by playing [42]; the development of informal education, openness and accessibility of education [36]; mobile learning [41]; the change of the teacher roles [1]. There are different points of view at the preconditions of mastering TDC at usual times and during the quarantine and the pandemic, but there are some similar points: the change of the teacher and student roles, practice-based learning, and mobile learning that indicate a decrease in the number and strengthening of certain preconditions of the influence on mastering TDC in the conditions of the quarantine. In usual conditions, teachers are more motivated for mastering the tools for working with electronic documents that proves their readiness to the transition to electronic document management that is also an important in both the quarantine and mass distance learning [23]. We should emphasise that in the conditions of the quarantine it is necessary to train teachers how to build the educational process on DT as the new system of work should be implemented, whereas in usual conditions it is necessary to improve teachers' qualification in the sphere of developing their digital competence, taking into account the blended learning: studying electronic documents, tools for scientific communication, communicating and sharing messages, managing the learning process, arranging activities, and demonstrating the opportunities of mobile devices in the learning process [23]. According to our research, the motivation for developing TDC in the conditions of the quarantine can be various and complex that combines inner motives and external stimuli. The other researches study only the inner motivation of teachers [23]. The assistance of colleagues and administrative staff of HEIs is required, but in the conditions of the quarantine the role of state authorities in organizational, technical, and informational support of DT and training teachers to do such work is increasing. Also, in the conditions of the quarantine it turned out to be that the necessary productive activity of teachers, new communication ethics and relations between teachers and students, as Garry

Falloon [6] emphasised earlier, do not depend on the quarantine, they are the conditions of effective DL. Thus, features of the development of TDC are common and different in usual conditions of HEIs work and in the conditions of the quarantine.

4. Conclusions

The carried-out research allows to assert that:

1. The chosen for research issue is relevant in the context of solving identified contradictions and problems in theory and practice of higher education in Ukraine and in the world. The issue is insufficiently studied problem of education theory. The researches, which are present, mainly reveal DL in the conditions of the quarantine and digital tools that are effective in DL. In the conditions of mass digital education during the quarantine the role of human factor in supporting higher education quality is increasing. This proves the necessity to turn to the problem of developing digital competence of teachers, in particular teachers of Humanitarian disciplines, whose main professional focus is a human but not technics.

2. The identified peculiarities of the influence of the quarantine measures on arranging DL by teachers of Humanitarian disciplines at HEIs. These peculiarities include increasing the workload of teachers and the necessity to master TDC, time management, and health preserving learning technologies; the lack of time for developing TDC and the sudden transition of all teachers with different levels of TDC to distance learning, even those who are not ready to do it that influences the education quality, the time spent to prepare for classes, and the motivation of teachers of Humanitarian disciplines to master TDC in the conditions of the quarantine, regardless of age and experience; the change of the content and forms of teachers' activities in distance education, the use of new digital tools, resources, and their search; mutual support, consulting and mutual help of teachers in arranging distance learning and educational process in the conditions of the quarantine; the increasing opportunities for improving the qualification in the sphere of developing TDC in informal education, the absence of financial support of the state in mastering TDC, the responsibility of HEIs administrative staff for supporting the information autonomy of HEI, which makes the exchange of the experience in arranging DL more complicated; giving the opportunity for teachers and students by communication technology company to freely use their platforms, digital services, and tools during the quarantine; a new document management and communication.

3. The peculiarities of developing digital competence of teachers of Humanitarian disciplines during the quarantine are revealed: the level of the development of TDC is different and it depends on teachers' ages, teaching experience, previous training for developing TDC and experience of implementing distance learning in educational process before the quarantine, stimulation and inner motivation of teachers for mastering TDC, as well as the presence of technical, organizational, informational, and financial opportunities for its development. There are similar and different features of developing TDC in the conditions of the quarantine and in the usual conditions. The scientific framework for its developing in the conditions of the quarantine includes pragmatic, practice-based, system-based, informational, organizational and competence-based approaches.

4. The needs of teachers of Humanitarian disciplines in education for developing TDC are distinguished. There is an urgent need of all the teachers to improve their qualification, participating in the courses of further training in distance education and short-term thematic webinars on a specific problem; the differentiated learning is required that depends on the level of the development of TDC, digital literacy, teaching experience, and teachers' ages.

5. The challenges in arranging DL are distinguished: the different levels of the development of TDC; the lack of organizational, material, informational, and technical resources, the absence of the conditions at home for carrying out DL during the working day; simultaneous training of teachers for developing TDC and the arranging of the real educational process.

6. The justified recommendations are given to HEIs administrative staff on developing TDC based on which the administrative decisions are proposed and made. Three internship programs of different

levels are developed, depending on the results of diagnosing on the basis of tested methods and survey results.

The prospects of further research are the development of the concept of digital education at HEI and training teachers for its further implementation, the development and implementation of topics of long-term courses for improving qualification of teachers who have different levels of the development of digital competence, the justification of DL system in the conditions of the quarantine, the development of stimulation and motivation of teachers of Humanitarian disciplines for enhancing their digital competence.

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Shift from blended learning to distance one during the lockdown period using Moodle: test control of students' academic achievement and analysis of its results

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Abstract. The article highlights the urgency of the problem of introducing blended learning into the educational process of institutions of higher education and ensuring the quality of education using the tools of e-learning management system. The experience of using electronic testing during the final control of students' educational achievements is covered. A thorough analysis of the results was carried out, in particular the relationship between current and final grades, test scores and its duration were established. The reliability of the test tasks separately and the test as a whole, among other indicators, were tested using mathematical statistics methods.

1. Problem statement

In the context of global computerization of education, the problem of searching the ways of optimal combination of traditional learning (face-to-face learning) and distance learning using ICT is still relevant. One of the modern educational trends is blended learning. According to a number of scientists, such as Nisha Shantakumari [28], Li Mei [20] and others this kind of learning makes it possible to eliminate the shortcomings present in traditional and distance learning, if considered separately.

Due to the fact that education was affected by the COVID-19 pandemic and as a response to the quarantine implementation with university closures and restrictions in a considerable number of countries worldwide in winter and spring of 2020 a shift to distance-learning has become a crucial matter in education [3], [6], [9], [36], [37]. In particular, it has become essential to enhance a teacher-student interaction and to provide guidance and support in the modes of synchronous and asynchronous learning.

The use of Moodle learning management system in the learning process during the lockdown on the conditions of providing appropriate methodological guidance and requirement of the development of a certain level of computer literacy; specifically, students' knowledge and abilities to use computers and related technology ensures a high quality of education.

2. Theoretical background

2.1. The theoretical background of blended learning use

Yurii V. Tryus and Inna V. Herasymenko contemplate the blended learning as synthesis of traditional, electronic, distance and mobile learning. Scientists give a rather complete definition of this notion:



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“Blended learning is a purposeful process of acquiring knowledge, competences and skills, digestion of ways of cognitive activity by the subject of learning; and development of his creative abilities on the basis of complex and systematic use of traditional and innovative pedagogical technologies and information and communication technologies of learning on the principle of complementarity for the purpose of improving the quality of education” [38]. This definition doesn’t contradict the interpretation by Andrii M. Striuk. He defines blended learning as a purposeful process of acquiring knowledge, competences and skills in the context of classroom and extracurricular training of the subject of learning process on the basis of mutual complementation of traditional, electronic, distance and mobile learning [30].

One of the positive features of Moodle is the ability to use it with the appropriate mobile application. So, learning really becomes mobile and dynamic [17], [23], [34], [35]. Mykola I. Striuk, Serhiy O. Semerikov and Andrii M. Striuk define the mobile learning (M-Learning) as a modern direction of development of distance education systems with the use of mobile phones, smartphones, e-books [31]. Researchers identify a number of advantages over other learning systems, including interactivity, instant feedback, time-limitation, and more. Thus, the students were able to pre-process study materials, tests at a convenient time and in a convenient place for them. Phones, which are constant companions of modern young people, in the described situation, turn into a powerful working tool.

Comparing the academic performance of students in blended and traditional learning, researchers conclude that blended learning contributes to enhancing students' academic achievements and improving the quality of education as a whole [4], [10], [13], [14], [25], [27].

Ajlan Al-Ajlan and Hussein Zedan are convinced that Moodle is the optimal VLE platform in terms of tool capabilities of a system and technical aspects [2]. Mugenyi Justice Kintu, Chang Zhu and Edmond Kagambe state that the characteristics of Moodle are good organization of online resources, their convenience and accessibility, structuring; efficiency of communication tools use [14]. Gabriela Carmen Oproiu marks the possibility of synchronous and asynchronous access, group work or personal communication organization [25].

As mentioned above, one of important factors of successful blended learning organization is ICT literacy of a teacher and a student [14], [26], [32]. Technology is just a tool, and its effective use totally depends on readiness of a teacher and a student for it [20].

According to D. Randy Garrison and Heather Kanuka, blended learning is a consequence of reconceptualizing and reorganizing of the learning process, changing its dynamics [8]. Thus, the closed teacher-oriented model of learning is replaced by more open, student-oriented one where a teacher becomes a mentor [18], [21].

Therefore, learning using the Moodle system has the undeniable benefits demonstrated by numerous studies of scientists. However, the specifics of preparing the materials for the final assessment and its implementation in the context of improving the quality of education are not sufficiently clarified yet.

2.2. The theoretical background of the application of testing technologies in education

Aleksei N. Maiorov defines the test as a tool consisting of a qualitatively validated system of test tasks, a standardized procedure of conducting and pre-designed technology of processing and analysis of results, designed to measure the qualities and properties of a personality, change of which is possible in the process of systematic learning [19].

Usually, the test is a standardized method of determining students' level of preparedness. All test participants are assigned the same tasks, under the same conditions and with the same rules of evaluating the answers. Due to this method, you can determine the order of the participants according to their level of knowledge and, respectively, to determine the place in the group objectively or rating of each student.

Analysis of the [1], [11], [12], [22], [24], [29], [33] allows to distinguish a number of **advantages of testing**, in particular electronic testing, in comparison with other forms of control of educational

achievements of students: objectivity of assessment, which excludes subjective evaluation judgments and conclusions of a teacher; minimizing the emotional impact of a teacher on a student, increasing the level of psychological comfort; the ability to submit test tasks using the text, audio and graphic information, multimedia effects, etc.; ensuring the same requirements for users' knowledge and skills due to the use of tasks of the same complexity, scope and content in the test; simplicity and unambiguity of the answer input procedure, independence of assessment from the writing technique; rapid testing, enabling large numbers of students to be reached at minimal time; automation of verification; possibility of its use at all stages of learning; the possibility of realizing not only the controlling but also the educational function. It promotes the development of students' independence and activity, increases the intrinsic motivation for learning.

However, the analysis of the test form of control will be incomplete without indicating its shortcomings: considerable time and effort consuming to create a bank of test tasks; high qualification requirements for developers of test tasks; remembering the correct answer by a student; limited ability to test the logic of the student's thinking, ability to formulate their own opinion, etc.

The disadvantages of testing include the possibility of guessing the correct answer.

In general, the testing process is divided into several stages: designing and creating a test bank; testing; processing and analysis of test results.

The authors of [5], [7] and [19] have developed clear recommendations for the test tasks development. Thus, the content of the test tasks must correspond the program requirements and the content of the training. The tasks formulation should be clear and contain one unfinished thought. The answer options are mutually exclusive, maximum homogeneous, similar in size, unambiguous and plausible. The answer options are mutually exclusive, maximum homogeneous, similar in size, unambiguous and plausible. It is desirable to avoid the answers "all of the above", "I do not know", "none of the above"; use the words "sometimes", "often", "always", "never", "all" carefully; avoid double objections or highlight them in another font. All parts of the task should be grammatically consistent. It is advisable to arrange the answers in a logical sequence – from smaller to larger (or vice versa), alphabetically and so on. Optimal number of alternatives for one task is 3-5 items.

The situations when the answer choices contain prompts or no correct answer at all are wrong; or formulating of one test question is a clue to another; or the content of the task contains contradictory statements.

It is a difficult to determine the time limits of testing. It is usually empirically resolved.

3. Problem

The purpose of this article is to present the experience of conducting final control of students' academic achievements through the means of electronic testing Moodle, to analyze the received results and to formulate recommendations for further improvement of the specified procedure.

The following research methods were used in the course of the study:

- theoretical methods – studying and analyzing scientific and methodological literature made it possible to distinguish blended learning as one of the priority areas of higher education development and to justify the expediency of using the Moodle system in the educational process; to realize the advantages and the disadvantages of the test control of students' educational achievements; to formulate recommendations concerning further improvement of the electronic testing procedure in the Moodle system;
- empirical methods – the final control of students' achievements has been carried out with help of electronic testing. The survey made it possible to determine the attitude of teachers and students to the electronic testing procedure;
- methods of mathematical statistics, which made it possible to interpret quantitative and qualitative empirical data, establish the significance and reliability of the received results.

4. Shift from blending learning to distance one during the lockdown period

4.1. Distance learning of future teachers during the quarantine period

A large variety of tools leads to significant differences in the ways of presenting academic transcripts, organization of assessment, which causes a certain fragmentation of perception. This, in its turn, can be a factor in slowing down the pace of learning and reducing the cognitive activity level. One of the ways to solve this problem is to unify the user interface and data sharing ways within a single integrated blended learning support environment. Moodle can be the example of such environment.

The advantages of using Moodle during the quarantine period are the following: the adaptability of the system, easy maintenance and low software requirements, the ability to integrate the electronic system for the needs of student learning. Among the positive features of this VLE there are interactivity, a wide range of tools, support for various multimedia formats, the availability of exchange of ideas (forum, chat, posts, etc.).

At the same time communication in the Moodle system is not widespread, apparently due to the prevalence of social networks and mobile applications. That is why Zoom and Skype software, instant messaging technology Viber and Messenger have been widely used as communication tools, services and tools offered by Google have been used for file-sharing purposes and document collaboration as well as the features of Whiteboard in Zoom. For asynchronous group collaboration the students used the Moodle forum module, while in the mode of synchronous learning the feature of Zoom breakout rooms has been used.

At Kryvyi Rih State Pedagogical University, the development and use of modern ICTs is one of the priority areas of activity. There is a process of the university electronic educational environment formation. Its structure includes an institutional repository, cloud repositories (Google Drive) of information-educational resources of departments, Google Classroom, Moodle and more. All first-year students are registered in Moodle before the start of each academic year. Moodle logins and passwords are obtained by students during an organized meeting with system administrators, including the authors of this publication.

Moodle e-learning courses can be used as means of studying for full-time and part-time students at all stages of student learning process during the studying relevant disciplines, as a methodical and didactic aid of classroom training, during independent work, practical training of students, for realizing control activities [15], [39].

The authors have developed a number of e-learning courses that are successfully used in learning by students, including mathematics and its teaching methods, foreign languages, etc. aimed at third year and fourth year students of German-English department respectively.

During the quarantine period the use of Zoom's features was effectively implemented within distance learning at Kryvyi Rih State Pedagogical University to intensify the students' progress in their English language proficiency. To be more precise, at the beginning of the class the Zoom's Polling feature was used as a tool for warming up activities. This very feature enabling to create multiple-choice questions was adjusted to boost students' receptivity during the class later. Via this feature teachers are free to create either general or specific topic-related questions. The choice of questions is justified by the class objectives. On collecting the students' responses the teacher had a possibility to arrange a short discussion afterwards (see figure 1).

Zoom breakout rooms were used to divide students into groups. Each of these groups received a task to voice over a video fragment which corresponded to the topic under discussion. For instance, if the topic in question was "Travelling", it could have been a video about various tourist destinations and the students performed the roles of narrators providing information on these tourist attractions. Speaking in terms of Zoom chat use during the process of English learning the students were encouraged to participate in story-telling. It favoured the improvements of their writing skills. They were suggested using different parts of a story to create their own one collaborating together via the chat feature in Zoom. As for the Whiteboard in Zoom rooms it was used to conduct Pictionary games in order to revise lexical material e.g.: idioms, phrasal verbs etc.

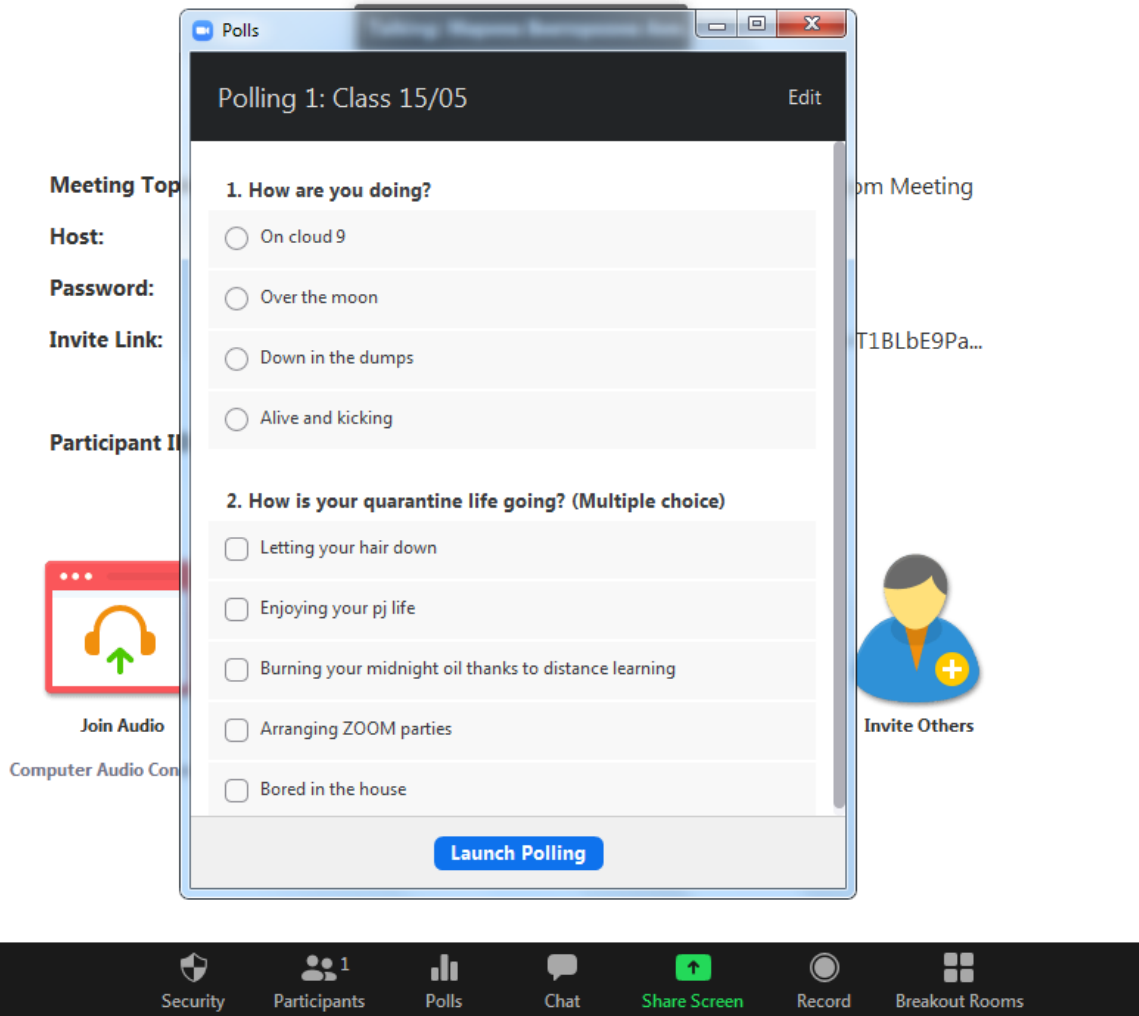


Figure 1. Example of Zoom Polling.

Through screen-sharing feature of Zoom Kahoot! was used in the English learning process (see figure 2). The platform in question offers a lot of options for creating quizzes to meet various educational demands. The advantage of this learning platform is that it provides a possibility to engage students into the team playing. The quizzes were aimed at the vocabulary revision.

Except for the use of Moodle as a platform for creating different tests the teachers used Google forms as an additional app to serve the same purpose. The tests were created to monitor the students’ progress after the new grammar material introduction. Consider the following example (see figure 3).

Participants of the distance learning process, compared with the traditional one, show less stress and more effective learning, increasing of interest in the subject, facilitating the perception of educational material.

4.2. The structure of the suggested tests for the final foreign language assessment

During the advanced training of mathematics teachers, as well as during the summer examination session of the 2018-2019 academic year, the final examinations in the selected academic disciplines at Kryvyi Rih State Pedagogical University were conducted in the form of electronic testing. For example, more than 300 students for whom this discipline is not profession-oriented, have participated in English language testing, including future teachers of computer science, physics, mathematics, geography, biology, chemistry, history, and more. As it is known, the test does not allow to test and

evaluate perfect, productive and creative knowledge of students. But the purpose of studying the mentioned discipline is to form a basic level of correspondent competence, that is why the chosen form of control is appropriate.

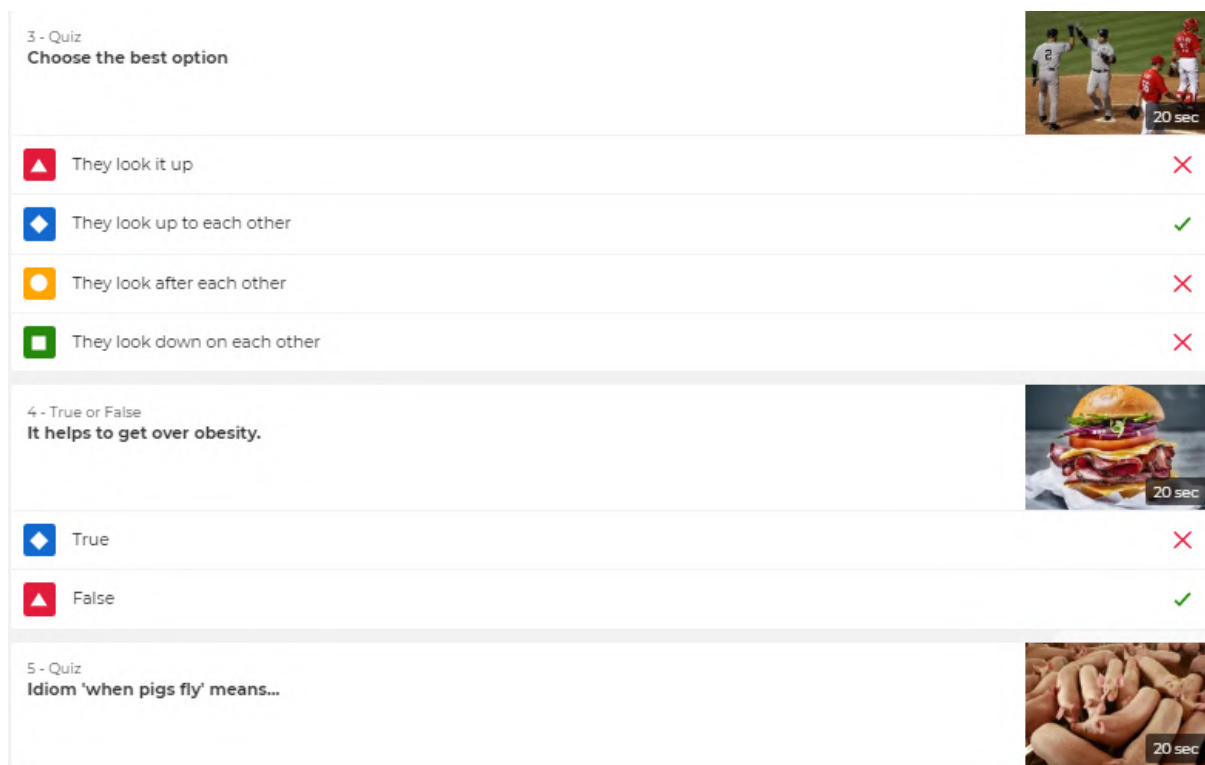


Figure 2. Kahoot! Quiz example.

The electronic testing was preceded by considerable preparatory work. The testing program covered 12 topics, including Family, Holidays, Our University, Ukraine, Kyiv, Kryvyi Rih, London, The UK and more. Exam topics were presented to the students. Their various aspects were learnt during the classroom lessons. Thus, 12 structurally unified tests were created by teachers of the Department of the English Language and Methods of Teaching and Department of English Philology in Kryvyi Rih State Pedagogical University. Each test consisted of four blocks.

The first block stipulated a selection of the title (from the suggested variants) to the paragraph of the text and contained the following instruction: “There are two choices you don't need to use”. There were 5 paragraphs in the text, with 7 answers respectively. Thus, the choice of each title had to be conscious and considered, each title provided an element of choice. Consider one of the suggested paragraphs Kew Gardens:

As well as being the most visited gardens in Britain, the Royal Botanic Gardens at Kew are also a world renowned botanical research centre and a place of training for professional gardeners. The massive 300-acre site has three huge glasshouses containing an astonishingly rich variety of plants. Many of the buildings at Kew are as interesting as the plants. There is a large Chinese pagoda built in 1762 and a model of a Japanese temple. Also of interest are the Palm House, a beautiful Victorian iron and glass building, and the Temperate House, which is the largest Victorian glass structure in the world. And let's not forget Kew's library which has one of the largest botanical collections in the world including books, drawings and photographs. The suggested choices: A a realistic garden that is very realistic; B well-known for its impressive architecture; C use alternative energy sources; D developed over a very long period of time; E garden with many illustrations of plants; F a garden its owners; G partly famous for the scientific studies (Answer: G).

Figure 3. Grammar test via Google Forms.

The second block stipulated filling the gaps in the text. There were 4 answer options for each gap. There were 8 such gaps in the text. For instance: The Best of Britain.

It's time for the "PlanetSong Music Competition" again. Several British hopefuls are working hard ahead of the finals in Brussels in the hope of (1) ... the contest for their country. Like the other contestants, Marcus Inman is excited to have an (2) ... to represent his nation. He says that it's every boy's dream to perform for his country at the (3) ... level. Marcus adds that he believes the contest is the most important music event of the year and that he feels he has a (4) ... to do his very best for the UK. Marcus isn't a newcomer to the music business, though. He was (5) ... the lead singer of the noted heavy rock band, "The Fortress". His band's first album sold hundreds of thousands of copies and as a (6) ... their first single, "*Missing a Piece of the Puzzle*": (7) ... number one in the music charts. After his huge achievement, Marcus (8) ... his mind to take a short break. From recording songs. However, he assures everyone that his new "PlanetSong" ballad means he's well and truly back!

- | | | | |
|-----------------|---------------|-------------|--------------|
| 1 A gaining | B earning | C winning | D beating |
| 2 A appointment | B opportunity | C option | D occasion |
| 3 A highest | B steepest | C tallest | D biggest |
| 4 A service | B duty | C job | D task |
| 5 A lately | B recently | C currently | D previously |
| 6 A reason | B cause | C reaction | D result |
| 7 A took | B reached | C arrived | D grabbed |
| 8 A made up | B put down | C set out | D got on |

To complete the tasks of **the third block**, students had to read the text firstly and then to determine if the statements after the text are true or false. There were 8 suggested statements. Consider the text Crazy Mom's Fashion with the related statements:

It started 20 years ago. One day, Jane Smith, a busy mom and a loving wife, went shopping for new clothes. After a few hours of searching, she came home exhausted and disappointed. In the mid-80s, few manufacturers made clothes for women over thirty. "Thousands of women in England have the same problem, and I will help them," – thought Mrs. Smith. With very little money, no connections in the fashion world and a husband who thought that her idea was crazy, the ambitious woman decided to start up her own business.

Jane designed her first collection of twenty clothing items, bought suitable material and sewing machines, and hired experienced tailors. The Smiths' balcony turned into a workshop. When the collection was ready, Jane offered it to a famous chain of stores. To her surprise, they bought the whole collection at once. When they asked her about the name of her company, Jane looked at her husband, smiled and said: "Crazy Mom". The collection was sold in a very short time – women liked Jane's models. In a month, the manager of the chain ordered more clothes from "Crazy Mom" and Jane had to hire more people and find a bigger place for the workshop. The next step was opening her own shop at the central train station in Manchester.

Now "Crazy Mom" has 50 boutiques all over the world. Mr. Smith left his job as an engineer and became head of the company. Their four children also work in the company and, according to Jane, this is what makes the business so successful.

- | | | |
|----|--|-------|
| 1. | Jane Smith came home after her shopping tired and sad. | T / F |
| 2. | It was not a problem for women over thirty to buy clothes. | T / F |
| 3. | She decided to set her own business with a few strings to pull. | T / F |
| 4. | Her husband did not quite believe her business to be a success. | T / F |
| 5. | The idea of calling her company "Crazy Mom" was suggested by her child. | T / F |
| 6. | The shop was opened at the railway station in Manchester. | T / F |
| 7. | Mrs. Smith is the head of the company. | T / F |
| 8. | According to Jane her business is successful because it is a family-run one. | T / F |

The fourth block anticipated the combination of the definition with its formulation, the notion with its characteristics, etc. (8 statements). For instance, there are notions connected with the topic Family and the definitions related to the notions in question:

- 1) *Mother-in-law*
- 2) *Sibling*
- 3) *Half-brother*
- 4) *Cousin*
- 5) *Father-in-law*
- 6) *Step-father*
- 7) *Sister-in-law*
- 8) *Great grandfather*
- A) *Father of someone's grandparent*
- B) *Mother of your husband or wife*
- C) *Father of your husband or wife*
- D) *A non-biological male parent married to one's preexisting parent*
- E) *A brother who is the son of only one of your parents*
- F) *A person who shares a common ancestor that is at least 2 generations away*
- G) *The wife of your brother or sister, or the sister of your husband or wife*

So, the bank of test tasks totaled 348 ones. The control test had a similar structure (4 blocks), with each block being randomly selected by a computer. Thus, students usually had questions on different topics in the test. In this case, each student of the group had a different set of tasks that made it impossible to cheat. In fact, a student had to complete 29 tasks during the test. The time limit was 45 minutes to complete the tasks.

As the test was open to all enrolled users during the testing, to prevent unauthorized entry into the test of other students at the beginning of the exam, a password was set in each group, which changed upon completion of the exam.

Before the session beginning, a schedule was set. According to it the teachers were present at the exams of those groups of students in which they did not teach. Thus, the teachers were not interested in the results of “not their” students. It additionally ensured the objectivity of testing and the conditions of its conducting.

The maximum score students could receive for the test was 60, for the work during the course of study – 40. The total grade was calculated by adding the first and second scores. So, testing was more important than current work. Such distribution of scores was dictated by the goal of creating identical conditions for students taught by different teachers using different methods, but according to one program.

4.3. Prerequisites for the final assessment

Students were acquainted with the testing procedure in advance and were informed of the results of their current work. Sometime before the test control, students were given access to a bank of exam assignments. Each student had two training attempts, i.e. each of the twelve suggested topics could be completed twice. At the end of both the training and control tests, students saw only the final score for the block and the overall result, without correct answers. The student was able to find out which topic or which component of the test needed more attention, but did not receive ready answer. It prevented mechanical memorization of the correct variant, and led to the analysis of mistakes.

The organization of training testing in the Moodle system enabled the teachers to monitor the process of preparing students for the exam, in particular the intensity of carrying out the tasks, the number of students involved in the work, etc.; to identify common mistakes and to work with them with students.

The testing results in the process of blending learning (the 2018/2019 academic year) have been pre-processed, the detailed suggestions regarding running the final assessment test during the quarantine have been taken into consideration.

5. The analysis of the final assessment test results

Let us to analyze the results of students testing. Let’s consider the table 1, which lists the students, the time of the test, the score for the test and for the current work, the total score.

Table 1. The results of students testing.

	Student	Test execution time	Test score	Current work score	Total score
1	Student1	26 min 43 sec	41	20	61
2	Student2	35 min 57 sec	48	40	88
...
324	Student324	30 min 46 sec	23	5	28
	Average	21.3 min	41	26	67

The results of testing for statistical analysis should be offered to students in the learning process. For example, when studying such disciplines as “Methods of mathematical statistics in scientific research” (specialty 014 Secondary education (Mathematics)), “Probability theory and mathematical statistics” (specialty 014 Secondary education (Informatics)), “Methods of mathematical statistics in sociology” (specialty 054 Sociology), “Probability theory and mathematical methods in psychology” (specialty 053 Psychology).

Specialized software for statistical calculations can be used to work out the results of the study. We used the easy-to-use Microsoft Excel tool (building histograms and graphs of correlation dependencies, analysis package to obtain descriptive statistics, comparison of averages and variances); GRAN1 (<http://www.ktoi.npu.edu.ua/index.php/uk/zavantazhyty/category/1-gran1>) to test the hypothesis of a normal distribution law for the test scores obtained and the current, test task completion times [40]; Google Sheets, GeoGebra. A number of numerical characteristics of the test can be obtained from the results of statistical analysis by means of Moodle (https://docs.moodle.org/dev/Quiz_statistics_calculations).

The main directions were defined for data processing:

- descriptive statistics for final and current control scores and assignment time;
- statistical evaluation of averages and variances for final and current control scores;
- search for correlation between test results and current control; between test results for different task blocks;
- statistical verification of statistical hypotheses regarding equality of variances, averages, significance of sample correlation coefficients, etc.

The average value of the test results is 41 scores (out of the maximum possible 60), which is 68%. The average score for the current job is 26 scores (out of a maximum of 40), which is 65%. The indicators are quite high. In order to compare the percentages averaged, it is first appropriate to test the hypotheses of a normal distribution law for the percentages of the samples and to compare the variances. Normal distribution hypotheses were tested by Pearson's criterion using GRAN1 [40]. In this case, it is advisable to take advantage of the proposed in the tool splitting the data range into 9 equal intervals (see figure 4). As well as expedient skewness and kurtosis test using built-in Microsoft Excel features ($t_s=1.71 < 3$; $t_k=0.17 < 3$).

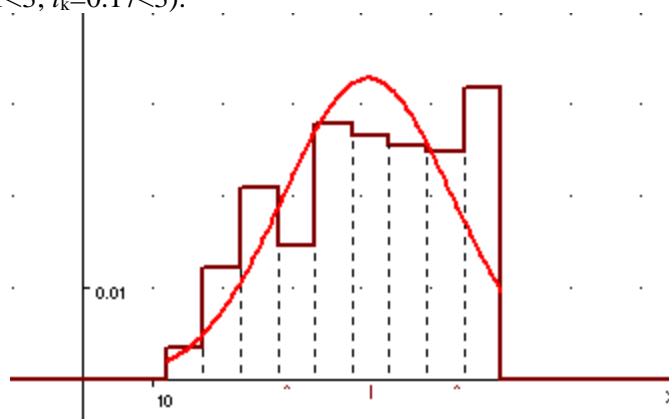


Figure 4. Histogram of distribution of relative frequencies of scores of final testing.

Next, it is advisable to compare the two variances. The results of the comparison of the variances show that they are different ($S_1^2 = 408.6$; $S_2^2 = 566.0$; $F = 566.0/408.6 = 1.38 > F(0.05; 322; 322) = 1.20$; statistical functions of Google Sheets FINV and F.INV.RT). There is less scattering of data around the average for the final test results. Therefore, for comparison of averages, they used a *t*-test with different variances (Tests of the Difference Between Population Means: Population Variances Unknown and Not Equal). It was found that the average scores for the testing and current scores would not be significantly different ($t = 1.82 < t(0.05; 628) = 1.96$; statistical function TINV).

In order to investigate progressive shifts in the study of a subject through the use of Moodle tools, it is advisable to compare the shifts in the scores of the first two diagnostic trials and the control trial. Statistical groups can be analyzed for three attempts on nonparametric Friedman and Page criteria, and for two attempts on the G-criterion and Wilcoxon test. However, these algorithms provide for the use of samples of small volumes. For example, you can test the hypotheses for individual academic

groups. If we monitor the trend of increasing values of the trait (points scored) in the transition from training exercises to the control, we can talk about increasing the level of knowledge and minimizing the ability to guess the right answers.

The capabilities of the above-mentioned software, including the Excel spreadsheet, make it possible to establish the level of correlation between the test results and the student's current scores (see Figure 5).

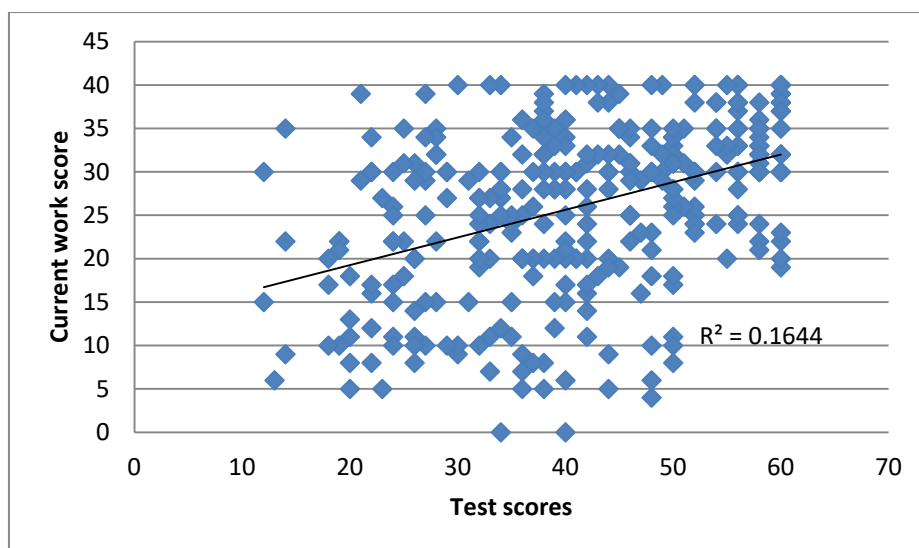


Figure 5. Graphical display of test scores and current work scores.

CORREL shows that Pearson's linear correlation coefficient is $r = 0.41$.

The hypothesis of the significance of the sample correlation coefficient is further tested ($t=7,96 > t(0.05; 322)=1.97$; TINV). This indicates a direct correlation of the average level. Therefore, there is a direct relationship between the test results and the students' current work. At the same time, an average rather than a high correlation coefficient may indicate one of two cases: 1) students who, for some reason, may not be entirely dependent on them, did not receive the desired number of scores during their studies, improved their test scores; 2) students who successfully completed the semester were unable to cope with the tasks (possibly due to excitement).

Since there is a direct correlation between the test results and the students' current work and the mean values are not significantly different, it is possible to ask whether it is appropriate to align the maximum possible score (go from 60/40 to 50/50). Testing results require further investigation.

It is advisable to attach the appropriate Moodle module (“Test Control” → “Results” → “Statistics” to the test results for processing). Based on the research of Victoria O. Koretska and Svitlana O. Shlianchak, we analyze the obtained indicators and interpret them in the context of the study [16].

The standard deviation for the test data is 20.2%, while the standard deviation is 12-18%. We will assume that the result obtained is slightly different from the norm. We can conclude that the estimates are not close to average.

Score distribution skewness is negative: -0.24. Left side skewness (see figure 4). Yes, values that are larger than average occur in the distribution. In other words, it is advisable to complicate the test. At the same time, the skewness value is slightly different from zero ($t_a = 0.17 < 3$), so the indicator can be considered satisfactory. Score distribution kurtosis is -0.82. We have a planar vertex distribution. The kurtosis value clearly shows the shape of the peak distribution. A negative value large enough for the module means that the test results are quite scattered relative to the mean.

Let us illustrate the preliminary conclusion more clearly. Let's translate the test scores into a 100-score scale and divide the results by four possible levels: “excellent” (90-100), “good” (71-89),

“satisfactory” (50-70), “unsatisfactory” (0-49). 62 students (19.1%) were tested for “excellent”; to 'good' 84 (25.9%); by “satisfactory” 111 (34.3%); at “unsatisfactory” 67 (20.7%).

Coefficient of internal consistency. The internal consistency ratio should exceed 64%. According to statistics, it is 70.3%, which is a satisfactory indicator. Yes, in a test, each individual test task correlates with the test as a whole, but retains minimal correlation with other test tasks. The correlation between even blocks and odd blocks was additionally investigated, which is respectively 0.38 and 0.32 and is noticeable ($t=7.30 > t(0.05; 322)=1.97$; $t=6,04 > t(0.05; 322)=1.97$).

Error ratio. An attitude error determines the percentage of standard deviation that can occur through chance, not as a result of differences between students' knowledge. A value greater than 50% cannot be considered satisfactory as it indicates a high probability of randomness in the test results. The statistics indicate a value of 51.2%, which is a negative result. Standard error. The standard error is at the level of 10.8% and slightly different from the maximum value – 8%.

Despite the fact that the student actually had to complete 29 tasks during the test, the evaluation of the results can only be done by blocks, not the result of each choice individually. This is due to the specifics of the discipline. After all, not individual fragmentary knowledge was tested, but the ability to work with the text, awareness of its content in general. We will assume that the tasks of the same blocks in different topics are equivalent.

Of course, in terms of the structure of the block, this is the case, in terms of content – the tasks cannot be exactly the same. But at least the teachers tried to reach maximum equivalence.

Let's analyze the complexity of the test by blocks. We find the percentage of correct answers and subtract it from 1. Yes, the coefficients of complexity of tasks 1 and 2 of the block are 0.3; 3 blocks – 0.2; 4 blocks – 0.4. So, the complexity of the blocks is moderate, but close to low. The test should be complicated.

Table 2 lists student scores for each block.

Table 2. Distribution of test scores by blocks.

Student	Block 1	Block 2	Block 3	Block 4
1 Student1	4.8	16.0	14.0	6.0
2 Student2	12.0	6.0	14.0	16.0
... ..				
324 Student324	12.0	16.0	16.0	16.0
Average	8.6	10.9	12.2	8.9
The maximum number of scores	12	16	16	16
correct answers	0.72	0.68	0.76	0.56
Block complexity factor	0.28	0.32	0.24	0.44

Let's check the correlation between the scores for each block and the average of the test results. Thus, for 1 block, the correlation is 0.59; for 2 parties - 0,76; for block 3 - 0.69; for block 4 - 0.78.

Therefore, the correlation is quite strong, which is a positive indicator. The test tasks really divide students with higher and lower levels of competence.

We analyze the standard deviation, the kurtosis value and the skewness of each block separately (table 3).

Although the questions are randomly selected from the category, Moodle provides a statistical analysis of this situation as well. The Statistics module covers issues that reflect extreme cases (with the highest and lowest complexity). Note that the test developed did not contain any question marked in red in this module, which is a positive result and indicates that there is no need to remove any question from the test bank.

Table 3. Standard deviation, kurtosis and skewness value of each block.

	Block 1	Block 2	Block 3	Block 4
Standard deviation, %	30.11	29.55	21.15	31.52
Skewness	0.80	0.51	0.66	0.02
Kurtosis	0.52	0.93	0.20	1.31

An analysis of the time students spend on completing the test shows that on average, students complete the work in 21 minutes. Given that the time of the task is a normally distributed random variable, let's test the hypothesis that it is substantially less than half of the allotted time ($p^* = 0.5$).

According algorithm Tests of the Population Proportion (Large Sample Sizes) $z = -0.95 > -z(0.05) = -1.65$. That is, the students completed the work in a time that is not significantly less than half of what was planned. Therefore, there is no need to reduce the time to complete tasks or to increase the number of tasks in the test. It is more expedient to supplement the test bank with new questions.

It should be noted that the correlation between the time of the test and its result is inversely proportional. The dependence is noticeable, the sample correlation coefficient ($r = -0.3$) is statistically significant ($t = -4.73 < -t(0.05; 322) = -1.97$). This suggests that the better the student is ready for the exam, the less time he/she needs to complete the tasks and the higher the score he/she gets.

The survey of students showed that the majority of them (71.3%) have a positive attitude towards the procedure of final electronic testing. Although the assessment situation is in any case an exhilarating one, the factor of human interaction is minimized, which is a favorable factor for most students. Teachers (65.5%) say that the preparatory phase of testing, including the formation of a test bank, its verification and initial testing, requires considerable effort. At the same time, further use of the e-test greatly simplifies the process of evaluating students' learning outcomes, and eliminates the teacher from routine work (writing tests, oral interviews, etc.), which is inevitable during traditional control.

The comparison of the final foreign language proficiency assessment test results within blended and distance-learning during the quarantine period. Two samples with scores of final testing according to the chi-square criterion were checked for homogeneity. It was found that the frequency distributions according to the levels of "unsatisfactory", "satisfactory", "good", "excellent" in the considered samples do not differ significantly. At the same time, computer-based testing cannot completely replace traditional methods of learning and knowledge control, but only become an essential complement to them.

6. Conclusions

Taking into consideration the review of the psychological and pedagogical, educational and methodological literature and materials as well as practical experience it has been concluded that challenges in the use of ICT and conducting final assessments in distance education during the quarantine period are a current scientific and practical issue which has many aspects and is far from being finally solved.

Over the course of the research the importance of the use of Moodle in the future teacher preparation process as one of the key online-environments for organizing distance learning during quarantine has been confirmed.

During the final assessments conducted to measure students' progress and performance and the analysis of the obtained results the advantages of the test developed by the part of the author team have been identified. Through the profound analysis of the previously obtained results via the applied method of mathematical statistics the proper conclusions on test validity and reliability can be reached. By taking into account the statistical data analysis it is possible to optimize the conditions of test conducting, in particular, to adjust the time limit required to accomplish the task.

Recommendations for improving the procedure of controlling students' academic achievement by means of the Moodle electronic testing are formulated. It is important to improve the quality of education by analyzing the results, including research to identify the relationship between current and final grades, test scores and duration. It is necessary to check the reliability of the test tasks separately and the test as a whole, etc.

It has been found that the attitude of students and teachers to performing electronic tests in Moodle is generally positive.

It has been confirmed that, in the presence of a quality test bank, Moodle testing can be one of the most effective means of ultimately controlling students' knowledge.

The engagement of students in the use of the Moodle platform and its mobile application enables to ensure interactivity and constructive feedback in the distance learning. Students should be provided with the opportunity to overview the structured learning materials hosted by the system, schedule a test at a time and location that is convenient for them.

It has become crucially important to create a bank of high-quality online resources at the state level in order to ensure education of high-quality during the quarantine and in general.

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Organization and conduct of classes in educational institutions during distance learning

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Abstract. The article considers the use of cloud technologies during distance learning. The implementation of the mechanism of distance learning in general secondary education in two areas is described: distance form as a separate form of education and the use of distance learning technologies in the organization of education in various forms (day, evening, correspondence, etc.). The software for the organization of distance learning of pupils and students is listed. Examples of development of own electronic educational materials for teaching mathematics and computer science are given.

1. Introduction

Because of the spread of the new coronavirus in many countries, was officially announced quarantine and closed schools. Among such countries was Ukraine, where quarantine was established for an indefinite period for the first time.

Pupils and students began to study all disciplines remotely. The administration of general secondary education institutions and the management of higher education institutions urgently developed programs, selected platforms and tools for the implementation of distance learning [8].

Prior to that, the topics that fell during the quarantine were studied in schools by consolidating the educational material. In this case, it was useless to count on such. Therefore, the teaching of pupils and students was carried out using various distance technologies and platforms, which were mastered and available to teachers and lecturers. Pupils and students had not only to study disciplines in new conditions, but also to learn to work with new services and programs.

Due to the difficult epidemiological situation and the urgent need to regulate the provisions of distance learning, the Ministry of Education and Science of Ukraine submitted for discussion the “Draft Regulation on the distance form of general secondary education.”

Schools in most countries around the world, realizing the growing trend of patients, are gradually switching to computer-based learning systems and using online learning platforms.

2. Theoretical background

The issue of widespread use of distance learning technologies to during quarantine arises for many: for children with special needs; to work with gifted children, in particular during the preparation for writing research papers and subject competitions; to independently raise awareness in a particular subject area; to close knowledge gaps, etc.



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Methodical, theoretical and practical aspects of the use of distance learning technologies are devoted to some scientific works of Olga V. Bondarenko [27], Liudmyla H. Havrilova [9], Anna V. Iatsyshyn [35], Tetiana H. Kramarenko [22], Hennadiy M. Kravtsov [12], István Lénárt [14], Nataliia V. Morze [18], Larysa M. Petrenko [21], Serhiy O. Semerikov [19], Svitlana V. Shokaliuk [25], Eugenia M. Smyrnova-Trybulska [26], Oleg M. Spirin [29], Yurii V. Tryus [28], Elena V. Vihrova [3], Vasyl V. Yahupov [31], Myroslav I. Zhaldak [33] and others.

In the “Regulations on distance learning” [7] distance learning technologies are defined as an individualized process of acquiring knowledge, skills, abilities and ways of human cognitive activity, which occurs mainly through mediated through telecommunications interaction of distant participants in the learning environment in a specialized environment, on the basis of modern psychological-pedagogical and information-communication technologies.

According to Eugenia M. Smyrnova-Trybulska [26], distance learning is an independent educational and cognitive activity, one of the forms of learning.

Distance learning is the interaction of teacher and students at a distance in which all the components inherent in the educational process (purpose, content, methods, organizational forms and teaching aids) based on the use of specific means of Internet technology [13].

Volodymyr M. Kukharenko believes that distance learning is the acquisition of education in such an organization of educational and cognitive activities, when along with full-time and part-time in the educational process uses the best traditional methodological achievements of the past and innovative tools and forms of learning based on computer and telecommunication technologies. He singles out the provision of feedback, determination of intermediate results of educational activities for further adjustment of the educational process, in order to achieve the planned results as one of the main problems in the implementation of distance learning [13].

Based on online lessons and feedback can solve problems that arise during the teaching and learning of pupils and students to exercise its control and adjust as necessary.

The possibility of constant consultation with the teacher is an integral part of the distance learning system. It is this element, is communication, the result of which is feedback and the results of adjusting the learning process, distinguishes a properly organized system of distance learning [10].

There are platforms used to organize distance learning for students: Moodle, Google Classroom [4], GIOS, Coursera, Khan Academy, Prometheus and others. In particular, the materials of the educational platforms “My Class”, “For a Lesson” and “All-Education” were used for primary and secondary school students.

Studies by individual authors ([1], [16], [17], [18], [24], [25], [28], [33]) are devoted to the creation of distance courses based on Moodle. These include several tools, the use of which provides both management of educational resources and management at educational and cognitive activities of students a distance; provides an opportunity for students to study and work together with each other and with the teacher. Most of the courses developed in this system are for students and very few for students. As teachers did not have access and methodological support for the development of Moodle-based materials, such courses were used for students in isolated cases.

Many platforms for distance learning with already developed materials are paid, in particular – the educational platform “Global Innovative Online School. Mathematics, 5-9 grades” (GIOS) [7], recommended by the Ministry of Education and Science of Ukraine. Daryna V. Vasilieva considers the above platform as an effective tool for implementing blended learning: that is, when part of the new material is studied by students at home using the GIOS platform, and in the classroom, together with the teacher, students perform tasks to understand and consolidate at home of new material, for the formation of skills for solving problems on the relevant topic, for the diagnosis of acquired knowledge and skills, etc. [30].

The materials posted on the GIOS, My Class, Na Urok, and Vseosvita platforms were used by most Ukrainian teachers to study mathematics and computer science, prepare for the state final certification, and external independent assessment. After registering the account of the user (account) of the teacher, each account of the student was attached to the account of the teacher. Accordingly, the teacher had

access to the material developed by the students, easily and quickly monitored and evaluated the completed tasks.

The Coursera [5] and Prometheus [23] platforms are more aimed at students and high school students. There are courses to prepare for an external independent evaluation.

The main part of the courses on Coursera lasts 6-10 weeks. Each homework or test must be completed within certain of time. Upon successful completion of the tests and the final exam, the student is issued a certificate.

Courses at Prometheus consist of video lectures, dynamic tasks, a forum that is available at any time.

In the Khan Academy Ukrainian provides video clips and courses in Ukrainian, links to which can be posted on your distance learning course or website to learn new material.

In the process of teaching mathematics in general secondary education, namely during the teaching of the basics of probability theory, where you want to use, repeat and consolidate knowledge of geometry, algebra and the principles of analysis, you can use the software Gran (Gran1, Gran 2D, Gran 3D) on the remote server by the link: *gran.npu.edu.ua* access password *gran* [32], [33], [34].

3. Results

The introduction of distance education at the end of the school year was unexpected, so it required rapid preparation. Each teacher had to choose a convenient learning platform (because a single platform was not recommended). However, students had to master the features of several platforms simultaneously, which greatly complicates the learning process. The consequence of distance learning was that its didactic support was insufficient in various fields of knowledge and led to the need to develop their own e-learning materials (recordings of screen demonstrations, presentations with relevant comments, video tutorials, tests, independent and control works with automatic testing, etc.). Lack of experience in this mode was compensated by teachers' self-educational activities (webinars, practical online classes, exchange of experience, etc.).

Establishing feedback between all participants in the learning process has been a priority for class teachers and group curators [6]. To do this, systems were used to provide real-time communication (chats) for all students. Such systems include software Viber, Telegram or other systems for instant messaging (messengers). Based on their use, participants learned the latest news, received invitations to online lessons (for example, through Zoom) and reminders about the need to complete tasks for self-study. Sometimes, using the same messengers, students sent completed tasks.

In the first computer science lessons, it is advisable to create an account in the Google system (for those who do not have one), because many cloud services used for distance learning are offered by Google [11]. Next, students should be introduced to the peculiarities of working with Google Drive, Google Forms, Google Meet and other.

Google Meet and Zoom have become the mainstay of online classes for students. Using the tools "Marker", "Screen Demonstration", it was possible to bring them closer to face-to-face classes, although each of the services had certain disadvantages: for Google Meet – a limit of 25 participants (sometimes more students per class) (in versions for schools) 100 people, and at the time of quarantine expanded to 250 people), and for Zoom – a time limit of up to 40 minutes.

Monitoring and determining the intermediate results of students' learning activities have become the main problems of distance learning, as not all students are self-disciplined, conscious and independent. You can solve this problem by joining the "My School" systems at the link: <https://www.not.org.ua/my-school/> (figure 1) or "Unified School" at the link: <https://eschool-ua.com/#/> (figure 2). The use of these automated systems makes it possible to simplify the organization of the educational process with the help of the latest technologies. These automated information and communication systems are designed for educational institutions, students and their parents, as well as for education authorities and are recommended by the Ministry of Education and Science of Ukraine. Teachers, administration, students and parents are registered in the system. The latter can receive up-to-date information about the success of their child and see its rating among students of the class and school (figure 2b).

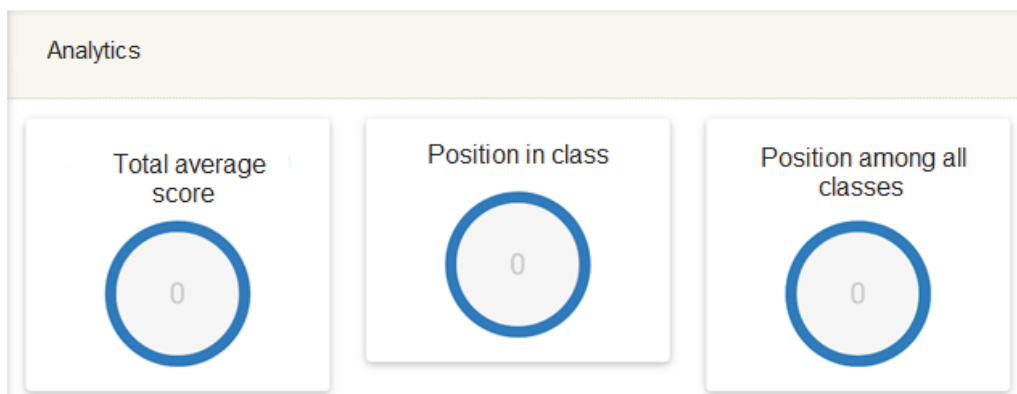


Figure 1. Information about the student's success in the system “My School”.

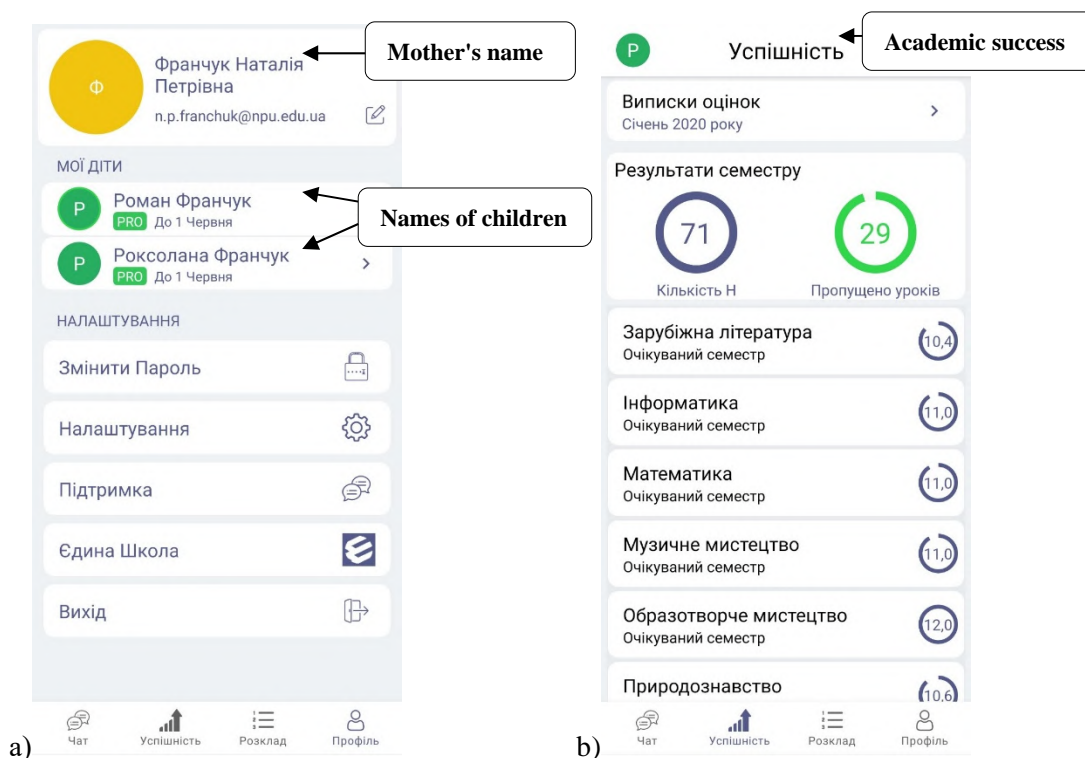


Figure 2. Information about the student's success in the system “Unified School”.

At the next stage it is necessary to develop a curriculum, which can include the following:

- theoretical material is submitted for self-study (paragraphs from the textbook, links to video lessons etc.), and the results of practical tasks are checked remotely;
- organization of online consultations of teachers: via video conferencing or telephone communication;
- providing students with distance lessons using Moodle for self-study (read theoretical material, answer questions, review examples of problem solving, perform test tasks to consolidate knowledge or creative task);
- online classes via Skype, Google Meet or Zoom (figure 3). The younger the age group of students, the more such classes need to be conducted;

- methodically motivated use of materials of platforms GIOS, “My class”, “On a lesson”, “All-education” considering individual features of pupils of a class;
- creation of virtual classes on “ClassDojo”, “Google Classroom” (figure 4), “Learning Apps” (the platform is available for use of laptops, personal computers, tablets, mobile devices);
- placement of forms of reference notes, schemes, algorithms, formulas that can be printed or filled out online;
- watching video lessons on real-time TV channels or on YouTube channels conducted as part of the School Online project. It is advisable to divide these video lessons into stages so that it is easier for students to get acquainted with them;
- to prepare students for external independent assessment to place tasks (in the form of Google Forms) on only one topic, pre-repeating the relevant material; offer to perform testing at the EdEra online education studio. The website www.osvita.ua contains the tasks of all external independent evaluation sessions with their automatic verification. If the task is done incorrectly, you can read the methodical comment on this topic and find out the correct solution. Topics in which mistakes were made should be further studied by notifying the teacher;
- use of communication tools in distance learning: e-mail (correspondence between teachers and students via the Internet for counseling and sending assignments); chat; teachers' personal web pages for posting materials (sites or blogs), Viber, Telegram or other messengers.

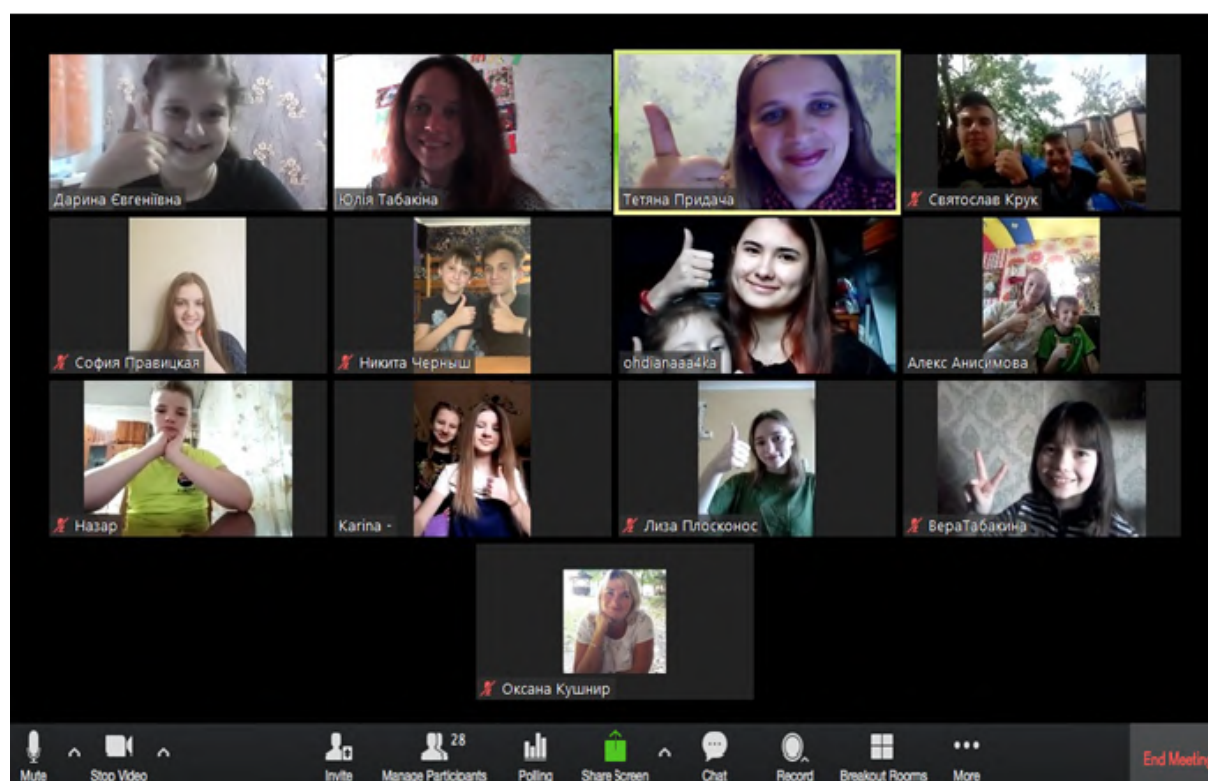


Figure 3. Screenshot of a consultation online math lessons.

One of the most effective forms of distance learning can be considered to conduct online classes via the Internet. According to the classification of types of lessons by Vasyl O. Onyshchuk [20], according to the didactic purpose and place of the lesson in the general system, the following are distinguished: the lesson of mastering new knowledge; a lesson of mastering skills and abilities; a lesson in the application of knowledge, skills and abilities; lesson of generalization and systematization; lesson of checking and adjusting knowledge, skills and abilities; combined lesson.

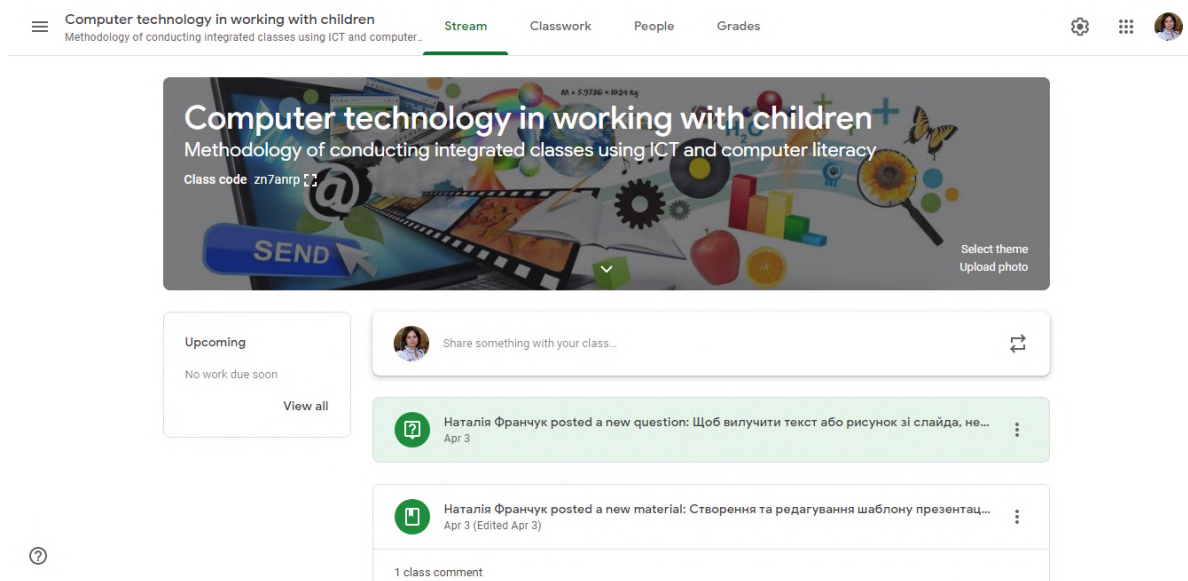


Figure 4. Creating virtual classes using the system “Google Classroom”.

Each type of lesson consists of certain elements that are mentioned below. Consider ways to present them during online math and computer science classes.

Organizational part. These include greetings, checking the means of communication, the availability of the necessary tools, announcing the lesson plan to increase attention, creating a working atmosphere, and so on. The time allotted for the implementation of this part of the lesson will depend on the quality of the preparatory work for the lesson: the availability of invitation links, the speed of data transmission over the Internet, the time to connect all participants to the meeting online. It is desirable to immediately show where the lesson record will be placed for re-viewing.

Homework check during distance learning can be done before starting the next lesson. At the same time, it is necessary not only to evaluate the work done, but also to comment on it, pointing out mistakes and inaccuracies, explain what caused them and how to correct them. For example, if it was a test, students receive a grade immediately after completing it with appropriate comments. During the online lesson, you can test your knowledge of formulas, definitions, etc. by interviewing several students. You can also give examples of tasks like homework, during which they caused the greatest difficulties. It is advisable to place these templates in the distance course or on the website so that students can get acquainted with them later, if they do not have time to write something down during the online lesson (figure 5).

Motivation and stimulation of educational activities is a very important stage of online lessons, because the effectiveness of the lesson in general depends on its effectiveness. It is better to interest students in studying a certain topic with the help of multimedia materials, demonstrations, dynamic models, etc. The teacher can comment on these materials, make notes, or ask the student to perform an experiment with a dynamic model and demonstrate its results using the demonstration mode of their screen. A significant number of resources of this type can be found on the Internet (YouTube videos, Khan Academy, educational portals “Na Urok”, “Vseosvita”). Links to these resources should be available to students after class.

When updating the basic knowledge, it is necessary to recall the previously studied material based on which new knowledge will be learned. This can be done by filling in mini-summaries, graphic diagrams, forms for which students transfer to a notebook or print out in advance. This will harmonize terminology and motivate students to deepen their knowledge on a topic. Such materials can be stored and used by students in the future to prepare for the state final certification and external independent

assessment, and students - for exams. In some textbooks, for example [2], you can find ready-made mini summaries (figure 6), located at the beginning of each paragraph.

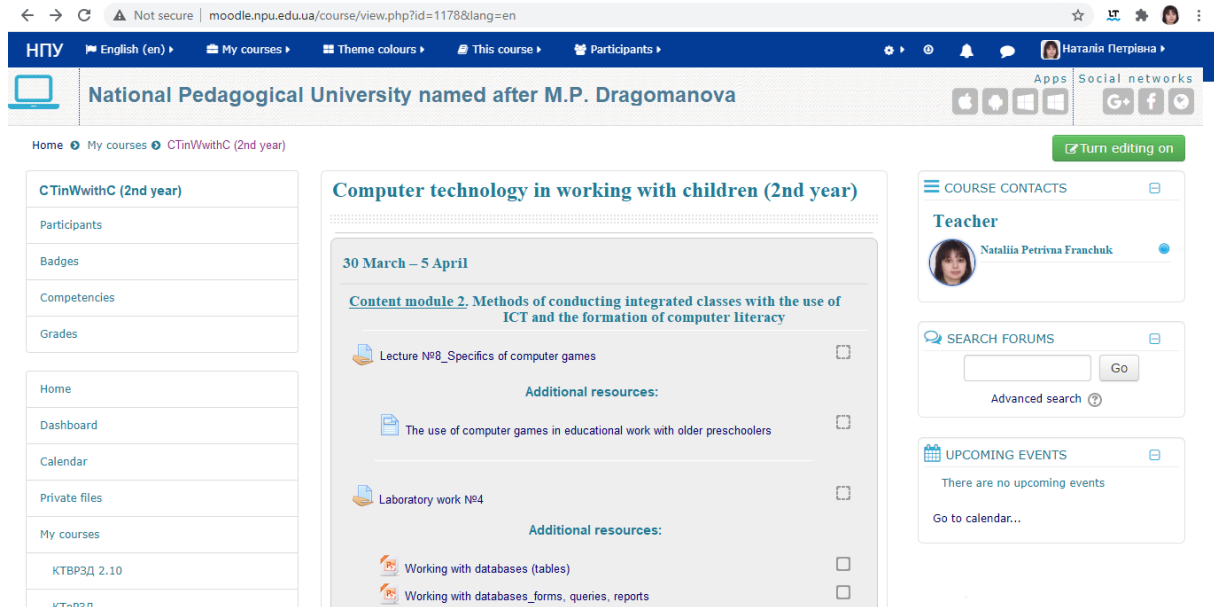


Figure 5. Placement of additional resources in the distance course.

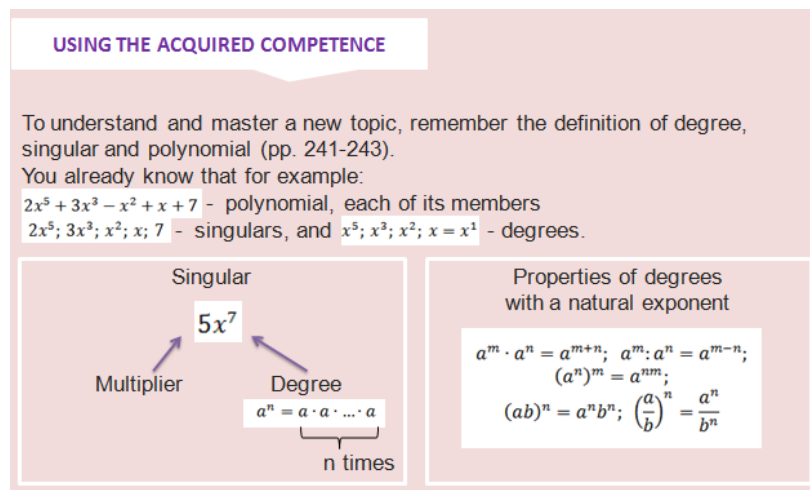


Figure 6. Mini-abstract for updating the basic knowledge on the topic “Division of degrees and singular” from the textbook [2].

The explanation of the new material is not only in its presentation, but also in the appropriate management of the process of assimilation of new knowledge by pupils. For successful mastering of new knowledge by pupils, the teacher must take care of:

- proper perception and understanding of educational material. It is advisable to present new facts in the form of presentations with animations. Only the basic concepts and statements that the participants should summarize while listening to the teacher's explanations should be presented on the slide. It is desirable that all presentations be created according to the same templates. Only the main thing should be distinguished by color and borders, then the participants will

know without comments what exactly should be written in a notebook. Also, at this stage, students should be offered algorithms and examples of solving typical problems, indicating the pages of the textbook on which they are placed;

- consolidation of new knowledge occurs by interviewing students, performing tasks under the guidance of the teacher (demonstration of screens), you can do a little independent work, etc.;
- the application of new knowledge in various situations can be carried out while working in online laboratories, showing the applied orientation of the material being studied. At this stage, you can perform tasks of increased complexity or tasks from the textbook under the heading “We use the acquired competencies”. Here you can use a group form of work to implement interdisciplinary projects, the topics of which can be found in textbooks or in the curriculum of the discipline. Specialists from different professions can be invited to participate in the online lesson to share experiences and further motivate them to study the subject.

Diagnosing students' knowledge helps teachers and students to determine the reason for not understanding a certain element of the content of learning, inability or erroneous performance of intellectual or practical action. It can be realized through the creative transfer of knowledge and skills to new situations; the student's work will be evaluated immediately if the tasks are automatically checked. It is better to make such tasks differentiated from several consecutive parts and to check not only the result, but also to control the process of obtaining it. When evaluating such work, it is necessary not only to set the obtained score, but also to comment on non-standard solutions and techniques, providing an individual approach to the creative findings of students. For example, for the beginner and intermediate levels, you need to choose the correct option from several suggested, for the enough one – enter the correct answer, for the high level – send a file with a full solution.

Generalization and systematization of knowledge is quite effectively controlled during discussions, which allows students to discuss with each other and with the teacher problematic issues. By checking, analyzing and evaluating the work and projects of classmates, the student analyzes his own work and can adjust his further educational activities to get the best possible results. Tests and independent work should be carried out either in several variants, or with a random selection of questions to prevent write-offs. Be sure to include not only test tasks, but also open-ended tasks sent as files. This will allow you to check the correctness of reasoning, justification of steps, the correctness of the construction of the drawing (photo of the work performed, dynamic model, drawing, video fragment, etc.).

Summarizing the lesson involves a brief analysis of what students have learned in class, what knowledge and skills they have mastered, what is the importance of this knowledge for the next stage of learning. At the end of the online lesson, it is important to find out whether the lesson was clear enough, whether the students are satisfied with their work and the knowledge gained. To do this, you can conduct a survey using the Google Forms service, sending the appropriate smileys (tags) in the general chat, directly interviewing students.

As a homework assignment, it may be suggested to repeat the lesson materials that will be posted on the course or on the website, view additional web resources (for example, lessons via television), perform differentiated tasks, take a test or participate in discussions (forum), dynamic exercises in Learning Apps, etc. It is advisable for students to include paragraphs from the textbook where the material on the relevant topic is placed, so that they can work not only on the computer. The content of the homework should be recorded in the electronic diary of the system “My School” (figure 7), where you can attach the necessary files for processing and specify the end date for its implementation. If there is no electronic diary, the grades are communicated through the class teacher to each student individually.

As the epidemiological situation is currently unstable, the continuation of distance learning is possible in the future. Therefore, for its successful implementation it is necessary to follow the following recommendations:

- register on the selected distance learning platform, create groups, including students;
- create e-learning materials: publications with hyperlinks to the glossary of terms, dynamic models, links to various resources, practical tasks, etc., which are posted on the Internet;

- develop forms for sending answers to tasks: tests, e-mail addresses (preferably for each class separately due to the large number of works), etc.;
- share documents for comment, additional questions, group work on the project;
- assessment should be conducted individually, the score should be posted in the electronic diary of the “My School” or “Single School” systems to provide feedback to parents.

Figure 7. Page of the e-journal by the teacher in the system “My School”.

4. Conclusions

The study identified the specifics of using cloud technology in online math and computer science classes. The use and harmonious combination of modern information and communication technologies create links between the content (topic of the lesson) and the ways of joint and individual activities of learners. Which in turn contributes to the deepening of knowledge, increase motivation to study and work independently on subjects; organization of fruitful individual, group, frontal work of pupils and students for the purpose of formation of subject and key knowledge, abilities and skills; implementation of automatic updating of methodical materials; improving the information culture of participants in the educational process.

It should be noted that the considered software should be introduced to increase the efficiency of general secondary education, the use of which will help facilitate the interaction between teachers, parents and students. This will help motivate students to attend classes and study subjects.

Didactic foundations of distance learning were formed based on various pedagogical innovations and require the use of advanced learning models (problem-solving approach, project method, research teaching methods, etc.). During their implementation, not only the principles of classical didactics should be implemented, but also the specific principles inherent in the implementation of distance learning.

Systematic, purposeful, pedagogically balanced, methodologically motivated and theoretically substantiated use of distance technologies in teaching mathematics and computer science strengthens the motivation of cognitive activity, forms a lasting interest in research, contributes to the effective formation of personal qualities of students. Therefore, the task of the teacher is to create conditions for the disclosure of individual abilities of students, directing their cognitive activities to achieve the goal during online classes.

In the process of further research, it is necessary to develop methodological systems for distance learning in mathematics and computer science based on the effective use of modern cloud technologies.

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Media technologies and virtual practices in creative approaches to educational training of a social worker

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Abstract. The educational system has undergone significant transformations in recent decades, the main catalyst of which is the development of the information sphere of society. Both individual elements and the structural, substantive content are modified and updated. Among the vectors that determine the dynamics and direction of this process is the growing socio-cultural role of modern media, which are based on digital technologies as a globalization platform and the main type of communication. The change of the information code - digitalization of the media sphere, creation of new media platforms of social interaction initiates the need to build an educational system that meets the demands of today. Among the many factors that are currently relevant in educational approaches are media technologies. Their role in the training of specialists in various fields is growing symptomatically, as it is associated with the functions of “new media”, which for the subject of activity become transgressive guidelines for constructing reality. Educational and further professional activity of a social worker needs to be reconsidered in the context of innovative strategies, first of all formation of media technologies in social work. Their formation is based on modern principles of new media: interactivity of communication and gamification of virtual practices. In social work at different levels of activity of the representatives of this sphere, media competencies are in demand, which include mastery of instrumental methods of implementing game, virtual, art practices as a motivational resource, technology of initiating social activity, cultural-adaptive and creative orientation of social assistance clients. This issue includes the specifics of the profession of social worker through the prism of the possibilities of filling his case with a creative resource - the tools of media technology in social work. The article outlines both the potential of gamification and virtualization of media practices in the educational and further professional activities of a social worker, and points out the possible dangers of implementing these technologies for certain categories of people in need. The article is a research exploration in the formation of a professional strategy of a social worker based on the involvement of the latest media practices as an expansion of media tools, the implementation of a creative approach to helping the client of social services.

1. Introduction

Education as an institutional sphere of society is the basis of socio-cultural progress of the state, through its main mission in forming the paradigmatic foundations of its development, is in a state of continuous renewal and modernization. One of the reformation directions of recent decades is the informatization of education and the creation of a media education system, which is relevant today in various forms: distance communication, online courses, training webinars, scientific and practical conferences on appropriate media platforms etc. Among the various forms of media education, one of the most relevant



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is media technology as a tool for acquiring and testing the practical application of professional competencies of the future specialist. In the zone of experimental, not fully researched and not disclosed in its potential technologies of media education, there are approaches in which the semantic (educational, upbringing) element is the constructs of virtualization of reality.

Gamification processes are also gaining modernized, transformed in terms of updating media practices, as different forms of educational and professional activity of a social worker in a network environment based on virtual reality, interactive communication and digital technologies (L. Manovich [10]). These trends, in their coverage through the prism of the dynamic start of media education, have ambivalent characteristics. That is, in the case of a non-systemic approach and methodological disregard, there are significant risks of irresponsible implementation. First of all, it is the danger of social deformation in the measurement of educational, cultural aspects of educational activities. However, it is obvious that for many professions the involvement of these technologies in the system of educational training today is a popular and even necessary task in the context of prospects and requirements for creativity of specialists in various fields. Among those specialties whose representatives need an updated, modern arsenal of successful self-realization, technologies of instrumental enrichment of their own activities are numerous areas of social work. At the same time, the profession of a social worker belongs to a special field of activity, which cannot be exhaustively described by a set of professional qualities and competencies. Even the most complete list of knowledge and skills in this specialty will not be able to reproduce the core of the profession. Namely: the moral and spiritual strength of man, whose activities should always be at the epicenter of social pain, conflict and life tragedy. And the essence of the profession is not only to be close, but to help overcome difficult circumstances, always dealing with a special life event – someone’s dramatic fate. That is, there is an obvious need for delicate training for social work, the balance of creative innovation and maximum awareness of those elements of communicative interaction, which have now become an important part of today’s culture. The study and implementation in the educational sphere, both the methods themselves and targeted instrumental technologies in pedagogical, psychological creativity of various professional activities of a social worker determines the demand for understanding this problem.

The rest of paper is organized as follows. Section 2 reveals the names of famous researchers who studied the processes of informatization in education in the context of media education, media technologies in education, gamification etc. Sections 3 and 4 describes the aim, problem statement, methodology and research methods, which are used in the paper. Section 5 describes media communication as a direction of development of educational technologies. Sections 6 and 7 presents media technologies in education and social work. Section 8 reveals gamification as a modern educational media technology, and the next one (Section 9) – the virtual practices in the disclosure of creative, cultural and socially adaptive resource of media technologies in social work. Finally, the last one (Section 10) presents general conclusions to the paper.

2. Literature review

The problem of informatization of the educational process is currently one of the most studied in scientific discourse. At the same time, the pace and scale of digitalization of the socio-cultural sphere in general and its educational platforms in particular, are constantly increasing approaches, practices and tools, and therefore require new understandings and detailed study. Taking into account the direction and subject matter of the article on the system of media technologies in educational training and their further demand in the professional activity of a social worker, we conceptually relied on the ideas of the information age M. Castells [2], M. McLuhan [11]; ideas of the “fourth industrial revolution” of such scientists as K. Kapp [7], K. Schwab [19], K. Schmitt [18]. The principles of understanding the modern educational role of media technology were formed on base of L. Manovych’s theory of “new media”. The issue of media education is covered in the scientific works of R. Hobbs [5], C. L. Scheibe [17], F. Rogow. The phenomenon of the game in the cultural, socially constructive aspect was addressed by F. Nietzsche [12], J. Huizinga [6], R. Caillois [1], G. Ritzer [16]. The role of gamification of education is studied today by researchers of various scientific schools and methodological strategies, in particular,

our views were formed under the influence of research by A. V. Tokarieva, N. P. Volkova, I. V. Harkusha and V. N. Soloviev [24]. An important vector of research is the numerical methods of the survey, in particular, those related to the self-reflection of the participants of the game interaction. According to the rules of the game, the subjects of activity register the details of the game process, which are factors in the formation of their qualities of 3D visualization, spatial thinking, developed imagination [3]. First of all, this applies to material presented using a certain semantic code in the content presentation. This area of theoretical research is reflected in the scientific works of such authors, as N. Vidakis, A. K. Barianos, A. M. Trampas, S. Papadakis, M. Kalogiannakis, K. Vassilakis ([13], [14], [26]). Features of virtualization of social reality are analyzed in various researches and concepts of many world scientists. In this article we relied on the work of the Ukrainian authors O. Kochubeinyk [8], L. Ridchenko [15], which is due to the mental, ideological orientation of the main trends in the formation of media reality through the tools of virtual practices in social work.

3. The aim of the article and problem statement

The aim of the article is to clarify the creative potential as a set of new professional opportunities in educational training and further activities of a social worker through filling and diversifying media technologies with innovative virtual practices and addressing the specifics of their gamification for further use in social work. To do this, it is necessary to consider the problem of media education, its current challenges, features of principles and technologies; clarification of the educational strategy for media literacy, that without denying the traditional understanding is considered by us in the context of various directions of application of virtual practices in professional activity of a social worker. It is also necessary to clarify the specifics of gamification and virtual practices both in the educational process and in the forms of media communication. The creativity of the approach appears in the two-dimensional focus of the objectives of this study. First, the identification of socially harmonizing, value-oriented prospects for the development of creative activity of media entities. Second, awareness of the role of virtual and gaming practices in the thesaurus of the social worker's professional case as a necessary technology, but not one that compensates for the live communication and human concern that underlies this activity.

4. Methodology and research methods

The methodology of the article is conditioned by the need to conceptualize the problem of introduction of educational technologies of "new media" in the training and professional activity of a social worker. The integrative, complex approach is based on the general scientific theoretical methods used in research of this problem: a method of convergence from abstract to concrete: through categorical comprehension to conceptual judgment; method of analysis and synthesis: through theoretical reflection of individual elements of the problem (principles of "new media", features of gamification and types of media practices) to the dialectical synthesis of general, individual and special in the areas of social work. The method of imaginary experiment to identify the risks and dangers of certain media technologies in connection with the specifics of certain social groups – clients of the social worker. Also, a method of comparison, as a way of drawing analogies in the educational effectiveness of creative media practices.

The life of a person with special health conditions, certain socially complex contexts, tragic events and many other insurmountable circumstances is always dependent on the immediate environment. In fact, this nature of lack of freedom, in addition to the pressure of life's circumstances, is a factor in the suppression of both human dignity and social activity, belief in their own ability to be in demand, find their purpose, achieve a goal, etc. Understanding this state of affairs and creating conditions for overcoming them should be the basis for ensuring social health, moral climate in the establishment of public relations. In other words, society as a complex single organism develops harmoniously when it is aware of the problems of vulnerable groups of the population as their own, rather than others, superfluous and extraneous. The implementation of this strategy is the basis of the mission of social work, from the formation of public awareness in this regard to the system of development and

implementation of social protection programs. That is, the professional field of this industry is multi-vector.

There is also an aspect of popularization of value factors, targeted care, effective assistance as a modern attitude of civilized society to vulnerable groups. Also, the initiation and implementation of various programs, projects in a synchronized system of accumulation and adequate allocation of resources (administrative, legislative, financial, etc.) in the prevention and timely assistance to those groups of people who need it. But the main and most difficult direction is direct work with victims, people with disabilities, with those who have survived or are in a situation of social trauma and life tragedy. In this area, specialists are most acutely aware of the need for new developments of medical, technical, psychological nature, which would help and improve the quality of care.

The process of increasing the technologies of social assistance, improving its means has another extremely important professional motivation in relation to the social workers themselves. Their work is most often associated with social problems that do not have the potential to overcome them in the long run. That is, specialists in this field, providing assistance, only in some cases get the result in the form of a resolved, overcome situation. If we compare in the psychological aspect with the profession of a doctor, then recovery does not occur: no matter how much effort is made, they can remain forever. Social assistance is not a solution to the problem, but a qualitative improvement of certain life circumstances in which a person finds himself. Self-identification of this fact by a social worker can lead to professional deformation of the personality: either burnout, or vice versa – distancing, alienation from human needs, indifference to the suffering of others. Thus, the content of the process of providing assistance, diversification of resources, activation of resources, new technologies acquires not complementary but stimulating value in social work.

All these areas of professional activity of a social worker require special attention to his professional training, education – mastery of the arsenal of modern technologies and media literacy. In fact, the vector of media competence appears today as a means, and as a goal, and as an element of the system in various approaches and educational technologies. In particular, these are pedagogical trajectories along which education moves in the organization of the process of acquiring knowledge: information and communication, design, game, case technology, etc. Currently, given the growing role of media education not only as a complementary, and therefore participatory – involved (online courses, virtual workshops and laboratories, etc.) to participate in the educational process, but also a self-sufficient system, there is a need for scientific, methodological structuring of media resources as educational technology. This issue is especially acute in connection with the situation of global challenges and dangers of health (pandemic) and environmental (man-made, climatic threats) nature [20]. Thus, the context of the reality around us stimulates: first, to define and systematize media practices as a structure, methods and mechanisms of educational technologies, first of all, in relation to the goal set in the article – in training a social worker, and secondly, to dwell on those technologies in media communication, which form creative horizons and the latest opportunities to improve the effectiveness of social work.

5. Media communication as a direction of development of educational technologies

The fourth industrial revolution determines the essential transformations in the education system, in particular in its higher level. On the political map of the world, the pace of educational change varies: some countries are only on the verge of digitalization of education (Ukraine); others successfully implement new educational technologies, primarily through distance education formats as an alternative to traditional learning (USA, Switzerland, UK); the third are among the countries that set the educational guidelines for the rest, because these countries are actively promoting the digital transformation of education (Singapore, Malaysia).

In fact, since the 19th century, educational postulates about teaching methods, the role of teachers in most countries have remained unchanged. Today, the professional profile of a teacher is no longer limited to the functions of a lecturer with an academic education, as he must have real practical experience and act as a mentor (educational coach) for his students. If before the teacher could be a monopolist of knowledge, now his task, no less valuable and important, is to be a facilitator, those who

help students to understand the array of information, in particular, through the procedures of processing and analysis of the latter. Instead, the digitalization of education brings profound changes in both the above aspects and actualizes the emergence of new components of quality assurance in higher education, including the emergence of Smart Small Lab, the development of “smart peripherals”; holography and virtual reality as an alternative to modern educational e-books [9]. Educational institutions of Asian tiger countries (South Korea, Singapore, Hong Kong, Taiwan) use smart-tables connected to the smart-screen, smart-boards, 3D-visualization and holograms, etc. in the educational process. A striking example of a new type of educational institution is one of Singapore’s schools called Ngee Secondary School, where students do not use electronic textbooks, replacing them with devices with modern digital technology.

Nowadays students, in our opinion, should learn at least two languages, in addition to the native (state): English and computer, the use of which will take place behind the school / student bench. That is why the list of educational competencies acquired in the education system includes “soft skills”, “hard skills” and “technical skills” [21]. In particular, we are talking about the existing schools today, where the implementation of educational inclusion involves the virtual presence of children with disabilities (or children who are absent for other reasons) in the classroom through VGO-robots.

Quite often there is a confusion of online education and distance education, due to the fact that both forms are the result of the process of digitalization in this segment. Online education involves the acquisition of new knowledge, often in the non-formal education system, through the use of modern information and communication technologies (online courses, virtual lectures, videos of workshops, trainings, etc.). Instead, distance education is a specially organized online system for the implementation of the educational process, which includes an information environment with the presentation of the content of training courses and the support of a teacher (mentor, facilitator) [22].

Also, quite often the process of digitalization of education can be reduced to the use of various video conferencing / video meeting services, such as Skype, Zoom, Google Meet. However, these services should be understood as effective technical capabilities for virtual communication and information exchange, but not as learning platforms, providers of digital education. To achieve meaningful educational goals, new platforms for distance education exist and are being created, on which the idea of “digital education” can be properly implemented.

For its implementation there are all the necessary conditions. The media sphere of society at the beginning of the third millennium includes various forms and means of communication, cultural texts and complex landscape of information space integrated into the system of “new media” (L. Manovich), based on digital technologies and in accordance with the updated capabilities of the global communication network – modern practices of social interaction. “New media” changed the value-semantic context of the landmarks of civilization, as they affected, provided information principles and communication platforms to various social spheres and forms of culture.

In this context, it is important to emphasize that it is wrong to identify “new media” with the multimedia of global network communication. Since digital technologies, the structure of media is a system of information development of society, while “new media” [10] is a way (algorithm) and principles of creating media content. That is, “new media” is not a list of new means of communication, but other approaches in the interaction of real reality (world of things, cultural artifacts) and “real virtuality” [2] – designing media objects not as duplicating and improving them material prototype, and those that do not depend on it. The basis of this autonomy is the digitization of information: reality, translated into the language of digital code, does not require “communication” with the original source. That is, in order to improve your image in the photos there is no need to make more and more photocopies. It is enough to use programs that can not only transform the image, but also create a new story: travel, friends, family, interior design, etc. At the same time, do not choose from the options available in the program, but create at your own discretion and taste. None of the above and depicted in real life existed (at least in this form), but there is no longer an obstacle in the form of a connection between two realities: real and virtual. This example illustrates only one of the algorithms of “new media”, but there are many more, and they are all related to the virtualization of “screen” content and

even the leveling of the “screen” barrier in the flow of different “worlds” as modules of modern media reality.

Today, it is easier to name those segments of our existence that remain outside the media sphere than to list those that have moved into digital reality and become entrenched in its media system. It is symptomatic that the first list, if it takes place, will be incomparably smaller than the second. From the first years, or even months after birth, from children’s toys, which are accompanied and provided by the process of socialization, a person enters the world of dual combined reality: real, in which complex space is organized, natural colours of material things, no clear visual and sound structure; and the other is a media, virtual reality with a bright screen conciseness, pleasant tactility of gadgets, stereo sound and a slowly fading ban from parents. We have all often witnessed how difficult it is to “exchange” a smartphone for the most attractive toy if it suddenly falls into the hands of a child. We will not analyse the educational aspect of this issue, but as a psychological fact it is representative information of the child’s obvious interest in such a presentation of the world, the way of acquaintance with it and the statement of today’s media reality of culture in the construction of living space.

Education as a system of organization of the educational process has various directions of its development, one of which is the vector of media education. Modern pedagogical methods, educational technologies are focused on the use in a certain proportion and appropriate content of information and communication resources of the media. This undoubtedly changes, diversifies, accelerates and scales the interaction of those curricula aimed at attracting media platforms of educational communication. However, despite all the changes, this process remains within the framework of an expanded, branched, but educational structure. At the same time, the use of the principles of “new media” involves the reformatting of the educational process in the aspect of media technologies.

6. Media technologies in education

We understand media technologies in education as a comprehensive approach consisting of an instrumental resource for implementing the principles of “new media”. This approach is aimed at interactive interaction of communication subjects, to minimize the information load (memory of the subject of activity, computer memory), significant, favourable (in the implementation of individual needs, ideas, meanings, etc.) assistance in the form of “artificial intelligence”, as a consequence – saving time, addressing the intellectual resource for the implementation of creative curricula and project goals of a cognitive nature. The digital, programmatic potential of “new media” is focused on the development of thinking that enables virtual, but does not allow real reality. For example, media technologies form stereoscopicity and stereophonic perception of reality in the dynamics of movement, change, development. This question is explored in the works of such scientists as N. Vidakis, A. K. Barianos, A. M. Trampas, S. Papadakis, M. Kalogiannakis, K. Vassilakis ([13], [14], [26]).

Computer intelligence helps the human mind “look” (“hear” and “see”) at the problem (object, thing, interior design, complex system as a whole and as individual parts, modules, etc.) simultaneously in different angles, at different distances, many time measurements, etc. That is, what is absent for a person at the level of sensory, perceptual – physical, bodily data, and hence analytical, critical thinking, is designed by the digital code of modern programs. The specificity of “new media” involves multidimensionality in the implementation and online control over the process, stages, individual elements and results of creating a media product. The correction itself is possible without interruption in the operation of this product. And it does not depend on its format and scale of changes in the form of constant information updates, improvement of web design (site, page), etc. Also, the process of working with “new media” makes it possible and aimed at ensuring that joint activities in intersubjective communication realize the synergy of the creative efforts of the team.

The principles of “new media”, and therefore the basis of the approach in the organization of media technologies of education, are controversial in relation to traditional educational methods. Thus, there is no motivation to memorize a large amount of information, criteria and implementation of the choice of available options, repetition as assimilation and consolidation of the material. A transparent system and clear mechanisms for quality control of the acquired knowledge are also impossible. In other words,

to incorporate media technologies into the classical structure of education, even the one that operates today with elements of distance learning courses, media programs, online learning, is problematic. Those milestones, meanings and landmarks that appear as a structural, semantic basis of education, need to be transformed in terms of media technology.

Thus, the introduction of media technologies in the educational process should have fundamentally different goals than training and education in the traditional sense of socio-cultural development and professional growth. Conversely, it is impossible to implement an educational project of intellectual training of a person in terms of basic knowledge, fundamental guidelines of the world, perceiving media technology as an adequate replacement for classical education. In our opinion, unlike other technologies available in education, which implement the modes of its social existence or have a complementary nature of the development of many competencies, modern media technologies reveal those aspects of personality that focus on the civilization of information society: patronage and human interaction over “artificial intelligence” and the complementarity of virtual (augmented, mixed) and real reality in today’s social, scientific and art practices. Thus, media technologies for education are a way to actualize new modalities, current meanings of its social, cultural functioning.

7. Media technologies in social work

The activity of a social worker as a readiness to implement professional competencies today requires a dynamic increase in media literacy, in which a special professional resource is media technology as a system of updating the modalities of “new media”. The complex of media technologies in social work must be considered from different angles. First, the potential of interactivity as a principle of functioning of “new media”. Social workers, receiving a specialty, develop their professional activities in a functioning structure of social services. They fall into a certain team with an established tradition, existing corporate relations, development strategies and more. Social workers are involved in this process in accordance with their job responsibilities. Thus, their acquired competencies are transformed, clarified and built into the established process of social assistance.

Among these competencies, there are obviously those that are becoming more popular in accordance with the industry specifics, the profile of activities, and those that are minimally or only situationally relevant. However, young professionals inevitably face a situation where they cannot fully understand what skills are needed in a given situation – their single efforts, minimal experience may be in vain in solving an urgent problem. However, the interactivity of communication and media interaction not only in the corporate structure, but on various information platforms, websites (with symbolic capital in the form of integrity) provides opportunities for rapid synergy, accumulation of their own professional efforts, supported by colleagues from other organizations and countries in globalized information network. In fact, it is a combination of ambulance strategy and long-term social care, in which the interactivity of media technologies becomes crucial in the incorporation of professional experience, the implementation of modern methods and approaches in social work.

The same principle of interactivity is also key in working with social assistance clients: the basis of prompt response to possible crises and a form of discursive communication, when initiative, ideas, motivation of demand, stimulate the participation of people in need of care. Secondly, the principle of gamification and thirdly, the virtualization of reality in the form of media in social work. These modalities of media technologies are multidimensional, so they need further separate consideration.

8. Gamification as a modern educational media technology

Modern students have such close contact with digital technologies that teachers are faced with the challenge of adapting established approaches to the educational process and the content of the proposed knowledge to the educational needs, preferences and requirements of the younger generation. Teachers should use teaching methods that allow students to be active participants in the process with strong motivation and interest in testing their own strengths in achieving specific educational goals. Under such conditions, the need for the development of the latest pedagogical paradigm, the components of which would take into account modern trends in education, is objectively formed, and one of these components

is the gamification of learning. The study of this educational tool should begin with the definition of the concept.

In modern scientific discourse, gamification is considered as a process, method and result in relation to a number of areas of human activity. According to Karl M. Kapp, this is “the use of game mechanics, aesthetics and game thinking to attract people, motivate them to action, promote learning and problem solving” [7]. Thus, gamification involves the use of game thinking, approaches and elements in a context other than the game itself. Its main purpose is to improve motivation and learning in formal/informal conditions. Gamification integrates elements of play and game thinking into non-game activities. It is also important to emphasize that it is not essentially related to knowledge, skills, abilities, but to motivation, commitment and influence on human behaviour.

The role of the game, as the beginning of culture, the origins of sociality, was studied in detail by J. Huizinga [6]. The author reveals the nature of game motivation in the formation of social interaction in various social systems and institutions in terms of organization of space, context, meanings of culture. J. Huizinga studied the universality of game thinking, modes of play as a phenomenon of integration of biosocial constants of culture and at the same time the uniqueness of civilizational design (through ritual, art, education, upbringing, sports) of various elements of game impulse of culturogenesis: rules, participants, plot, support system, encouragement and punishment for violating the rules. The dialectic of creation, implementation (reproduction) and destruction of the game reflects the socio-cultural dynamics of civilizational progress of mankind. Thus, the gamification of the media has deep ontological foundations in the organization of cultural space, today it is a multimedia information sphere of network communication of society.

The structure of the gamification process is embedded in the following elements: players (workforce in the case of enterprises; pupils / students – in educational institutions); tasks to be performed by players to achieve specific goals; points that players receive in case of successfully completed tasks; levels that record the progress of players in the implementation of tasks; honours that players receive in addition to points for successfully passing a specific task; ranking of players, depending on the level of their achievements.

According to Gabe Zicherman, the use of game mechanics in the learning process can increase the level of information assimilation by 40%. In addition, it is gamification that has a positive effect on motivation and an overall positive attitude to the processes in which a person is involved. All this fully applies to education, as the main problems in this area are related to the insufficient level of both students in our education. One of the effective ways to change this situation is the introduction of rewards for results and efforts (not everywhere), which stimulates learning and creative activity, and is based on the use of game approach and game elements [4].

Dissemination and integrated application of ICT in education (E-learning) has created a favourable environment for the implementation of gamification both in content (game as an element of the educational process) and in the organizational (educational game becomes more accessible to students; processing, accounting tasks, generating reports are simplified) measurements [25].

The integration of game elements into the education system seems quite a logical step, because in the case of traditional play and learning, participants realize that achieving the goal involves consistent implementation of a successful strategy, and in this way, the quality of each step based on quality at the achieved level of knowledge and skills of “players”. Also, gamification, used in group forms of learning, promotes the development of such “soft skills” as the ability to command procedural activities, basic mediation skills, personal and group time management, etc.

The specifics of gamification in media technologies of social work have important semantic differences. To establish them, a certain familiarization stage is necessary, on the results of which a social worker can rely in his activity. Methods of empirical sociology (surveys, questionnaires, interviews), and in the case of a social worker – the usual conversation with elements of psychological test, then monitoring the client’s attitude to the elements of gamification in education, leisure, creativity, it is necessary to clarify the general client’s attitude to this form of interaction. In those areas of social activity where age groups, whose mental maturity coincides with one or another form of play, the

recommendations for the introduction of these technologies are clearly positive. The main issue is the problem of selection and diversification (with different educational, adaptive, educational goals) of the repertoire, and hence the creation of the amplitude of gaming technologies with a moderate (in terms of mental, cognitive, physical capabilities) balance of media games. It is important to note in this context that the variability of gamification in media communication can be directed towards the “translation” into the score of modern media samples of intellectual game, whose ideas are related to the famous examples of Hermann Hesse “The Glass Bead Game” or Lewis Carroll “Through the Looking-Glass, and What Alice Found There”, etc. In these works, the game is not a form, a genre, but acts as a semantic motivation for the development of the plot, the direction of communication. In our opinion, such guidelines for gamification of media practices will be especially valuable in cases of a social work with clients, for whom such an arsenal of cultural experience is a need for creative development, personal spiritual enrichment. It is a completely different matter when it is necessary to solve the problem of working with those social categories whose life context excludes the assumption of playfulness of their problems, as the client of social assistance can interpret it as bullying, moral humiliation by a social service agent. Therefore, a phase of preparation is needed, leveling the line between the game and the life situation with the use of highly qualified psychological support. Psychological, psychoanalytic training is the foundation of a positive communicative climate: building trust between the representative of the social service and the person being assisted, establishing its individual characteristics and more. These include the causes and consequences of life trauma, as well as creative inclinations, aesthetic preferences, strong artistic impressions, images of heroes and more. The reference points of the typology of social models of media game are the philosophical and cultural concepts of F. Nietzsche about combination of Apollonian and Dionysian principles of culture [4]; R. Caillois’s theory on rational and irrational in the social structure of the game [1]; J. Huizinga’s theory on sacralization and desacralization of game [6] and other studies of the specifics of modern virtual game practices, including Ukrainian author O. Kochubeinyk [8].

The semantic core of the game, as form and method in social work technologies is the realization of creativity of the subjects of the game, passing through virtual labyrinths, encountering and experiencing the absurdity of the situation, etc. without evaluating (except in terms of the rules of the game). “Only by denying the opposition “real – pseudo”, “existing – imaginary”, “reality – fiction” we can understand the game of conventions in which a person plays to assemble his possible world from the many options offered for choice in the social constructor” [8]. That is, the result is a deeply psychological, therapeutic effect of immersion in the reality of the game. Defining a favorable, individually selected context and joint, team interaction in the inclusion of elements of media practice to their gradual diversification by game models provides significant advantages in advancing the subjects (employee and client) of social work towards solving the problem, its reassessment as a life situation. The advantages of media games as a method in the complex of social work technologies are as follows: aestheticization (visual, semantic intensity) and virtualization of this form of communication removes barriers of intolerance, immerses in another socio-cultural context and motivates creative activity of participants. The dangers are associated with the risks of over-indulgence in such practices and reverse transfer – playfulness [16], virtualization of real reality. Thus, game methods in the use of media technologies are an important modern and requiring high professional training (primarily in terms of risk control), tools in competence, thesaurus of the professional case of a social worker.

9. Virtual practices in the disclosure of creative, cultural and socially adaptive resource of media technologies in social work

The role of virtual practices in the educational segment of media technologies is multi-vector: in the elements of the organization of educational space; in terms of inclusion as a collective interaction in the situation of online and distance education (these aspects were discussed above); as a simulated reality – a way to gain professional experience (e.g., surgeons, pilots, representatives of other specialties), etc. This fact of the multifaceted role of virtuality is further enhanced by the heterogeneity of understanding the term “virtual reality”. Even in the context of modern discourse on the problems of information space,

this phenomenon is interpreted as an improved, artificial and imitative media reality of the possibilities of constructing information and semiotic worlds [23].

In this article, the application of the connotation of “virtuality” was narrowed down to the instrumental implementation of the principles of functioning of “new media”. In fact, the professional resource of virtual practices in social work is associated with life-synchronizing, adaptive opportunities in working with social assistance clients. Focusing on the modality of “new media”, virtual practices provide opportunities to search for the plurality of the subject’s self-identification, variability of life scenarios, reveal “...the possibility of the existence of man-made worlds either through sensations or through use information and other technologies” [15] – thus destroying the constants of negative previous experience as doomed and fatal. For example, this applies to victims of domestic violence, terror, people who have experienced deep shocks from military conflict, forced migration, etc. Virtual practices with a change in the perception of reality, with new sensory experience focused on the mental structures of the human psyche, tectonic shifts in behavior and the search for new guidelines for constructing their own worldview.

An important aspect of media literacy in the use of virtual practices in social work is the dangers associated with possible psychopathologies of the ward. Those conditions that have a medical diagnosis of schizophrenia, psychosis, hysteria, etc. are prohibited from implementing any techniques and tools of virtual reality. Thus, this is a matter of a different professional qualification, so the practice itself with elements of virtual technology can take place under the auspices of a team of specialists with the obligatory consultation of a psychologist. In the absence of a prohibition, virtual practices as a tool of media technology are an effective mechanism for awakening and realization of creative activity of the individual.

Of particular interest in terms of creative approaches in social work and the multiplicity of experimental explorations in the space of virtual reality are practices in which subjects of media activity are co-creators (based on a favourite literary/film plot) of modern audiovisual texts with complex semantics of “new media” and “new semantics” and experiencing their own presence in cyberspace and time (with the “physical” characteristics that they endow this reality). Modern children’s animated films can be an inspiring experience in implementing developmental virtual practices for social work with children’s audiences. For example, the film “Sonic the Hedgehog”, where the main character – a blue hedgehog – enters different worlds through the ring that opens the space. The peculiarity is that moral, social and cultural factors are unchanged for each of the “worlds”, but these constants hold expanded ideas about reality: the impossible is possible, the imaginary – real. For other age groups, modern cinema also has many examples of high-quality content that adapts the viewer to the meanings of virtual reality. Virtual practices focused on such a development strategy combine elements of spectacular aestheticization of cinema and animation in the form of virtual art practices. So, a person acts as a co-creator (through virtual communication) of a certain artistic reality and at the same time gains experience of new sensory and cathartic identification with the experiences and shocks of his/her own characters.

10. Conclusions

Thus, considered current opportunities, new technologies for training and further professional activity of a social worker in the context of the dynamically growing importance of media education provide grounds for further generalizations. Media education as an existing segment of the socio-cultural space is present in various forms and stages of information technology implementation in many regions of the world. Together with its participatory, auxiliary embedding in the traditional education system, the educational function of media technologies, which present the principles of “new media”, is actualized. Among these principles of professional demand in the activities of a social worker are platforms of interactivity, gamification and virtualization of reality. Under the conditions of appropriate qualification and media literacy of the subject of communication, media technologies in social work provide professional tools for a specialist in this field. Identification of socially harmonizing, value-oriented prospects for the development of creativity of subjects of media activity in the field of social work is made by extrapolating the experience of gamification in educational communication and virtualization

and aestheticization of media practices in the forms of social interaction. Thus, the case of a social worker is considered in terms of acquiring creative tools. Their activities are aimed at interactive interaction as a professional discursiveness and synergy of problem solving.

A separate conclusion is needed for transgressive experience, which is related to the specifics of the use of virtual practices in social work with certain categories of the population. Regarding this set of media technologies, we emphasize the dangers and risks that are related to the mental status of the client of social assistance, so the essential basis for their implementation is teamwork with a psychologist. For those groups - clients of social work, whose state of health allows the involvement of virtual practices, experimental explorations in the field of virtuality can become a reliable basis for the formation of new positive experiences, expanding horizons of self-identification and motivation of social and creative activity. The universality and at the same time the exclusivity of the targeted application of gamification in education acquires specificity as an element of media technologies. The main feature of the game practice, which directly reflects the task of social assistance is the lack of goal-setting outside the rules of the game itself.

Thus, the projectiveness of intentions is not extrapolated beyond the game virtual space, which distances the subject of communication from the trauma of life situations and immerses in a maze of creative search, understanding of the proposed rules and game circumstances. This mechanism, combined with an individual approach, the potential benefit to the client who is provided with social assistance, his further social adaptation are important factors in this area. While researching the principles of designing virtual and art practices, we found out that the basis for involving the client in the communicative process is the existing cultural, literary and cinematic experience. On its basis, in the process of live communication, the social worker forms creative guidelines for further social interaction with the person being assisted. Thus, media technologies today reveal new perspectives in the activities of a social worker, form the conditions of social activity and demand of each person.

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PhD student training: principles and implementation

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Abstract. The article deals with the problem of PhD student training. The Salzburg Principles about the improvement and quality assurance of doctoral programs at universities in every country from European University Association are analysed and materials of LERU on quality culture in Doctoral Education in Europe are used. The three focuses of the research component of doctoral program are proposed. The first focus relates to reproducible research principle. The second focus is related to the use of multivariate models of phenomena’s study and SEM methodology. The SEM methodology is mostly based on deductive logic, involves the preliminary construction of a structural model of the relationships between the variables in order to further check for consistency with the experimental data. The third focus combines qualitative and quantitative methods and the use of triangulation (data triangulation, investigation triangulation, theory triangulation etc.). The content of selected courses for doctorate students is proposed: Reproducible Research and Multivariate Methods in Scientific Research courses. The importance of courses related to the future career is demonstrated, in particular the career of academic researcher. Further development of our work is the creation of teaching and methodological support for selected course “Twitter for professional development of PhD students”.

1. Introduction

1.1. Problem setting and analysis of research

In recent years, we have seen the attention of scientists to the quality of PhD training programs. It is time to accredit such programs, and thus increase the requirements for their design, conceptualization and implementation.

The Salzburg Principles outline a set of ideals that are relevant to the improvement and quality assurance of doctoral programs at universities in every country (European University Association, 2005, 2010) [8]. The materials of LERU [15] present the quality culture in Doctoral Education in Europe.

In 12.02.2021 at the site of the Ministry of Education and Science of Ukraine [16] there were projects of standards in the following sciences: 122 Computer Science (MSc), 122 Computer Science (PhD), 142 Power Engineering (PhD), 151 Automation and computer-integrated technologies (PhD), 185 Oil and Gas Engineering and Technology (MSc), 185 Oil and Gas Engineering and Technology (PhD), 186 Publishing and Printing (PhD), 192 Construction and Civil Engineering (MSc). Thus, to date, there is neither an approved standard, nor a project of PhD standard on educational, pedagogical sciences and sociology.

The first Salzburg principle says “The core component of doctoral training is the advancement of knowledge through original research. However, doctoral training must also meet the demands of an



employment market wider than academia”. Principles also include institutional strategies and policies of Universities; the importance of diversity doctoral programs in Europe; understanding doctoral candidates as early stage researchers; crucial role of supervision and assessment; increasing mobility, and other.

The complex and successful training programme of PhD students to prepare them for research-focused careers both in academic and non-academic settings has to be based on three major foundations: research, teaching and leadership [6]. Each of these components as building blocks of the future successful career inextricably intertwines with the others creating an integrated complex. Research skills can be efficiently performed and perfected in the process of teaching which “helped students develop their professional identity as they broadened their subject knowledge and practised a disciplinary research discourse in the relatively safe environment of the classroom” [11]. Both research, especially in teams, and teaching are instrumental in the mastering and practicing soft skills, including leadership, while the latter contribute to the competent performance of the social roles of researcher and teacher.

The importance of harmonious development components of modern doctoral training (education, science, business) is emphasized by the Rector of the Igor Sikorsky Kyiv Polytechnic Institute Michael Z. Zgurovsky. Science Park “Kyiv Polytechnic” was the first experience of organizing innovation activities on the basis of combining the interests of all participants from education, science and business. The purpose of such innovative activity is commercialization of scientific research’s results and their implementation in the employment market of Ukraine and foreign countries [31]. Such harmonious development can be ensured by the creation of the “Sikorsky Challenge” business incubator and a business start-up school at Kyiv Polytechnic Institute.

In the present article, we deal with the research component of doctorate programs which should be based on the ideas of reproducible research supported by scientists of various specialties [2], [5], [4], [18], [23], [28]. In reproducible research, scientific statements are published along with the collected data and program code, so that other researchers can verify the data obtained and rely on them.

Among the possible advantages of such studies are greater confidence in the reliability of the results; improving the quality of data analysis; expanding the possibilities of further research based on existing ones; opportunities for training future researchers and their cooperation with experienced ones; introduction of standards for the submission of PhD research materials.

The relevance of this topic is evidenced by our experiment conducted in May 2019 to find sources of relevant topics on the amazon.com website and a number of mass online courses and initiatives [20].

The *second focus* of the research component should be aimed at training future researchers in the field of multidimensional statistics to build multidimensional models of pedagogical or sociological phenomena that they will study. Qualitative scientific research is impossible without a systematic description of the studied phenomena; multidimensionality of the investigated phenomena requires the use of multidimensional analysis methods that are capable to identify causal relationships, latent factors, etc. A promising area in the field of multidimensional applied analysis is the structural modeling or structural equation modeling, which is becoming an increasingly popular tool for researchers in the field of education, psychology and social sciences [1], [19].

As a *third focus*, we propose to combine qualitative and quantitative methods in research practice with the method of triangulation as a path for cross-checking the results of the study and their interpretation [7], [13], [14], [24], [25].

The research question of the article is: what is the content of training PhD students in the field of education on the subject of the research component and in which courses it is appropriate to do so? The research methodology included analysis and generalization of scientific articles on reproducible research, on research methods as well as analysis of the content of PhD programs; analysis of EUA-CDE survey data of [12] on doctoral education in European universities. Survey focuses on key aspects: doctoral candidates’ qualifications, funding, completion rate and time to completion; purposes; organization; application and admission; supervision; training and activities; quality assurance; career development; decision-making powers and strategic priorities in doctoral education and their implementation.

2. Results of study

From the results of the EUA-CDE survey [12] in 2017-2018 on doctoral education in European universities we can clearly see that universities in Europe focused on research competence training (table 1).

Table 1. How important are the following elements of doctoral training? ([12], p. 15)

	Specific research competencies	Generic academic competencies	Knowledge valorization	Teaching competencies	Management and leadership competencies
Extremely important	75	35	11	11	6
Important	22	47	36	34	31
Somewhat important	2	14	38	38	40
Somewhat unimportant	1	3	11	13	20
Unimportant	0	0	4	3	3

We calculated a weighted average and visualized this data (figure 1).

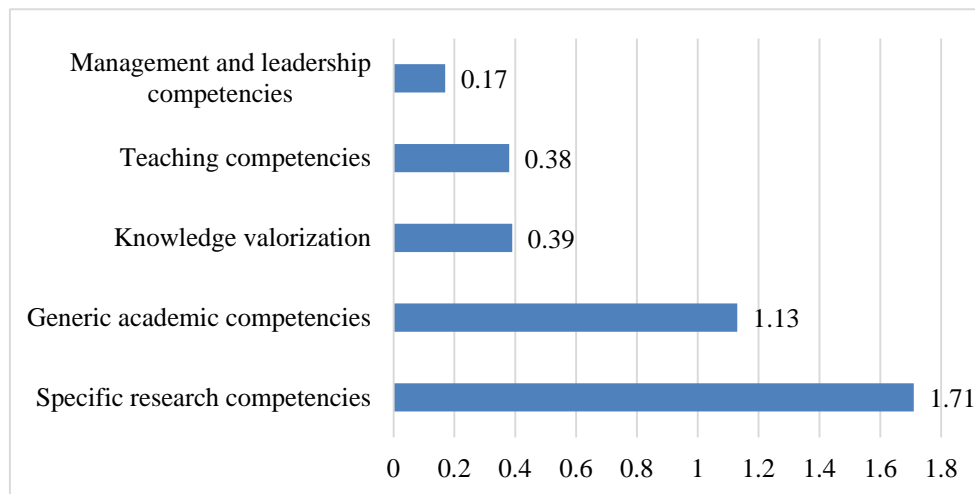


Figure 1. Importance of skill training evaluation on doctoral training (weighted average).

Doctoral education is dominated by training activities focused on specific research competencies: 97%, with 75% finding it “extremely important” and 22% “important” (weighted average is 1,71). They included advanced methods, up-to-date data knowledge, new techniques. Generic academic competencies – grant writing, publishing, ethics – were chosen by 82% universities (35% finding it “extremely important” and 47% “important”), the weighted average is 1,31. Knowledge valorization (intellectual property rights, entrepreneurship, product development) is a focus for 47% of universities, who find it either “extremely important” (11%) or “important” (36%), weighted average is 0,39; and management and leadership competencies were chosen by 37% of universities, finding it either “extremely important” (6%) or “important” (31%), weighted average is 0,17. 45% of universities note the importance of pedagogical competences, finding it either “extremely important” (11%) or “important” (34%), weighted average is 0,38.

Consider the authors' proposed three focuses of research component: Reproducible Research, Multivariate Modeling and Mixed Methods.

2.1. Reproducible research

During research we studied the reproducible research content in PhD program. OSF initiative [4] involves ungraduated and graduated courses on these topics for different fields of science [2], [18], [23], [28]. We selected courses for PhD programs (table 2) and presented their distribution by the fields (figure 2).

Table 2. Courses for Reproducible Research in PhD Programs.

Course name	University, Institution	Author	Fields
Scientific Computing and Visualization	Doctoral school Frontières du Vivant, Paris	K. Hinsen, 2015	Interdisciplinary
Meta-Analysis and Open Science	Summer schools. The Swedish Institute for Disability Research	H. Danielsson, 2017	Interdisciplinary
Ethics, Open Science, and Reproducible Research	PhD course Stockholm University	G. Nilsonne, 2018	Interdisciplinary Social Science
Rigorous & Reproducible Research Practices	Experimental Psychology Ph.D. program, Tufts University	H. L. Urry, 2018	Psychology and Neuroscience
Open Science and Reproducible Research	Karolinska Institutet	G. Nilsonne, 2018	Medicine and biomedical sciences

As we see in the figure 2, there are 2 interdisciplinary courses, 8 in the category “Psychology and Neuroscience”, 2 in “Social Science”, 2 in the category “Medicine and biomedical sciences”. There are no such courses in the field of pedagogy.

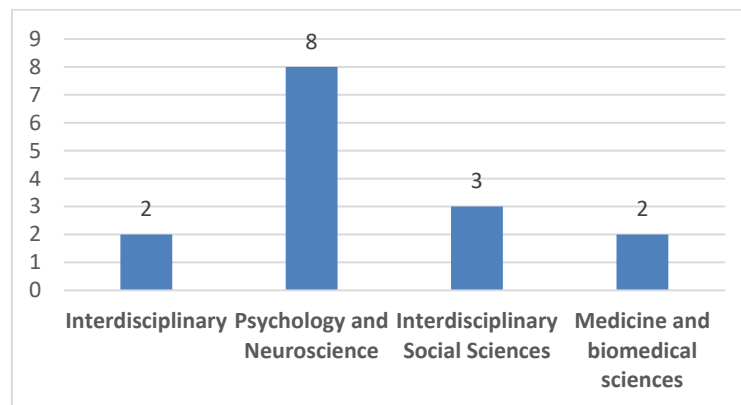


Figure 2. Reproducible research courses in PhD programs (according to [4]).

We analysed also the content of mass online courses on relevant topics, including the course “Transparent and Open Social Science Research” offered on the Future Learn platform, courses “Reproducible research” and “Communicating Data Science Results” offered on the platform Coursera. The topics and subtopics of the courses, software and services used in them were analysed. We collected generalized data in the table 3 [20].

The Transparent and Open Social Science Research course [29] can be seen as an introduction to transparent and open research; it proposes a plan for preliminary analysis of research and re-registration data; the state and future of open science is clarified.

Table 3. MOOCs for Reproducible Research.

Course name	Platform	Part of specialization	Software
Transparent and Open Social Science Research	Future Learn	–	OSR, Stata, R
Reproducible research	Coursera	Data Science	R, R Studio
Communicating Data Science Results	Coursera	Data Science at Scale	Elastic Map Reduce, Pig, Amazon Cloud Service

The Reproducible research course [22] is part of the Data Science specialization, which includes 10 courses and is offered by Johns Hopkins University on the Coursera platform. The course focuses on concepts and tools that allow you to reproduce modern data analysis. R-Markdown and knitr tools are discussed in detail as tools for developing reproducible research reports. The Checklist for evidence-based data analysis is provided.

The latest course in Communicating Data Science Results states that reproducibility is important not only for scientists: data analysts must be able to share data, explain it, and protect their methods and data from unauthorized access. The course uses Amazon's cloud services, Elastic Map Reduce, and Pig to perform big data analysis. Cloud computing is seen as a friendly environment for reproducible research with powerful capabilities.

Analysis of scientific sources and content of PhD programs and mass online courses on relevant topics showed the need to include the topic of reproducible research in PhD student training in Ukraine in the form of a special selective course. Such a special course may consist of the following three blocks: 1) introduction to reproducible research; 2) tools and services for reproducible research 3) environment R as a basis for reproducible research.

The first block plans to introduce Ukrainian PhD students to key terms related to open science, including re-registration, registered reports, p-hacking, HARKing, open articles [27].

- Re-registration is the practice of digitally registering an in-depth data analysis plan before data collection.
- Filed reports are scientific articles whose potential for publication is assessed through peer review and editorial decisions.
- p-hacking is the use of data mining methods to identify patterns in data that are “statistically significant”, based on the use of p-values, but for which no previous causal hypotheses have been developed.
- HARKing is the practice of formulating hypotheses by scientists after obtaining scientific results (by the first letters of English words – Hypothesizing After Results are Known).
- Open articles (OA). There are two types of open articles. Green OAs refers to the practice of creating a copy of a published journal article that is freely available in the repository or on the researcher's personal website. Gold OA is the availability of journal articles on a journal's website, sometimes at additional processing costs.

Within the framework of the second block of the special course the software of information technologies for use in realization of transparent research is studied: Swirl, Dataverse, Git Version Control, Zotero. The third unit focuses on the use of the R environment and its markdown and knitr packages as means to develop reproducible research reports.

As areas of further research, we consider the development of methodological support for a special course on reproducible research on the technology of blended learning.

2.2. Multivariate methods

Recently, there is a growing need to train future researchers in the field of multidimensional statistics. Future specialists should study, understand and explain the phenomena and processes that occur,

investigate their relationship, the influence of certain factors, predict development, build multifactorial and multidimensional models of such phenomena.

In our opinion, the selected course “Methods of multidimensional analysis” offered to doctorate students of pedagogical specialties may play an important role in the formation of the research culture of future professionals. The study of master's programs and training programs for doctors of philosophy in the field of social and behavioral sciences of the world's leading universities has shown the mandatory presence of such a course for future researchers.

Consider the content and structure of such a course “Methods of Multidimensional Analysis”, which is offered to PhD students in the Social Sciences as selective course. The list of topics studied includes the following:

- Introduction to multidimensional statistics and its use in research in the social sciences;
- One-factor and multifactor one-dimensional analysis of variance;
- Multidimensional analysis of variance and its use in sociology research;
- Discriminant analysis and its varieties;
- Use of cluster analysis in sociology research;
- Factor analysis and features of its use in sociology;
- Use of multidimensional scaling and collaborative analysis in sociological and marketing research;
- Modeling by structural equations as a means of constructing and verifying multidimensional models of social reality.

We have developed educational and methodological support of the course, which consists of Power Point lectures on each topic, laboratory class on methods of multidimensional analysis, examples of data files used in the classroom and independent work. An important part of the course is the discussion of the relationship between the various methods used in it.

As software support for the course, we proposed the use of three environments, namely: spreadsheets, SPSS statistical environment (or PSPP), and free environment for statistical modeling R. Spreadsheets that implement only some methods of multidimensional statistics (one-factor and two-factor analysis of variance). It can also be used to demonstrate and perform individual calculations in the study of complex methods, such as calculations in the analysis of variance, comparing different approaches to calculating distances between objects, cluster analysis, construction of spatial maps by given coordinates in multidimensional scaling, etc.

Among the tools of statistical data analysis, the free environment R has recently received a lot of attention. It includes descriptive statistics functions, tools for intelligence data analysis, analysis of variance, methods of multidimensional analysis, neural networks, decision trees, and so on. R functionality can be extended through packages that are available on the CRAN website.

The R environment is evolving with the participation of the entire world community and is used in virtually all mass online data analysis courses, including many specializations of the Data Science Coursera projects and in academic research. Methodological aspects of the use of R were considered in the works of John Fox and Robert Andersen [9], and others. An important feature of the R environment is the ability to create dynamic reports based on the data being processed (R Markdown). Such features contribute to the conduct of reproductive research conducted by the scientific community around the world [10].

Our experience shows that the proposed content and structure of the course and its program support can be used to prepare graduates and future doctors of philosophy in other humanity fields, particularly in the field of pedagogy.

2.3. Combining qualitative and quantitative methods in research practice and use of triangulation

The third focus in PhD training research component is the combination of qualitative and quantitative methods in research practice and triangulation use [7], [13], [14], [24], [25]. Norman K. Denzin identifies four basic types of triangulation [7]: data triangulation, investigator triangulation, theory

triangulation, and methodological triangulation. Data triangulation includes time, space, and persons. Investigator triangulation involves multiple researchers in an investigation. Theory triangulation assumes using more than one theoretical scheme in the interpretation of the phenomenon. Methodological triangulation implies using several methods of gathering data (interviews, questionnaires, observations, experiment, expert analysis and documents analysis).

Note also the special issue “Mixed Methods and Triangulation in History Education Research” recently published by the “International Journal of Historical Learning, Teaching and Research” (<https://doi.org/10.18546/HERJ.16.1.01>).

In the table 4 four periods of history of doctorate education are presented in [17] (p. 7). As we see in the modern period the focus is on the research and research based training and academics and professional school’s fields.

Table 4. History of doctorate education.

Period	Purposes of Doctoral Education	Subjects Studied	Type of Examination
Medieval Europe (1200-1535)	To foster communities of scholars teaching and writing textbooks	Medicine, law, theology	Oral (teacher wrote thesis, student had to defend or oppose it)
Reformation Europe (1535-1750)	To train priests and church administration	Theology, law	Examination by board of professors in all subjects (no specialization)
Enlightenment Europe (1750-1865)	To create new knowledge; to train future professors	Philosophy, humanities, natural sciences	Written (student wrote thesis, faculty took role of opponents)
Era of modern research university (1865-present)	To foster settings for research and research based training	The subject matter of most academic fields as well as that of professional schools	Written and oral (student writes and defends dissertation)

In search of strategic priorities of doctorate education, we turned to the EUA-CDE survey data [12] (table 5). Universities rated the importance of the following parameters: funding of doctoral education; research ethics; attracting doctoral candidates from abroad; career development of doctoral candidates; gender equality; Open Access / Open Science; health /wellbeing of doctoral candidates; increasing the number of doctoral candidates; university-business cooperation within doctoral education; societal engagement of doctoral candidates.

We calculated a weighted average and visualized the data (figure 3).

Therefore, we can clearly see that universities in Europe mainly focused on strategy priorities: funding of doctoral education: weighted average 2,68, research ethics: weighted average 2,64, career development: weighted average 2,33, gender equality: weighted average 2,22, open access / open science: weighted average 2,21 (figure 3).

It is interesting to compare strategic priorities based on data from a survey of European universities [12] with the content of scientific reports of All Ukrainian Science and Practice Conference 2017 “Training of Doctors of Philosophy in the minds of reforming high education” [30]. We presented the results of content analysis in the table 6.

Table 5. Strategic priorities in doctoral education (according to [12], p. 30).

	Not at all (%)	To a small extent (%)	To some extent (%)	To a great extent (%)
Funding of doctoral education	2	2	22	74
Research ethics	1	4	25	70
Attracting doctoral candidates from abroad	3	10	26	61
Career development of doctoral candidates	1	12	40	47
Gender equality	9	11	29	51
Open Access / Open Science	4	15	37	44
Health /wellbeing of doctoral candidates	6	16	37	41
Increasing the number of doctoral candidates	14	11	32	43
University-business cooperation within doctoral education	5	19	48	28
Societal engagement of doctoral candidate	6	28	46	20

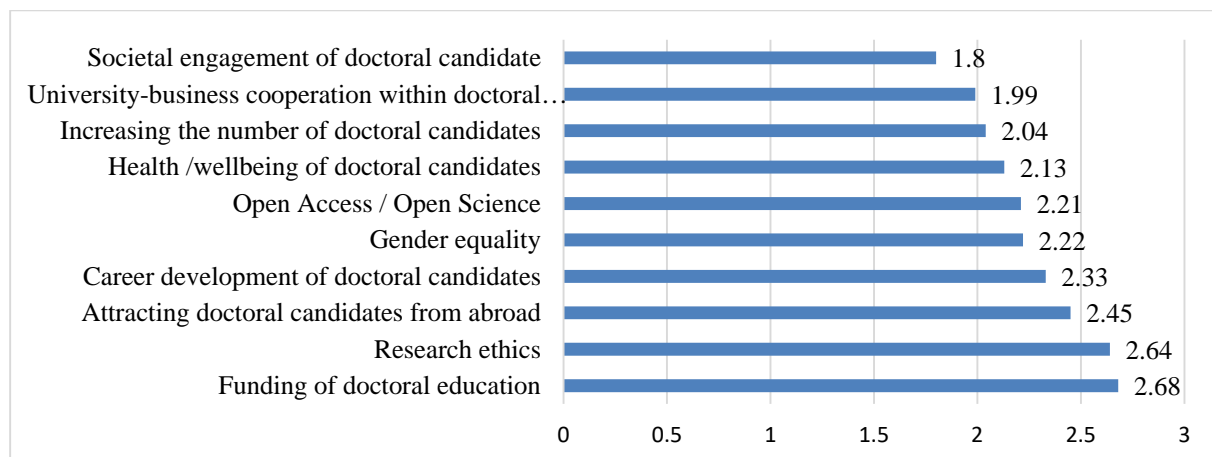


Figure 3. Strategic priorities in doctoral education.

We can see in the works of Ukrainian researchers, little attention is still paid to the issues of career, grants and funding, Open Science, the well-being of doctoral students, and societal engagement of doctoral candidates.

3. Conclusion

Research component is an important part of PhD training. Some focuses for PhD student training in Ukraine in the research field were proposed: reproducible research, multivariate methods and mixed methods, as well as content of relevant selected courses.

The characteristics of future Doctors of Philosophy according to the Salzburg Principles are: “Advanced knowledge of the discipline; Capacity for Research; Proficiency in English; Technical and Contextual Intelligence; Transferable Skills”. To help prepare PhD candidates for an academic career several courses on skills are offered in PhD programs, such as Art of Presentation; Advanced Academic Writing; Academic Career Building; Social Networks for Academics.

Table 6. Main aspects of the scientific reports in materials of the All Ukrainian scientific-practical conference 2017 “Training of Doctors of Philosophy (PhD) in the context of higher education reform”.

Aspects	Number of reports	% of reports
General issues of training and improvement	12	25
Academic integrity	8	17
Foreign experience, European experience	5	10
Mobility	4	8
Publications and scientific journals	4	8
Doctoral training experience of a certain university	4	8
Competences	3	6
Funding, projects, grants	2	4
Research training	2	4
Career	1	2
Leadership	1	2
Inclusion	1	2
Communication	1	2

A comparison of strategic priorities in a survey of doctoral programs in Europe [12] and in the materials of a conference on training PhD in Ukraine [30] shows a general interest in academic integrity, mobility and insufficient attention of Ukrainian scientists to finding funding, open science, leadership, the well-being of doctoral students, societal engagement of doctoral candidates, and scientific communication.

Further development of our work in this direction is the creation of teaching and methodological support for the selected course “Twitter for Professional Development of PhD students” [21] in the field of pedagogy and social sciences.

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Development of informational and research competence of postgraduate and doctoral students in conditions of digital transformation of science and education

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Abstract. Digital transformation of education and science puts forward new requirements for training of graduate and doctoral students, in particular for development of informational and analytical competence. It is described in international documents governing scientific field. Analysis of digital systems and consideration of their services allows us to say that their existing list and functionality can be used to develop informational and research competence of postgraduate and doctoral students. It is confirmed that important role in development of informational and research competencies of postgraduate and doctoral students is given to digital technologies, in particular, to digital open systems. Their use contributes to improving and expanding opportunities in research, presentation of research results and image of the researcher and institution. Digital society requirements to informational and research competence of postgraduate and doctoral students are defined and described. They include: readiness and ability to carry out research activities; ability to search and select necessary information and data, their transformation, storage and transmission using digital technologies; ability to critically evaluate found information (check their accuracy, timeliness, expediency); ability to perform scientific research (organization, planning, conducting) with use of digital technologies. Course of experimental work is presented; the obtained results are given and their interpretation is carried out. Fisher's angular transformation was applied in order to confirm reliability of obtained results of experimental study. Experimental verification of the proposed methodological system of using digital systems in postgraduate and doctoral students training, aimed at the development of information and research competence confirmed its effectiveness and pedagogical feasibility.

1. Introduction

Digital transformation processes of society and improvement of digital technologies changed way of organizing and conducting research and contributed to development of digital science. The



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international document “Plan S” [1] emphasizes that from 2021 all scientific publications on the results of research funded by public or private grants, provided by national, regional and international research councils and funding bodies, should be published in open access journals, on open access platforms or directly accessible through open access to storage without interference. Openness of publications and research results is the main goal for development of open digital science among basic principles of open science.

The Concept of Development of Digital Economy and Society of Ukraine [2] emphasizes that development of scientific digital infrastructure (for scientific and educational institutions) is also crucial to ensure open access to scientific data and knowledge, further commercialization of research, innovation, products and services. New knowledge and developments carried out by financing from the state budget should be openly available and become property of society as a whole. Also, one of the important elements of the European Digital Single Market and part of the Open Innovation – Open Science – Openness to the World paradigm is development of the European Open Science Cloud and European Data Infrastructure.

Implementation of Ukraine’s strategy for integration into the European research environment and the country’s prosperity is impossible without development of human potential, in particular researchers training as the main drivers of the nation’s progress. “Increasing of high-tech industries, creating favorable conditions for internationalization of education and science, mobility and continuing education of scientists, providing information and technical resources for research, development of modern information and communication technologies should be prior mission of the state” [3].

Currently, an important factor that determines development of society in modern conditions is staffing of science and higher education. Therefore, it is important to determine strategic directions of development of scientific personnel training system of the highest qualification. This is determined by the fact that development of scientific personnel training system is an integral factor in scientific and technological progress of society. Mastering modern achievements in the development of digital technologies determines new tasks for highly qualified specialists training, modernization of educational and qualification levels structure, requirements updating for the third degree - Doctor of Philosophy. The effective approaches search to scientific personnel training aimed to achieve science and education in modern world levels and growth of intellectual potential of society have special relevance [4].

Digital transformation of science and education requires updating and modernizing process of preparing postgraduate and doctoral students. Introduction of digital systems, and their use both for dissertation research and for management process organization of training graduate and doctoral students is prior and important. Therefore, it is important to analyze and substantiate digital society requirements to the competencies of graduate and doctoral students as professionals who will work in the new technological era. And it is the development of research and digital competencies of graduate and doctoral students that is one of the key aspects for outlined problems solution.

2. Literature review

The authors selected, summarized and systematized publications in the following areas during analysis of scientific literature on the main topic of this study:

- features of digital technologies development and implementation into the educational process ([5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27]);
- digital systems application for scientific research ([28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45]);
- features of development of information-analytical, information-research competence of post-graduate students, scientific and scientific-pedagogical workers ([46], [47], [48], [49], [50], [51], [52]), etc.;

- training problems of postgraduate and doctoral students ([4], [31], [46], [47], [48], [49], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63]).

However, there was no purposeful development of information and research competencies of graduate and doctoral students using digital systems in the publications analyzed above. The author's methodological system of digital systems using in the training of postgraduate and doctoral students was developed and proposed. It directly affects development of information and research competencies.

The purpose of the study is to describe course of research and experimental work on the development of information and research competence of postgraduate and doctoral students and summarize results of pedagogical experiment.

3. Research results

The authors team [42] emphasizes that digital transformation processes of education and science, international initiatives to evaluate and open access to research results encourage search, selection and wider use of statistical, information and analytical services of open digital archives, journals, monographs, scientometric platforms, bibliographic databases and other educational and scientific systems for evaluating the results of scientific research [42]. Digital open science involves use of Web-based systems to support and develop it. Such systems are, first of all, Web-based systems for monitoring of publication, dissemination and use of research results. Methods of data collection and analytical processing used earlier can no longer meet the urgent needs of science and education in the period of society digital transformation. Therefore, the use of digital technologies for information and analytical support of research is relevant [19].

Currently, the most important area of modern scientific thought is integration of higher education and science in order to prioritize the development of new scientific research aimed at the formation of developed civil society. Changes in the educational activities of Ukraine in recent years, growth of professional, intersectoral and other types of labor mobility require thorough process review of highly qualified scientific personnel training [1]. Today, many universities and research institutions have licenses to train graduate students, but use of digital systems in the teaching of graduate and doctoral students is not fully implemented. Also, use of these systems is relevant and forced measure, as general public will be able to get acquainted with scientific results, which will affect scientific image formation of graduate and doctoral students and image of institution where the researcher studies or works [4]. Indeed, professional development of specialists in modern conditions is impossible without free orientation in the digital space, ability to quickly perceive and process large amounts of information, constantly update their knowledge, expand range of necessary skills and abilities. This is increase in competence level associated with ability to find necessary information, analyze it, structure and qualitatively transform and use it in their own professional activities [52]. Therefore, digital systems use for graduate and doctoral students training is mandatory and important component for development of informational and research competence.

3.1. Informational and research competence of postgraduate and doctoral students: criteria and indicators

Development of informational and research competence of scientific and research and pedagogical workers is systematic and natural process of progressive changes in professional competence of individual in accordance with digital society needs. It provides ability to acquire new knowledge, improve skills, gain new experience in digital technology. In the collective work [51] the concept of "informational-research competence (ID-competence) of scientific and scientific-pedagogical workers" is defined as ability of individual on the basis of acquired knowledge, skills, abilities and acquired experience to use information-digital technologies for organization, planning, conducting own research, as well as to evaluate and implement their results and monitor.

Based on analysis of scientific sources and personal experience the concept "informational and research competence of postgraduate and doctoral students" is defined as readiness and ability of the

individual on basis of acquired knowledge, skills, abilities and acquired experience to carry out research, ability to search and select their transformation, storage and transmission using digital technologies, ability to critically evaluate found information (check their accuracy, timeliness, feasibility), ability to perform research (organization, planning, implementation) using digital technologies. Also, the authors of this study identified criteria and indicators of information and research competence of graduate and doctoral students, which are described in table 1.

Table 1. Criteria and indicators of informational and research competence of postgraduate and doctoral students.

Criterion	Indicator
Value-motivational	awareness of need to use digital technologies for research; systematic use of digital technologies for scientific research; motivation to deepen knowledge, skills and abilities to work with digital technologies for research activities
Cognitive	knowledge of basic concepts, methodology of research activities; knowledge of mathematical and statistical methods of processing research data; awareness of available digital technologies to support research
Activity	ability to analyze current research; ability to use digital technologies for research planning; skills mastery in working with scientific literature and ability to compile bibliographic lists; ability to use digital technologies for statistical data processing and presentation of results; skills of safe application of digital technologies in searching and storing data process; ability to use software and hardware for data protection; ability to use open digital scientific and educational systems to search and store information; ability to select optimal digital technologies at each stage of scientific research; ability to search for like-minded people on scientific ideas, innovations and their implementation; skills to carry out scientific communication with the use of digital technologies; skills to apply digital technologies to solve a specific research problem
Evaluative-reflexive	self-reflection, self-assessment of own research activity and received scientific results, choice of actual directions of further scientific researches

Development levels of informational and research competences of postgraduate and doctoral students were identified in accordance with the listed above indicators:

- *high level* implies presence of deep knowledge of basic concepts, methodology of research activities, mathematical and statistical methods of processing research data; systematic use of digital technologies for scientific research; motivation to deepen knowledge, skills and abilities to work with digital technologies for research activities; awareness of available digital technologies to support research; ability to use digital technologies for research planning; mastery of skills in working with scientific literature and the ability to compile bibliographic lists; ability to use digital technologies for statistical data processing and presentation of results; safe application skills of digital technologies in searching and storing data process; ability to use open digital scientific and educational systems to search and store information; ability to select optimal digital technologies at each stage of scientific research; ability to search for like-minded people on scientific ideas, innovations and their implementation; skills of scientific communication with use of digital technologies; self-reflection and self-assessment skills of own research activity and received scientific results, choice of actual

directions of the further scientific researches; focus on achieving a high level of information and research competence;

- *sufficient level* implies presence of knowledge about basic concepts, methodology of research, mathematical and statistical methods of processing research data; inconsistency in digital technologies for research; importance understanding of digital technologies using to support research; readiness to use digital technologies for research planning; mastery of skills in working with scientific literature and the ability to compile bibliographic lists; readiness to use digital technologies for statistical data processing and presentation of results; safe use of digital technologies in the process of searching and storing data; readiness to use open digital scientific and educational systems for search and storage of information; readiness to select optimal digital technologies at each stage of scientific research; skills of scientific communication with use of digital technologies; readiness for self-reflection and self-assessment of one's own research activity and its results; readiness to increase level of information and research competence;
- *low level* implies shallow knowledge of the basic concepts, methodology of research, mathematical and statistical methods of processing research data; lack of motivation to use digital technologies for research; weak motivation to deepen knowledge, skills and abilities to work with digital technologies for research activities; poorly developed digital technology skills for research planning; poorly developed skills of working with scientific literature and compiling bibliographic lists; weak orientation in the existing open digital scientific and educational systems for search and storage of scientific information; lack of motivation to select optimal digital technologies for each stage of research; weakly expressed skills of scientific communication with use of digital technologies; lack of motivation for self-reflection and self-assessment of one's own research activity and its results; unwillingness to increase the level of information and research competence.

3.2. Organization, conduction and results of pedagogical experiment

Pedagogical experiment was organized and conducted to the pedagogical feasibility and effectiveness of the developed methodological system aimed at developing the information and research competence of graduate and doctoral students. The pedagogical experiment involved scientists, research and teaching staff, management staff, graduate students and doctoral students from seven universities and one research institution in Ukraine. Totally 280 people were involved in the research and experimental work, 222 postgraduate and doctoral students and 58 scientific and pedagogical workers. They were involved in various stages of the pedagogical experiment. The experiment lasted during 2014-2020 in several successive stages.

1. Stage (searching) 2014-2017. At this stage institutions for research and experimental work were identified, namely: Institute of Information Technologies and Learning Tools of NAES of Ukraine (1), Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (2), Zhytomyr Ivan Franko State University (3), National Aviation University (4), National Pedagogical Dragomanov University (5), Drohobych State Pedagogical University of Ivan Franko (6), Kryvyi Rih State Pedagogical University (7) and Bogdan Khmelnytsky Melitopol State Pedagogical University (8).

A questionnaire of the teaching staff and management of universities and research institutions that train graduate students was conducted. The state of readiness and competence for use of digital scientific and educational systems in the training of graduate and doctoral students was determined. To this end, 58 people (teachers, supervisors (consultants) and management staff) providing training for graduate and doctoral students were invited to undergo interviews. It was determined that 100% of respondents use digital open systems and technologies in the training of graduate and doctoral students summarizing results of the questionnaire. But when it was proposed to list which ones, only 50% named: scientometric databases, electronic libraries, ESD, specialized programs, cloud services and etc.; the other 50% named: e-mail, electronic social networks, messengers: Viber, Telegram, Skype; only 30% of respondents use digital open systems when teaching their subject to graduate students;

100% agreed to make more active use of digital systems and technologies in the training of graduate and doctoral students.

Also, partial testing of author’s methods was carried out during seminars and master classes for postgraduate and doctoral students. Three authors of this study have organized and conducted on the basis of the Institute of Information Technologies and Learning Tools of NAES of Ukraine All-Ukrainian methodological seminar for young scientists “Information and communication technologies in education and research” since 2010. Postgraduate and doctoral students from various universities and research institutions of Ukraine regularly take part in this seminar. The seminar was held 8-4 times a year. Number of seminar participants was 15-35 people. Materials of the conducted seminars and audio recordings are placed in the Electronic library of NAPS of Ukraine: 2014 [64], 2015 [65], 2017 [66].

II. Stage (ascertaining) 2017-2018 years. Institutions (experimental base) were specified and experimental (EG) and control (CG) groups were formed among postgraduate and doctoral students to participate in the pedagogical experiment. The distribution of participants in the pedagogical experiment (postgraduate students and doctoral students) on CG and EG are presented in table 2.

Table 2. Criteria and indicators of informational and research competence of postgraduate and doctoral students.

Criterion	Indicator				Total
	1	2	3	4	
EG	16 p +4 d	46 p +4 d	24 p +2 d	14 p	110
CG	16 p +4 d	50 p +2 d	22 p +2 d	16 p	112
					222

The CG included postgraduate students who studied according to the traditional system provided in experimental institutions, as well as doctoral students. The EG included postgraduate students whose education involved introduction of the author’s methodological system, and doctoral students were invited to attend training seminars and master classes.

Levels of information and research competencies development of postgraduate and doctoral students were determined (statement section). Postgraduate and doctoral students were asked to fill questionnaires and take tests in electronic or printed form. They were asked to independently determine development level of information and research competencies. The questions in the questionnaires were related to certain criteria and indicators of information and research competencies and were aimed to check level of their development. Each question had certain rating scale from 1 to 3 points, or required to enter your own answer. All answers were then summed in accordance with evaluation scale. It determined level of certain criterion manifestation. And in addition, there was pedagogical observation during interim reports of postgraduate students and doctoral students (intermediate certification, reporting at meetings of departments, divisions, speeches at methodological seminars and conferences).

It was also generalized results of development level assessing of information and research competence in CG and EG on all criteria and indicators. The average values in % for each development levels of (high, medium, low) in relation to the number of graduate and doctoral students in CG and EG are given in table 3.

Let’s describe in detail results of development of information and research competence in CG and EG on all criteria and indicators (statement section). According to the value-motivational criterion, the following distribution was: “high” level – 30.7% in CG and 31.3% in EG, “sufficient” level – 54.6% in CG and 54.7% in EG, “low” level – 14.7% in CG and 14% in EG. According to the cognitive criterion – at “high” level was 14.7% in CG and 14.6% in EG, at sufficient” 46% in CG and 44.7% in EG, at “low” 39.3% in CG 40.7% in EG. The following results were recorded according to activity

criterion: at the “high” level 25.1% in the CG and 25.1% in the EG, at the “sufficient” 49.6% in the CG and 49.8% in the EG, at the “low” level 25.3% in CG and 25.1% in EG. The following distribution was according to evaluation-reflexive criterion: at the “high” level 6% in CG and 6% in EG, at “average” 44% in CG and 42% in EG, at “low” level 50% in CG and 52% in EG. It was determined that significant part of postgraduate and doctoral students developed information and research competence at “sufficient” and “low” levels due to result of distribution comparing of postgraduate and doctoral students according to three-level evaluation system. Therefore, we believe that it is necessary to carry out purposeful development of information and research competence of postgraduate and doctoral students according to the author’s methods.

Obtained quantitative results during implementation of ascertaining sections of development levels of information and research competence of postgraduate and doctoral students were also statistically processed using the Fisher's angular transformation. Obtained result proves that differences between the indicators in CG and EG in the development of information and research competence during the statement are absent, and groups are equivalent.

Table 3. Development levels of information-research competence criteria of postgraduate students and doctoral students in CG and EG (statement and control section).

The name of the criterion	Group		Commentary		
			High, %	Sufficient, %	Low, %
Value-motivational	CG	before	30,7	54,6	14,7
		after	31,3	56	12,7
	EG	before	31,3	54,7	14
		after	51,3	48,7	0
Cognitive	CG	before	14,7	46	39,3
		after	16	50,7	33,3
	EG	before	14,6	44,7	40,7
		after	28,7	61,3	10
Activity	CG	before	25,1	49,6	25,3
		after	27,1	50,5	22,4
	EG	before	25,1	49,8	25,1
		after	41,3	56,4	2,3
Evaluative-reflexive	CG	before	6	44	50
		after	6	48	46
	EG	before	6	42	52
		after	18	56	26

III. Stage (formative) 2018-2019. The formative stage of the pedagogical experiment was carried out after statement sections in CG and EG. At this stage there was experimental test of the methodological system effectiveness of digital systems using during training of postgraduate and doctoral students and there was a purposeful process of developing information and research competencies of postgraduate and doctoral students. Components implementation of the author’s methodological system included:

1. Consultations, seminars-trainings for lecturing staff and management of universities and research institutions were held.
2. Disciplines were taught to graduate students.

3. Seminars-trainings and master-classes for postgraduate and doctoral students were held.

In order to ensure equal conditions during the pedagogical experiment, the following features were observed: training in CG and EG was carried out by the same teachers if possible; competencies development of postgraduate and doctoral students in CG and EG was carried out in statistical equivalence. The training of postgraduate and doctoral students in EG was provided according to the author's methods, and the training of CG participants was carried out according to traditional methods. The pedagogical experiment results showed an increase in development levels of informational and research competencies of postgraduate and doctoral students, provided that they are actively introduced digital systems and specially developed methodological system into the training.

The author's methodological system was implemented in universities and research institutions directly by the authors of this research, and the management and teaching staff of these institutions were involved. Important component of the methodological system was the author's set of seminars and workshops with digital systems use. It was aimed to develop informational and research competencies of postgraduate and doctoral students. After completion of the formative stage of the pedagogical experiment, Assessment of development levels (control section) of informational and research competencies of postgraduate and doctoral students was re-performed according to special diagnostic tools after completion of the formative stage of the pedagogical experiment. For example, photos in figure 1 are taken after the pedagogical experiment on the basis of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.



Figure 1. The pedagogical experiment on the basis of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

IV. Stage (control) 2020 year. Assessment of development levels of informational and research competence of postgraduate and doctoral students was performed according to each of the developed criteria at this stage. Table 3 presents generalized (averaged) quantitative results of development of informational and research competence of postgraduate and doctoral students on all criteria (control section). Also, the comparative distribution of levels and criteria of informational and research competence of postgraduate and doctoral students in EG and CG at the beginning and end of the pedagogical experiment is presented in the form of histogram in figure 2.

Following conclusions were made after analyzing the data from table 3 and figure 2: there was an increase in number of postgraduate and doctoral students in EG compared to the number of CG by all criteria as result of the introduction of the author's methodological system in the training of graduate

and doctoral students. The following redistribution took place after formative stage of the pedagogical experiment: according to the value-motivational criterion – 0% in EG and 12.7% in CG had “low” level of development of informational and research competence. According to the cognitive criterion - at “low” level was 10% in EG and in 33.3% CG. According to the activity criterion “low” indicators were recorded: 2.3% in EG and in 22.4% CG. According to the evaluation-reflexive criterion, 26% of EG and 46% of CG were at a “low” level. Also, assessment of development levels of informational and research competencies of postgraduate and doctoral students after the formation stage of the pedagogical experiment showed some changes in the participants of the CG. These changes could be more significant if the author’s methods for purposeful development of information and research competence would implement. The control section results in EG and CG showed that the participants of EG had higher results in development of informational and research competencies than the participants of CG.

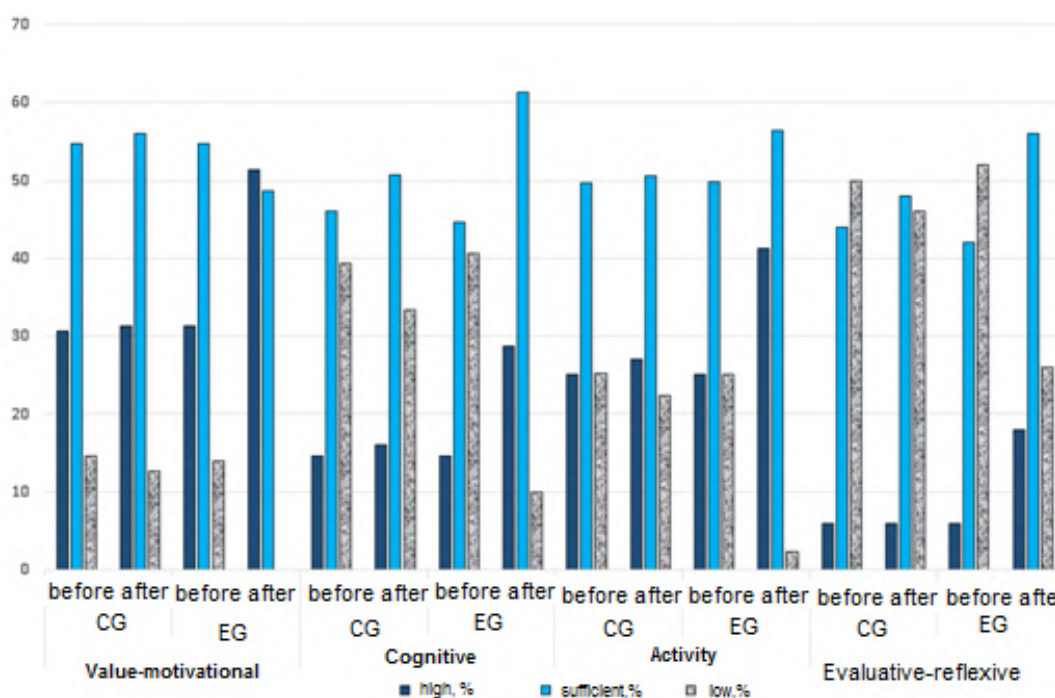


Figure 2. Comparative distribution according to levels and criteria of informational and research competence of postgraduate and doctoral students in EG and CG (statement and control section).

Changes in development of information and research competence are determined as a result of introduction of experimental methodical system in preparation of postgraduate and doctoral students. It is presented in Figure 3. These changes are: number of postgraduate and doctoral students with “low” level decreased in EG from 32,94% to 9,59%, respectively, the number of postgraduate and doctoral students with “sufficient” level increased from 47.79% to 55.59% for EG; number of postgraduate and doctoral students with “high” level also increased from 19.27% to 34.82% for EG. The developed author's methodological system confirmed its effectiveness and pedagogical expediency, because in EG a large number of graduate and doctoral students reached “high” and “sufficient” levels of information research competence. It is showed during comparison and interpreting the data of observational and control sections in EG and CG.

Following conclusions were made after analysis of quantitative results of the development of information and research competence: the number of postgraduate and doctoral students with a “low” level decreased in EG from 32.94% to 9.59%; “sufficient” level increased from 47.79% to 55.59% for EG; the number of graduate and doctoral students with “high” level also increased from 19.27% to

34.82% for EG. Therefore, we believe that the developed methodological system contributed to qualitative changes in graduate and doctoral students, namely growth of development levels of information and research competence.

Also, statistical processing of obtained quantitative data was performed. It was determined whether there are differences between development levels of information and research competence in EG and CG after the control section using the Fisher's angular transformation. It was confirmed that there are statistically significant differences in these samples after the control section. It was concluded that author's methodological system is more pedagogically appropriate and effective than the traditional one.

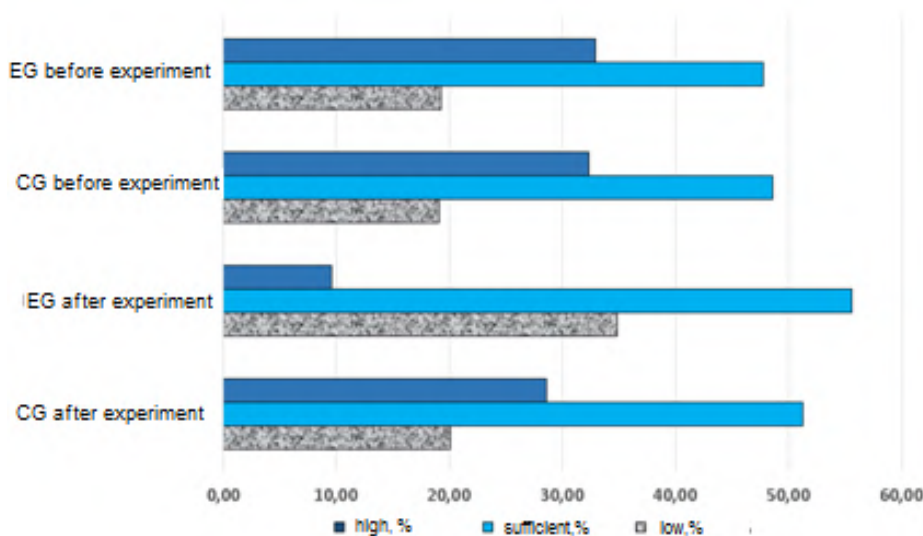


Figure 3. Comparative histogram of growth levels of development of informational and research competence of postgraduate and doctoral students in CG and EG after the formative stage of pedagogical experiment.

4. Conclusions

Process of society digital transformation puts forward new requirements for the competencies of postgraduate students and scientists, in particular for digital technologies use for scientific activities. It directly affects development of informational and research competence. It is confirmed that important role in development of informational and research competencies of postgraduate and doctoral students is given to digital technologies – digital open systems. Their use contributes to improving and expanding opportunities in research, presentation of research results and image of the researcher and institution. Also, use of outlined tools for research will significantly reduce financial and time costs and promote faster dissemination of scientific results.

The digital society requirements to the information and research competence of postgraduate and doctoral students are determined and described. They include:

- willingness and ability to carry out research activities;
- ability to search and select necessary information and data, their transformation, storage and transmission using digital technologies;
- ability to critically evaluate found information (check their accuracy, timeliness, feasibility);
- ability to perform scientific research (organization, planning, conducting) with use of digital technologies.

Thus, the author's methodological system was the most effective for postgraduate and doctoral students with "low" level of information research competence. They were able to reach higher level, so number of those who had a "low" level decreased due to acquired skills and knowledge. Significant

shift in distribution of postgraduate and doctoral students and increase in number of those who had “sufficient” and “high” levels of information research competence was observed where the author's methodological system was implemented. It confirmed its pedagogical feasibility. Quantitative data were statistically processed using Fisher's angular transformation at different stages of the pedagogical experiment. So, experimental verification of the author's methodological system aimed to develop informational and research competence of postgraduate and doctoral students confirmed its effectiveness and pedagogical expediency.

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Research of professional responsibility of students of technical specialities by means of information and communication technologies

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Abstract. The article is devoted to the use of information technologies for pedagogical research aimed at studying the formation of key competencies and learning outcomes in higher education institutions, in particular, the professional responsibility of students of technical specialities. The diagnostic capabilities of the ATutor system, which operates at the Ternopil National Technical University named after Ivan Puluj (Ukraine), are presented. The process of data collection involving distance learning technologies and the results of the analysis of the study are described. The state of formation of professional responsibility in students of technical specialities is determined, the main problems and difficulties in the formation of professional responsibility of future specialists in the technical field are clarified, and the possibilities and role of social disciplines are revealed. The structural and logical scheme of integrating disciplines of a humanitarian cycle in a distance learning course “Professional Responsibility of a Technical Specialist in Modern Conditions” is presented.

1. Introduction

Information and communication technologies are able not only to diversify methods, forms and means of teaching, to provide effective mechanisms for quality control of knowledge, but also to open new horizons for research, to form powerful diagnostic tools that can be widely used in pedagogical research. The implementation of remote communication with respondents allows an in-depth understanding of the essence of pedagogical processes. It also clarifies the content component and assesses the quality of training of future professionals. The use of virtual learning environment in higher education institutions greatly simplifies research work [13]. It is both time and money effective way to collect data on solving current and strategically important tasks set by higher education. One of such tasks, conditioned by the realities of our life, is the formation of professional responsibility of future workers in the technical field. The concept of sustainable development of socio-economic systems, which is based on the principles of social responsibility of all economic entities, is gaining popularity all over the world. This is especially true of engineers, because they improve the quality of human life and open opportunities that can drastically change the environment. Technology today involves into all sectors of society, helps to organize social, political, economic processes, and, accordingly, the role and importance of professional responsibility of those who create it.



As part of research work conducted at Ternopil National Technical University named after Ivan Pului (hereinafter TNTU) on “Personal and Professional Development of Students of Technical Universities in the Study of Social Subjects”, number of state registration 0119U001322), a diagnostic study of professional responsibility formation in students of technical specialties has been conducted with the use of information and communication technologies. The research is aimed at identifying practical problems of formation of professional responsibility in future engineers and finding ways to solve these problems while mastering social subjects.

2. Methodology of research

The concept of responsibility is complex and multifaceted. Domestic and foreign philosophers, sociologists, psychologists, and teachers studied and researched it. The structural type of social responsibility is traditionally referred to as professional responsibility that is the central category of our study. Professional responsibility is a system-forming professional quality. Under professional responsibility we understand the characteristic of an individual which reflects the attitude of the subject to its content and results, to other subjects and himself in the process of work. The nature of this attitude is specified by the need for clear and full compliance with the proposed requirements and rules in professional activities, as well as the willingness to report on the results of their own activities [23]. A review of scientific sources on the problem of professional responsibility shows that this phenomenon is studied from the following perspectives: professionally significant personal quality; category specified by a set of personal qualities; personal property that has individual psychological correlates (locus of control). In the context of our study, the approach of scientists M. Berulava [1], E. Ilin [6], V. Miasishchev [4] and others on the relationship between professional responsibility and the locus of control and success in the field of professional activity is the most relevant.

In the context of our study, it is important to understand the structure of the concept of professional responsibility. The systematization of theoretical concepts available in the scientific literature was carried out by M. Sadova [19]. She identified three main approaches to solving the issue: *three-component approach* (M. Savchyn [20]), *factor approach* (V. Priadein [14]) and *functional approach* (K. Muzdybaev [12]). The first approach is based on the selection of cognitive, emotional and behavioral components of professional responsibility. The factor approach emphasizes the relationship between the essence of professional responsibility and the mechanisms of its implementation. It is proposed to define professional responsibility through the functional unity of motivational, emotional, cognitive, dynamic, regulatory and productive components. The analysis of all these components indicate that there are the harmonic (balanced) and anharmonic (imbalanced) constituents of responsibility [14]. The functional approach is based on the selection and analysis of objective and subjective aspects of professional responsibility. The main components of responsibility in this case are the subject, object, instance of responsibility and its time perspective [12].

Responsibility is grounded on basic psychological formations such as self-awareness of the individual and its components such as self-esteem, I-concept of personality, as well as the relevant psychological mechanisms (self-regulation and reflection). The internal instance of responsibility is conscience [20]. Attitude to professional responsibilities depends on the vital and professional position of the specialist. With the responsible attitude to the professional duties they show the maximum activity and productivity, with the indifferent they just formally carry out the requirements, and with the negative attitude they seek to do as little as possible and do not ensure the quality of work and its outcome.

The professional responsibility of a technical specialist is of paramount importance today. E. Conlon claims that in the framework of sustainable development, modern labour market requires employees to understand the broad social context of vocational issues and the responsibility of engineers for the results of their work [3]. S. Semerikov, A. Striuk, L. Striuk, M. Striuk and H. Shalatska distinguish fifteen basic general professional competencies of a specialist in software engineering, among them there is the ability to act in a socially responsible and conscious manner [21].

In addition to the theoretical understanding of this problem, in educational practice there is a number of activities aimed at nurturing a sense of belonging to global processes and responsibility for their

consequences in students of technical specialties. Professional responsibility is one of the main general engineering competencies and learning outcomes in higher education. In foreign professional pedagogy a new method is being developed at the University of Western Australia to determine general engineering competencies. In particular, S.A. Male offers to work not only on the formation of general or professional competencies, but emphasizes the importance of integrated general engineering competencies which include professional responsibility [8]. Sydney University of Technology implements a sustainable development program for engineers [2], etc.

Professional responsibility integrates the moral, volitional and professional qualities of future professionals in a new entity which is purposefully developed in the conditions of special training. Therefore, it is important to monitor the state of formation of professional responsibility of students of technical specialties, to develop tools and ways of its purposeful formation at the time of getting higher education. This determined the purpose of our study.

In determining the levels of professional responsibility of technical specialists, the key to our study were the four main modes of studying professional responsibility, identified by M. Sadova [19]: 1) what is professional responsibility? 2) what is a person responsible for? 3) who is a person responsible to? 4) in what way is a person responsible? In order to create diagnostic tools that would allow to determine the levels of professional responsibility, the following methods have been used: Rotter's Internal-External Locus of Control Scale, developed by J. Rotter based on his social learning theory [18]; methods of diagnosis of responsibility, developed by V. Priadein [15], questionnaire for diagnosing the level of moral and ethical responsibility of an individual (I. Tymoshchuk) [24] and DPSR (I. Kocharian) [7].

3. The implementation of the testing

For data collection, a virtual learning environment of Ternopil National Technical University named after Ivan Pului was used. It has been developed on the basis of the Learning Management System (LMS) ATutor and has been successfully used to organize the learning process since 2002 (figure 1).

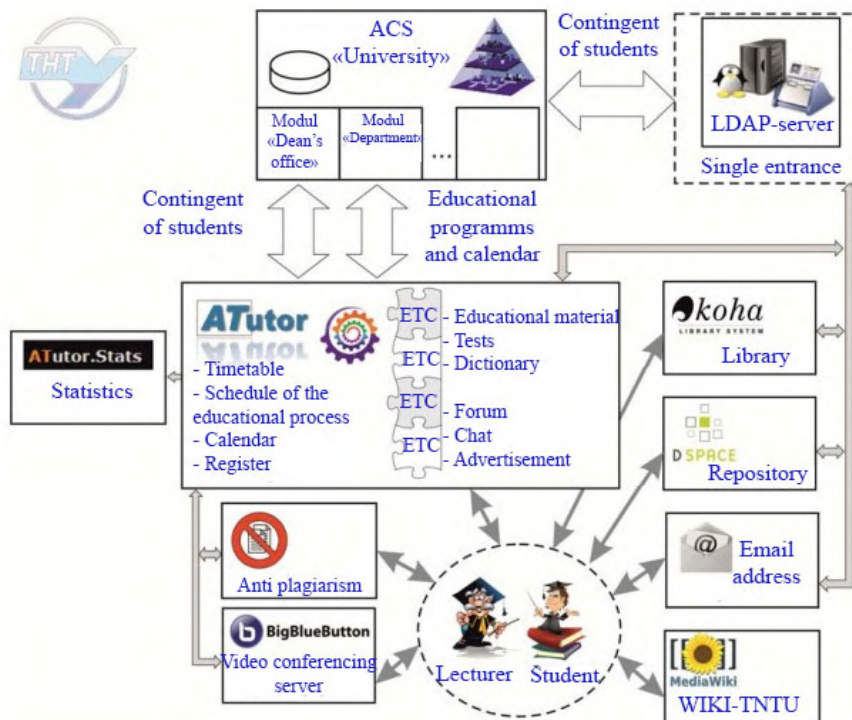


Figure 1. TNTU Virtual Learning Environment.

A questionnaire containing 65 questions and brief instructions for its use were entered into the database [9]. The questions were divided into three sets that correspond to the levels of professional responsibility defined by us:

- Formal and technical responsibility. It is characterized by a formal approach to work, lack of initiative and desire to develop and create something new. Basically, the understanding of the professional responsibility of an engineer is reduced to compliance with safety standards when working with technical devices, their proper operation. All that should be the focus of a specialist (according to students) is about reliable results, accurate calculations. They are the ones that testify to professionalism;

- Managerial and communicative responsibility. At this level the social significance of the work of a technical specialist is manifested. The main focus is on communication between the consumer and the manufacturer, relationships with colleagues and management. The responsibility is primarily treated as collective. The main features of this level are: honest performance of tasks set by management, responsibility to the end user for safe use and quality of the product, as well as to colleagues for the success of the project;

- Research and prognostic responsibility requires a comprehensive understanding of the history and significance of the future profession. This is about a sense of belonging to the outcomes of scientific and technological progress, creating a future human environment, responsibility to future generations, solving global problems through technology and more. It provides a creative approach to business, the ability to act autonomously.

Each of the sets contained 20 questions. Also, students were asked five provocative questions, the answers to which may indicate respondents' veracity. There were five possible answers to each of the questions: "I strongly agree", "I agree", "It is difficult to answer", "I disagree", "I strongly disagree". The first two options counted as affirmative (with varying confidence degrees), the last two as negative. The option "It is difficult to answer" was classified as the one that indicates the respondent's lack of interest in the question, lack of knowledge and experience, it was a sign of inability to have an opinion in order to determine the answer.

The university students of the Faculty of Computer Information Systems and Software Engineering took part in the survey. They major in *121 Software Engineering*, *122 Computer Science*, *123 Computer Engineering* and *126 Information Systems and Technologies*. The results were processed in the Excel program. The study covered 87 people.

4. Results and discussions

The analysis of respondents' answers showed the following results:

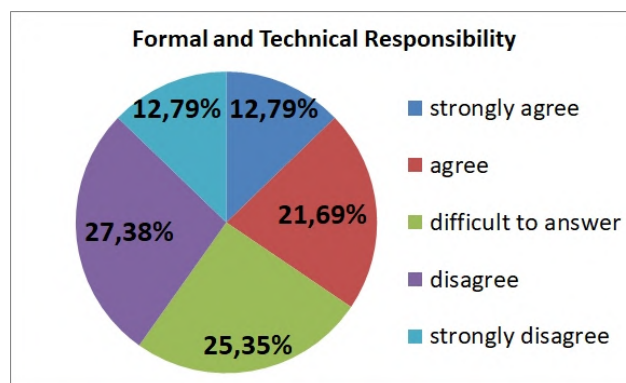


Figure 2. Distribution of students' answers to the questions of set 1 of the questionnaire "Professional Responsibility".

As can be seen from the diagram (figure 2), only 12.79% of respondents strongly disagreed with the proposed statements, most of which were provocative and indicated a formal approach to work. This

proves that students are focused on their own interests, they lack in creative approach to business.

Only 13,95% of respondents strongly agree that the concept of professionalism implies knowledge that goes beyond the subject area; 18,61% of respondents claim that creativity and multipotentiality is not their option, and 34,88% could not provide any answer to the question at all. 27,91% of students who participated in the survey agree that they will never need humanities in the real professional life, and 23,26% opted for “It is difficult to answer”. To some extent, the concept of “creativity” is correlated with technical specialties for 45,35% of respondents which is less than half of those surveyed. 24,42% agreed with the statement “Let scientists do scientific work. They are paid for it” and 18,60% did not provide any answer. Only 26,74% consider that it will be possible in their future professional activity to go beyond the job description. 40,7% called material remuneration to be a priority in choosing a job, 26,74% of future specialists did not come up with the answer to this question. Only 11,62% of respondents would not agree to give up their specialty for a higher salary.

Analysis of answers to the questions of managerial and communicative responsibility set (figure 3).

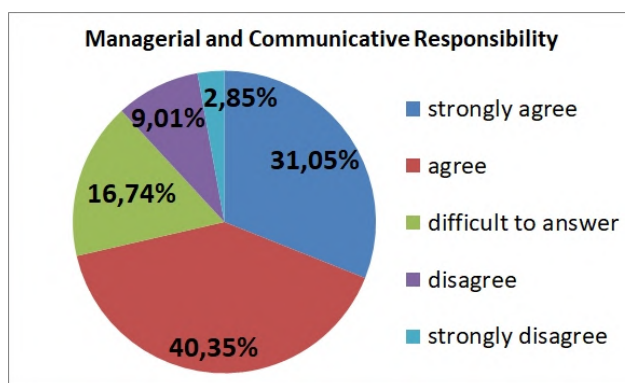


Figure 3. Distribution of students’ answers to the questions of set 2 of the questionnaire “Professional Responsibility”.

The level of managerial and communicative responsibility is quite high – 71,4%. This allows us to say that students are able to maintain good relations with colleagues and the management, feel responsible for the results of their work to other people. Some questions were tricky. Affirmative answer to them indicates unwillingness to work autonomously and a lack of personal responsibility. In particular, only 13,96% of respondents do not associate career growth with good relationships with management. To the question “The manager, first of all, should control employees and not rely on their responsibility” the answer “strongly agree” was provided by 22,09% respondents, “agree” – 29,07%, “difficult to answer” – 23,26%. Only 1,16 % of students strongly disagreed with the statement. Exactly half of the respondents put the blame for the failure of the project solely on the management. However, only 3,49% of respondents can be critical of colleagues’ mistakes, claiming that “everyone makes mistakes.” 19,76% of respondents allow “shortcuts” while performing the duties (what they only cared about is that no one can notice), 25,58% did not decide on the answer.

For the success of the common enterprise, 58,13% of respondents are ready to sacrifice their interests. Only 3.49% prioritize their own interests over the collective ones. 86,05% of students agreed to admit their mistakes and would be willing to rectify the problems and eliminate their consequences. Only 2,33% do not want to do this. It should be noted that with the generally high level of managerial and communicative responsibility, it is usually perceived by respondents not as a personal but as a collective responsibility.

The results of the study showed a high level of formation of research and prognostic responsibility (figure 4). This can be largely explained by the fact that purposeful work was carried out in this direction. During the study of social disciplines (philosophy, history and culture of Ukraine, political science, law) special attention was paid to the issues related to the value of the chosen specialty, personal and

professional responsibility of a technical specialist in modern conditions, understanding global processes of technocracy of public life. For comparison, in a previous survey (October 2018) [5], only 20% of respondents showed signs of research and prognostic responsibility.

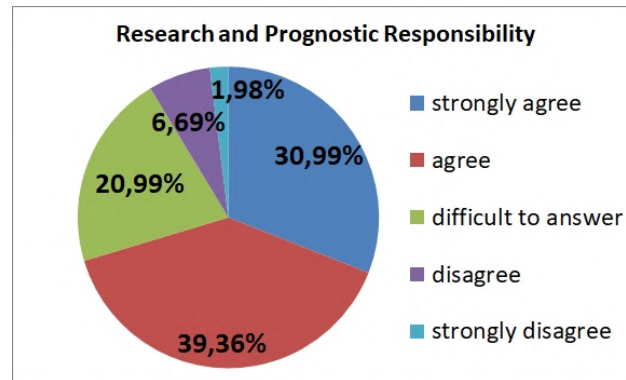


Figure 4. Distribution of students' answers to the questions of set 3 of the questionnaire "Professional Responsibility".

The vast majority of students realize that the technical sphere today is a collective mind capable of bringing humanity to a qualitatively new level of existence. The answers were distributed as follows: "I strongly agree" – 29,07%, "agree" – 52,33%, "difficult to answer" – 15,12%, "disagree" – 3,49%, "strongly disagree" – 0%. However, 76,74% agreed with the statement that an engineer, first of all, is an intellectual, an erudite, a researcher. 89,53% of respondents agreed that technology can both help and harm people. The results of the survey shown that only 18,61% of respondents indicated that they know the history of the development of their specialty to some extent. 32,56% of students who took part in the survey could not answer the question whether they are proud of their future profession. Only 34,88% of respondents to some extent feel their belonging to the global processes of technocracy.

A large percentage (20,99%) of responses "difficult to answer" was revealed in the questionnaire.

Based on the analysis of the obtained results, the main factors influencing the formation of professional responsibility of students of technical specialties are identified. They are as follows: universal cognition and capability of scientific and technical creativity; professional empathy and collectivism; priority and profession certainty; capability of autonomous activity and personal responsibility.

Four scales were created, each included 15 questions, the answers to which indicate the presence of the above factors of professional responsibility: if there are up to 5 answers on the scale, it indicates low level; from 6 to 10 is of average level; from 10 to 15 is a sign of high level.

According to figure 5, the level of formation of universal cognition and ability to do scientific work and to be technically creative cannot be considered sufficient, as only 30,23% of respondents showed a high result. The formation of professional empathy and collectivism in the respondents (figure 6) is quite high which generally corresponds to a high level of managerial and communicative responsibility (figure 3). This only confirms the previous conclusions that the vast majority of students understand professional responsibility as collective. The level of formation of priority and value certainty of the profession (figure 7) is very low, as only 9,30% of respondents showed a high result. The level of capability of autonomous activity and personal responsibility of the surveyed students (figure 8) is very low, because only 8,14% of respondents have a high score.

Thus, the study revealed shortcomings in understanding the essence and content of the concept of "professional responsibility", its insufficient level in students of technical specialties. Therefore, it is necessary to purposefully form professional responsibility of future technical specialists. In this aspect, it is advisable to use the complex capabilities of social disciplines. In foreign engineering education it is often proposed to strengthen the humanitarian component. For example, H. Sjursen argues that the

need to diversify engineering training with subjects of humanities is an imperative of our time [22]. M. Reimer develops the concept of “emotional intelligence” as a necessary component of the success of a technical specialist [16]. This quality is responsible for the formation of professional qualities of an engineer, important in the modern technogenic world in general and responsibility for the results of their work, in particular. The problem of humanization of technical knowledge was also addressed by D. Missingham [11], P. Vohra, R. Kasuba, D. Vohra [25] and many other scholars. In our opinion, the experience of the Massachusetts Institute of Technology is very interesting. They offer a two-degree training program with a bachelor’s degree in the humanities or technical sciences or the humanities and natural sciences. The introduced program provides a generally balanced training.

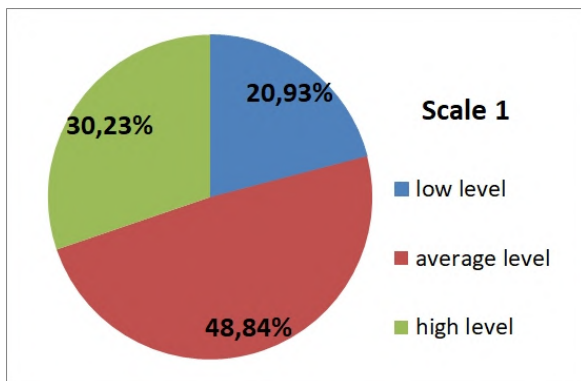


Figure 5. Formation of universal cognition and capability of scientific work and technical creativity.

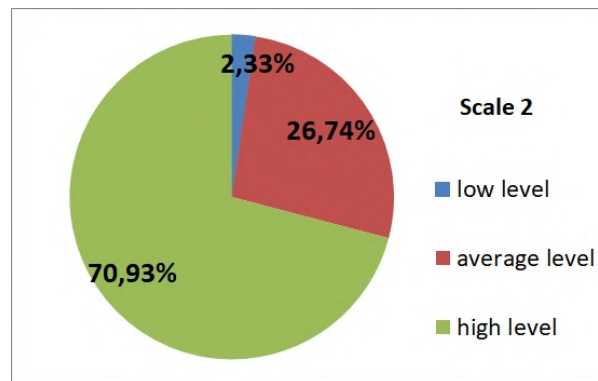


Figure 6. Formation of professional empathy and collectivism.

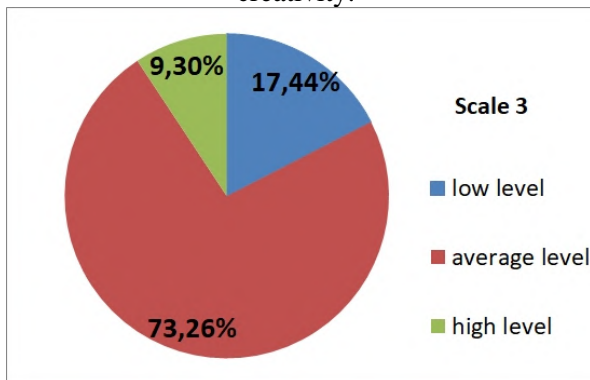


Figure 7. Formation of priority and value certainty of the profession.

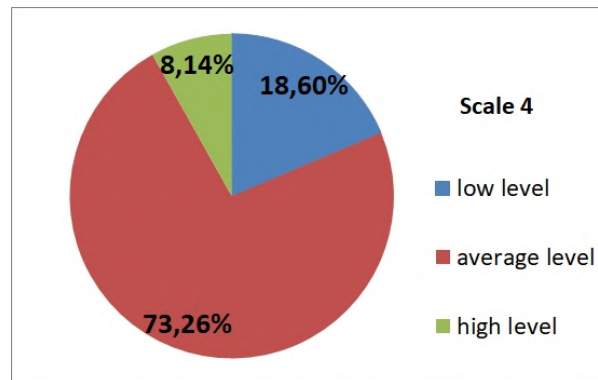


Figure 8. Formation of the capability of autonomous activity and personal responsibility.

Purposeful use of opportunities of social disciplines in the process of formation of professional responsibility of students of technical specialties will help future specialists to be more competitive and mobile in the world of labour market. The knowledge of humanities will lead them beyond narrow specialization and will open new horizons.

The task is complex and requires an integrated approach. What is particularly advisable is to create an integrated distance learning course “Professional responsibility of a technical specialist in modern conditions” (figure 9). The virtual learning environment provides a sufficient number of tools for effective work: the ability to post lecture notes, guidelines and presentations, a glossary of key terms used to present material, links to materials of seminars, conferences, etc., posted on the Internet. Communication of participants can be carried out by means of a forum, chat, the built-in e-mail. It is possible to use a file hosting server, perform individual and group tasks.

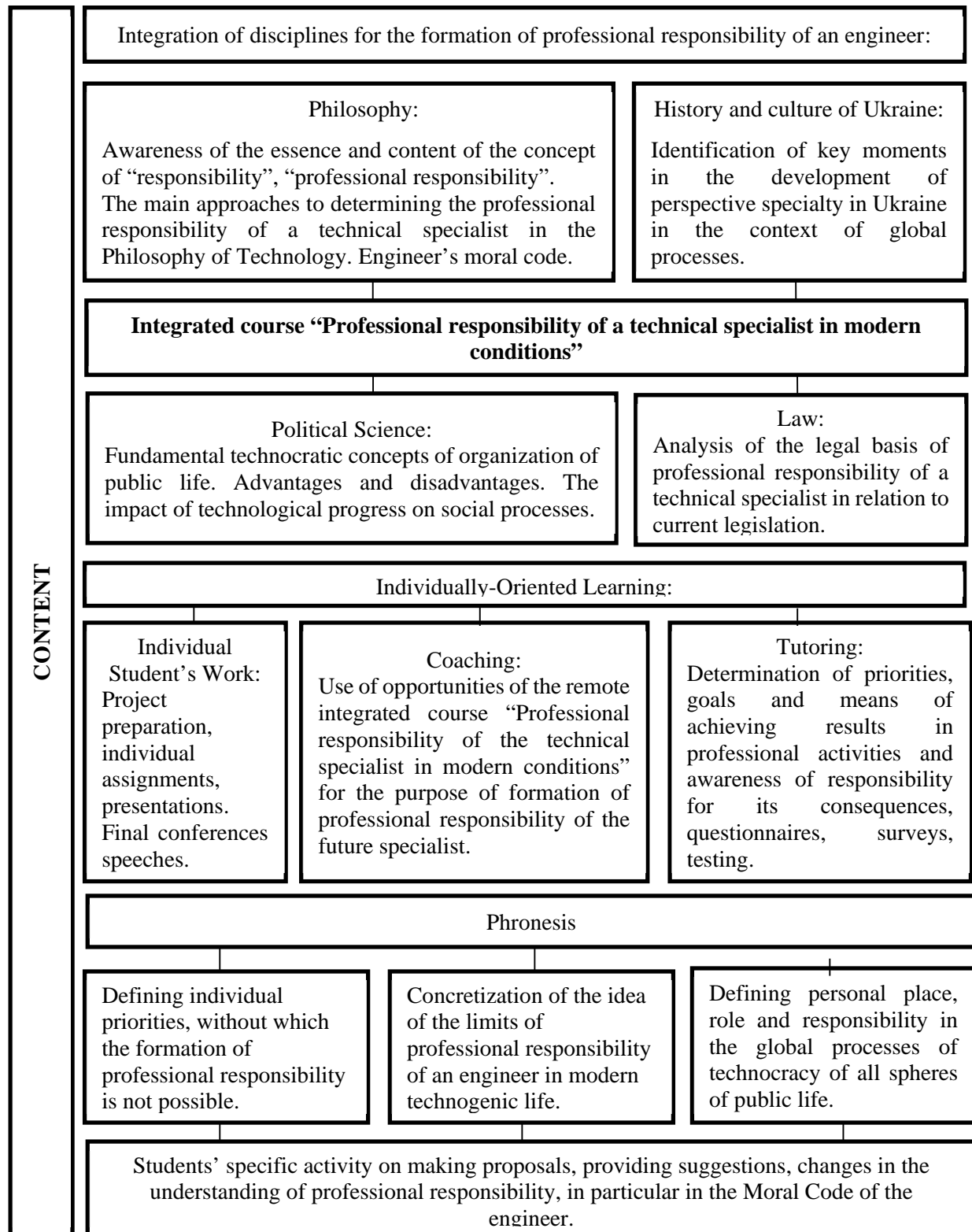


Figure 9. Scheme of the integrated distance course “Professional Responsibility of a Technical Specialist in Modern Conditions”.

The suggested course provides two modules: “Professional responsibility as a key competence of an engineer” and “Professional responsibility of an engineer in the context of global problems nowadays.” The first module summarizes the theoretical approaches to the definition of “responsibility”, “professional responsibility”, “professional responsibility of an engineer”, focuses on the philosophical understanding of these categories. The content of the second module is aimed at revealing the practical problems of the engineering profession which are studied through the prism of the history of the specialty, outlining the specifics of legal aspects of professional responsibility of technical specialists, public policy to determine the prospects of the specialty. By covering the course, students will be able to be part of the solution to global problems of today, they will familiarize themselves with the Codes, the Credo of professional ethics of an engineer (USA, Germany, France, Japan), they will form their professional position. It is also a good idea to bring the materials of international conferences, forums, symposiums, etc. for discussion.

The use of a distance learning course provides more opportunities for personality-oriented learning than classroom work. The students communicate directly with the teacher, they have the opportunity to ask questions, receive information of their interest, express their views, voice comments, suggestions and more. The teacher, respectively, through individual communication has the opportunity to take into account the psychological characteristics, abilities and interests of every student. Teachers can offer tasks that would be not only useful in terms of obtaining information, developing skills and abilities, but also interesting for a particular student. This will facilitate the implementation of subject-subject interaction in the educational process.

Problematic issues should be brought up for collective discussion. The distance learning system provides an opportunity to hold web conferences, webinars, round tables in video and audio modes, communicate in chats, exchange useful information.

Phronesis is important for the formation of professional responsibility in the framework of the study of the proposed integrated course. This approach, which indicates to a person what needs to be done for his/her own good and for the good of others, is actually a synthesis of the social and the individual defined in particular actions and is aimed not at the abstract but at the concrete common. That is, everyone knows their Truth “in general”, and can act freely, in accordance with the specific priorities set by a particular situation [17].

For broadening the opportunities of basic version of ATutor system, the Institute of Distance Learning at Ternopil National Technical University named after Ivan Pului (<http://idn.tntu.edu.ua>) has developed and introduced a number of additional modules: event planner calendar; module for importing educational material from Microsoft Word documents; module for testing knowledge by adaptive algorithms (Computerized adaptive testing CAT); module and the corresponding server of the automated authentication of educational works and materials; video conferencing server module BigBlueButton [4].

5. Conclusions

Today the problem of training a new generation of engineers with a formed professional position, high moral standards and competitive spirit is becoming especially relevant. Professional responsibility is the key to successful activity; it guarantees a positive result, reduces the risk of professional errors and faults. In our understanding, professional responsibility is viewed as an integral quality of a specialist’s personality. It involves conscientious performance of professional duties, it guarantees the appropriate level and quality of professional activity, even in the conditions of unpredicted difficulties.

The use of information and communication technologies can significantly facilitate and simplify the work of data collection in pedagogical research. Higher education institutions which provide opportunities for virtual learning environment can diagnose the formation of educational competencies, identify shortcomings and eliminate them. During the questionnaire involving the virtual learning space created on the basis of the learning management system (LMS) ATutor, we identified and confirmed three levels of professional responsibility of students of technical specialties (formal and technical, managerial and communicative, research and prognostic) and the main factors influencing their

formation (cognition and capability of scientific and technical creativity; professional empathy and collectivism; priority and value certainty of the profession; capability of autonomous activity and personal responsibility). They are all interconnected, complementary and determine the general level of professional responsibility of the future specialist. Based on the analysis of the results of the study, weaknesses in students' understanding of professional responsibility were identified. They include the focus on the material component of the future profession and lack of its value certainty; low level of personal responsibility and its transfer to management; ignorance about the historical aspects of the chosen specialty; low level of initiative and the inability to be creative, etc.

For purposeful formation of professional responsibility in students of technical specialties it is expedient to use complex possibilities of social disciplines which promote development of abstract thinking and the general erudition, given the chance to go beyond narrow specialization and to understand a place, role and value of the chosen profession in the modern technogenic world, consciously and responsibly. The proposed distance learning course "Professional responsibility of a technical specialist in modern conditions" integrates the possibilities of philosophy, political science, law, history and culture of Ukraine for the formation of professional responsibility of students of technical specialties, for their understanding of personal significance, their place and limits of professional responsibility in the changing technogenic environment.

We see prospects for further scientific research in the development of technology for the formation of professional responsibility of students of technical specialties in the study of social sciences.

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The peculiarities of the usage of AR technologies in the process of hardiness of future professionals

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Abstract. One of the main challenges of today is to increase the resilience of individuals to stressful environmental factors and preserve the quality of life and efficiency. Hardiness is a psychological phenomenon, the essence of which is a productive way out of the crisis towards personal growth. Taking into account the effectiveness of information and technological progress, the issue of internalization of AR technologies in the process of training a competitive, viable specialist who is able to mobilize and self-realize internal potential resources is vital. The scientific article analyzes the possibilities of using innovative AR technologies in the process of developing the hardiness of the future specialist on the basis of the implementation of competence and subject-personal approach to the introduction of AR technologies in the educational process in the system of higher education. The article describes the experience of integrated implementation of elements of augmented reality in the program of development of hardiness - Hardiness Enhancing Lifestyle Program based on the concept of BYOD. According to the results of the obtained empirical data the efficiency of using innovative AR technologies in the structure of mobile applications in the process of development of the components of hardiness of the personality of the future specialist is proved. Prospect for further research is the development of a methodology for integrated implementation of AR technologies in the practice of higher education in order to optimize the training of future professionals.

1. Introduction

Unrestrained social and economic as well as informational and technological development of society increasingly requires the ability to take advantage not only of adaptive potential, but also of reserve regulatory resources from each of us. Modern pandemic conditions of the society existence [51], the growing role of remote interaction of the subjects of labour pose more and more challenges to man as a subject of his own life. The subjective qualities of the personality that determine its hardiness are increasingly valued. Studies show that vitality and hardiness interact with activity, a person's ability to make independent decisions, professional and academic success, faith in his own strength, ability to cope with difficulties, stressful situations, maintain his health and psychological well-being. An integral feature of the current situation is the process of globalization, which affected all spheres of public life and the higher education system. Global transformations of all aspects of society and the higher education system lead to increased demands on individual resources [14]. To meet the requirements of innovative social development, it is necessary to have certain personal attitudes, qualities and values that would allow full participation in innovation processes – high potential for self-realization, resilience to frustration, the ability to turn problem situations into positive experiences, willingness to change



patterned behavioral stereotypes, tolerance for uncertainty, developed motivation for self-improvement and innovation, etc.

Current trends in the digitalization of education and the transformation of the competency approach involve the active implementation of innovative information and communication strategy for higher education. The corresponding innovative strategy determines not only the search for adaptive, resourceful IT technologies, but also the development of new competencies of modern specialists [8]. One of the key competencies of a modern specialist is the ability to implement hardiness as the ability of the subject to find a degree of compliance with existing conditions, determines a person's protection from various threatening influences associated with human perceptions of his ability to implement successfully the behavior necessary to achieve expected results, to overcome the negative effects of the environment and realize the potential of man in a competitive space [23]. The impact of pandemic trends on the process of self-realization and training of future professionals has led to a global reorientation from the “subject-subject” relationship to the realization of the ternary process space “subject – information environment – subject”. The field of higher education actively uses the advanced achievements of scientific and technological progress in many areas of human activity and, in particular, the achievements of information technology, proving the feasibility of their use in the educational process. The digital revolution, which has spawned smart connected devices and explosive data growth, is boosting productivity and opening up opportunities for higher education. Today, the future specialist is not limited by the lack of information, but the complexity of its understanding and application – in other words, we need a new type of interface. The most promising solution is augmented reality [9], [10]. Accordingly, taking into account the spread of augmented reality technologies and changes in the competency approach in the process of training future professionals, the issue of internalization of AR technologies in the process of training a competitive, hardiness specialist capable of mobilizing and self-realization of internal potential resources is vital.

The purpose of our interdisciplinary study is to determine the functional impact of AR technologies on the proprium of hardiness of the future specialist in the training process.

2. Literature review

Analyzing the hardiness as an integrative phenomenon, it is necessary to pay attention to its various aspects and manifestations, the structural components of this phenomenon. Based on the definition of the diversity of life as well as various manifestations of such a quality as resilience, we can talk about the multifaceted phenomenon of hardiness. Applied research has identified a personal construct of “hardiness”, which characterizes the degree of individual ability to withstand a stressful situation, maintaining internal balance without reducing the success of the activity [17].

Studies by Salvatore R. Maddi and Suzanne C. Kobasa have shown that hardiness is a personal characteristic that is a general measure of a person's mental health and reflects three life attitudes: involvement, confidence in the ability to control events, and willingness to take risks ([29], [36]). In addition to these attitudes, “hardiness” includes such core values as cooperation, trust and creativity. A high level of hardiness contributes to the assessment of events as less traumatic and successful coping with stress. Indicators of hardiness are a set of characteristic features, according to which we can conclude about the development of this personality trait [31]. The authors include genetic predispositions, immune system parameters and neuroendocrine response to stress (Christyn L. Dolbier [38], Robert R. Cocks [21], Jenn A. Leiferman [21], Alse M. Sandvik [4], Sigurd William Hystad [25], Terry Martyn Phillips [49], Julian Francis Thayer [49], Bjørn Helge Johnsen [25]), strength and speed of response of the sympathetic nervous system on stress (Suzanne C. Kobasa [29], Salvatore R. Maddi [36], [37], Mark C. Puccetti [45]), cardiovascular reactivity in response to stress (Richard J. Contrada [6]). The individual psychological (social and psychological) indicators of hardiness should be identified and grouped as follows: cognitive (locus of control, critical thinking and creativity, optimal response to criticism; divergent thinking, predictive abilities, search activity, effective assessment of the situation, its perception as a challenge, rather than threats), emotional and volitional (stress resistance, purposefulness, emotional stability, ways of emotional self-regulation), behavioral indicators (effective

behavior patterns, constructive coping strategies, coping style, task-oriented rather than emotional experience, readiness for action, social communication skills such as active listening, confident demandingness, flexibility and independence in decision-making (Roos Delahajj [20], Anthony W. K. Gaillard [20], Salvatore R. Maddi [37]). Most researchers of hardiness agree that this phenomenon embodies in addition to psychophysiological, individual, social and psychological indicators, certain characteristics of personal and semantic level, level of values and motivation [38]. A hardiness personality is characterized by a positive outlook, increased subjective assessment of quality of life, the search for meaning as the leading goal of life, and the search for meaning in a given situation, a high level of awareness of his own interests, values and meanings [57]. An important factor in the development of human hardiness is the ability to have his own personal potential [29].

Based on the research of Velly Ndlovu and Nadia Ferreira about the actualization of the development of psychological resilience as a dominant component of professional adaptation, the question of finding adaptive and innovative ways to develop the hardiness of the individual is quite relevant [41].

In the context of digitalization and informatization of the modern cultural and sensory environment, the priority is to find ways to use augmented reality technologies in the process of professional and personal development of the future specialist [52].

Analyzing the work on the introduction of AR technologies in the educational environment ([26], [28], [30], [32], [33], [39], [40], [43], [48], [47], [53], [54], [59]) it should be noted that the growing popularity of augmented reality technology and interest in it, at the moment, is due to researches that justifies the prospects for use augmented reality technologies by expanding the production sphere and creating completely new areas and opportunities for education. Among the main arguments are: the ability to design thematic databases with visualized data, capable of working with different operating systems and devices; the emergence of crowd sourcing platforms for the creation of augmented reality content by users, the creation of new computer systems.

A significant number of modern researchers (Pietro Cipresso [16], Irene Alice Chicchi Giglioli [16], Hsin-Kai Wu [13], Hsin-Yi Chang [13]), pay special attention to the integrative processes of introduction of AR technologies in the system of higher education. Scientists study the process of introducing innovations in virtual development, augmented reality in the psychological and pedagogical structure of training future professionals, the formation of professionally important qualities, professional competencies. Wilma Lorena Gavilanes López, Blanca Rocio Cuji, Maria José Abásolo and Gladys Lorena Aguirre Sailema analyze the degree of technological acceptance of educational contents enriched with Augmented Reality (AR) by university students, mainly if these contents have been designed by some students to others. Researchers have scientifically substantiated the relevance of implementing the Technological Acceptance Model (TAM) using Augmented Reality in University Learning Scenarios [35]. Especially innovative in the coaxial realities, according to Hsin-Yi Chang, Hsin-Kai Wu and Ying-Shao Hsu [13], Matt Bower, Cathie Howe, Nerida McCredie, Austin Robinson and David Grover [8], is the integrated combination of traditional pedagogical technologies and models with innovative technologies of augmented reality, in order to optimize educational activities and increase the effectiveness of research activity of students.

Analyzing the scientific trends of the introduction of AR technologies in the process of training and formation of hardiness and stress resistance of the individual, it is necessary to pay attention to the research of Cristina Botella, Rosa M. Baños, Helena Villa, Conxa Perpiñá and Azucena García-Palacios [7]. Scientists have substantiated the effectiveness of the use of virtual and augmented reality in the process of correction and treatment of claustrophobic phobia, proposed a technology for the development of stress and hardiness of the individual. In turn, Oliver Baus and Stéphane Bouchard [5] emphasize the effectiveness of the use of feedback, technological video games with augmented reality in the formation of stress resistance and the development of a constructive coping strategy of behavior in a stressful situation.

According to the analysis of existing scientific and practical developments on the introduction of AR technologies in the competency and subject-integrated approach to training future professionals, in the

existing digitalized realities of higher education the issue of studying the applied impact of augmented reality technologies on the development of professional competencies, on the example of vitality.

3. Empirical introduction of AR technologies in the process of development of hardiness of future specialists in the conditions of modern higher school

This study was conducted within the scope of joint research work of teachers and students (future psychologists and computer scientists). Methods used in the research process are: method of analysis of theoretical sources, studying of advanced psychological and pedagogical experience of foreign and local scientists on the implementation of competency and personality-oriented approach in the educational process in the system of higher education, development of hardiness in training, generalization of the conceptual issues of the research; design and modeling of technological and empirical construct of introduction of AR technologies in the process of development of hardiness of future specialists.

The theoretical construct of our study is the analysis of priority opportunities and mechanisms for the usage of AR technologies in the process of developing the hardiness of the future specialist in the system of higher education. AR applications are used to combine a wide range of virtual learning resources with the real environment, thus improving the opportunities for internalization of theoretical and practical experience, influencing the personal and professional resources of future professionals [42], [44]. Augmented reality is a technology that allows computer programs to create and identify a virtual layer of information with any marker or object in the real physical world [11]. The role of the marker can be played by any graphic visual object, to which virtual objects of different formats can be added using special software. Jeremy N. Bailenson, Kim Swinth, Crystal Hoyt, Susan Persky, Alex Dimov and Jim Blascovich [3] found that the simulation of experience in augmented reality directly affects human behavior in the real world. In the study, the authors came to the idea that augmented reality technology can change the way you behave: how you walk, how you turn your head, how you approach a problem, how you communicate with other people. It is interesting to note, however, that the augmented reality scheme of coping strategy of human behavior remains even after the end of the session in augmented reality. Accordingly, the created effects and auras in augmented reality affect the neural connections in the human brain and are projected onto consciousness, which allows a person to feel and perceive objects in augmented reality as close as possible to real ones. AR technology has the following psychological and pedagogical advantages in the development of sustainable coping strategies for the behavior of future professionals:

1. *Accessibility.* AR can make education more accessible and mobile. AR does not require special equipment; learning resource using AR is implemented using such available to most target audience technology tools as a tablet or smart phone.

2. *Involvement.* Learning with the use of AR is personality-oriented, it allows to realize individual abilities. Interactive, “playful” learning with the use of AR motivates students, increases their interest in self-development and finding resource opportunities for self-realization [15].

3. *Cooperation.* Students' learning activities and their ability to learn are formed, including through participation in joint groups and communities. AR's extensive interactive activities encourage students to work together, develop soft-skills, resilience to frustration and choose constructive behavioral strategies in stressful professional situations.

4. *Interactivity.* AR creates a multidimensional space for self-expression, allows individuals to explore the world and their own potential in an interactive way. Students achieve the best results in learning through visualization and full immersion in certain cases, which allow in the closest to the reality situation to analyze and choose the appropriate behavioral strategy. Thus, the use of AR provides an opportunity to develop professionally important qualities and develops the ability to be resilient and competitive in a changing world.

5. *Integrity.* AR technology opens up new opportunities for learning theory and training practical skills. The practical combination of virtual and real experience enriches the personality-oriented activities of students. The display of the simulated space and the effect of one's own participation in virtual events make AR technology a relevant psychological and pedagogical tool, universal for all age

groups and at all levels of education. AR has the potential to make the process of internalizing theoretical and practical life and professional competencies more effective, as it promotes the integration of knowledge with reality.

Currently, there is a sufficient number of platforms (AR libraries) designed to create AR applications. Among them are such as Vuforia, ARToolKit, Kudan, Catchoom, WikiTude, LayAR, BlipparEON Reality, InfinityAR and others [19]. Let us consider the functionality of some of them and evaluate the feasibility of their usage in the development of hardiness of the future specialist.

The most common application is Qualcomm's Vuforia, which has paid and free versions and provides developers with a wide range of tools for creating augmented reality objects. Vuforia's functionality allows not only scanning several real 2D and 3D objects at the same time, but also to identify them, as well as play additional elements through a set of specifications and view a virtual display of the desired object, which may even be out of sight. When recognizing objects, the application allows you to use data stored on a mobile device or in cloud storage. Thus, this platform provides opportunities for individual personality-oriented approach in the process of developing hardiness, because it is the individual who can independently regulate the time and place of using certain markers. A set of open source ARToolKit software libraries allows you to get an augmented reality interface by tracking camera pre-known markers of objects, their subsequent recognition and playback in 3D with a mobile device. ARToolKit supports a large number of operating systems, free software environments, implementations for each of which are available on all platforms [22]. Thus, the accessibility and mobility of the program using expands the possibilities of its implementation within the competence approach in training future professionals. The HP Reveal platform, being an updated version of the AR library Aurasma, combines AR and IoT (Internet of Things) technologies. The principle of HP Reveal is similar to the widely used technology for recognizing QR codes. Using the camera of a mobile device, GPS, Bluetooth, Wi-Fi, accelerometer and gyroscope, the application identifies various objects from the surrounding space. Then, with the help of visual interactivity, files of various formats (graphics, audio, video, etc.) are superimposed on these objects and the received objects, called auras, are transferred to the screen of the mobile device. The wide-ranging use of the updated platform allows bringing objects and forms as close as possible to reality, which can be combined into thematic cases and form sustainable personal qualities [58]. Analyzing the possibilities of using AR libraries in the process of modernization of the educational space of higher education, special attention should be paid to the technological principles of using AR technologies in the implementation of competence approach and development of professionally important personality traits, for example (table 1).

Table 1. Technological possibilities of using AR technologies in the process of developing the hardiness of the future specialist.

Subtechnology	Example	Solution description	Components of personal hardiness
Graphic output technologies	Augmented reality helmet Augmented reality glasses	With the help of computer vision technology, self-inclusive and compact devices with built-in sensors and cameras allow to analyze the space around the user, to form a map of space for orientation in it. Most glasses are equipped with voice and movement recognition, they can be controlled without using your hands. Images are projected on spectacle lenses or special mini-displays, there is no need for additional labels to	The use of helmets, glasses and an augmented reality optical system allow to implement situational, personality-oriented cases that affect the development of hardiness personality structures: – cognitive structure (creativity, divergence of thinking, prognostic abilities); – emotional and volitional structure (stress resistance, emotional self-regulation);

Subtechnology	Example	Solution description	Components of personal hardiness
		generate content. There are binocular (Hololens, DAQRISmartGlasses, Meta 2) and monocular (GoogleGlass, Vuzix M3000) models of glasses and helmets.	– behavioral structure (readiness to solve professionally important tasks, flexibility of behavior, tolerance to uncertainty
	Augmented reality system – an optical element	Optical system for creating holograms. Can be used as a basic element of an augmented reality helmet, i.e. the creation of holograms.	
Motion capture and photogrammetry technologies	3divi gesture recognition system	Hardware platform for developing interactive applications based on body tracking and face recognition TVico and SDK for gesture and face recognition (Nuitrack). This is a solution for tracking the position of the body at 19 points and gesture recognition, which provides the capabilities of the Natural User Interface (NUI) for Android, Windows and Linux operating systems.	These technologies help to improve the physical and mental health of the future specialist, successful adaptation in stressful situations with the level of transadaptation associated with self-determination and self-realization of the individual. The use of these hardware platforms with augmented reality allow to implement the principles of physiological and psychological feedback, which stimulates the manifestation of the insight effect, introspection and the formation of constructive resilient coping strategies of behavior
	TauTracker	Gloves. Motion capture technology for virtual and augmented reality applications, 3D simulators, providing the user with the best immersion due to high accuracy of capture and the absence of restrictions associated with shading tracked objects and accumulated error. TAU tracker is created on the basis of its own magnetic inertial technology, with sensors located on the human body to transmit the coordinates of various parts of his body in a virtual reality system. This avoids using cameras, solving the problem of blind spots and cumulative error (in inertial tracking systems) and ensures maximum immersion of the user in virtual reality	
	Ntech Lab	A set of high-precision photogrammetric algorithms based on flat video streams. Algorithms provide verification of persons, identification of persons, determination of age and sex,	

Subtechnology	Example	Solution description	Components of personal hardiness
		recognition of emotions. Based on algorithm data, the following products have been created: FindFace Enterprise Server SDK (platform for face recognition based on client scripts)	
	The Psycho	Outside-in tracking and tactile feedback system to ensure high simulation reliability.	
	Vision Labs	LUNA SDK Enterprise is a face recognition and analysis system that provides efficient and accurate processing in images and video streams, and can run on a variety of operating systems and platforms. LUNA SDK Enterprise consists of several modules, each of which solves certain tasks. FaceEngine is a module that contains basic functions and algorithms for face detection and retrieval of descriptors; LivenessEngine is a module that allows to distinguish the face of a real person from an image or video; TrackEngine is a module for tracking faces and choosing the best frame from the stream.	
Applied technologies for education	ISP Platform	Platform solution for the creation and implementation of hard and soft skills simulators with the functionality of network interaction, behavioral data analytics, language recognition and analysis, object libraries, etc.	An important cognitive component of the hardiness of the individual is the developed prognostic abilities and critical thinking. These platforms and simulators provide an opportunity to train practical professionally important skills and internalize theoretical knowledge and practical experience. This allows to form a set of resilient behavioral markers that increase the opportunities for effective professional self-realization of future professionals, for example: – ability to solve complex specialized problems and practical problems;
	hrvr.Academy Platform	A platform solution for learning with the help of interactive simulations in virtual reality. A full-fledged ecosystem has been created, consisting of modular educational simulations in virtual reality with an AI system for providing feedback on learning outcomes and a web portal with standard LMS functions. Ability to adapt scripts	
	PraxisVR	Training simulators and simulators in virtual reality for hard and soft skills)	

Subtechnology	Example	Solution description	Components of personal hardiness
	X-Reality Conference room	Virtual reality training simulators and simulators for hard and soft skills. Virtual space interaction system with motion recognition, user gestures when using widely available VR equipment and visual space reproduction of behavior and reactions in a multi-user network mode. Users see each other, interact with each other through XR-avatars (projections of a real person) and reproduce the user's face on the uploaded photo in 3D.	<ul style="list-style-type: none"> – ability to apply knowledge in practical situations; – knowledge and understanding of the subject area and understanding of professional activity, readiness to take responsibility for decisions within professional activity; – skills in using information and communication technologies; – ability to make informed decisions, analyze activities;
	Luden.io	A platform for creating interactive VR visualizations to promote knowledge to the general consumer. In the game form in VR-format, certain knowledge is conveyed to the target audience, stimulating the continuation of the process of learning through the positive emotional coloring of the process.	<ul style="list-style-type: none"> – ability to generate new ideas, to make non-standard solutions in problem situations (creativity); – interpersonal skills, ability to tolerant behavior; – ability to analyze and systematize the results obtained, to formulate reasoned structured conclusions and recommendations, to inform about the results and recommendations provided;
	UniVRsity Platform	A platform for creating online courses using VR / AR technologies, which allows the user to assemble a training course with VR / AR elements without special programming skills. The platform is open, contains script designers, is implemented within the digital project “Virtual University 4.0”.	<ul style="list-style-type: none"> – ability for personal and professional self-improvement, learning and self-development; – ability to apply methods of emotional and cognitive regulation of the psychological state and activity

Software and hardware for working with three-dimensional images to create training VR / AR lessons for trainers EON Reality and software for creating educational kits Virtualis are the examples of platforms for AR simulators. The platforms for creating educational AR content are Amazon Sumerian, BrivoVR, Engage, Visible, The AVR Platform from EON Reality (consists of three separate products – Creator AVR, Virtual trainer and AR Assist), SecondLife, VRLively, Vrchat and High Fidelity. Marketplaces for educational AR content are Zspace and Hologate. In the professional and educational segment, the introduction of these technologies in terms of creating accessible tools for users and supplementing with interactive visual AR content can increase learning efficiency, provide continuing professional education, implement a healthy approach, the formation of hardiness as a dominant component of future professionalism [56].

The ways of applying augmented reality technologies in education are reflected in the methodology of MARE (Mobile Augmented Reality Education). The proposed MARE structure consists of three hierarchical layers: basis, functions and results [46]. It is based on the analysis of different ways of learning from theoretical knowledge to the development of practical skills. Whatever the theory of learning is adopted in an educational institution, for example, associative and reflexive theory of learning

or the theory of problem-based learning, the main criterion for acquiring knowledge is application in practice for high school. The functional level depends on the individual approach and actions of the learner and his interaction with educational resources.

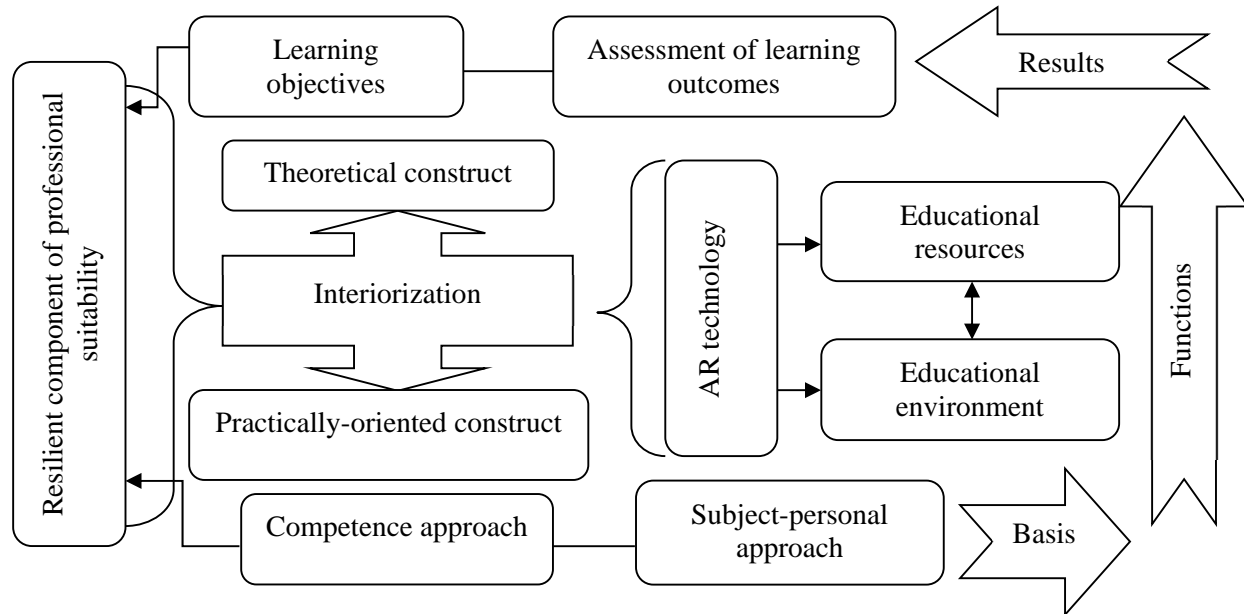


Figure 1. Scheme of implementation of competence and subject-personal approach to the introduction of AR technologies in the educational process in the system of higher education (the basis of the MARE methodology).

As can be seen from the above diagram (figure 1), the fields of augmented reality (AR) technologies include primarily educational resources. These resources and their combination, which comprise the educational environment, are designed to fill the gaps between the required competencies and learning outcomes and contribute to the internalization of theoretical and practical experience on the path to professional suitability and competitiveness [56]. In the corresponding scheme AR technologies act as an interiorizing link, which provides an opportunity to bring the theoretical and practice-oriented construct of professional training to the realities of life, which affects the development of hardiness of the individual. Focusing on this model of complex integration of AR technologies in the process of professional training and development of hardiness of future specialists (psychologists), an interdisciplinary study was implemented on the basis of Bogdan Khmel'nitsky Melitopol State Pedagogical University. The purpose of the study is to investigate the constructive use of AR technologies in the process of developing the hardiness of the individual, as the dominant construct of the professional and personal component of training future professionals. The study was conducted with future psychologists. The total number of the sample is 70 people; the sample is randomized, formed on the principle of stratification. The corresponding research consisted of ascertaining and forming stages. As part of the ascertaining stage, a diagnostic survey was conducted using the Google form. Respondents in the online mode had to pass the test of hardiness by Salvatore R. Maddi (adaptation of Dmitrii A. Leontev and Elena I. Rasskazova [34]).

The formative stage of the research was implemented within the scientific and practical online course “Modern practice-oriented technologies in education”, which includes a module “Innovative ICT in psychology: the experience of implementing augmented and virtual reality in psychological practice”. As part of the formative research on the basis of the online course, an integrative combination of the standardized Hardiness Enhancing Lifestyle Program (HELP) [2] and the augmented reality construct was implemented. Considering hardiness as a key personal variable that mediates the impact of stressors on physical and mental health, as well as the success of the individual, it can be formed in the process

of mastering the profession, stimulating independence, voluntary activity, responsibility, teaching future professionals to manage their emotions, behavior and ability to mobilize in difficult life situations. The corresponding program also included elements of development of the general stress resistance of the person, methodologically presented in the form of five-R model of Roger S. Ulrich, Robert F. Simons, Barbara D. Losito, Evelyn Fiorito, Mark A. Miles and Michael Zelson [61]: Recognition – understanding of the possible reasons and sources of stress; Relationships – identification of the sources of support and people who can come to the rescue; Removal – elimination of stressors and their management; Relaxation – the use of relaxation techniques (breathing exercises, meditation, massage, imagination); Re-engagement – repetition of immersion in stress by desensitization [24]. The program to increase the resilience of the individual was divided into appropriate blocks [27], which are presented in figure 2.

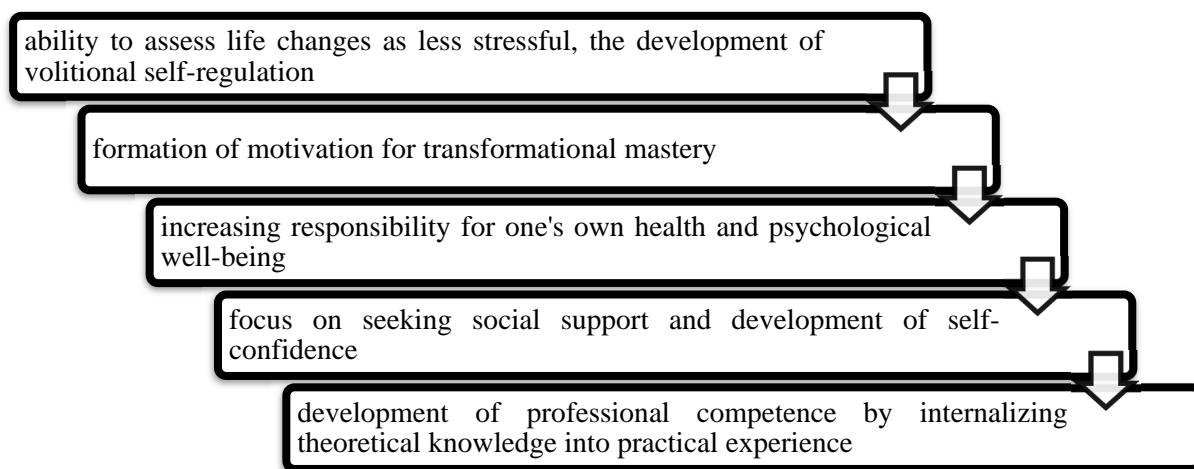


Figure 2. Features of the Hardiness Enhancing Lifestyle Program, HELP.

In our study, we emphasize the unity of traditional training technologies and innovative AR technologies. The peculiarity of the scientific and practical online course is not only individual and group psychological support in the implementation of the Hardiness Enhancing Lifestyle Program, HELP using Zoom, Google Meet, Skype platforms, but also the inclusion of mobile learning elements using augmented reality technology:

- creation and application of QR-codes as hyperlinks for navigation on them by means of mobile devices;
- creating auras of images that connect a static image with video with a help of free installed augmented reality program on a mobile device;
- use of interactive 3D markers for educational purposes by independently adding subject content to the already developed content;
- creating and conducting online surveys to update knowledge, consolidate the studied material, check the level of assimilation of material, reflection without the use of special equipment with remotes (only a gadget with an augmented reality application, a computer with Internet access and a projector). These elements are used to deepen the study of material, visualization of objects, increase individualization and interactivity of the Hardiness Enhancing Lifestyle Program, HELP.

According to the implemented BYOD concept (“Bring Your Own Device”), when organizing classes with the help of mobile learning technology, respondents can use their own gadgets with the necessary software installed [50]. The organization of classes with the use of mobile learning technology with elements of augmented reality can be carried out both individually and in groups. The choice of the appropriate concept is justified by the possibilities of individual, personality-oriented approach, the availability of implementation.

According to Salvatore R. Maddi's three-component model of hardiness, we analyzed the possibilities of using ergonomic and accessible Google Play content with elements of augmented reality.

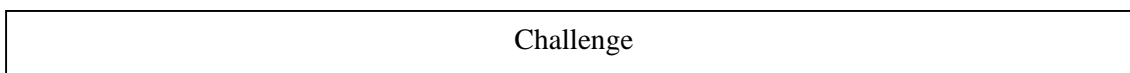
Commitment	
<p>NeuroNation – exercises for the brain</p>	<p>NeuroNation brain training is an endless improvement of achievements:</p> <ul style="list-style-type: none"> – Improve memory – Increase concentration – Increase intelligence, concentration and attention – Development of logical thinking <p>Features:</p> <ul style="list-style-type: none"> – 27 interesting exercises and personalized courses – Detailed report on the strengths and weaknesses of the respondent – Personalized training based on the latest scientific discoveries – Comparative analysis with a certain age group and interpretation of individual successes
<p>Diaries of Therapy Sintylapse</p>	<p>At the moment, the application contains 4 diaries with elements of additional reality. The Diary of Wishes will help to find more joy every day, with the Diary of Fears you can realize the insignificance of fears of change, the Diary of Emotions will help to get rid of negative thoughts and fix positive moments from life, and using the Diary of Thanksgiving you can find truly pleasant things in your life.</p>
<p>AR ARLOOPA Inc. Augmented and Virtual Reality Apps</p>	<p>The application focused on generating augmented reality elements. Leader in the augmented reality revolution with 3 main AR functions, marker-based scanning, marker-free tracking. The application uses a yang learning resource.</p>
<p>Diarize</p>	<p>Motivational diary with elements of augmented reality is a tool for the development of inner motivation, goal setting, values and self-development. The application includes:</p> <ol style="list-style-type: none"> 1. Diary of success. Based on these parameters, the application calculates the effort and displays personal performance in the form of graphs. The diary gives significant motivation to maintain and improve the pace of self-development, lifts the mood and self-esteem, reminds of priorities. 2. Plan. Now planning is much easier and faster, thanks to the new methodology “Spontaneous planning”. Achieve what you want without burdening yourself with tight deadlines and other horrors of time management. 3. Habits. Connect a new habit to the priority areas of life, thanks to this application. 4. Balance wheel. Estimate the current situation using a pie chart. After the assessment you will be able to get recommendations based on used methodology. The diary will tell you what you need to do and what to pay attention to become happier. By reevaluating your life in the future, you will be able to see progress clearly. 5. Statistics of activity and progress. It will reflect your efficiency in achievements and spheres of life in detail. Statistics are simple and informative. Thanks to this, looking at the current results, you will be able to achieve great results in the future. 6. Challenges 7. Management of spheres of life

	8. Management of activity levels
PFSscanner Bonus	<p>Online psychodiagnostic service</p> <p>The mobile application PFSscanner Bonus (psychological face scanner) is a convenient mobile tool that allows you to perform automated psychodiagnostics of personality on a photo in a couple of seconds. By downloading and installing PFSscanner Bonus on your mobile device, you will be able to get objective information about your individual psychological characteristics. Periodic use of PFSscanner Bonus makes it possible to track the dynamics of positive or negative changes, adjust tactics of behavior, plan daily activities, choose the best ways of personal development.</p> <p>PFSscanner Bonus allows you to diagnose the following features:</p> <ol style="list-style-type: none"> 1. Emotional stability 2. Interaction with the environment 3. Flexibility 4. The pace of behavior 5. Moral normativeness 6. Sociability 7. Adaptation potential



NeuroNation Ease: Mindfulness & Meditation	<p>Personal and effective application for emotional self-regulation.</p> <ol style="list-style-type: none"> 1. Reduction of fatigue and learn how to prevent stress before it occurs. 2. Focus on important events. 3. Development of constructive coping strategies of behaviour, psycho-correctional work with anxiety, worry and panic attacks. 4. Help in preventing depression.
Paint Draw AR Vaytricks	<p>In this application, the respondent can draw in 3D space using augmented reality. This program is aimed not only at drawing. It supports many features:</p> <ul style="list-style-type: none"> – promotes the development of self-control and emotional self-regulation; – acts as an art-therapeutic tool; – develops spatial thinking and memory.
feel better - Mood & CBT therapy	<p>The application promotes the development of self-control, self-reflection and emotional stability. The application is built on the principles of behaviorism, cognitive and behavioral therapy, contributes to the formation of constructive goals, the development of positive thinking and personal growth</p>
eQuoo: Emotional Fitness Game	<p>An exciting game “Choose your adventure”, which increases emotional readiness and teaches new psychological skills, helping to increase your level of resilience in real life.</p>
Pocketcoach - Anxiety Helper	<p>Self help for anxiety, stress and panic based on CBT, mindfulness and ACT (Acceptance and Commitment Therapy). Pocketcoach is a digital coach for more happiness and less stress. When you feel anxious, about to have a panic attack, have trouble sleeping or feel restless, Pocketcoach offers scientifically validated techniques and self-help programs. Just download the Pocketcoach app for free and step by step, you learn how to be more resilient and less stressed.</p>
Timia	<p>Timia is the world's number one application for regulating emotions through behavioral geometry, designed to manage stress, reduce anxiety symptoms and train memory and attention, based on sensory stimulation and innovative psychological techniques, the use of geometric shapes, colors , which</p>

	<p>contributes to the stabilization of self-esteem and development of resilience. Timia is an ideal psychological supplement designed for people with little experience in mental health, but it can also be used by therapists. During the action in the Timia application, you are first asked to take a personality test, after which the number of sessions will be determined, an activating image will be presented, asking you to visualize for 10 seconds the worst scene of the problem you encountered. Then perform a breathing exercise with geometric shapes, which helps to regulate the sympathetic system, which was activated after the visualization of the activating image.</p>
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Expeditions AR	<p>Google Education Initiative is an application that allows you to conduct cognitive virtual tours. Inside there are many different experiences: there are 360-video tours, there are adventures in VR, there are trips to various objects, such as a meandering volcano in augmented reality. With the help of the application, a person develops the belief that everything that happens to him contributes to his development through knowledge, which is internalized from experience - no matter positive or negative.</p>
CubeAR: maze 3D & AR	<p>CubeAR is a maze game, with 3D and AR game modes with new interesting mechanics. In the application there are 10 different cubes, each with its own unique texture and the complexity of passing the maze. In the game you need to roll the ball on all sides, passing from point A to point B. Mazes and each subsequent level is more difficult than the previous one, which adds interest to the passage of the maze. Also, CubeAR is an educational puzzle game, it develops logical thinking and memory. The game promotes self-control and strengthens the skills of constructive decision-making in changing conditions.</p>
Reality Hacker VR	<p>Project VisoR is built on the idea of using computational transformations on augmented reality (AR) and virtual reality (VR) devices to view the world in ways you never thought possible! Reality Hacker allows binocular rivalry experiments with all of its computational lenses, and also gives you the ability to rotate/flip your view of the world along the XYZ axes (mirror view, upside down, etc). Use retinal rivalry with the color space permutations to see “impossible colors.” The application promotes creativity and emotional intelligence.</p>
SuperBetter	<p>SuperBetter increases resilience which is the ability to stay strong, motivated and optimistic even in the face of change and difficult obstacles. Playing SuperBetter reveals the potential for overcoming difficult situations and achieving the most important goals.</p>

Figure 3. Technology for implementing mobile applications with AR technology in the Hardiness Enhancing Lifestyle Program, HELP.

The Hardiness Enhancing Lifestyle Program, HELP with AR technology elements, described in accordance with Salvatore R. Maddi's three-component model of hardiness (figure 3), includes practice-oriented cases. Relevant cases affect the cognitive, emotional, volitional and behavioral structural components of the personality, which, when integrated, form the resilient potential of the personality of future professionals.

From January to May 2020, with the help of the Moodle platform, a scientific-practical online course “Modern practice-oriented technologies in education” was introduced. This course was first implemented online as part of the BYOD concept in connection with the pandemic environment of

education. The module “Innovative ICT in psychology: the experience of implementing augmented and virtual reality in psychological practice” was implemented in the structure of the relevant course. The corresponding module combined Hardiness Enhancing Lifestyle Program and components of mobile applications with AR technology (figure 3). The course was monitored and feedback was provided through the Moodle platform, the Zoom program. The psychodiagnostic survey was conducted using the Google form. Respondents were also asked to conduct a self-analysis of the effectiveness of the Hardiness Enhancing Lifestyle Program with augmented reality elements using the SafeDiary mobile application [55].

In order to evaluate the effectiveness of the integrative implementation of the Hardiness Enhancing Lifestyle Program, HELP using AR technology a repeated diagnostic study was conducted with Google Forms. The results of correctional and post-correctional activities are presented in figures 4, 5.

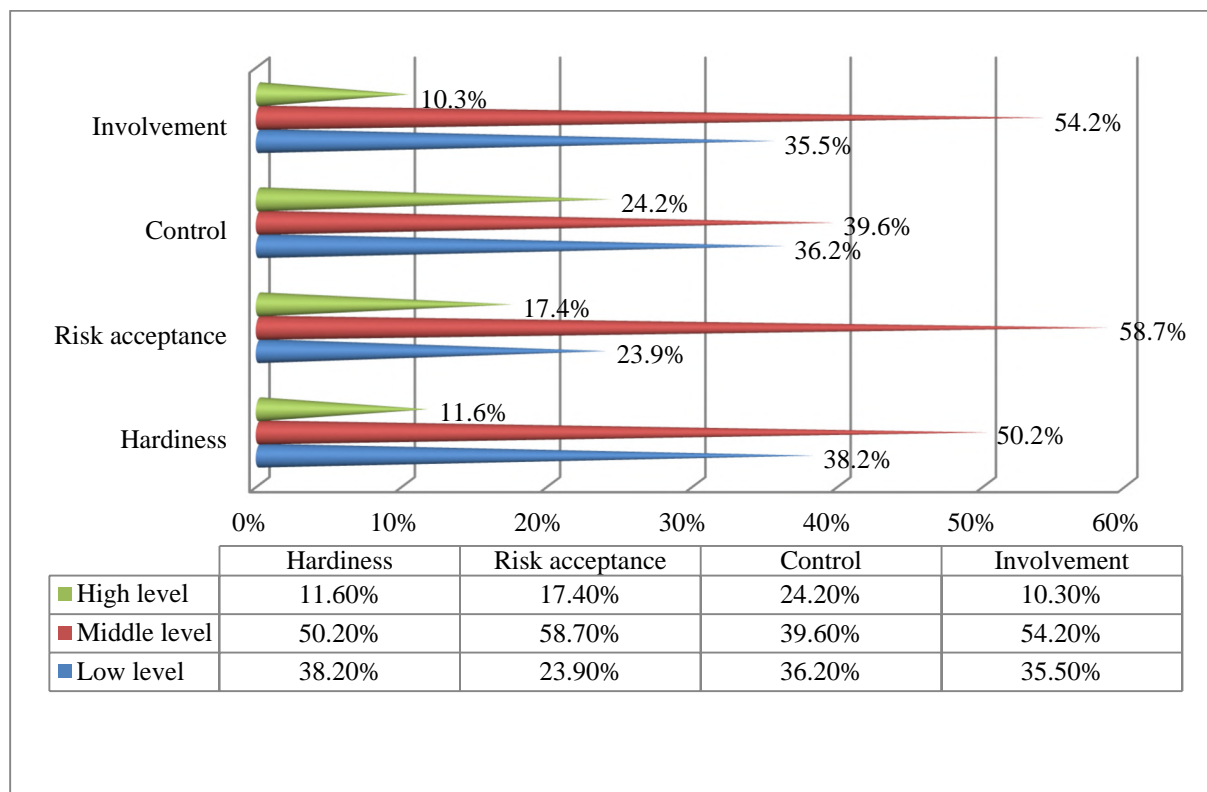


Figure 4. Indicators of the development of the components of the vitality of the individual before the implementation of the program with elements of augmented reality.

After the implementation of the Hardiness Enhancing Lifestyle Program, HELP using AR technologies, according to the obtained data, a significant increase in the development of components of hardiness was revealed. To determine the significance of the changes that occurred after the implementation of the program with elements of AR technology, we used the G-criterion. The G criterion is intended for establishment of the general direction of shift of the investigated feature. First, we formulate hypotheses. H_0 : the significance of shifts in the typical direction does not exceed the significance of shifts in the atypical direction. H_1 : the significance of shifts in the typical direction exceeds the significance of shifts in the atypical direction.

After the implementation of the program, the absolute number of respondents with a high (29.7%) and medium (61.2%) level of overall hardiness increased. Also, the results of correlation analysis revealed that at $n = 108$ typical shift is positive. Negative shifts are 32.

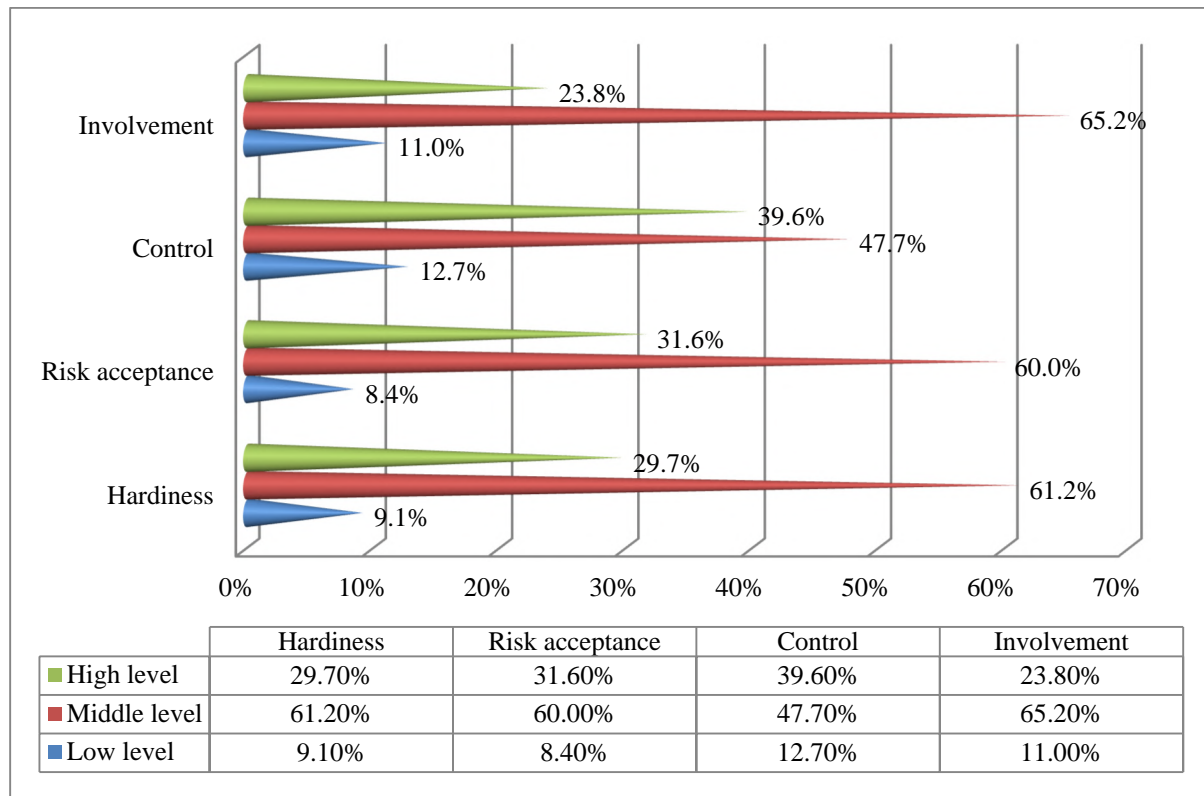


Figure 5. The dynamics of development of the components of vitality of the individual after the implementation of the program with elements of augmented reality.

$$G_{crt} = \begin{cases} 45 (\rho \leq 0,05) \\ 42 (\rho \leq 0,01) \end{cases}, G_{emp.} - \text{the number of atypical shifts, i.e. } G_{emp.} = 32, G_{emp.} < G_{crt}.$$

Accordingly, H_0 is rejected and H_1 is accepted. Thus, positive changes have been confirmed as a result of the implementation of the Enhancing Lifestyle Program, HELP with augmented reality component. The increase in indicators on the scale of “involvement” indicates an increase in motivation for self-realization, the desire of respondents to self-realization and self-improvement, constructive use of internal resources and internalization of experience. The dominance of medium (47.7%) and high (39.6%) levels on the scale of “control” after the implementation of the Hardiness Enhancing Lifestyle Program, HELP with elements of AR technology indicates the development of emotional self-regulation skills, updating the search for ways to influence the results of stress change, as opposed to falling into a state of helplessness and passivity. The percentage on the scale of “risk acceptance” also increased significantly – medium level (60%), high level (31.6%). Accordingly, respondents have increased motivation for the process of transformation and mastery of their own emotional states, based on openness to the new, willingness to act actively in a stressful situation (the use of resilient coping strategies); strengthening the immune response through mental and physical mobilization; strengthening responsibility and care for one's own health; search for effective social support that will contribute to the process of transformation of self-mastery, through the development of communication skills. Thus, in the process of interdisciplinary research proved the effectiveness of integrated use of Hardiness Enhancing Lifestyle Program, HELP and AR technologies in the process of developing the hardiness of the future as a dominant component of effective professional self-realization.

4. Conclusions and prospects for further research

The analysis of available sources allows us to define hardiness as a system of personal beliefs that promotes the willingness of the subject to participate in situations of increased complexity, control them,

manage them, be able to perceive even negative events as experience and successfully cope with them [12]. Based on this, we can talk about the features of a resilient personality as a holistic system of interaction with the world. A resilient person is a person who has resilient beliefs (involvement, control, risk), who leads a resilient lifestyle (maintains his physical and mental health), uses resilient coping to overcome stressful and difficult life situations [1]. The main components of the concept of hardiness are considered to be strong character, sense of purpose, optimism. Hardiness, based on individual and personal (natural) properties (extraversion, spontaneity, introversion and anxiety), which are based on innate features of the nervous system and mediate social activity, is more manifested in the ability to create personally meaningful meaning of life and reality. Hardiness, as a characteristic that reflects the ability of the subject to find a degree of compliance with existing conditions, determines a person's protection from various threatening influences associated with human perceptions of the ability to successfully implement the behavior necessary to achieve expected results, overcome negative environmental influences [18]. Psychological phenomena such as optimism, dispositional hope, integrity of the locus of control, high self-esteem, focus on the present and the future play an important role in a person's positive assessment of his life and his choice of productive strategies in crisis situations. As part of the implementation of competency and subject-oriented approach, in accordance with the concept of BYOD, Hardiness Enhancing Lifestyle Program, HELP with elements of AR technology was introduced in the scientific and practical online course "Modern practice-oriented technologies in education", which includes a module "Innovative ICT in psychology: experience in implementing augmented and virtual reality in psychological practice". According to the results of the obtained empirical data the efficiency of using innovative AR technologies in the structure of mobile applications in the process of development of components of hardiness of the personality of the future specialist is proved.

Prospect for further research is the analysis of the results of integrated implementation of AR technologies in the practice of higher education in order to optimize the training of future professionals of a "new format" who are capable of competitive self-realization in a changing information transformation.

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Theoretical and methodological bases of designing the educational institution information and consulting environment

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Abstract. In article the definition of the educational institution information and consulting environment has been formulated. It was found the such environment is a relevant part of the information education society, within which it becomes possible exchange of information and consultative support of subjects of the educational process via the computer focused technologies. The semantic and functional content of an educational institution information and consulting environment have been specified. Its social, spatial-object, psychological and pedagogical components have been analyzed. The criteria for assessing the quality of the information and consulting environment have been described. The main factors and leading pedagogical technologies of organizing and forming of the information and consulting environment have been determined. The pattern of the educational institution information and consulting environment covering organizational, technical methodical resource areas have been established. Based on the results of empirical research with use of content analysis and factor analysis the benefits and risks of the educational institution information and consulting environment have been reviewed and summarized. It is concluded that the organization of the educational institution information and consulting environment will promote increase the efficiency of the educational process and the quality of educational services.

1. Introduction

A modern and efficient education system that capable of satisfying the social mandate of society and training competitive personnel, is one of the main directions of the state socio-economic policy. It undoubtedly determines the role of the country in the world community.

It should be noted the former education system has been quite successful in training highly qualified staff for the country throughout many decades. However, the time requirements and the widespread ICT, rapid growth of standards to the level of their mastery, the openness of educational systems, the popularity and demand for electronic educational resources in general and in the terms of pandemic the COVID-19 in particular [8], all of these require changes in approaches to the organizing of study process



in vocational education institutions [24], [44], [47]. Today's realities claim from specialist not only a high level of professional education, but also a new type of intelligence, way of thinking, quickness in communication and professional mobility [55]. In the end this will change him/her attitude to the rapidly variable economic, technological, social and informational factors of production and the world around them.

Conceptual changes in the vocational education system are prompted by the widespread of new computer-based technologies including distance learning [49], data personalization [31], virtual classrooms [57], cloud [32] and Internet technology [35], autonomous learning and information consulting [25], and whatever. Successful modernization of educational systems with the use of ICT is possible within a lot of projects. One of which is the creation of a united educational institution information and consulting environment which will provide effective support the specialists' professional formation. This environment does not mean a simple replacement of paper workflow with electronic one. This process involves a radical restructuring of consulting services on basis of a personal and activity approach, change ways of working with information and clients, reconstruction the channels of accumulation, exchange, storage and processing of data via ICT and tools.

The purpose of the paper is to determine the essence and content of the educational institution information and consulting environment to find out the main factors of its successful organizing and forming in the vocational educational institution, as well as its trends for development.

2. Materials and methods

Recently, in the process of studying different levels pedagogical systems, researchers tend to comprehensively assess the formative factors that can initiate the personality development. A such viewpoint about realizing possibilities of an environment approach for creating the special space and initiation by means of it the qualitative and various influence on the subject vital activity is quite substantiated one. Mariia M. Levina [27], Iurii S. Manuilov [30], Sergei F. Sergeev [46], Viktor I. Slobodchikov [52], Viktoriia V. Zhelanova [66] and others established that such approach allows to diagnose, design and produce certain circumstances into a specially organized space to make qualitative positive changes in the personality structure.

In the scientific literature there are a lot of deserving research models of environments for different purposes. Among them, such relevant environments as information, consultative, educational, upbringing ones and others are distinguished for the educational area. At the same time, rapid changes in the information society space require constant updating the educational institution environment, the search for new organizational, legal and other mechanisms of its function.

Valerii Yu. Bykov [4], Nataliia I. Klokar [17], Iryna S. Mintii [33], Iulii A. Shreider [50], Serhiy O. Semerikov [34], Mariya P. Shyshkina [43], Vitold A. Iasvin [13], Irina G. Zakharova [64] consider the issues of management of the education system and its innovative potential in light of modern information technologies introduction, as well as modeling and design of information-educational and information-communication educational environment. Dmytro Ye. Bobyliev [2], István Lénárt [26], Kateryna V. Polhun [42], Tetiana V. Prydacha [5], Myroslav J. Syvyi [56], Iryna M. Trubavina [59], Tetiana A. Vakaliuk [60], Nataliia P. Volkova [58] and others study various aspects of the of distance learning and e-learning organizing. Problems of consulting support of the educational process are studied by Therese S. Christiani [6], Rickey L. George [6], Alla Y. Kapska [15], Alla O. Krasneichuk [63], Valentyna I. Saiuk [45], Alona P. Tsyganenko [15], Serhii V. Zahorodniuk [63] and others.

Therefore, elaborating the content of the educational institution information and consulting environment the semantic analysis of the constituting categories has been used; the content and functional filling of the information and consulting environment has been specified, by virtue of analysis of primary sources and own researches (they included content analysis and factor analysis) the main factors of its successful organizing and forming in the educational institution has been selected; its evolvement prospects has been predicted.

3. Theoretical background

At the heart of understanding the essence and designing the content of the information and consulting environment is the *environment conception*. For the first time its scientific interpretation as a special functional system was given by Iurii S. Manuilov [30]. The system includes: the conceptual apparatus, a number of semantic statements (principles) and pragmatic provisions (rules). The key concept of the approach is the “environment”, which is being analyzed in the context of its impact on the individual’s functioning and elaborating. The category “environment” is source to the “mediating”, “averaging” and “facilitating” concepts. Iurii S. Manuilov defines the functional environment as a certain space in which the subject is, and through which his/her way of life is formed. The environment mediates the subjects’ development, averages them to the typical indicators of space, but doesn’t standardize and unify them ([30], p. 22).

The environmental conception apparatus is also represented by the “way of life” notion (it way of being into an environment) and the “action” one. They are basis for understanding the way the subject interacts with the environment and its transformation into a means of personal development. Important for the design of the educational institution information and consulting environment is the study and interpreting of various types of management actions, including diagnostic, design and educational ones, and also such that initiate the environment.

Describing the environment structure, Iurii S. Manuilov singles out certain substances, namely: “niches”, “elements” and “marked” by them individuals. “Niche” means a limited space for opportunities of a particular individual (natural, social and cultural ones) which mediate his/her development. In contrast to the niche, the “element” refers to all sorts of dynamic processes that occur in environment and also affect the individual’s life. “Marked” individuals are representatives of environmental substances, potential carriers of any changes in it. The niches of the educational institution environment are the architectonics and infrastructure, a virtual educational space, socio-cultural groups created within the institution. “Marked individuals” who are able to influence changes are teachers, students, administrative and support staff. The main control mechanism in the educational environment is a purposeful resonant impact on the marked individuals by the environmental tools ([30], pp. 21–23).

Iurii S. Manuilov identified the main provisions of the environment conception which formed its semantics and can be used in the design of a particular environment, such as:

1) the environment averages or typifies the personality. This pattern allows to shape a form and project the result of environmental impact on the individual;

2) the environment mediates the person by a range of opportunities, that is able to either enrich or, conversely, burden him/her. Took into account this provision it be possible to design and create certain environmental “niches” for the individua’s necessary qualities development;

3) the environment contributes to lifestyle changes in the direction due to the elements. Therefore, it is necessary to diagnose, design and produce formative influences with the help of dynamic processes that specially initiated in the educational institution environment;

4) the environment becomes a means of individual development only if it has the appropriate parameters, the values of which are determined by the characteristics of niches and elements. This pattern demands the working up criteria and indicators of the educational institution information and consultation environment;

5) the shaping of the environment with the appropriate values of parameters is a corollary of the subject’s creative actions into the environment. It means that the environment is not created spontaneously, but is the result of purposeful subject’s activity. Hence, there is a potential possibility of creating an environment with certain designed characteristics ([30], p. 23).

The philosophical concept outlined above was the basis for both the elaboration of general provisions of the environment approach and the design of various environments to solve special research and practical problems.

Based on the works of Iurii S. Manuilov [30], Sergei F. Sergeev [46], Viktoriia V. Zhelanova [66] and others we define *an environment* as a system of conditions that created within a certain space in

which the subject's activities take place. For its part, we consider *the environment conception* as a strategy based on managing of personal development process through the creation of a definite environment ([66], p. 102).

In course of designing pedagogical systems, which include the educational institution information and consulting environment, the application of the environment approach has a number of advantages, namely: 1) it allows to get results naturally through the creation of the environment; 2) enables to implement others methodological approach; 3) shifts the focus and mediates the collaboration between subjects by means of their interaction with the environment ([66], p. 114).

The development of ICT and information and consulting technologies is crucial in the organization of the educational institution environment. Their use in this process has the following benefits:

1. It improves the quality of education through the use of special information and expanding the range of information needs of different categories of students and teachers, ensures transparency and objectivity of education quality monitoring systems.

2. It eliminates the territorial barriers in education due to distance technologies, provides motivated students' independent work during the profession acquisition.

3. It significantly accelerates the movement of management information, automats the organizing and management of educational process.

4. It greatly reduces the cost of education as a result of the combined action of previous factors, which contributes to the further development of the educational process in the institution and improve its quality [64].

Based on the environmental approach positions and the facts concerning the spread of informatization in educational sphere, next it will outline the concept of the educational institution information and consulting environment.

4. Results and discussion

4.1. Semantic analysis of the essence of the information and consulting environment

In the previous text it was emphasized the need for semantic analysis of the constituting categories to the information and consulting environment concept. These are, first of all, "information educational environment" and "consulting".

The *educational environment* is defined as a set of objective external conditions, factors, social objects necessary for the successful functioning of education [13]. The content of the educational environment should be considered from the standpoint of the subject and object of educational activity, namely:

- from the subject's standpoint it's a system of influences and conditions of personality shaping, as well as opportunities for his/her development which are contained into the social and spatial-objective environment;

- from the object's standpoint it's a set of objective external conditions, factors, social objects necessary for the successful functioning of education.

It ought to emphasize the concept of "education" has a multifaceted meaning now. This is a process, a result, a social institution that provides intellectual and moral development of a personality. Among the variety interpretations in the context of designing the educational institution information and consulting environment, it is necessary to accentuate another modern understanding of education as a service sector.

In Sergey I. Ozhegov's Dictionary, the meaning of the token "service" is "an action that brings benefit and does a help to others" [37]. Educational service in this sense is a purposeful activity of education management bodies, educational institutions and establishments to meet the educational needs of social customers. For the consumer of educational services, the education quality is one of the important elements of life quality. A harmony is undoubtedly possible if the society interests and the individual coincide and when the influences, initiated in the educational environment, accommodate one another and overlap.

And if the educational environment is a more or less clearly defined phenomenon, then the concept of the information environment until now is under working up. It was first proposed by Iulii A. Shreider [50]. The scientist considered the information environment not only as a conductor of information, but also as an active source that affects its participants. In particular, Iulii A. Shreider proposed a semantic approach to the description of the information phenomenon and the mechanism for determining the degree of semantic information (as a way to change the a person's thesaurus under the influence of incoming data), as well as the concept of information-and-knowledge potential (these are knowledge accumulated in society, data available through the information environment, the means of knowledge transfer, processing, storage, retrieval and transmission of information) [50].

Nowadays, the *information educational environment* is contemplated as a set of components ensuring the systematic integration of information technology in the educational process in order to increase its efficiency, as well as those that are a means of creating the personal focused pedagogical systems. Researchers (Olga V. Bondarenko [3], Tetiana M. Derkach [19], Olena G. Glazunova [7], Roman M. Horbatiuk [9], Oleksandr H. Kolgatin [18], Olga V. Korotun [20], Olena O. Lavrentieva [39], Alona T. Litvinchuk [22], Svitlana H. Lytvynova [28], Andrii V. Morozov [36], Larysa M. Petrenko [40], Olga P. Pinchuk [41], Yevhenii B. Shapovalov [48], Mariya P. Shyshkina [51], Nataliia V. Soroko [53], Aleksander V. Spivakovsky [54], Serhii A. Voloshynov [61], Irina G. Zakharova [64], Snizhana O. Zelinska [65] and others) define such an environment as a united information space of an educational institution that combines information both in traditional format and electronical one; computer-telecommunication and study-methodical complexes, and technologies of pedagogical interaction. It is a pedagogical system of a new level support covering logistical, financial and economic, and regulatory aspects. The environment can function at following levels:

- it's information and communication educational environment of the educational institution inserting in all communication tools;
- it's subject information environment that support the teaching subjects or a cycle of disciplines;
- these are individual information and communication environments formed by each student in the course of study activities withing environments of the two previous levels [13].

What is impotent is that the more diverse the information educational environment, the more effective the study process. In this case, as Iraida S. Iakimanskaia notes, the environment constructs in line with individual capabilities of each students, his/her interests, inclinations, and subjective experience [12].

The main purpose of the educational institution information environment is to bring it to a new level, to increase the standard of information culture and information awareness, to form of intellectually and creatively developed personality of students, teachers, and education managers. That is, the subjects of such an environment must be ready to use ICT and tools in management activity, as well as in methodological, teaching, educational and self-educational scopes. The environment actually unites all participants of educational process among themselves the corresponding information streams.

In the information environment it is possible to combine high economic efficiency and flexibility of the educational process, a significant resource provision, sizeable expansion of traditional study forms, prospects for creating new effective forms and methods of teaching and learning. The unified educational institution information environment allows to optimally and qualitatively solve a number of issues, including:

- planning the study process according to different curriculums, levels and forms of education;
- organizing the teaching and educational events in electronic form;
- submission an educational material and reference information;
- transition from the dominating reproductive study activities to creative and consultative one;
- providing access to participants in the educational process to data related with planning, organizing and monitoring of study activities;
- ensuring communicative interaction between teachers, students and management;
- effective using and constantly operative updating of study and methodical complexes and materials [38].

Information services in the educational institution cover various types of permanent and one-time services provided to interested parties. With their help it is possible to present the activities of the educational institution, to get acquainted with practical and theoretical developing's, to solve various current and future problems about organizing of an educational process.

As practice shows, for the efficient use of ICT and the effective functioning the educational institution information environment the network coordinators – consultants, executives, education managers are necessary. These consultants create an informational educational environment, launch and complete various telecommunications projects and provide the essential advice. It should take into account the information service is a valuable direct service for the client and a source of new contacts and development for the institution. With the help of this service a client can not only receive certain information, but also recommend the consultant to study it in order to implement in a practice. In that way, it would seem appropriate to considerate a consultation as a specific activity into the information and consulting environment.

Consultation (from the Latin it is translated as “advice”) has a broad semantic meaning. This is a form of training (it is teacher’s assistance to students in mastering the discipline or gaining competencies), and expert advice on any issue, and the name of the institution that ensures assistance and advice (there are professional consultation, legal consultation, children’s consultation, etc.), and a specific advice providing by a specialist (it is conversation with the client on the elaboration of educational projects, didactic materials and whatever). In any case it is realized specially trained specialists (professional consultants) or a person who has experience in solving a specific situation or problem and can give an advice ([45], p. 12).

Professional consultants, thanks to their knowledge, competencies and education, themselves determine the specifics and methods of activity by which they solve the problems of the client (student or teacher) at the professional level.

A type of professional counseling is a *pedagogical consultation*. It is the provision of consulting services by qualified professional (consultant) in the field of education to the managers and staff of educational institutions, and various relevant groups. It can be issues about professional pedagogical activities and development, about information support, assistance, identification and analysis of professional or pedagogical problems, as well as elaboration references for their solution, promoting the implementation of the recommendations [63].

Unlike other types, pedagogical consultation is carried out by specialists in the field of pedagogy, including high school teachers, supervisors and consultants of educational projects, methodologists of educational institutions, independent experts. The main purpose of pedagogical consultation is to solve problem situations of professional direction, namely: evolution of educational institutions; professional development of teaching staff; optimization of interaction between parents and students; increasing the level of study achievements, education and development; overcoming the learning difficulties of children and students, and so on ([45], pp. 12–14).

Valentyna I. Saiuk singles out three main areas of pedagogical consulting where professional counselors are working. It’s following:

- accompanying the students in the educational process and providing their with consulting assistance in solving problems related to educational activities and personal development in general;
- provision of counseling services to various person involved into the educational environment (parents, relevant groups, social partners);
- scientific and methodological support of professional activity of heads of educational institutions and pedagogical staffs [45].

Obviously, the pedagogical consulting is a type of social service provided to a particular client. Consulting services, according to Alla Y. Kapska, have to improve the client’s relationship with the social environment creating psychological comfort in society and in the workplace [15].

In socio-pedagogical activities consulting is the technology of supply the social assistance through targeted informational impact on a person or a small group in order to socialize, restore and optimize social functions, landmarks, development of social norms for communication [6].

Analysis different interpretations allows to conclude that a *consultation* should understand as a specially organized information interaction between the counselor and those who need help to solve the problem and make positive changes in the activities of an individual or organization as a whole. Into the information and consulting environment a such service is provided via computer focused technologies.

Consequently, the *educational institution information and consulting environment* is relevant for the information society part of the space within which it becomes possible to exchange information and advisory support of the subjects of the educational process and other stakeholders by means of computer focused technologies. Our vision of the essence of the educational institution information and consulting environment is presented in figure 1.

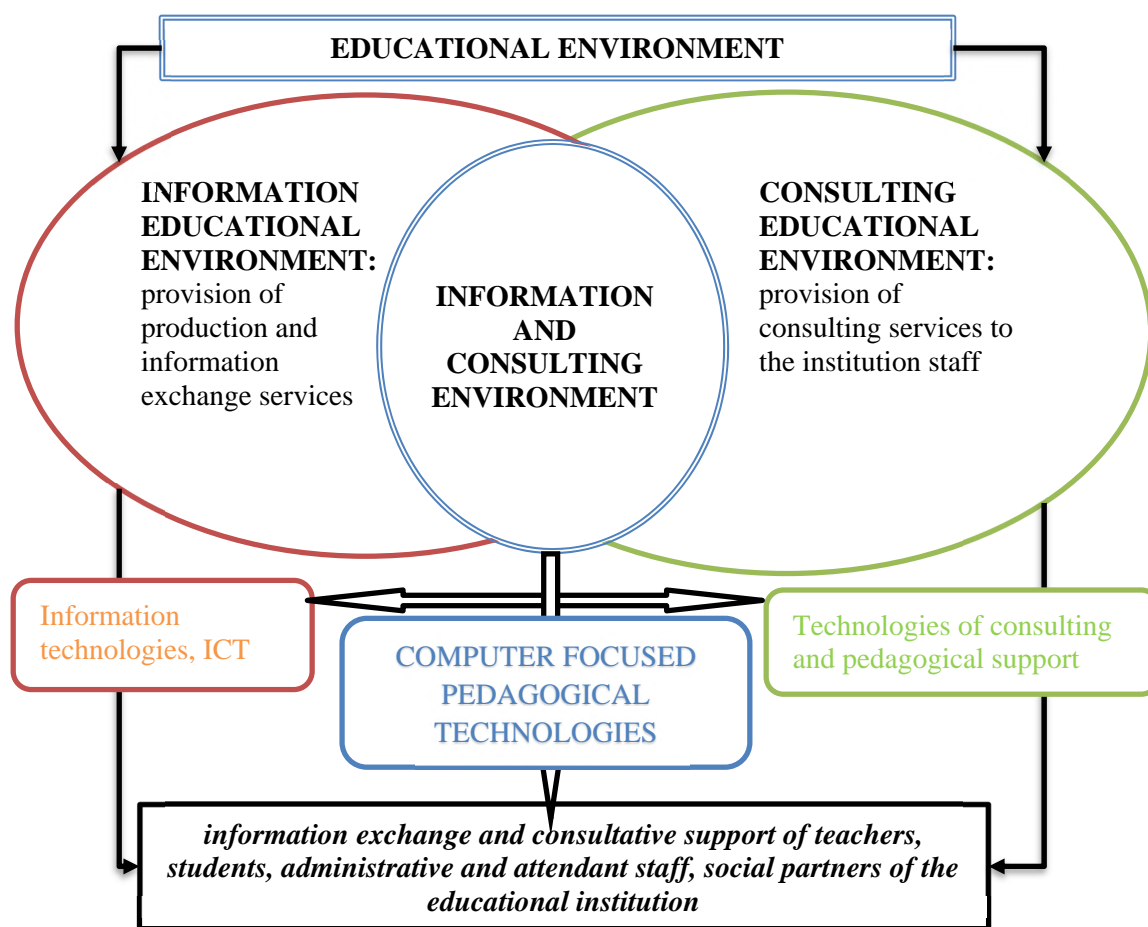


Figure 1. The essence of the educational institution information and consulting environment.

The information and consulting environment can be presented as a system, which has such properties like integrative, emergence, orderliness, structuredness, development, stability and reliability ones. Integrating the qualities of both kinds of educational environment, the information and consulting environment is able to enhance the benefits and compensate for the separate issues of each of them. Among problems, in particular, are those related to the insufficient level of digital competence of the subjects of an educational process and the degree of their openness and readiness to accepting consulting services. Computer focused pedagogical technologies used for the purposes provide follow:

- round-the-clock pedagogical support whenever and wherever, and with simultaneous coverage by various methods of counseling for several customers’ typological groups;
- personalized feedback and interactions;
- expanding the range of tools and aspects of consulting services;

- variation of rate and volume of the provided information together with orientation on needs of each client;
- giving to consultations for physically challenged persons;
- increasing the information channels capacity and diversity, as well as individual support in accessing to them;
- dynamism, interactivity, gamification, a qualitatively new level of visualization of reference and support information and the consulting process;
- positive emotional background and friendly interface;
- potential opportunity to combine information and consulting resources of different educational institutions, organizations, research centers, and whatever.

Accordingly, into the information and consulting environment there are objective opportunities for social and professional adaptation and personal development of all subjects of the educational process.

4.2. *The content of the educational institution information and consulting environment*

The educational institution information and consulting environment can be presented as a spatial surrounding where all participants of the educational process, including teachers, students, parents, entrants and others stakeholder, can receive qualified advice, information assistance, pedagogical support in solving specific problems with the use modern ICT and tools.

First of all, a such environment is educational one (Viktor I. Slobodchikov [52], Iraida S. Iakimanskaia [12], Vitold A. Iasvin [13]). Furthermore, this is informational (Liubov F. Panchenko [38]), communicatively focused (Alla S. Lobanova [14]), professionally oriented (Viktoriiia V. Zhelanova [66]), developmental (Iurii S. Manuilov [30]), reflexive-contextual (Sergei F. Sergeev [46]) and reflexive-active environment of innovative promotions.

The above semantic analysis of the essence of the educational institution information and consulting environment makes it possible to form its *content* as a set of certain components that are inextricably linked with a person as a subject of the educational process. Among them are the following *components*:

- *social* one that provides satisfaction and development the needs of subjects of educational process advisory assistance of the learning and teaching, and professional activities organizing;
- *spatial-objective* one which determines the environmental design with the interconnectedness of different functional elements, as well as hardware and software of ICT;
- *psychological and pedagogical* one covering pedagogical and methodological support for the implementation of the goals of the environment ([27], p. 101).

The *criteria for assessing the quality of the information and consulting environment* could be defined; they cover following ([10], p. 161; [46]; [52]):

- an immersion is involvement of subjects' emotional and cognitive structures into the environment,
- it is a presence as the experience of being into the environment,
- an interactivity is the participation of subjects in changes and the forming of the environment content,
- a saturation is the environmental resource potential,
- a structuredness is a way of the environment organizing,
- it is an openness to external and internal consumers of consulting services,
- a scalability is the number and scope of services, information and consulting resources;
- it is an integration with various institution structures or social partners;
- it is an adaptability to the demands of a particular consumer of consulting services.

The information and consulting environment is a multicomponent set of educational resources and technologies that provide informatization and automation of consulting services. For these aims the environment creates opportunities for the implementation of a number of computers focused pedagogical technologies. First of all, ICT that is widely used in the information educational environments, among them [23]:

Multimedia technologies functioning on base of audiovisual and suggestive methods of counselling organizing with use a computer support [57]. Such technologies create certain sensorimotor stimuli for

better perception, processing and reprocessing of information, allow to manipulate information, create a positive emotional background and friendly interface, enable to provide inclusive counseling using all possible information channels.

Hypertext technologies that transform text from a linear form into a hierarchical one and thus provide fast navigation, control, correction and feedback within consulting services.

Internet technologies are technologies and services allowing for pedagogical interaction via the Internet. These primarily include e-mail, electronic pagers, communicators, thematic websites dedicated to the transmission of information and providing consulting services.

Cloud technologies are a variety of hardware and software, methodologies and tools that are demined to the user as Internet services for the implementation of goals, objectives, and projects. The cloud storage can save up-to-date background or study information, document templates, samples of tasks solving and other things that customers can get with regulated access rights. Today's cloud technologies include the simultaneous work and editing of various documents with the ability to support the consultant in synchronous and asynchronous modes, as well as conducting surveys, collecting data, organizing meetings and conferences at any level. Such technologies significantly expand the educational institution information environment and improve the quality and range of consulting services.

Web technologies are technologies of web-resources creation and application (sites, models, virtual environments, events and meetings) for consulting purposes. To their well-known advantages should be added the capability to involve external consultants, and, what is more, specialized thematic and educational sites, portals, Internet projects, planetary classes, virtual universities created specifically to provide consulting services.

Telecommunication technologies are ways of intersubjective interaction organizing on the basis of multifunctional network multimedia study complexes and automated educational systems. These technologies provide multimedia-enabled video communications and widely use scribing and computer visualization to enhance the quality of the counseling process.

Automated library and information systems are technologies for managing information resources at all stages of their life cycle in the library, as well as automation of main library and bibliographic processes [11]. Their use allows to make the consulting process mediated by ICT. Technologies let automating the search for answers to the most typical customer requests, supply access to relevant information "in one click", register and solve clients' problems with help of a moderator if it necessary.

SMART technologies are an interactive study and consulting complex that permits to create, edit and distribute information in a multimedia format. In the era of massive smartphones and other gadgets distribution, various information boxes and displays exploit, such technologies are becoming more widespread.

Document automation and management systems are information systems and technologies ensuring the process of creating, controlling access and distribution of electronic documents, as well as control over documentation procedure in the organization [62]. They allow educational institutions to minimize information entry, to do time and financial savings due to decreased paper handling, document loading, storage, distribution of manuals and guidance for clients' needs.

To this list it ought to be added those pedagogical technologies that provide the appropriate level of advisory services, namely:

Interactive technologies that support pedagogical interaction in the mode of dialogue [1], [16], [21], [29]. Their varieties are group work technologies, coaching and training ones.

The pedagogical interaction and cooperation organizing technologies ensure the coincidence of the direction of pedagogical influence and the appropriate reaction of educational environment subjects aimed in order to develop their personality in solving educational tasks.

Technologies for monitoring the educational process quality are technologies for the arrange of purposeful activities for the collection, storage, systematization, generalization and use of information about the state and development trends of the of the manpower. They also include test and reflexive

technologies, portfolio (portfolio of achievements, portfolio of process, portfolio of result, presentation portfolio), case-study [29].

The spectrum of technologies is presented in figure 2.

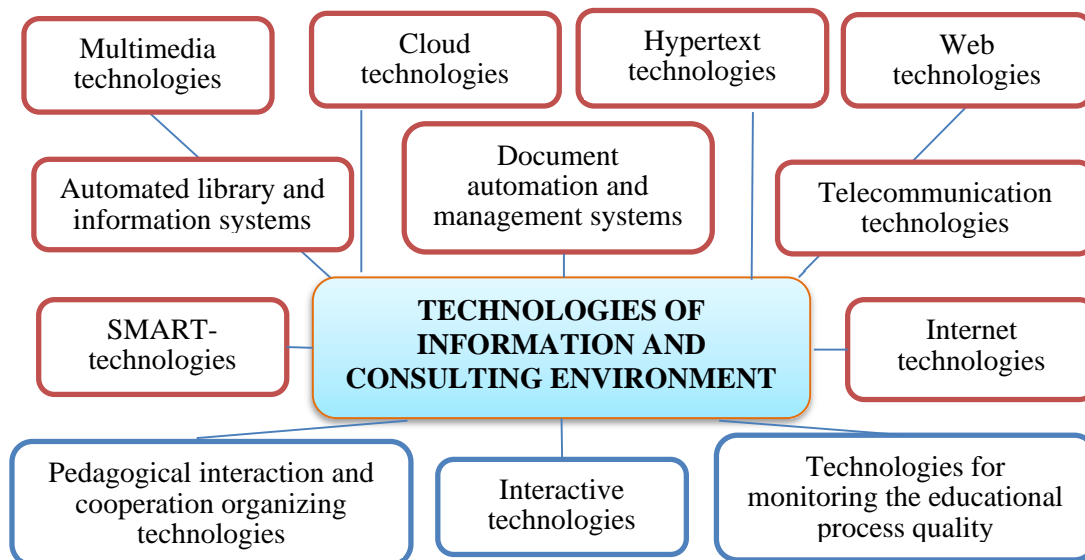


Figure 2. Computer focused pedagogical technologies of information and consulting environment.

Based on the analysis of primary sources the *pattern of the educational institution information and consulting environment* have been established; it covers the following main areas:

- *organizational area* to construct an educational institution organizational structure (service, council, center, whatever) to ensure the creation, operation and development of the environment, to working out its regulatory framework;
- *technical area* to support technical and technological solutions;
- *methodical area* to form the training system and to prepare methodological guidance for work into the environment;
- *resource area* for development, support and improvement of information and consulting resources [17].

Therefore, in order to implement innovations, educational institutions need to implement ICT in study and administrative processes, to create information and consulting environments and centers for the transfer of educational and industrial technologies. Finally, it will improve the quality and accessibility of educational services.

4.3. Review and analysis of the benefits and risks of the educational institution information and consulting environment

The overview of the open information resources, sites and other presentation and working materials reflects significant achievements in the direction of expanding the range of educational and consulting services provided within the functioning of educational institutions. We supplemented the review with our own research on the state of the problem of organizing the educational institution information and consulting environment. Our research involved 50 educators and 60 students of Kryvyi Rih State Pedagogical University and Drohobych Ivan Franko State Pedagogical University, as well as Kryvyi Rih Professional Mining and Technological Lyceum. Among them were 15 representatives of the administrative apparatus and management of institutions.

Based on the survey results it is established that creating of the modern information and consulting environment is not only demands of the times but also necessity for survival and promotion educational

institution. This idea was confirmed by 96% educators and 83% students. According to the 82% respondents' viewpoint the development of educational systems and professional counseling based on the use ICT considerably improves the quality of the educational process, greatly expands the possibilities of giving both on basic and additional educational services. By means of information and consulting environment students have the opportunity to plan independently, do training by their own trajectory, at any time to receive pedagogical support and qualified counseling, receive answers to current and future requests, and even get around to personality and professional evolution.

The managers and leaders of the educational institutions which took part in our research called a number of advantages the information and consulting environment. We summarized them into the following types:

- to organize a reasonable and rational document automation and management systems within the institution, to implement ICT in the management of educational institutions;
- to introduce a system of collecting, processing information about various aspects of the educational process;
- to carry out detailed monitoring of the institution activities;
- to create electronic databases of pedagogical staff and student body;
- to support the educational institution website, web pages of educational projects;
- to organize a distance learning;
- to expand information interaction and social partnership with other institutions and potential employers;
- to provide the consulting services in the context of educational, public, advertising, volunteering activities to stakeholders outside to the educational institution.

Thus, the creation of a united information and consulting educational environment will promote the development of study, pedagogical, managerial activities of educational institutions. Due to the survey results the functioning scheme of the educational institution information and consulting environment was made; it shown in the figure 3.

As the figure 3 demonstrates, the united educational institution information and consulting environment is a system in which all subjects of the educational process (administration, teachers and students) are involved at the information level and interconnected by the relevant information flows.

Properly organized and functional information and consulting environment automates and modernizes the study process and makes it more accessible, flexible and attractive to young people. We share standpoint of Halyna B. Hordiichuk [10] and regard that such an environment is able to achievement the implementation of information, consulting, diagnostic, interactive, coordinating, professional and developmental functions and the function of pedagogical and educational support.

Meanwhile, researchers emphasize certain risks and problematic issues in the functioning of the educational institution information and consulting environment. We summarized them and offered respondents to rate the level of their influence on a ten-point scale. The factor was considered significant if it scored more than 7 points on average. The results are presented in table 1.

However, these and other problematic issues can be solved by creating a scientifically sound concept of the educational institution information and consulting environment. In this context it's important not only the current state of the educational environment, but also the strategy of its development, a specific program of action that reflects the general quality culture of the educational institution.

5. Conclusions

The article reveals the essence and content, as well as the main approaches to the forming of the educational institution information and consulting environment. At the heart of the presented research is the environment conception. In this regard, the environment is a system of conditions that created within a certain space in which the subject's activities take place. And the environment conception is defined as a strategy based on managing of personal development process through the creation of a definite environment.

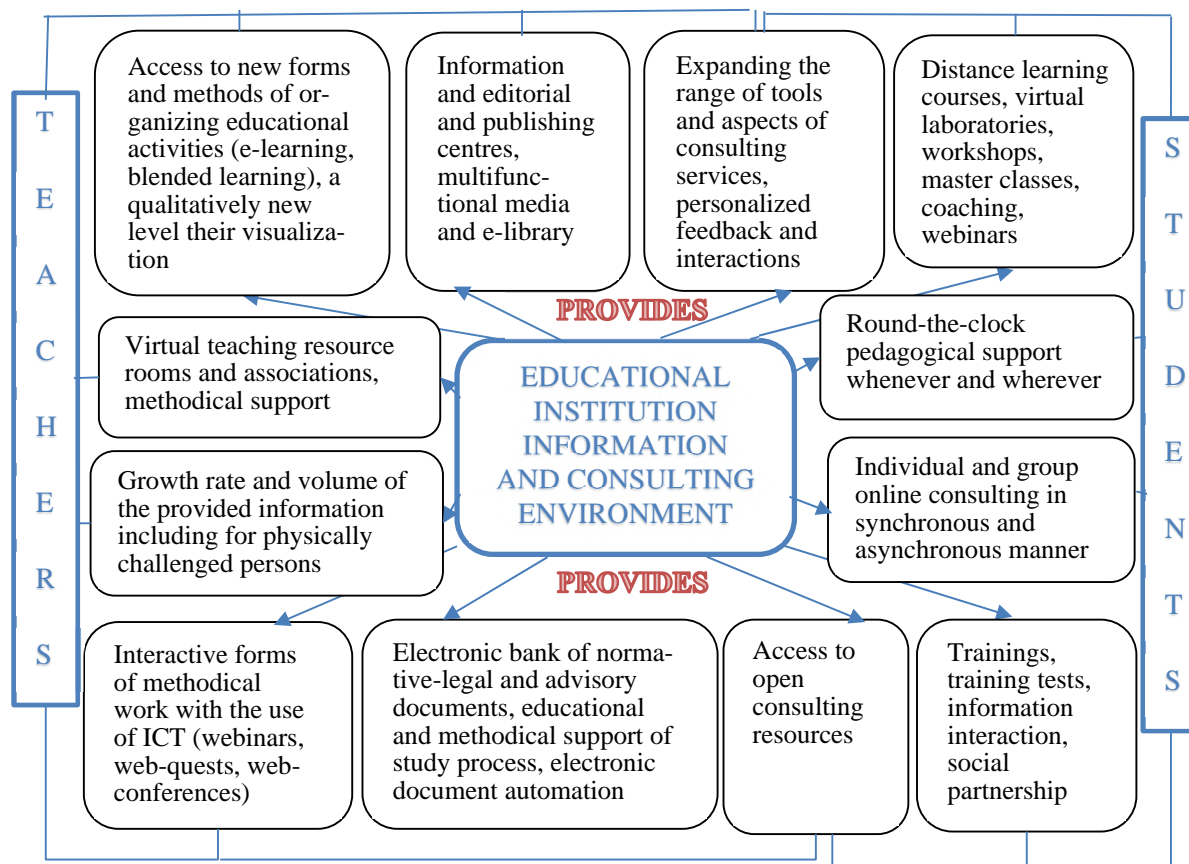


Figure 3. Functional capabilities of the educational institution information and consulting environment.

Reasoning from a semantic analysis of the constituting categories it was found that the educational institution information and consulting environment is relevant for the information society part of the space within which it becomes possible to exchange information and advisory support of the subjects of the educational process and other stakeholders by means of computer focused technologies. Integrating the qualities of both kinds of educational environment, the information and consulting environment is able to enhance the benefits and compensate for the separate issues of each of them. Such an environment is educational, informational, communicatively focused, professionally oriented, developmental, reflexive-contextual, and reflexive-active environment of innovative promotion.

The information and consulting environment can be presented as a system, which has such properties like integrative, emergence, orderliness, structuredness, development, stability and reliability ones. At the same time, it is a multicomponent set of educational resources and technologies that provide informatization and automation of consulting services. These include computers focused pedagogical technologies (multimedia, hypertext, cloud, telecommunications, Internet technologies, web-technologies, smart-technologies, automated library and information systems, document automation and management systems) and technologies that provide the appropriate level of advisory services (interactive technologies, pedagogical interaction and cooperation organizing technologies, and technologies for monitoring the educational process quality).

The components of the information and consulting environment, inextricably linked with the person as a subject of an educational process, are social component, spatial-subjective, psychological and pedagogical ones. The pattern of environment covers the organizational, technical, methodical, and resource areas.

Table 1. Risks, threats and problematic issues in the functioning of the educational institution information and consulting environment.

<i>Environment component</i>	<i>Problem field</i>
<i>social component:</i>	Competition from other educational structures in shaping the image of the institution Insufficient orientation to the typical demands of society Negative impact on the institution reputation due to imperfect information campaign
<i>spatial-objective component:</i>	Incomplete information and physical infrastructure Threat of irreversible loss of electronic data bank due to viruses or cyber-attacks Violation of confidentiality and threat to intellectual property over open information flows Failure or information delay through the use of imperfect software Problems of recognition and confirmation of the received information during document circulation The need to restructure the organizational of the institution
<i>psychological and pedagogical component</i>	Information and cultural barrier Insufficient subjects' digital competence Resistance from the subjects of the educational process in the implementation of ICT to consulting services Lack of initiative in the development of consulting services Distortion the results of monitoring educational services due to the overly formalized and automated procedures Cyberbullying due to the leakage of personal information Risk of refusal or reduction of consulting services quality Reducing the level of subjects' independence during the search and processing of information Absence or reduction the personal contacts

Based on the analysis of primary sources and held own researches (including the use of content analysis and factor analysis) it is established that properly organized and functional information and consulting environment automates and modernizes the study process and is able to achievement the implementation of information, consulting, diagnostic, interactive, coordinating, professional and developmental functions and the function of pedagogical and educational support. The significant advantages in the functioning of the educational institution information and consulting environment which are able to compensate for certain non-critical shortcomings, have also been shown.

The concept of the educational institution information and consulting environment, principles and methodological approaches, tools of pedagogical counseling through computer focused methods, techniques, forms and technologies still need further development.

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An electronic environment of higher education institution (on the example of Zhytomyr Polytechnic State University)

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Abstract. The article considers the expediency of developing and using the electronic environment of a higher education institution. It was found that the existence of such an electronic environment of a higher education institution would allow us to effectively use the available resources of higher education. A model of the electronic environment of a higher education institution is proposed, which consists of 4 components: educational, scientific, organizational, and managerial. The structural elements of each of the components are described. An example of the implementation of such an electronic environment on the example of the Zhytomyr Polytechnic State University is considered. The personal offices of the student and the teacher, which are realized according to the given model at the Zhytomyr Polytechnic State University, are considered in detail. It is established that the indisputable advantage is the complete identification of the person who went to different parts of such an environment, another advantage is the integrated use of logins and passwords to all these components.

1. Introduction

Recently, higher education institutions (HEI) have been paying attention to the development and implementation of various electronic systems and environments for the automation of management and educational activities, including document management systems. At the same time, the complexity of the unique identity of the subject of the educational process in different systems leads to some confusion and the difficulty in exchanging data between them.

The existence of this electronic medium institution of higher education would allow effective use of available resources HEI.

2. Theoretical background

The issues of management of different educational systems were considered by Eva Huang [12], Apostolos Koutropoulos [18], Iryna S. Mintii [27], and others. At the same time, the informatization of education was covered by Olga V. Bondarenko [1], Oleksandr Yu. Burov [3], Andrii M. Hurzhii [6], Anna V. Iatsyshyn [14], Alla M. Kolomiiets [23], Mariia P. Leshchenko [24], Yevhenii O. Modlo [28], Nadiia S. Ponomareva [35], Serhiy O. Semerikov [29], Oleg M. Spirin [45], Aleksander V. Spivakovskiy [40], Illia O. Teplytskyi [38], Yurii V. Tryus [42], Vladyslav Ye. Velychko [8], Myroslav I. Zhaldak [48], and others. The design and use of educational environments have been studied by Dmytro S. Antoniuk [46], Roman M. Horbatiuk [10], Olena O. Lavrentieva [22], Alona T. Litvinchuk [20], Maiia V. Marienko [26], Olga P. Pinchuk [33], Kateryna I. Slovak [21], Vladimir N. Soloviev [17], Stanislav T. Tolmachev [32], Snizhana O. Zelinska [47] and others.



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In particular, Valeriy G. Hrytsenko in his work HEI as an object of management considers “as a formal structure, the main elements of which are the participants in the educational process” ([11], p. 48). As a result, the researcher claims that the management of free economic education means “management of the participants of the educational process (research and teaching staff, teaching and support staff, doctoral students, graduate students, students, etc.)” ([11], p. 48).

Valerii Yu. Bykov and Mariya P. Shyshkina considers the current problems of in-service education and training of skilled personnel for high-tech industries in Ukraine [4], also the researcher investigates the theoretical approaches to developing computer tools for organizing and supporting cognition, learning and teaching in Eastern European countries [5]. Yurii V. Tryus and Inna V. Herasymenko substantiates the necessity and expediency of using the dual form of education in training specialists in the field of information technology in technical universities of Ukraine [43]. The effectiveness of GitHub cloud services for implementing a programming training project is also considered by Olena G. Glazunova [9], Svitlana H. Lytvynova offers for consideration a cloud-oriented learning environment of secondary school [25], and considers the possibilities of Web-based education of computer science bachelors in higher education institutions [37].

The information and educational environment of the institution of higher education is also studied by Vasyl P. Oleksyuk [30], Liubov F. Panchenko [31], Andrii M. Striuk [41].

Mariya P. Shyshkina explores promising learning technique of the cloud technologies use for students collaboration support [36], as well as the technologies of distance learning on the principles of integrated development of key competences [39]. Anna V. Iatsyshyn considers various aspects of the use of ICT in higher education ([19], [13]).

That is why the article aims to describe the possibilities of the electronic environment of higher education institutions (on the example of Zhytomyr Polytechnic State University).

3. Results

Currently, various higher education institutions either use self-developed systems or purchased from popular developers.

In particular, the most common in the use of management systems of the educational process among higher education institutions of Ukraine is “Directive” [16], “University” [44], “Polytech-software” [34]. There are also higher education institutions that use their developments: the Borys Grinchenko Kyiv University (see figure 1) [2], Khmelnytsky National University (see figure 2) [15].

In particular, Borys Grinchenko Kyiv University offers access to its various components from the main page of the university (with some restrictions – some resources are available only from the internal network), in turn, Khmelnytsky National University presents this environment as a list of links to necessary materials.

Therefore, it was decided to develop an electronic environment of the university, which could be used in modern conditions. As a result, there was a problem to develop a model of the electronic environment of higher education, as well as to describe the functions of each component of this model.

The proposed model consists of 4 components: educational, scientific, organizational, and managerial (see figure 3).

First, consider the organizational component, which involves the administration of the entire electronic environment of higher education. The administrator manages the roles, distribution of user access rights. In turn, its actions involve not only the establishment of certain restrictions but also the definition of rules for the establishment of roles. As a result, all employees of the higher education institution have one login and password, which gives access to personal accounts of users (teachers, students, teaching staff, management of departments, administrator), the internal network of the higher education institution, corporate mail, and to the educational portal where semester training (LMS Moodle) is carried out.

This provides unambiguous identification of the subject of the educational process in the various components of the electronic environment of the university.

Excursion to the main e-resources of Grinchenko University

Available from external network:



Figure 1. E-environment of Borys Grinchenko Kyiv University.

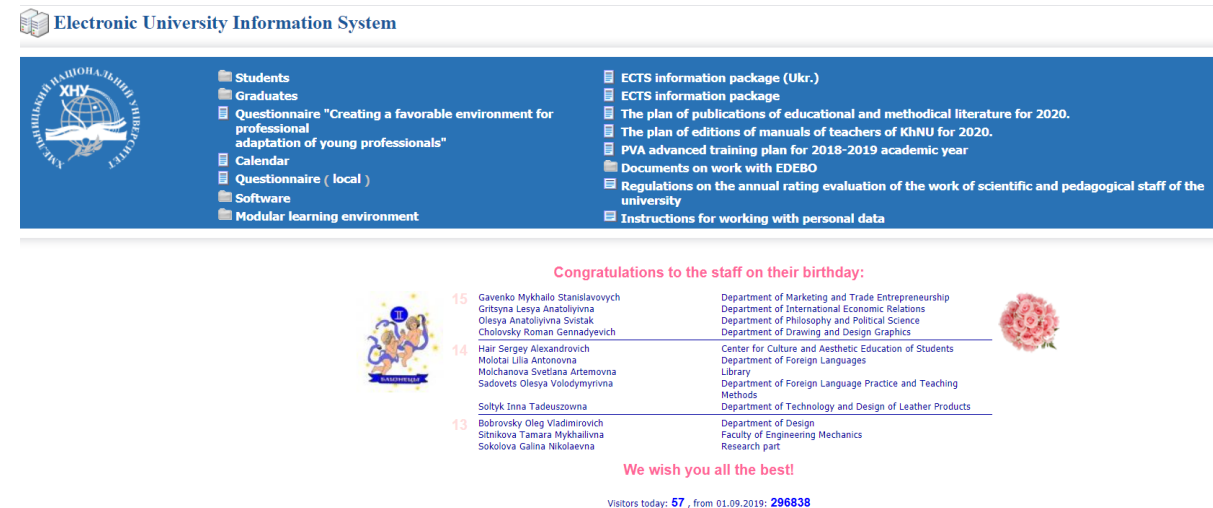


Figure 2. Information system “Electronic University” of Khmelnytsky National University.

In addition, the organizational component provides a clear structure of the institution of higher education with all its departments, as well as maintaining a single calendar of events of all structural units of the university in one place.

The next – the management component involves the separation of heads of all departments of the university and, accordingly, their areas of work.

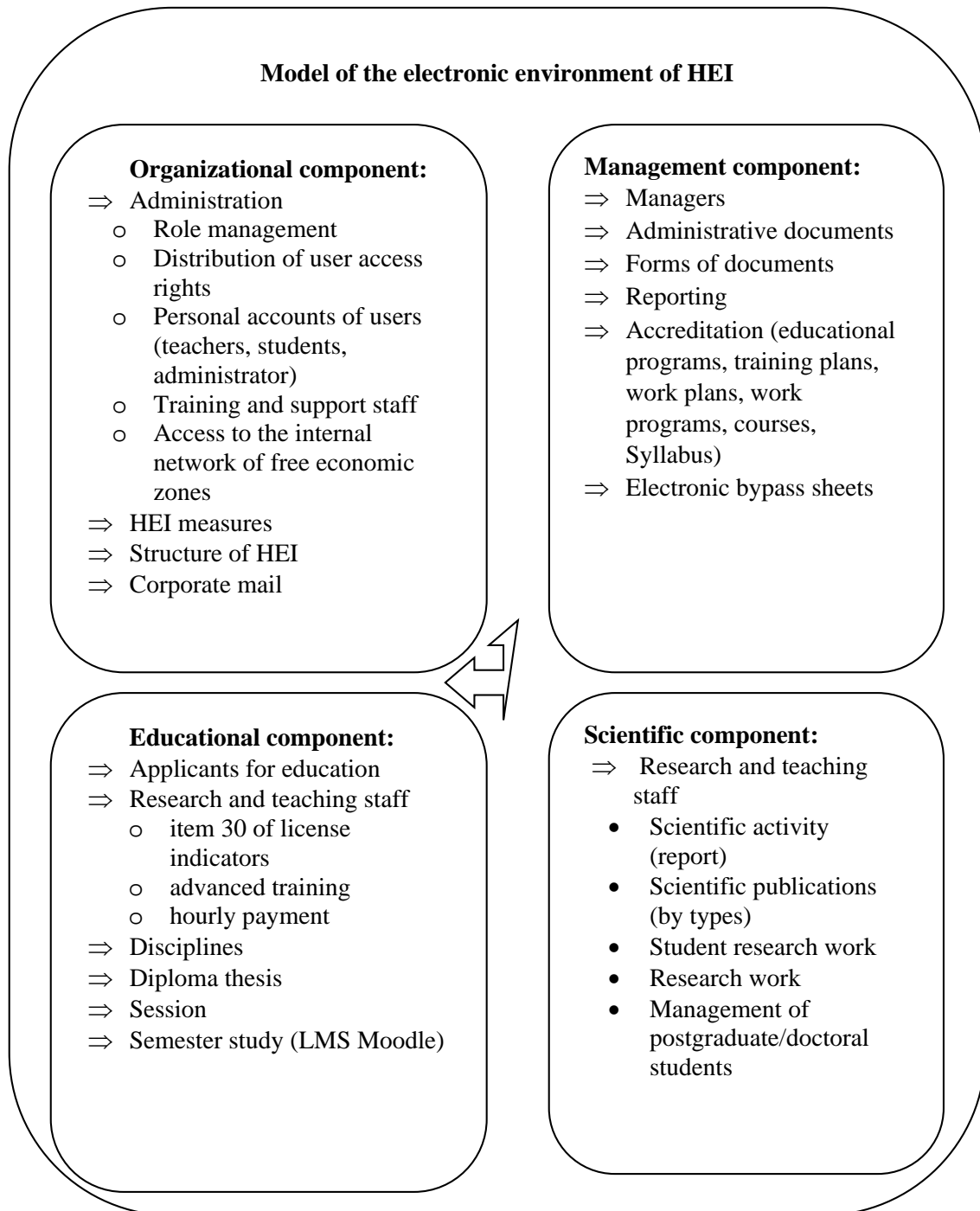


Figure 3. Model of the electronic environment of HEI.

This component provides for the maintenance of administrative documents, the provision of generally accepted forms of certain documents for all structural units of higher education. In addition, an integral part of this component is the formation of reports on various parameters.

Also in the light of new requirements for accreditation, it is advisable to separate and document for accreditation in each speciality (educational programs, curricula, work plans, work programs of

disciplines, syllabuses). After all, such material should be available to all participants in the educational process.

The educational component, in turn, is implemented in the following areas.

1. Applicants: information on each higher education applicant, registration on the only professional exam, relevant statistics, lists of applicants by groups, group management, and information on tuition fees.

2. Scientific and pedagogical workers: fulfillment of item 30 of license indicators, advanced training, hourly payment.

3. Academic disciplines

4. Diploma thesis

5. Session: information on the admission of students to the test or exam, information for research and teaching staff (open and closed), information on individual groups, and summary information.

6. Semester training, which is carried out through the learning management system Moodle.

In addition, of course, the scientific component, which contains the following elements for research and teaching staff: report on scientific activities, scientific publications (by type), student research, research, and guidance of graduate / doctoral students.

Consider in detail the personal offices of students and teachers, which are implemented according to the above model at the Zhytomyr Polytechnic State University.

3.1. Student's account

The student in his account [49] (see figure 4) (<https://cabinet.ztu.edu.ua/>, logging in with his login and password) can see information about training (faculty, educational level, a form of study, group number, specialty, and educational program), information on tuition fees for students studying at the expense of individuals and legal entities and dormitory payment information (payment status for the current month, amount per month, student serial number, details for payment, and the ability to download a payment receipt).

The screenshot displays the student's personal office interface. At the top, there is a navigation bar with 'Home' and 'Log out (kik_vta)'. The main content is divided into three sections:

- Training information:** A table with fields: Name (Vakalyuk Tetyana Anatoliivna), Faculty (Faculty of Information and Computer Technologies), Educational degree (Master), Form of study (Correspondence), Group (ZIPZmh-19-1), Specialty (121 Software Engineering), and Educational program (Software engineering).
- Test and examination session:** A table listing exam results:

Agile and project management	exam 06.06.2020 11:40	100 A is excellent
Data mining languages	offset 08.06.2020 13:30	100 A credited
Cloud technologies and IoT	exam 09.06.2020 13:30	95 A excellent
Technologies of administration and protection of information systems	exam 10.06.2020 13:30	91 A excellent
- Information on tuition fees:** A table with fields: Status (paid), Amount per month (1440 UAH), Sequence number (37466), Details for payment (Payer: Vakalyuk Tetyana Anatoliivna, Recipient: Zhytomyr Polytechnic State University, Bank: SCSU in Kyiv, Account: UA708201720313241001201000321, Code: 05407870, Purpose of payment: For training. Name: Vakalyuk Tetyana Anatoliivna, ordinal №37466, message №792820), and Receipt for payment (Months: 1, Amount: 1440 hryvnias, Download).

Figure 4. Personal office of the student in the electronic environment of Zhytomyr Polytechnic State University.

Also, in the student's account, there is a section “Credit-examination session”, where students following the “Regulations on the assessment of students' knowledge in terms of a credit-module system of the educational process” Zhytomyr Polytechnic [7] can agree with the assessment he received during the semester (if it is 60 points or more), or go to the test/exam – if the student scored 50 or more points, but he is not satisfied with his assessment.

To connect to the test/exam, it is possible to connect to the zoom conference and take the appropriate subject.

In this case, if the student agreed to the assessment, the cell with the assessment is painted green. After closing the information on the day of the exam or exam, the student and teacher are no longer able to edit this grade.

Also, the student with the same login and password has the opportunity to enter the corporate mail, the internal network of the university, and the educational portal, where the semester training (LMS Moodle), which is located at <https://learn.ztu.edu.ua/> [51] (see figure 5). This portal contains all the materials necessary for semester study, as well as which do are necessary for the implementation of educational activities.

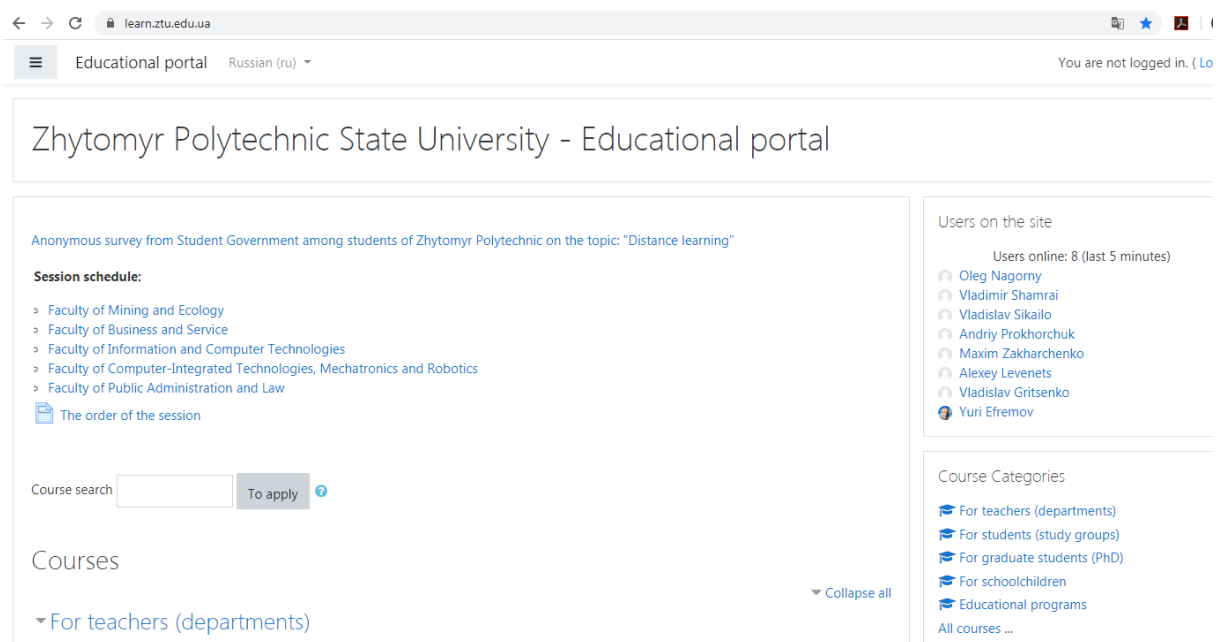


Figure 5. The educational portal of Zhytomyr Polytechnic State University.

3.2. Personal office of the scientific and pedagogical worker

Researchers with the help of their unique login and password can similarly enter all these structural elements of such an environment. To enter the personal account [50], researchers need to use the link <https://portal.ztu.edu.ua/> and your login and password.

In this personal account, the teacher has the opportunity to work with the following elements: university events, students, the educational process, the teacher's profile, and the session (see figure 6).

The “University Events” section includes the ability to add an event (both at the structural unit and at university level), view the calendar of events, the list of events, and the ability to edit events (see figure 7). This is convenient for organizing meetings at different levels (from the meeting of the department to the rector).

The section “Applicants” contains a list of applicants by groups (see figure 8). You can browse or search for applicants by faculties, forms of education, educational degree, specialty, etc. This section is designed to record all students in different forms of education.

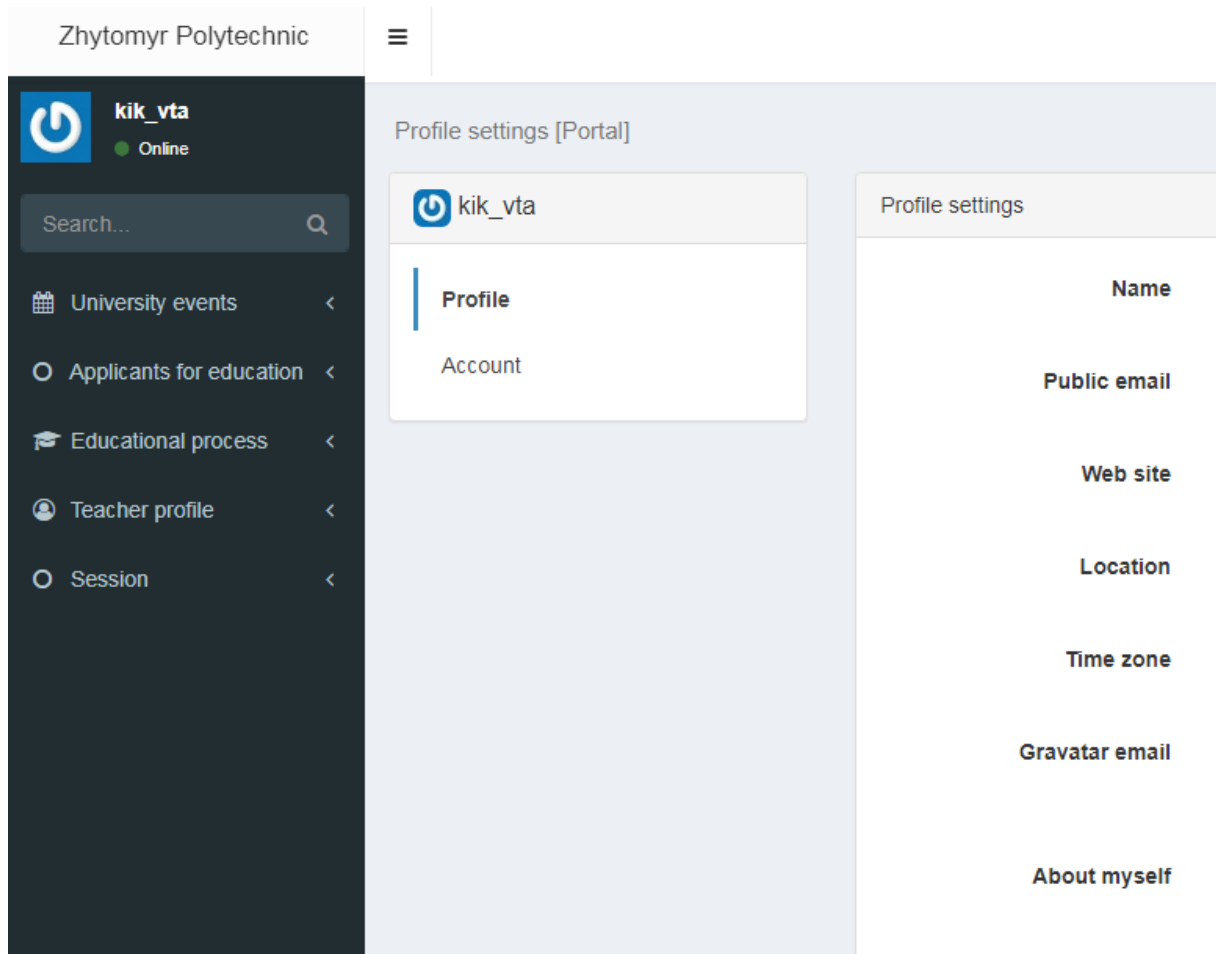


Figure 6. Personal office of research and pedagogical worker in the electronic environment of Zhytomyr Polytechnic State University.

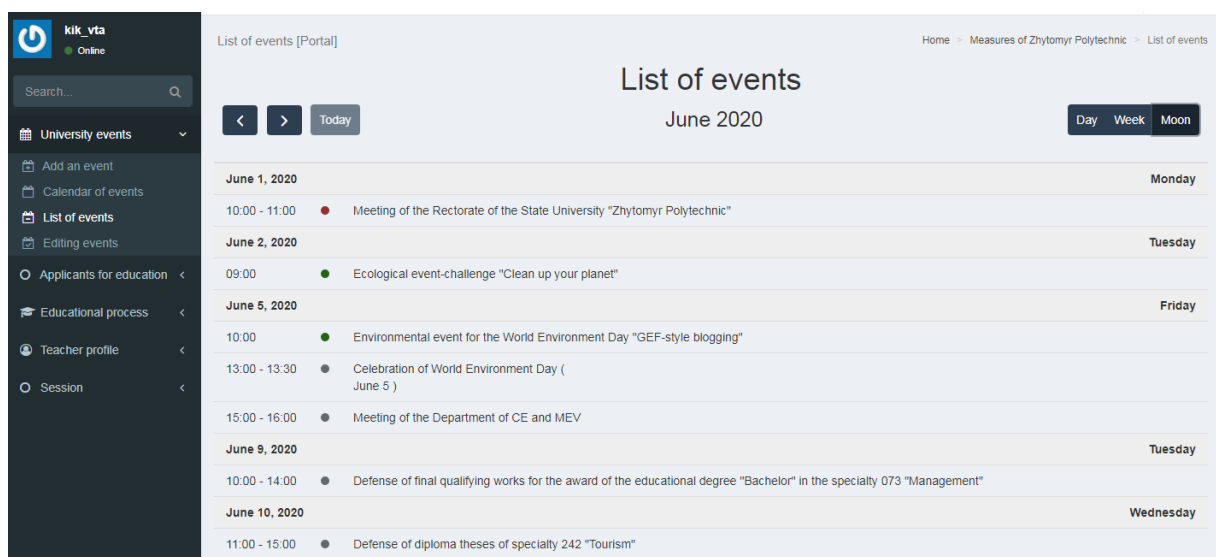


Figure 7. University events in the electronic environment of Zhytomyr Polytechnic State University.

Academic groups [Portal] Home > Applicants for education > Academic groups

Academic groups

Academic groups Showing 1-20 of 313 records.

#	ID	Group name	Course	Number of students	Faculty	Form of study	Educational degree	Specialty	Educational
1	1	GG-24	4	24	GEF	Day	Bachelor	184 Mining	Mining
2	2	GG-25k	3	3	GEF	Day	Bachelor	184 Mining	Mining
3	3	EC-36	4	6	GEF	Day	Bachelor	101 Ecology	Ecology
4	4	ZGG-17-K	3	4	GEF	Correspondence	Bachelor	184 Mining	Mining
5	5	ZEO-16-1	4	12	GEF	Correspondence	Bachelor	101 Ecology	Ecology
6	6	ZEO-17-K	3	12	GEF	Correspondence	Bachelor	101 Ecology	Ecology
7	7	ZRR-16-1	4	11	GEF	Correspondence	Bachelor	184 Mining	Mining

Figure 8. An example of an intellectual map for learning foreign languages, created by students during a distance-learning course.

The section “Educational process” contains a repository of forms (see figure 9), which are necessary and standard for all departments of the university. This section currently contains the following forms:

1. Form of the order on personnel issues (personnel).
2. The form of the order on the main activity or administrative and economic issues.
3. Protocol form.
4. Form of the dean's order.

Album forms

Album forms Showing 1-4 of 4 records.

#	ID	Document name	Category
1	1	Form of the order on personnel questions (personnel)	General documents
2	2	The form of the order on the main activity or administrative and economic issues	General documents
3	3	Protocol form	General documents
4	4	Dean's order form	General documents

Figure 9. Album forms.

This section will be constantly updated, currently; the educational and methodical department is developing such forms.

In the teacher's profile, we have: a list of personal scientific publications, add a publication (both your own and any other employee), review the profile, training, implementation of paragraph 30 of the license indicators, and scientific activities (see figure 10).

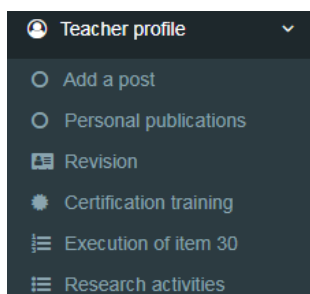


Figure 10. Teacher profile.

In the list of publications, you can view all the scientific papers included in the database, with any of the scientific and pedagogical staff. Publications can be viewed by year of publication, as well as by type of publication (see figure 11). To add a publication, you need to click the “Add publication” button and fill in all the appropriate fields (see figure 12). In your profile, you can view all the data that were entered in this section (see figure 13). The advantage of this environment is that all teachers have a complete list of the implementation of paragraph 30 of the license indicators (see figure 13).

Posts added by me

[Add a post](#)

Posts that are entered with errors are highlighted in red! If you have such publications in your list, please double-check that you entered the information correctly

We also draw your attention to the fact that when making it is necessary to note all the authors of the publication, including yourself!

#	ID	Year of publication	Complete publication data	Type	I added
1	802	2019	Vakalyuk TA, Korotun OV, Antonyuk DS Selection of cloud-based means of training databases of future specialists in information technology [Electronic resource]. Information technologies and teaching aids. 2019. № 3 (71). Pp. 154-168. URL: https://journal.iitta.gov.ua/index.php/itit/article/view/2880/1502	Article in a magazine published in Ukraine	Vakalyuk Tetyana Anatoliivna
2	803	2019	Spirin OM, Vakalyuk TA Formation of information and communication competence of bachelors of informatics on the use of cloud-based learning environment [Electronic resource]. Information technologies and teaching aids. 2019. № 4 (72). Pp. 226-245. URL: https://journal.iitta.gov.ua/index.php/itit/article/view/3262	Article in a magazine published in Ukraine	Vakalyuk Tetyana Anatoliivna
3	807	2019	Information technologies in higher school: Monograph / [Antonyuk DS, Boychuk ID, Bolotina VV, Bolukh VA, Vakalyuk TA, Zhmurko OI, Kontsedaylo VV, Korotun OV, Litvinova SG, Marienko MV, Mahometa TM, Medvedeva MO, Mintiv IS, Mintiv MM, Mishchenko OA, Osova OO	Monograph	Vakalyuk Tetyana Anatoliivna

Figure 11. Publications of teachers.

The item “Advanced training” contains the names of disciplines and the number of lecture hours in each of them, which are taught in the current academic year at the State University “Zhytomyr Polytechnic”, the name of the institution where the training took place, the topic of training, type of training document, number of the document on professional development and date of issue.

Add a publication

Year of publication

Year

Type of publication

Select the type of publication

Name

Name

Name of the magazine / publication

The name of the magazine or publication

Number of pages

Number of pages

Home page

Home page

End page

End page

Link to the electronic version

Link to the electronic version

Figure 12. Adding a publication.

Vakalyuk Tetyana Anatoliivna [Portal] Home > Teacher profile > Vakalyuk Tetyana Anatoliivna

Research and teaching staff: Vakalyuk Tetyana Anatoliivna

Last name, first name and patronymic	Vakalyuk Tetyana Anatoliivna
Position	professor
Chair	Department of Software Engineering
User	Vakalyuk Tetyana Anatoliivna
Full-time position or part-time	The main place of work

Compliance with clause 30 of the License Terms [Edit](#)

1) Availability for the last five years of scientific publications in periodicals that are included in the scientometric databases recommended by the Ministry of Education and Science, in particular Scopus or Web of Science Core Collection

- Kontsedaylo VV Criteria for the selection of game simulators for the formation of professional competencies of future software engineers [Electronic resource] / VV Kontsedaylo, TA Vakalyuk // Information technologies and teaching aids. - 2018. № 3 (65). Pp. 133-151. URL: <https://journal.iitta.gov.ua/index.php/itit/article/view/2039/1347> (WoS)
- Карплюк С.О. Review of functional possibilities of software for management of educational process of institution of higher education [Electronic resource] / SO Karplyuk, TA Vakalyuk // Information technologies and means of training. - 2018. № 3 (65). Pp. 262-276. URL: <https://journal.iitta.gov.ua/index.php/itit/article/view/1961/1341> (WoS)

Figure 13. Data on teachers in the section “Teacher's profile”.

“Scientific activity” includes the following information: the main publications in the speciality of the teacher, research work, participation in conferences and seminars, work with graduate and doctoral students, the guidance of scientific work of students.

No less important is the section “Session”, where the teacher has access to electronic information, where he can put grades for each subject (see figure 14). Information is divided into open and closed. Open information is available from the end of the semester until the day of the credit/exam. Closed information is information that has expired (information is moved from open to close the day after delivery) (see figure 15).

Open performance records

#	ID	Status	Fill check	Date of semester control	Start time	Academic group	Number of students	Estimates	Academic discipline	Form of control	Structural unit	Semester
Nothing found.												

Figure 14. Session. Open performance records.

Closed performance records

#	ID	Status	Fill check	Date of semester control	Start time	Academic group	Number of students	Estimates	Academic discipline	Form of control	Structural unit	Semester
1	666		OK	06/03/2020	11:40	EC-3	10	10	Digitization of document management and e-office	credit	FBSO	2019/2020 n.r. 2nd semester
2	928		OK	06/05/2020	13:30	PL-1	17	17	Application packages	exam	ФПУП	2019/2020 n.r. 2nd semester
3	929		OK	06/05/2020	13:30	PL-2	17	17	Application packages	exam	ФПУП	2019/2020 n.r. 2nd semester

Figure 15. Session. Closed performance records.

At the time of grading, you only need to set a score in the 100-point system; everything else is filled in automatically by the system. If the student agrees with the grade – the cell is highlighted in green, if not – yellow. If the cell is white – the student either has not yet confirmed or has not scored the required minimum for admission to the form of control (see figure 16). If the student took the test – under the appropriate cell in red will be marked for the test, which the teacher must transfer to the appropriate cell.

4. Conclusion

As the experience of Zhytomyr Polytechnic State University staff shows, the use of such an electronic environment of a higher education institution is not only convenient but also useful. An indisputable advantage is the complete identification of a person who has entered different parts of such an environment; another advantage is the integrated use of logins and passwords to all these components.

Faculty of Public Administration and Law

Form of study: **Day**
 Educational degree: **Bachelor**
 Specialty: **035 Philology**
 Educational program: **Philology (Applied Linguistics)**

Group: **PL-2**
 Course: **1**
 Academic year: **2019/2020**
 Semester: **2**

SUCCESS ACCOUNTING STATEMENT № 87/20 dated 18.05.2020

Application packages
 form of control: **exam** , number of credits: 3
 date: **05.06.2020** , start time: 13:30
 scientific and pedagogical workers: **Vakalyuk Tetyana Anatoliivna**

Group: PL-2

Legend:
The student takes a test / exam
The student agreed with the assessment

Nen / n	Surname, name and patronymic of the student	100-point rating	ECTS	On a national scale	Date	NPP
1	Bondarchuk Ruslana Ruslanivna	39	FX	unsatisfactorily	27.05.2020 23:38	Vakalyuk Tetyana Anatoliivna
2	Vencheslavskva Olga Vladimirovna	62	E	satisfactorily	05/29/2020 16:53	Vakalyuk Tetyana Anatoliivna
3	Voznyuk Dmitry Pavlovich	56 Test: 56	FX	unsatisfactorily	05.06.2020 15:17	Vakalyuk Tetyana Anatoliivna
4	Grigorchuk Yana Viktorivna	62	E	satisfactorily	05/29/2020 10:12 AM	Vakalyuk Tetyana Anatoliivna
5	Zalizniak Maria Andreevna	86	B	okay	25.05.2020 13:27	Vakalyuk Tetyana Anatoliivna

Figure 16. Type of completed performance records.

The promising areas of research include the definition of criteria and indicators of the effectiveness of such an electronic environment of free economic zones and, accordingly, the application of the method of expert evaluation according to certain criteria and indicators.

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Implementation of adaptive learning at higher education institutions by means of Moodle LMS

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Abstract. E-learning courses have become popular means of delivering knowledge to students in higher education institutions. Most participants of learning process note that they benefit from the possibility to gain knowledge regardless of time, location and device they use. Among other advantages possibility to return to learnt material several times, divide material into parts, consume information through different types of educational materials (video, infographics, presentations, text, quizzes etc.) are mentioned. At the same time most of the surveyed students chose that they lack personalization both of materials and studying process, limited in terms of fulfillment and would like to have a choice of the level of study. The educational trend that is able to put into practice the above mentioned requirements is blended learning as it has a range of advantages such as usability, consideration of individual abilities, additional materials introduction, activities monitoring. Although it combines offline and online learning, effectiveness of e-learning courses designed for its implementation play a crucial role. To make a learning process correspondent to the students' needs adaptive learning can be introduced in higher education institutions. Adaptive learning is a methodology that allows to identify 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. LMS Moodle offers different solutions for adaptive learning. They provide administrators and teachers with tools to vary all stages of a learning process starting with delivery of information and ending with assessment.

1. Introduction

Utilization of digital instruments in educational process changed approach to learning of both teachers and students considerably. The concept of blended learning was developed which gave students more autonomy and requires increasing independency at the same time. Having implemented blended learning technology, its online part allows choosing place and time of performing tasks, planning own studying schedule, returning to studied material if needed, but that also requires from teacher's preparation of high quality learning materials and providing students with access to the materials. These changes correspond today's students' inquiry for digitalization of education and partly satisfies the needs in personalisation of educational process. However, most higher educational institutions still have unified learning materials which do not consider students' learning styles, knowledge level difference, needed depth of study, time frameworks for the course completion etc. Therefore, implementation of adaptive learning remains one of current HEI's tasks. Special attention from this perspective must be paid to electronic learning courses (ELC) as self-study process has rapidly been moving online during the recent decade, and electronic learning courses has become the basis for extracurricular work for both extramural and intramural programs. Thus, studying tools that allow adapting and personalizing ELCs



for students' individual needs is relevant today. That is why in Borys Grinchenko Kyiv University attention is paid to research on e-learning based on e-content utilization including e-learning courses and electronic collaboration (e-collaboration) of all educational process participants, particularly adaptivity in LMS Moodle and implementation of advanced digital technologies into educational process. Specialized solutions for adaptive learning such as Smart Sparrow, Alta, DreamBox, ScootPad are offered today for educational institutions, but they are only gaining their popularity and are not included into top 200 tools for learning in 2019 (<https://www.toptools4learning.com>). Moreover, their implementation in higher educational institution requires additional financing. Therefore, it is early to talk about wider usage of such solutions, and HEIs have to look for ways to implement adaptive learning with the systems they have already been using. One of such popular systems is Moodle LMS. That is why the task of this article is to analyze the ways of adaptive learning implementation using Moodle LMS.

2. Literature review

American psychologist and behaviorist B. F. Skinner who is considered to be a founder of personalized (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 [40]. Elements of adaptive learning were reflected in works of Hermann Astleitner and John M. Keller [3], B. Bloom [4], Volodymyr I. Bondar and Iryna M. Shaposhnikova [6], Lee J. Cronbach [12], Harold E. Pashler [33] and others. With the development of informational technologies educational process has shifted online. That led to appearance of such notions as "blended learning" and "electronic adaptive learning". In particular, research on blended learning was conducted by scientists Nadiia M. Boliubash [5], Olga V. Bondarenko [7], Donald Clark [10], Charles Dziuban, Patsy Moskal, Constance Johnson and Duncan Evans [13], Charles R. Graham and Jared Stein [19], Volodymyr M. Kukharenko [23], Nataliia Morze and Liliia Varchenko-Trotsenko [27] Anthony G. Picciano [35], Kateryna V. Polhun [36], Natalya V. Rashevskaya [38], Heather Staker and Michael B. Horn [41], Kaye Thorne [43], and implementation of adaptive learning by digital means was studied by Peter Brusilovsky and Christoph Peylo [8], Vatcharaporn Esichaikul, Supaporn Lamnoi and Clemens Bechter [16], Pavlo I. Fedoruk [17], Meg Coffin Murray and Jorge Pérez [28], Ok-choon Park and Jung Lee [32], Pedro Paredes and Pilar Rodríguez [31], Serhii M. Pryima [37], Lex van Velsen, Thea van der Geest, Rob Klaassen and Michaël Steehouder [44], M. L. Zueva [45] and others. Among the tools for implementation of adaptive learning in HEIs a 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 Gökhan Akçapınar [1], Valentina Caputi and Antonio Garrido [9], Deborah Couëdelo [11], Aleksejs Jurenoks [21], Vladislav Kukartsev, Ekaterina Chzhan, Vadim Tynchenko, Oleslav Antamoshkin and Alena Stupina [22], Linawati, NMAE Dewi Wirastuti and G. Sukadarmika [24], S. Nikitopoulou, E. Kalabokis, Z. Asimakopoulos and A. Apergi [29], Mark Rollins [39], Herman Dwi Surjono [42] and others.

3. Theoretical background

Prior to integration of any innovative tools and methodologies into educational process of a HEI the factors that influence the effectiveness of the process, satisfaction of all participants must be analysed as well as tendencies in educational technologies on international level. One of promising educational technologies according to "NMC Horizon Report: 2018 Higher Education Edition" [15] 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 as well as students' learning styles, habits and preferences. Thus, taking into consideration global tendency of shifting from a classroom learning to online learning many universities use blended learning to adapt a learning process to current educational process requirements.

Under such conditions a teacher is able to use innovative technologies such as mobile learning, gamification, storytelling, formative and peering assessment etc. This helps to vary the ways of delivery information to students and make learning process more flexible and corresponded to their needs.

According to the results of the survey of Borys Grinchenko Kyiv University students (<https://forms.gle/nZsjMtT6wEmvrSVk8>), where 119 students of 4 different fields of study took part, the respondents prefer the following sources of knowledge (fig. 1): electronic learning courses, mobile applications, video channels, social networks, googling, MOOCs, e-books.

What digital learning instruments do you prefer?

119 answers

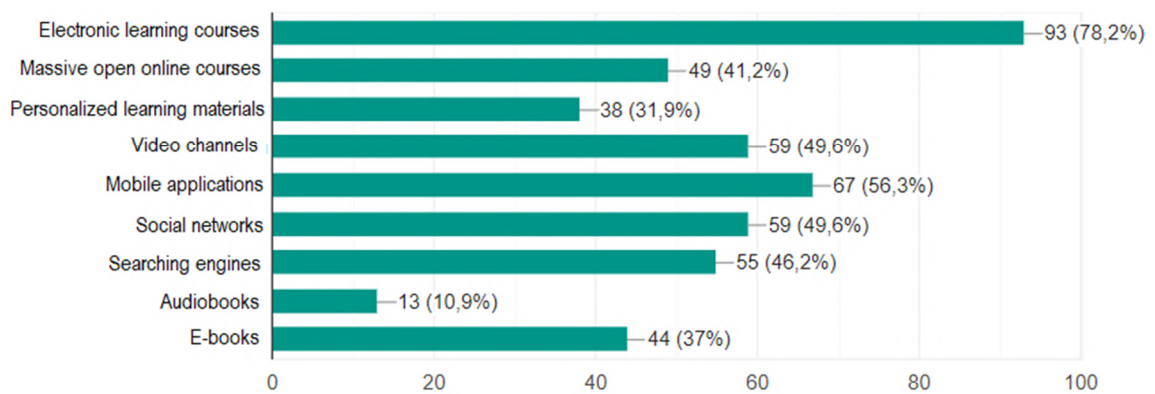


Figure 1. Students’ preferences of digital learning tools (own survey).

Thus, we can sum up that students prefer structured online resources. An effective solution is using e-learning and distant educational technologies; standardization in e-content and electronic learning environment development and global transition from Learning Management Systems (LMS) to Training Management System (TMS) [26]. The surveyed students noted the following advantages of e-learning as possibilities to choose time for learning, perform tasks online, separate tasks into parts for completing them, return to mastered material and availability of various formats of materials (figure 2).

At Borys Grinchenko Kyiv University e-learning system is used. Please mark advantages of using e-learning courses:

119 answers

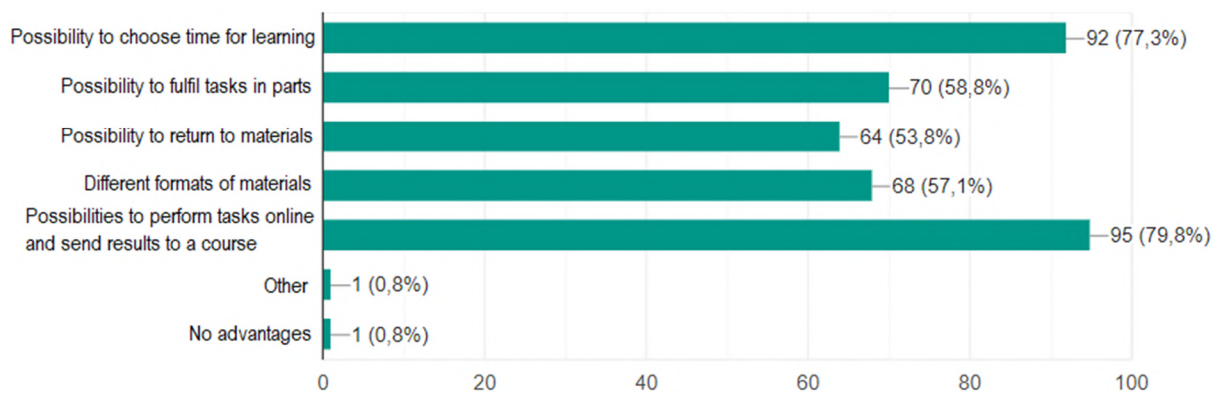


Figure 2. Advantages of e-learning courses (own survey).

Thus, e-learning courses (ELCs) provides adaptation of learning process to some level. However, unified ELCs do not fully cover students' request for individual approach to learning. In particular, the respondents of the survey noted among the main disadvantages of ELCs restrictions in time given for the course, lack of consideration of different learning styles in the choice of materials. A part of surveyed students also marked as negative factors lack of learning process personalization and unification of quizzes (figure 3).

Mark disadvantages in utilization of e-learning courses:

119 answers

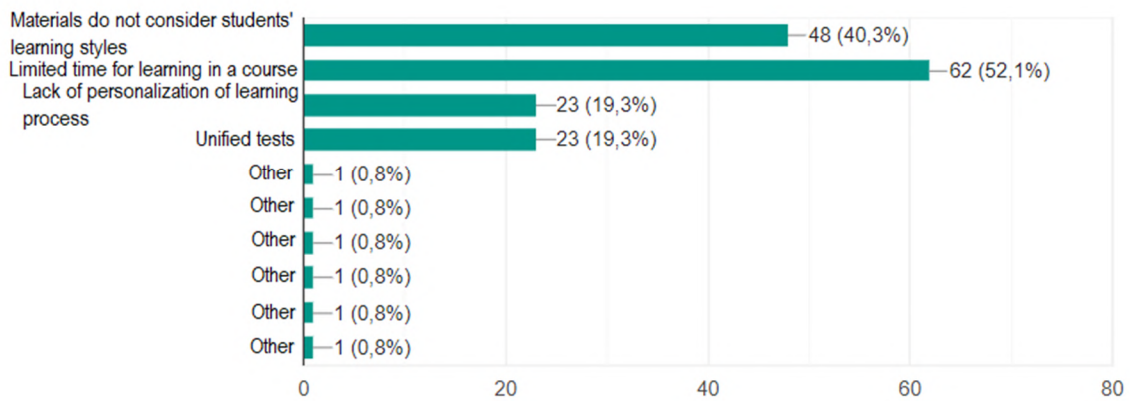


Figure 3. Disadvantages of e-learning courses (own survey).

Designers of e-learning courses face the need to consider users' requirements to provide better education results. The main challenges according to the results of the survey are providing various formats of materials delivery, offering terms of study choice, dividing quizzes and tasks into different levels of difficulty as well as providing courses at various difficulty levels in general, giving options of choosing sequence of study. Satisfaction of these needs is possible through implementation of adaptive learning (figure 4).

Mark what can improve quality of e-learning courses:

119 answers

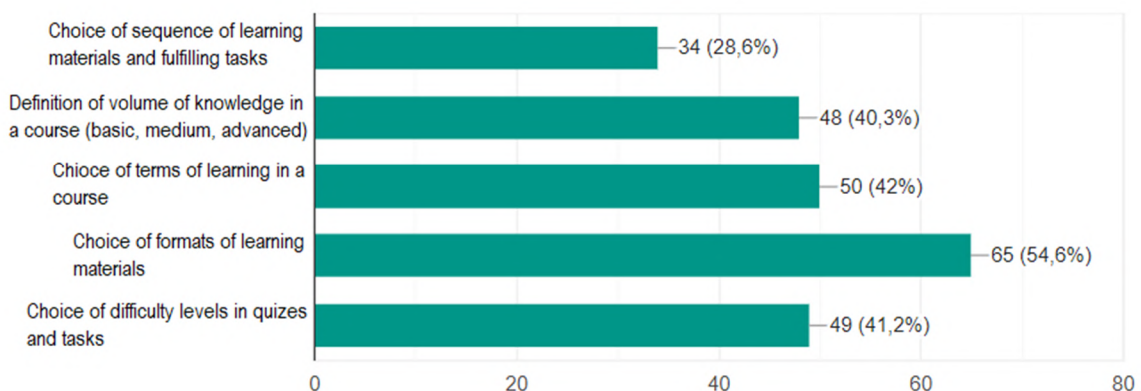


Figure 4. How ELCs can be improved (own survey).

Adaptive learning is a methodology that involves periodic information gain about knowledge level, learning styles of students and configuration of learning resources, tasks and assessment accordingly.

The aim of adaptive learning is to provide students with the means to acquire information according to their training needs and cognitive peculiarities. Requirements to adapted learning materials are formed considering aims of educational process. Current level of students' knowledge is to be taken into consideration as well as difference in learning styles and individual needs. One of the tasks of an educational institution is to provide the same effectiveness of educational process for the students who are new to the academic field and those who have prior academic experience.

Adaptive learning tools are technologies that are able to synchronize with learning process and being based on machine learning technologies can adapt to the progress of each student and change learning content in real time without outside help. Adaptivity can be displayed in one or several elements of technology: content, assessment, sequence [14].

Adaptive content means providing learning materials in the format that allows students to move their own educational trajectory. Adaptive content is fulfilled through contextual help, content splitting, separation of material into parts, possibility to choose volume and format of material. For example, in the process of an online lecture students' level of knowledge can be assessed with the help of questions and a student can be directed back to the part of information which is not mastered enough or they can be allowed to skip some part of information as mastered before.

Adaptive sequence involves automated choice of relevant content, difficulty level and order of studying the material on the basis of learning activities analysis. The tools with adaptive sequence are the most complicated ones as they analyse data, form and change individual trajectory of a student in real time simultaneously.

Collecting data is not limited to accumulation of information about right and wrong answers. To design an individual learning trajectory adaptive software considers many different indicators such as accuracy of answers, number of tries, use of additional tools, interests of a student (e.g., which subjects they prefer).

Adaptive sequence is implemented in three steps: collecting data, analyzing it and adjusting a sequence of the material layout to the needs of the student. The main advantage of a learning tool with adaptive sequence is filling existing gaps in knowledge. If a student missed a class or did not master it enough and now it complicates learning new material, the sequence of tasks and topics changes. A student initially fills the gap in his or her knowledge and afterwards moves to current topic.

Adaptive assessment means that any question depends on the answer to a previous one. The better it is, the more difficult tasks are given afterwards; and vice versa: if it is difficult for a student to answer a question, the tasks will become simpler until the student acquires the knowledge. Adaptive assessment tools are usually used for periodical monitoring once in a few months. students receive a relatively sizable quiz task to check the level of material acquisition during a module, a semester etc. After a monitoring data is analysed and the results are used for further correction of the program and of individual learning trajectory of each student. That is why one of the advantages of adaptive assessment is detailed statistics.

One of the ways to implement the above mentioned elements of adaptive learning is introduction of specializes complex solutions (systems, platforms, software) like Smart Sparrow, Alta (by Knewton), DreamBox, ScootPad and others.

Smart Sparrow (<https://www.smartsparrow.com>) is an educational platform which offers adaptive and interactive learning solutions. For implementation of **adaptive sequence** it uses designed adaptivity and algorithmic adaptivity. Designed adaptivity is a method that provides a teacher with tools to create a sequence to lead a student through the content with the best result. The model is programmed to react to a student's feedback and change a sequence according to their needs including offering advanced materials for well performing students and slower pace for those who cannot master materials in short terms. Algorithmic adaptivity is based on estimation of a student's current level of knowledge and definition of next required learning experience. The platform offers also options for **adaptive content** and **adaptive assessment**. The main idea behind Smart Sparrow solution is to provide students with as

much personalized learning experience as possible giving educators pedagogical freedom in planning their courses. Learning analytics is one more tool to evaluate students' performance and to customize courses to their needs and learning abilities.

Alta (<https://www.knewton.com/why-alta>) is adaptive learning courseware offered by Knewton company. The software strongly relies on real time analytics tools which help to **manage content and sequence** of a course. The main idea is to help student perform the best in their courses by revealing their gaps in the process of assignments completion and providing them with materials to fill in the gaps. Being concentrated on sequence and content, the solution claims that formal assessment is not required to direct learning process, as the software evaluates students' performance in the process of tasks completion. However, learning objectives have to be chosen to build a learning trajectory.

DreamBox (<https://www.dreambox.com>) is an example of an adaptive solution for a very specific market. It is focused on providing schoolchildren with math knowledge. Adaptation of learning trajectory is assured through constant formative assessment and adjusting instructions and offered materials according to the results of the assessment. In terms of **adaptive content** level of difficulty, number of hints, tempo and **sequence** of materials are chosen for each individual student on the basis of their previous performance.

ScootPad (<https://www.scootpad.com>) offers adaptivity at several levels: adaptive diagnostic, adaptive practice, just-in-time lessons, automatic remediation and automatic assessment. The platform allows to combine automated and teacher-driven activities. The main focus is on **adaptive sequence** that is aimed at mastering topics where gaps were detected in the assessment process.

The above mentioned solutions are able to cover an educational institution's needs in adaptivity of learning process. However, they require solid investments as well as integration with existing learning management systems. That is why HEIs might consider possibilities of implementation adaptive learning elements with the means already used at a particular university. One of such examples can be LMS Moodle which is popular among educational institutions as it is open source, can be customized and offers a lot of different solutions for various learning purposes.

LMS Moodle offers fragmentary solutions for all types of adaptive technology - sequence, content and assessment. However, we have to consider that adaptivity is not the only task of the system. Implementing different adaptive elements in an electronic learning course, we must take into account tasks of a particular course, ways it is delivered to students and students' needs in personalization. Utilization of blended learning makes it easier to structure an e-learning course and define how it can be adapted. The model below (figure 5) determines the stages of e-learning course design and implementation including those ones where adaptivity can be offered as well as highlights the resources of Moodle used to materials and tasks. These resources will be analyzed below in terms of adaptivity.

The important stage in the implementation of the model is determination of intended learning outcomes (ILO) that could be based on Bloom's taxonomy [4] modified by Lorin W. Anderson and David R. Krathwohl [2]. According to the taxonomy there are six levels of cognitive skills: remembering, understanding, applying, analyzing, evaluating and creating. In blended learning system remembering and understanding – lower levels of cognitive skills – are achieved through out-of-class activities which require only familiarization with the materials. Whereas analyzing, evaluating and creating – higher levels of cognitive skills – are mainly formed during in-class activities. This kind of determination might be helpful in defining learning levels and their further utilization in adaptation of content, sequence and assessment (figure 6).

At the stage of determining ILOs the criteria for evaluation of students' knowledge and skills initial level and of their learning styles are determined to be used for further choice and graduation of learning materials. In Moodle LMS that can be implemented with the help of Feedback, Quiz or Survey activities.

The **Feedback** resource provides an opportunity to create a survey with different types of questions including multiple choice, yes/no, short text answer, numeric and other types of questions which are suitable both for identifying learning styles, levels of knowledge and for level of satisfaction definition during the learning process. The resource allows reviewing statistics data in the form of diagrams, tables and downloading them for further working out.

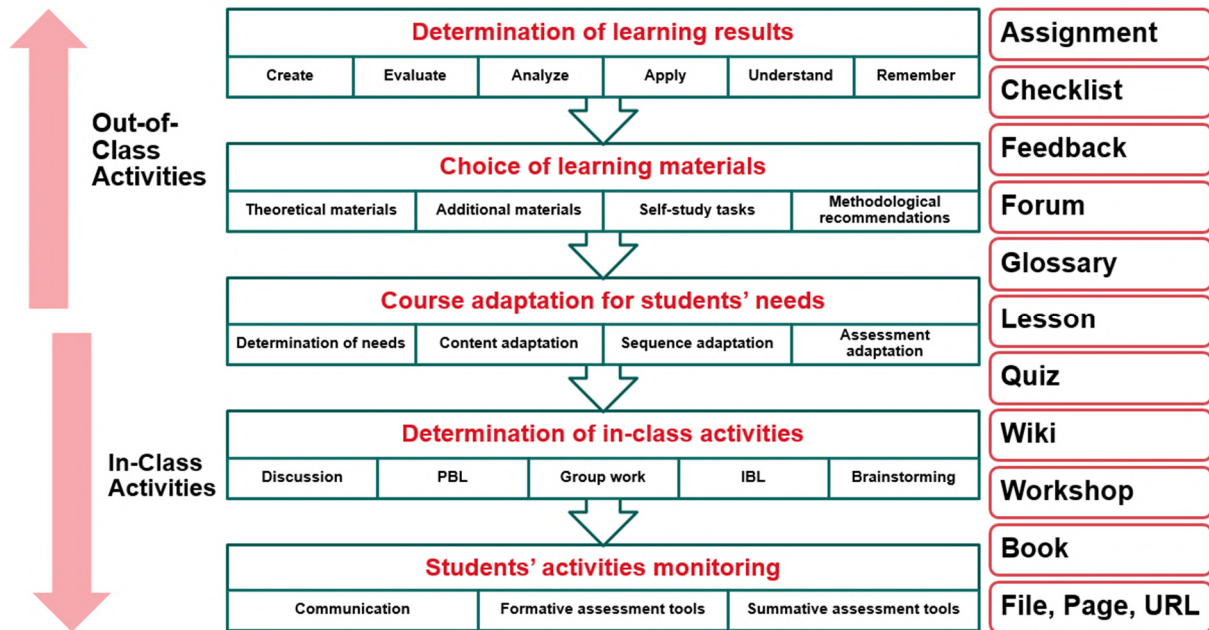


Figure 5. Model of blended learning implementation in e-course.

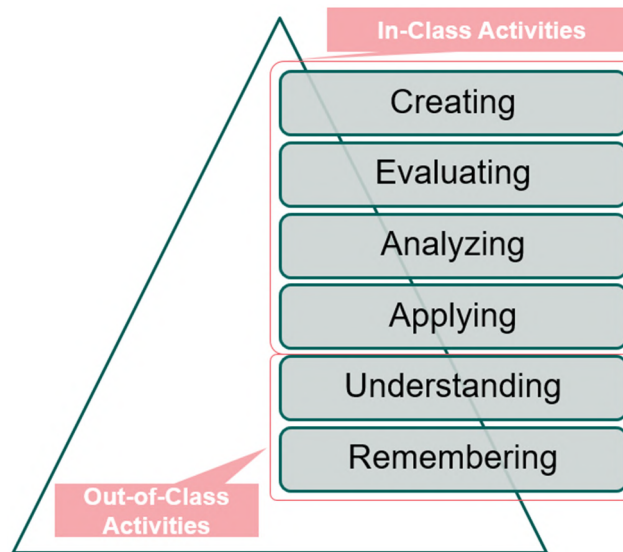


Figure 6. Utilization of flipped learning [20] and Bloom's taxonomy [27].

The **Quiz** resource allows ranging students' levels of knowledge using standard tests. With the option *Overall feedback* the borders for each level of knowledge are set up and a student receives a corresponding feedback after passing a quiz. For example, students with the results higher than 80% could be offered to take an advanced course, those who have their results between 60 and 80% get standard course, and the students whose achievements are under 60% will be offered a basic course.

The **Survey** resource can help to evaluate the collaborational level of a group using *Attitudes to Thinking and Learning Survey* (ALLTS) option. This allows estimating optimal ratio of individual and group work in a particular group.

At the second stage of implementation of the above mentioned model a teacher prepares learning materials according to the determined ILOs. At this stage adaptation of e-learning course is being fulfilled.

In the process of adaptation of learning materials students' learning styles ought to be considered, for example, using VARK model [18].

Activities of Moodle LMS allow simultaneous utilization of different types of materials to provide better information acquisition by students with different learning styles (figure 7).

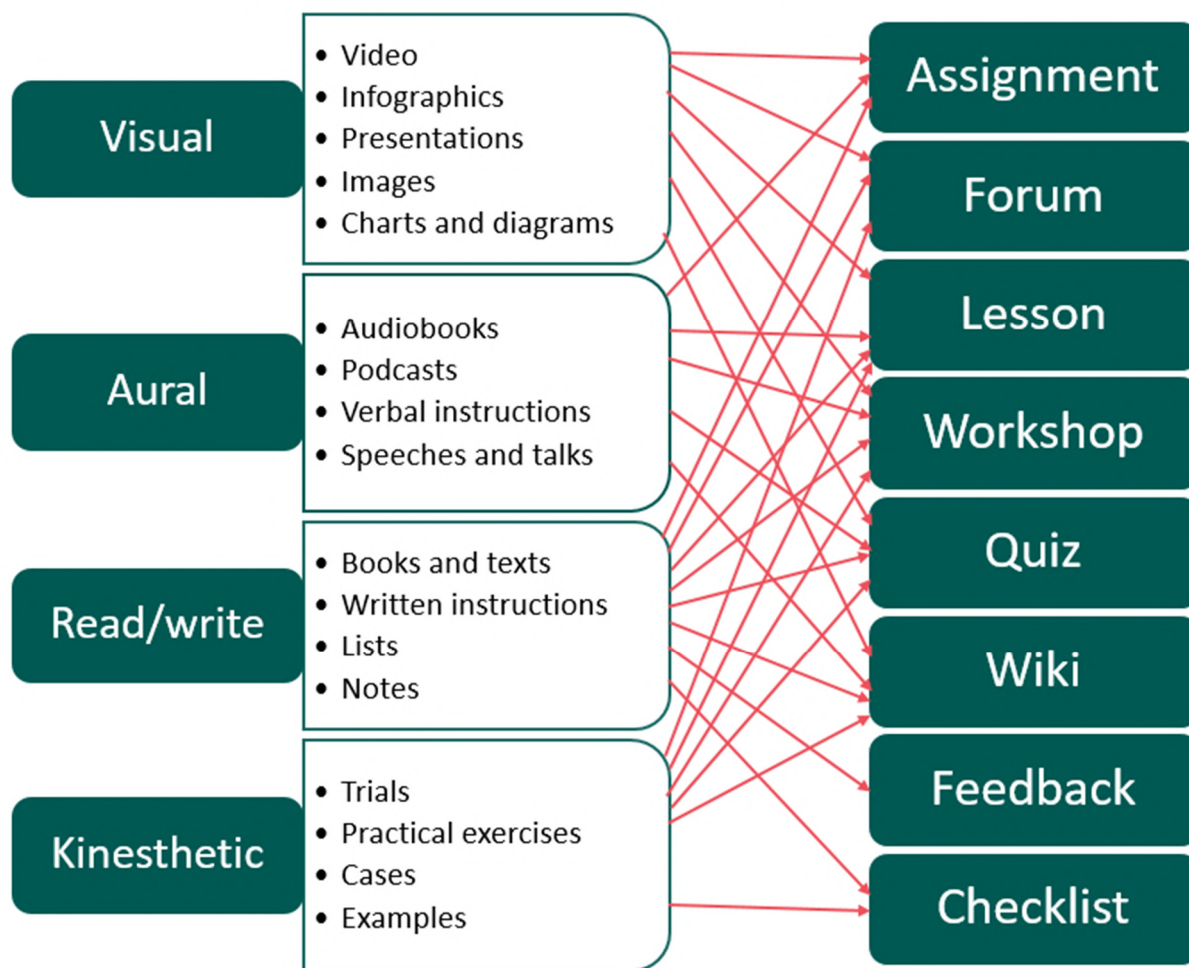


Figure 7. Utilization of Moodle activities for preparation of learning materials using VARK model.

A teacher can create groups of users in an ELC according to their learning styles if required, and then assign correspondent groups to different added activities. That means that every student will see individually assigned materials.

Let us have a look at the scheme of possible adaptive sequence in an ELC (figure 8).

A teacher can use **Lesson** activity to provide consequent theoretical materials (that is a set of pages with lecture materials) or to organize 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 9). Depending on student's answers 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 other way that correspond 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.

Lesson	Assignment, Workshop	Quiz
<ul style="list-style-type: none"> • Pages branching system design with different options of passing a lesson <ul style="list-style-type: none"> • Minimal level • Medium level • High level • Advanced level • Additional materials 	<ul style="list-style-type: none"> • Transmission to a task depends on the level of a lesson passing • Limitation of passing score • Depending on the gained score transmission to different level of a test 	<ul style="list-style-type: none"> • Quiz passing depends on the score level for practical tasks • Different quiz modes (using hints, etc.)

Figure 8. Scheme of adaptive sequence example.

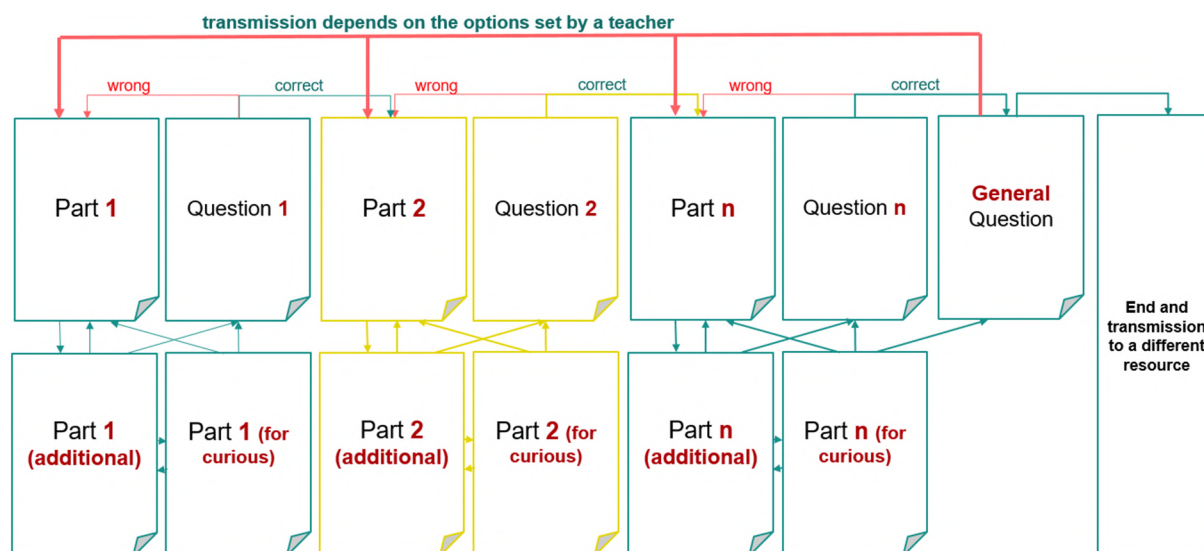


Figure 9. Logical scheme of an adaptive lesson.

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 tools that can be helpful for implementation of adaptive materials, in particular, assessment is a **Quiz** as some options in the quiz resource allow students not only to answer questions, but also interact with the system, impact possible frameworks of getting a note.

Design of such questions is provided with the help of the option **Question behaviour** that is used to choose test passing mode by students. Let us go into details about the quiz modes.

The modes **Adaptive mode** and **Adaptive mode (no penalties)** allow students to make many tries before going to the next quiz task. That is if a student is not sure about the answer, it's possible to check it during the quiz and change the answer. However, during the second and following attempt a note will be calculated including penalties set up by a teacher. Adaptivity of assessment using these modes is in giving students choice whether they want to check correctness of an answer and change it, which will lead to decreasing of the overall score but at the same time lower the risk of failing a particular test.

Using the mode **Interactive with multiple tries** a teacher can provide students with hints to help them answer the questions. As soon as a student provides a correct answer, a hint is not offered. When a student used all available hints for a question, the latest answer is marked as either incorrect or correct including the penalty for using hints and feedback is provided. A student can have different feedback after each try. The number of attempts is limited to the number of hints plus one. Utilization of such

mode gives students choice whether to use hints for regulation of their results or not. Using hints increases the possibility of choosing correct answers but makes it impossible to gain maximum score.

In the mode **Deferred feedback with Certainty-based marking (CBM)** or **Immediate feedback with CBM** a student not only answers a question but also marks the level of certainty in percentage. The classification of the answers is adjusted depending on the level of students' certainty. That means if they answered correctly, but it was just a guess about the correctness of the answer, their score can vary from 1 to 0.33 points. If students answered wrong, but showed high level of confidence in their answers, their score can be adjusted from 0 to -2 points.

Adaptivity of assessment using this mode is in the fact that students can get different marks depending on their level of certainty in their knowledge. A student is able to decrease the percentage of confidence consciously which lowers the risk of receiving a negative score, but at the same time makes the highest possible score also lower. Utilization of the mode motivates students to estimate their level of knowledge objectively and stimulates to pay attention to problems and solve them unlike traditional testing.

The Quiz activity can also be a part of adaptive sequence of an e-learning course as with its help depending on the score of a student they can be offered different feedback and directed to different parts of the course if some materials require revision or deeper learning.

The assignment activity module allows teachers to design tasks, collect students' answers, assess them and provide feedback on them. With the help of this resource adaptive assessment can be implemented giving students tasks of different difficulty levels based on their previous answers.

That means the activity can be used for collecting and traditional assessment of students' activities at all stages of a learning process. Students are able to send any type of digital content (files) such as text documents, spreadsheets, pictures, audio and video files. In addition, students can be allowed to input answers in a text editor in an e-learning course. Tasks also might be used as a reminder for students about activities which must be done during in-class lessons.

At the stage of defining results of students' in-class activities attention should be paid to achieving ILOs aimed at developing higher levels of cognitive skills. While choosing tools for students' activities monitoring a teacher defines how different types of communication among students and between students and a teacher will be implemented.

Considering all above mentioned information, Moodle LMS provides teachers with possibilities to implement personalization and adaptation of educational process tasks.

4. Conclusion

Adaptive technologies have both advantages and disadvantages. Among the advantages there are productive learning and accurate recommendations for every student. The disadvantage is that they require much more time for implementation compared to traditional learning and adaptive technologies do not solve the problem of knowledge usage in real life.

To introduce adaptive learning in the learning process of higher educational institution specialized solutions can be used. However, Moodle LMS which is already implemented at many HEIs offers wide range of options for a teacher to plan and implement adaptivity in the process of an e-learning course design at all levels - adaptive content, adaptive sequence and adaptive assessment. In the centre of this process there is a teacher who can choose the ways of implementation understanding peculiarities of students and their educational needs and learning styles. That is why the main task in implementation of personalization and adaptive learning is training lecturers, as their role is no more limited to mechanical knowledge giving and testing, but requires design of practical and creative tasks, project supervision and help with time management. That is why educational process with implementation of adaptive technologies emphasises the role of teachers even more.

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Developing and using open electronic educational resources in educational activities

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Abstract. The article looks into the effective use of open electronic educational resources. The concept of open electronic educational resources is exposed, their structure and key elements are presented, issues of implementation in educational practice are considered. Requirements for open electronic educational resources are defined, tools for designing and platforms for their support and dissemination are identified. The analysis of the existing open electronic educational resources and the experience of their use is conducted. The principles of open electronic resources design based on crowdsourcing are revealed. The stages of creating e-learning resources that meet open Creative Commons licenses on the examples of pre-service teachers' training are explored. The essence of Creative Commons licenses is reflected. The theoretical and methodological principles of the use of open electronic educational resources in the educational activity of pre-service teachers are considered. There is a direct link between open educational resources and university education.

1. Introduction

Open education, despite its close connection with information and communication technologies, is considered not only in the field of information. The modern ICTs are powerful tools of intensifying the educational process and related organizational processes and activities within the framework of education gaining greater openness and enhancing the unity and coherence of the educational and scientific system. However, informatization and the implementation of new means, tools and materials into the educational process cannot be considered the ultimate goal of open education.

Open education is not also limited to providing free access to a variety of educational materials. Modern educational practice requires tools not only for publication and storage, but also for a sophisticated set of tools for working with different materials according to clearly defined criteria within educational systems, both within and outside the education institutions. In addition to providing free access, users should also be given the opportunity to work collectively with the materials, modify and adapt them to the needs of their own teaching and learning.

2. The results and discussion

The penetration of computer technology into the educational space has led to the creation of new forms of learning activities and electronic content. The development of the global computer network in 1999 enabled the University of Tübingen in Germany to publish video lectures [40]. The Massachusetts Institute of Technology supported the initiative and launched its MIT OpenCourseWare project in 2002. MIT's reasoning was to "enhance human learning worldwide by the availability of a web of knowledge"



[43]. Researchers at MIT were convinced that the availability of open learning materials would be an additional opportunity for students to prepare better for classes and make learning more active. In the same year, 2002, with the support of Hewlett Foundation, the research began on the issue of using information and communication technologies to increase access to quality educational content.

Identifying free access to quality academic content as a strategic international initiative to extend people's material freedom, Daniel E. Atkins, John Seely Brown and Allen L. Hammond have planned to overcome such problems as: "poverty, limited economic opportunity, inadequate education and access to knowledge, deficient health care, and oppression" [2]. The overriding task is to use ICT to balance the distribution of high quality knowledge and to increase educational opportunities for people, teachers and institutions around the world. A combination of the following components is required to enable access to high quality educational content:

- *sponsorship of high quality open learning content* (funding and promoting of the best samples of high quality open content; setting quality metrics for different forms of educational content);
- *removal of barriers* (focus on web technology; adherence to open standards; multilingual learning content; availability of technological infrastructure);
- *awareness and stimulation of use* (creating networks of developers and users for sharing and collaboration; supporting scientific research on ways of improving efficiency and enhancing evaluation of results).

Liudmyla H. Havrilova's research [10] raises issues of open access to scientific information in connection with the development of "green" and "golden" ways of science development. In particular, the researcher highlights the important role of social networks for scholars, which also become popular and describe role of Ukrainian and international educational global networks Academia.edu, ResearchGate, iEARN, ResearcherID etc. for scientists.

Today, this initiative is often known as the Open Content Initiative or Open Educational Resources (OER). We will use the term which, in our view, is more successful "Open Educational Resources" or "Open E-Learning Resource". OER are teaching resources, learning materials, or research resources that are in the public domain or released under an intellectual property license that allow them to be freely used or reassigned to others. Open educational resources include full courses, training materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or methods used to support the access to knowledge.

Electronic libraries of books, electronic archives and other scientific and educational resources have become very popular in Ukraine in recent years, and information and communication technologies are widely used in the promotion of scientific knowledge. Electronic research and educational resources open to widespread network access are usually funded by donations. National funding programs are also working in several countries. In particular, such programs are available in the USA, Japan and some European countries. We should note that the budget of each program can be up to several million dollars. Online libraries of books and information resources are very much in demand, but not with a great amount of sponsorship money, such as contextual advertising for the sites of publishing houses or best-seller books. These resources live in accordance with the completely different laws. Their goal is not to make money for their owner, but to accumulate and disseminate information electronically to the interested audience. Electronic book libraries greatly contribute to the preservation of scientific and cultural heritage, the development of literacy and knowledge; they increase the efficiency of work and study, regardless of the social status of those who want to study.

In the current legislation of Ukraine, electronic educational resources are divided into the following types: electronic documents, electronic publications, electronic didactic demonstration materials, information and analytical systems, depository of electronic resources, computer tests, electronic dictionaries, electronic directories, electronic libraries of digital objects, e-tutorials, e-textbooks, e-teaching materials, distance learning courses, and e-labs, including virtual labs [28]. However, the issue of openness of electronic educational resources has received little attention.

The quality of e-learning resources is the equally important factor. The International Standard ISO/IEC 40180:2017 "Information Technology – Quality for Learning, Education and Training –

Fundamentals and Reference Framework” [15] is the basis for describing, comparing, analysing, managing quality and approaches to quality assurance in the sphere of e-learning resources. The standard is a tool for comparing already known approaches and agreeing them on the basis of a common quality model. A key element of the standard is The Quality Reference Framework (QRF) for E-Learning. The QRF combines an elaborated and extensive process model with a descriptive model for the processes. ISO/IEC 40180 harmonizes existing approaches, concepts, specifications, terms, and definitions related to quality for E-Learning, education and training. But, unfortunately, most of the requirements of ISO / IEC 40180 apply only to the quality of development of IT systems for teaching, learning and vocational training. Therefore, we can assert that international standards also do not disclose the concept of quality of OER and do not contain requirements for its provision.

In Ukraine, the quality of electronic educational resources is determined by the following state standards: DSTU 7157:2010 “Information and Documentation. Electronic Publications. The main types and background information”; DSTU 4861:2007 “Information and Documentation. Publications. Background Information”; DSTU 3017-95 “Publications. The main types. Terms”. It should be noted that these regulatory documents contain only general classification information. The most extensive information on the classification of e-learning publications is given in the Order of the Ministry of Education and Science of Ukraine [28], which defines the concept of electronic educational resources (EER), their types, and the order of development and implementation. But, unfortunately, these documents do not contain any requirements for the completion and formation of EER.

According to the functional feature, which determines the value and place of electronic educational resources in the educational process, they can be classified as:

- educational and methodological electronic educational resources (curricula, syllabi of disciplines, developed regarding to the curricula);
- methodological electronic educational resources (guidelines, methodological manuals, guidelines for the study of a specific course and guidance on project work, thematic plans);
- teaching electronic educational resources (electronic textbooks and manuals);
- supervising electronic educational resources (testing programs, banks for supervisory questions and course assignments, and other EER to ensure quality control of knowledge);
- auxiliary electronic educational resources (collections of documents and materials, indexes of scientific and educational literature, scientific publications of teachers, proceeding papers, electronic directories, dictionaries, encyclopedias).

A significant number of different types of e-learning resources also cause a significant number of structural components, which they consist of. The simplest version of electronic educational resources is an electronic version of a printed document. And even in this case, it can only be about the availability of electronic document navigation, the ability to search in the content and formats of electronic document presentation. A more sophisticated version of an e-learning resource, such as an e-learning course, consists of several simpler e-learning resources, including: background information, training tools, testing and monitoring quality of learning material, background information on available tools and resources of the e-learning course etc.

Similar components are distinguished in an electronic textbook – an educational tool that contains a systematic presentation of course materials and meets the requirements of interactivity, integrativity, adaptability, modularity, etc. Nowadays, there is a finite number of such publications for higher education institutions in Ukraine, therefore, according to Inna A. Khyzhniak [19], educators should regularly explore the market of electronic textbooks on the sites of Ukrainian publishing houses (“Nova Shkola”, “Atlantic”, “Osnova”, “Ranok” and others), on general and special educational sites (<http://www.mon.gov.ua/>; <http://osvita.ua/>, etc.), as well as they should critically assess their quality and master methods of their use.

The issue of determining the form of an e-learning resource presentation that is the most appropriate for the certain category is more complex. The correspondence between the style of activity in solving the practical range of problems encountered during life, and the style of learning, and vice versa is proved by David A. Kolb [22]. Nataliia V. Morze and Olena G. Glazunova discuss the relationship

between learning styles and online course performance in detail [30]. This study identifies the optimal structure of the e-learning course and the presentation of learning resources for the students of IT profession according to their learning style. The formats for the presentation of study materials should be selected taking into account the students' dominant learning style.

Vladyslav Ye. Velychko defines standards for the development and transfer of digital e-learning from one e-learning course to another [41], analyses available tools based on free software for the design of digital e-learning objects. A study of free software tools used to create e-learning courses makes it possible to conclude that the software products not only allow them to be used in the specified way, but also have every reason and are a powerful and practical arsenal that should be purposefully aimed at the process of system use in the creation of automated systems for the development of e-learning courses [6], [42]. These findings are further supported by existing standards for the exchange of educational facilities and their support for e-learning systems, which testifies to the long-term prospects for the use of EER in education and the modernization of teaching methods.

Olena G. Glazunova et al. describes the similar method for designing sophisticated electronic educational resources by the use of digital learning objects [9]. The result of the process of creating e-learning resources should ensure that each discipline has a certified e-learning course, the resources of which correspond to: substantively – the standards of education on the profile; the form of presentation – the order on electronic training courses, and educational style; methods of use – provide an individual trajectory of learning, using both local and network resources. The process of creating electronic educational resources is based on a systematic, synergistic, personally centred and reflective methodological approaches. To create high-quality electronic educational resources, it is necessary to consider the principles of adaptability, flexibility, modularity, accessibility, and individuality.

The use of electronic educational resources in teaching activities is a complex issue [18]. Firstly, it is necessary to determine the very fact of the need for such application. Determining the effectiveness of the use of e-learning resources in educational activities is possible if at least one of the following indicators is improved:

- enhancing the motivational and emotional side of learning;
- improving the quality of training;
- releasing study time;
- reducing financial costs for training.

In this regard, the readiness of pre-service teachers to use e-learning resources is an important issue [23]. To measure this teacher personal phenomenon, Inna A. Khyzhniak [20] has developed a detailed criterion-level structure that illustrates the relationship between components (motivational-value, cognitive, operational-active, and projective) and levels of readiness to use electronic educational resources in professional activities: intuitive-receptive, reproductive, productive, and research-creative. Exploring the practical aspects of creating electronic educational resources by both students and teachers, Inna A. Khyzhniak [21] notes that the degree of teachers' motivation is generally sufficient, but the level of their technical skills in creating high-quality electronic learning tools, especially using open source software, is a problematic issue for modern secondary and higher education. However, the linear multimedia PowerPoint presentation is the most commonly used in educational practice, and sometimes it is the only variation [3].

The second issue is the quality of e-learning resources. As it has already been shown, the quality of e-learning resources is a complex issue that needs to be taken into account. Thirdly, there is a need to gain sufficient experience of using e-learning resources in educational activities. Pavlo P. Nechypurenko et al. consider the electronic educational resources to be the basis of the modern educational environment of education institutions [31]. The creation of e-learning resources, which has become widespread in countries with a high level of development of education systems, is a necessary process for education increase. This process is also taking place in Ukraine, but its effectiveness is far from desirable. The target of education informatization in Ukraine [7], which has been relevant for more than 30 years, remains completely unfulfilled, since the system of creation and introduction into the educational practice of electronic educational resources is far from perfect. Simple calculations show that it is almost

impossible to fully commercialize the development and production of electronic educational tools in Ukraine. Hence, it becomes clear that we should return to state-level support for this process and begin the creation of a public e-learning repository.

There are tools for meaningful visualization of educational material [16], [27]. An example of such a visualization is an interactive image or video. An interactive image is understood as a photo, image or video fragment in which there are active areas, the choice of which leads to the corresponding action. For example, following a link, showing a card, an additional text, a photo demonstration, etc. With these images, you can create many interesting projects: interactive biographies, timelines, experimental results, content and history of mathematical and physical formulas, etc. [17], [25]

The benefits of such systems usually lie in a wide range of project types (travel maps, tutorials, posters, interactive diagrams, virtual tours); each project can be created both individually and together with other users of the platform, including teamwork; other users' library, each project can be copied and then edited; editing projects is possible at any time with a wide range of options. The completed project can be saved online, distributed on social networks, or embedded in HTML into your own blog or site.

Interactive image creation tools include Thinglink (thinglink.com), Glogster EDU (edu.glogster.com), H5P (h5p.org); many other systems can be used for creating tests, crossword puzzles, quizzes, educational games, surveys, etc. [1], [29], [34], [37], [39].

Vladyslav Ye. Velychko's study examines in detail the tools for developing e-learning courses that include Xerte Online Editor, eXe e-learning XHTML editor and Reload Editor [41].

Founded in 2001, the Creative Commons Initiative is a satellite of the Open E-Learning Resource initiative. The main purpose of the organization is to help to revive the public domain among creative achievements, as the level of copyright for the produced electronic content has repeatedly increased due to the pressure from the media industry. Creative Commons as well as the initiatives for free software and open source are promoting collective goals focused on community and based on the principles of crowdsourcing. Creative Commons has developed a Web application that helps people provide their creative work with public license or partly retain copyright while licensing them as free for certain uses under certain conditions. Unlike the General Public License, Creative Commons licenses are intended not for software, but for other types of creative work: websites, music, movies and videos, photos, literary works, training courses, and more. The purpose is not only to increase the amount of open content on the Internet, but also to make access to materials free and easy. Regarding to this, metadata has been developed. They can be used by search engines and other online applications for searching photos that are free of charge when the original photographer is mentioned, or songs that can be copied, distributed or downloaded without any restrictions.

Today there is a considerable range of e-learning resources available for information supporting, functioning and developing of the education system. Among them Mariya P. Shyshkina distinguish the following resources [36]:

- local and network electronic educational tools, in particular optical digital media;
- educational web-resources: special sites, electronic collections, libraries, collections of learning materials, etc.;
- electronic databases and bases of knowledge of educational purpose;
- e-learning systems and platforms, including distance learning and virtual learning.

Also, there are other types of classification of electronic educational resources in accordance with: areas of use, interaction architecture, form of implementation, spatial limitations, etc. It is a significant issue for our study to classify the electronic educational resources by the type of learning activity (table 1).

Tian Luo, Kirsten Hostetler, Candice Freeman and Jill Stefaniak present an analysis of the current state of using the open electronic educational resources. The researchers came to the following conclusions: "discoverability, sustainability, and remixing are significant barriers that stand in the way of OER disrupting traditional textbook models; there is no significant difference in learning outcomes

when instructors incorporate OER; implementation of OER as instructional strategies is challenging but can be effective in supporting positive learning outcomes when properly designed” [24].

Table 1. Classification of the electronic educational resources.

Type of learning activity	Electronic educational resources
story, explanation, conversation, lecture, illustration, demonstration	demonstrative, referative, multimedia
writing exercises, problem solving, training and consolidating skills, lab work	expert systems, simulation and modelling environments, electronic textbooks, manuals, electronic workshops, simulator programs, electronic laboratories, training programs, laboratory stands
written control, laboratory control, machine control, self-control	e-learning training laboratories, e-assessment systems, tests, e-exams, e-assessment systems

Stefanie Panke, Rick Morse and Spencer Stone [32] investigate the use of open e-learning resources in non-formal learning and methods of implementing open e-learning resources in learning activities. Researchers discuss the benefits of using and creating open textbooks and, as a result, describe the process of creating the textbook “Local Government in North Carolina”. The theme example provides an overview of the open content and resources for developing a creative community for multimedia content and electronic books that meet specific educational requirements of promoting digital citizenship at the local government level.

The development of high-quality electronic educational resources requires considerable material and human costs. The published materials make it possible to get an approximate cost of developing electronic educational resources. Companies engaged in developing e-learning courses demand minimal expense in 2000 dollars for creating of the script, design, layout, and testing. There is an extra charge for video and audio, animation design etc. The cost of one online course at Coursera, a Stanford University project, is estimated at \$ 15-30,000 [5]. Developing the MIT OpenCourseWare course costs \$ 10,000 – \$ 15,000 [26]. As we can see, the development of e-learning courses is very expensive. Understanding that each e-learning course includes e-learning resources, it is possible to propose the development of an open e-learning course through a combination of an open learning management system and open e-learning resources. And if open learning management systems exist and their functionality is sufficient to organize and support e-learning, there are some difficulties with the development of open e-learning resources at this stage [38].

In order to develop open e-learning resources, we suggest engaging prospective professionals in their training. Learning activity involves not only the study of certain topics and disciplines, but also the practical reproduction of the acquired knowledge in teaching practice lessons. Adding to the practical tasks the condition of creating electronic content rather than paper one, we get a significant number of electronic documents that can serve as a basis for future electronic educational resources. Providing prospective experts with ready-made templates for the results of their research or certain rules for the design of electronic content, we will eliminate the need for formatting. Moreover, such tasks will increase the level of digital competence and introduce practice-based tasks into the learning process. The use of the project method, especially collective ones, is advisable. The project activity of like-minded people not only increases the ability to work in a team, but also improves the content quality of the work performed [4], [8], [14], [33], [35].

The next step to creating open e-learning resources is to publish them with mandatory licensing. Open licenses for Creative Commons electronic content, which are usually ignored, will educate prospective professionals about the licensed purity of electronic content. While training prospective professionals are using existing electronic content for their own reports. Therefore, the legal use of electronic content on the basis of academic integrity is one of the tasks of modern vocational training.

The final step is developing and building a repository of open e-learning resources. There are two different ways to resolve this issue. The first is that the state deals with it, and such projects of the repositories with the open electronic educational resources exist. Unfortunately, it is not the first year when in Ukraine such a repository is going to be created, but to no avail. Experts alone provide access to the electronic content developed on their own sites, pages and blogs, but finding the necessary information is extremely difficult. The second way is the use of resources from various foundations that support the ideas of open education. This example is OER Commons resource (oercommons.org). In any case, a dedicated system is essential for the dissemination of the open electronic educational resources. It will not only motivate professionals to create high quality open e-learning resources, but also maintain a high level due to the competition and collaboration.

A practical example of the introduction of these principles is the work on creating the open electronic educational resources at the SHEI “Donbas State Pedagogical University”. Pre-service teachers at different faculties are developing open e-learning resources that are both a complement to the university’s distance courses and standalone products. The course “Modern Information Technologies in Education”, taught at the faculties of the SHEI “Donbas State Pedagogical University” is aimed at providing prospective specialists with theoretically grounded knowledge and clearly developed skills of using modern information technologies in educational activities; preparing for self-educational activity and self-improvement, and therefore the lecture material contains, in addition to operational information about the considered systems, the methodological component of using their work results.

For the e-learning courses created by the Master students, in accordance with the curriculum of the discipline, their didactic capabilities were analysed. The results of the analysis showed that the selected free software allowed to create courses that: diversify forms of presentation of educational information and types of learning tasks; provide response to learners’ actions; individualize the learning process using basic and auxiliary learning influences; apply game techniques; reproduce fragments of educational activity; activate educational work, increase motivation to study.

The e-learning courses were implemented in two ways. For the courses using blended learning, they were imported into the distance learning system of the Faculty of Physics and Mathematics. The subjects taught in the traditional form used e-learning courses as educational material in independent work.

The reform of New Ukrainian School has given impetus to the development of electronic educational resources at the Faculty of Primary, Technological and Vocational Education of SHEI “Donbas State Pedagogical University” where since 2017 the process of developing electronic educational resources has taken place. For example, the implementation of Interactive Communication Electronic Training Simulator for prospective primary school English teachers [13] has undergone diagnostic, corrective, and analytical stages while being created. The final electronic questionnaire among students using Google Forms shows that the implementation of the simulator has increased the students’ motivation to study, strengthened their practical skills in using a foreign language, and developed acmeological aspirations.

Except of distance learning courses designed on the Moodle platform (“Introduction to the Teacher Profession”, “Linguistic Country Study”, “Electronic Linguomethodics”, “Multimedia Technologies in Art Education”, “Electronic Content of Studying Art Courses in Universities”, “Information and Communication Technologies in Pedagogical Research”), students of the faculty use the following electronic text-books and manuals in the educational process, developed by Liudmila H. Havrilova: “History of Ukrainian Music” and “Ukrainian Spiritual Music”, “Ukrainian Culture of the End of XIX – Beginning of XX Century” and “Information and Communication Technologies in Pedagogical Research” [12]. The electronic textbooks on professional methods of teaching primary school subjects and special courses has been developed: “Methods of Teaching the Ukrainian language”, “Children Literature and Methods of Teaching Literary Reading”, “Methods of Teaching the Subject “I explore the World”, etc.

Aiming at more systematic use of open educational resources, the lecturers of the Department of Primary Education Theory and Practice are designing the educational portal “Primary Education: Lifelong Learning” [11]. Its use, according to Liudmyla H. Havrilova and Olena S. Beskorsa, will help

to upgrade the system of professional training of primary school teachers, to create high-quality digital educational content that meets the requirements of New Ukrainian School and global trends of education informatization, based on studying the world and, in particular, the European higher education experience (see figure 1).

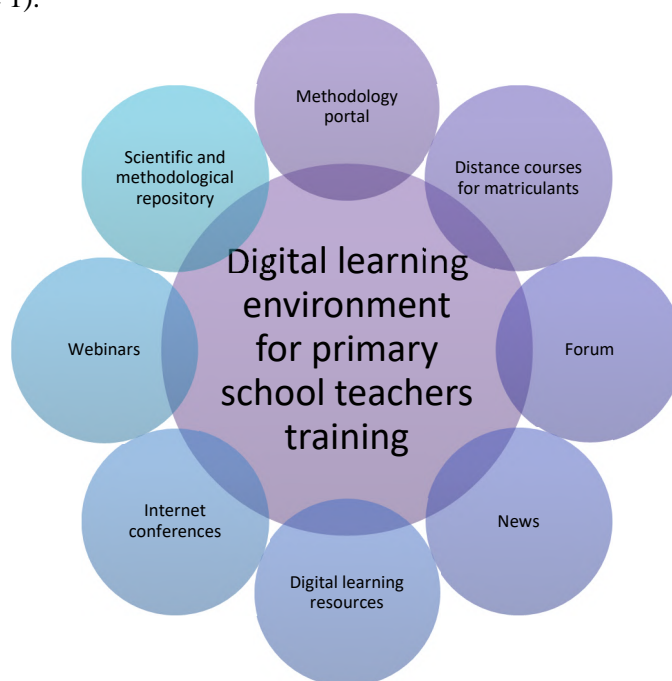


Figure 1. The structure of educational portal “Primary Education: Lifelong Learning”.

The educational portal is planned to be launched in 2020, taking into account the requirements of the platform Next Generation of Digital Learning Environment (NGDLE), which is a new generation of learning resources with modern software and has the following structure ([11], p. 55).

The Digital Learning Resources section provides online learning tools for primary school teachers. The Internet Conferences section includes effective scientific communication events by using both free and commercial software: Apache OpenMeetings, Adobe ConnectPro Meeting, BigBlueButton, Microsoft Teams, Microsoft Lync and others.

The Webinars section is used to provide educational online services on a free webinar platform: MyOwnConference, Google Hangouts, Facebook live, Skype Group Calls, and others. The Scientific and Methodological Repository contains an electronic library for students, the Methodological Portal includes the most successful lesson plans and extracurricular activities for primary school. The Distance Courses section contains links to Moodle or Google Classroom platforms where teachers have developed a great number of distance courses.

3. Conclusion

Providing comprehensive and equitable quality education and promoting opportunities of lifelong learning for all are priorities of society sustainable development. This form of education is realized through the implementation of the ideas of open education, in which open electronic educational resources play a crucial role. The development of electronic educational resources is a responsible and costly process. Implementation of the development of quality electronic educational resources is possible only in cooperation with specialists in various specialties.

We propose to involve pre-services teachers in this activity during their practical training. Developed by the prospective professionals, open e-learning resources hosted on the open platforms are expanding the learning content available. Prospective professionals will gain the skills of teamwork, participating in projects and increasing the level of mastering of information and communication technologies both

for their personal and professional needs. The design and development of open electronic educational resources is a creative process that reflects the level of training of future professionals. Fundamental training of pre-services future teachers, training in teaching methods in combination with ICT competence and soft skills under the guidance of a mentor give good results when working on projects. In addition, we solve issues of practical training for blended learning.

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Implementation of professionally oriented ICT in the process of managers training

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Abstract. The article touches upon the problem of introducing professionally oriented software products based on information and communication technologies into the educational process of training managers of the hotel, restaurant and tourism business. The purpose of the study is to prove the effectiveness of the implementation of professionally oriented software products based on ICT in the training of managers. The research is based on the analysis of recommendations of employers and managers of the specialties “Tourism” and “Hotel business”, the content of educational programs for training bachelors in management, the content of general professional and special competencies, the structural and logical scheme of disciplines. The most effective information and communication technologies using computer software products that contribute to the formation of a set of professional competencies in future managers have been identified: MS Project, Teamwork, TeamLab, Open Workbench, GanttProject, dotProject, Outlook, OneNote, EverNote, Nirvana, Wunderlist, Toggl, MS Office, Office 365, Document.Online, AllFusion Process Modeler 7, MS Visio, MS PowerPoint, MS Sway, Libre Office.Impress, FreeMind, Mind42, ViSta, MacANOVA, Matrixer. The effectiveness of these technologies has been experimentally tested in the course of practical training in the format of full-time distance learning and practical training of student managers. The research describes the technology of using professional software products in the educational process. The effectiveness of these technologies has been experimentally tested in the course of practical training in the format of full-time distance learning and practical training of student managers. The research describes the technology of using professional software products in the educational process. The results of the pedagogical experiment confirmed that the introduction of information and communication technologies contributes to the formation of professional competencies in the field of ICT among students of this specialty. The conducted research proves the need for changes in the working curricula of disciplines “Information systems and technologies”, “Practices of information and communication technologies”, “Statistics”, “Management and administration”, “Finance, money and credit”, “Accounting and audit”. “Business foreign language”, “Professional rhetoric”, “Foreign professional language”, “PR and advertising technologies”, “Business accounting”, “International business management”, “Electronic business information technologies”.

1. Introduction

According to the Unified Electronic Database on Education [28], in recent years in Ukraine the specialty of management (in particular, international companies’ management, hotel, resort and tourist service



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management, urban management) is among the top 5 popular specialties. In 2018 the statistics of submitted applications by specialties is as: law – 45 191 (of which for the budget – 23 443); management – 32 377 (of which at the budget – 14 778); philology – 24 582 (17 728 of them at the budget); computer science – 21 674 (of which at the budget – 15 129); journalism – 19 796 (12 867 of them at the budget). In 2019, the management ranked 4 by the popularity among the applicants. Applicants plan to assimilate the profession mainly in the cities of Kyiv, Kharkiv, Dnipro, Lviv.

At the same time, the results of the analysis of vacancies from popular job search sites [29], [30] at October 18, 2019 indicate the necessity in managers, in particular, management staff – 49 vacancies, administrative staff – 316 vacancies, tourism managers – 212 vacancies.

Surveys of freshmen in the specialty “Management” demonstrate a rather general idea of candidates about their future functional responsibilities and the perception of the profession as purely managerial. Therefore, during the first two years of study, students experience disappointment and loss of motivation to learn the profession. Often, employers’ negative references on graduating students training, the constant large number of job vacancies at the labor market require the reconsideration of approaches to training managers in the higher education institutions.

At present, there is a necessity in reconsideration of the content of educational program, to approach the issue of organizing the training of future managers, managers of different business groups in a new way, and to modernize the teaching process. In our opinion, one of the ways to solve this problem is the introduction of professionally oriented information and communication technologies in the educational process.

2. Literature review

For our study, the importance of scientific work in two directions: 1) to analyze the level of training of modern managers, society's requests for the competencies of managers in the tourism and hotel and restaurant business; 2) to analyze on the problems of selection and implementation of professionally oriented ICT in the educational process in order to meet the needs of employers and clients by the level of professional training of specialists.

The opinion of scientists is convincing ([1], [3], [5], [6], [8], [9], [10], [12], [16], [20], [22], [25], [27], [31]) that the introduction of ICT in the educational process helps to increase the efficiency of future specialists.

Priority directions for tourism and hotel and restaurant business are being formulated in major forums, such as “ENTER 2020” – XXVII Annual International Conference on E-Tourism, held January 8-10, 2020 at the University of Surrey in Guildford, United Kingdom [18]. In particular, the conference presented the latest case studies on the use of ICT in travel and tourism. The reports of the 2020 conference are devoted to the topic “Responsible e-tourism”, they raised the issue of ensuring the positive impact of tourism on society, including, among the problems reflected the training of relevant specialists [11].

Among the scientific works of the first direction, it is necessary to pay attention to the article Aleksandr I. Dikhtyar “Innovation and information support in tourism” ([3], p. 81), in which the state and prospects of development of tourist industry in Ukraine are analyzed. One of the ways to increase its competitiveness is to improve information support from the state (introduction of bar codes in smartphones, 3D tours of hotel complexes and restaurants, etc.). The author argues that the development of the industry is not possible without the qualified training of experts, knowledgeable in ICT.

The continuation of the problem raised can be seen in the article by Elena V. Vasileva and Anna E. Terekhova “IT competences of the management director's graduate in accordance with actual labor market questions” ([27], p. 249), which outlines requirements for a modern specialist in the field of tourism and hotel and restaurant business. One of the solutions, the authors propose to introduce on the basis of the discipline “Management Information Systems” special courses in the study of software special products: “CRM-systems”; “SAP Enterprise Corporate Information Systems”, “Oracle Enterprise Corporate Information Systems”.

In the context of our research, among the works of a scientific and methodological nature, we take

into account are important the such positions. Until recently, a limited number of specialty products were used in the preparation of managers of the hotel and restaurant and tourism business: 1C, Parus, Galaxy, Scala, Axapta. The methodology for their implementation is described in the publications of Natalia V. Repetckaia ([23], p. 215), Olesia L. Dyshko, Tetiana V. Zubekhina and Nataliia B. Pavlyshyna ([5], p. 78). In particular, Natalia Riepietskaia based on the results of pedagogical experiment on implementation of software products of 1C company in the training of managers (1C: Accounting, 1C: Management of a small firm, 1C: Document management, 1C: Salary and personnel management) concludes that the effectiveness of training will increase significantly with the active use of active and interactive technologies such as computer simulations, training, review and resolution of industrial situations in professional activities, including role and business games. The greatest effect, according to the author, can be achieved by combining business games with the use of modern professionally oriented ICT based on cloud technologies [24], [26].

Semen V. Drozdov and Nadezhda I. Almazova [4] based on the questionnaire of teachers involved in the training of managers (in particular, the specialty “Tourism”) concludes that it is advisable to expand the list of ICTs (e-learning platforms, Internet sites, multimedia presentations) with professionally oriented software. According to scientists, it will allow “to improve the quality of learning, to increase the efficiency of the educational process, to improve the methodology of content selection, methods and forms of education and upbringing, to activate the process of assimilation of information and to prepare future specialists for life in the conditions of the information society”.

Andrii Lytvyn, Vitalii Lytvyn, Larysa Rudenko, Yuriy Pelekh, Oleksandr Didenko, Radosław Muszkieta and Walerij Żukow ([13], p. 602) covered the results of a pedagogical experiment that demonstrated that the use of ICT technologies in the training of skilled workers and the use of pedagogical software tools would solve the problem of matching graduates of higher education institutions to the needs of society.

Meanwhile, the issue of the use of professionally oriented software products in the training of managers (in particular, hotel, resort and tourist services) remains disregard. In our opinion, the study of this issue will help in forming of the professional competencies of future managers.

The article is devoted to the problem of implementation professionally oriented information and communication technologies into the process of professional training of managers.

3. Method

Methods of theoretical research were used: scientific works were analyzed on the topic to determine the degree of research of the problem; to study the list of competences and tools for their formation, the educational programs for the preparation of bachelors of the specialties “Tourism” and “Hotel and Restaurant business” were studied; textbooks and manuals for the disciplines studying the bachelor of the above specialties are analyzed to determine the topics to be followed by ICT.

From the methods of empirical research, the following were used: conversation with teachers to discuss the hypothesis of the experiment, to coordinate actions during the experiment; Student questionnaire to identify the level of ICT proficiency and the level of awareness of the importance of ICT in professional activity.

Methods of studying the products of students' activities (completed practical tasks, independent work, individual tasks, results of practice, participation in didactic games) were used to confirm the hypothesis.

A formative pedagogical experiment was conducted to confirm the hypothesis of the study.

4. Results of the research

Agreeing with the opinion of scientists that the introduction of ICT in the educational process favours the efficiency of training of future specialists, we emphasize the reasonability of using professionally oriented special software products in the professional education of students of each specific specialty.

In particular, the purpose of the training program for the training of management specialist is “to train specialists capable to solve practical problems and complex specialized issues in the field of

managing organizations of different types and forms of property and their units on the basis of acquisition of the system of professional competencies”, which is impossible without implementation in educational process of information and communication technologies ([4], p. 182). Such training will not only make the training innovative, dynamic, more interesting and closer to the realities of the profession, but also intensify it, will give to the students a real opportunity to acquire professional competences. The abilities of the World Wide Web and its resources (websites, e-mail, e-textbooks, encyclopedias, reference books, research portals, etc.) allow effectively organizing and conducting online conferences, seminars in chats and blogs, individual consultations using visual communication. The modern student is eager to join these and other well-known communication tools that turned into learning tools. In combination with e-resources used both in the lectures and in independent work, they provide the formation of necessary for the successful manager’s professional activity complex of professional competencies.

Having regard to the specifics of future profession, the implementation of ICT in training of managers is considered from different positions: first, it allows to intensify the educational process, make it dynamic, modern, interesting, and secondly, the introducing of students with the software that used in management (by specialization), application of imitation methods of working with them, fulfillment of case calculation tasks, implementation in the educational process of didactic games with the using of ICT capabilities allow to form for students the necessary in future professional activities competencies, introduce into the specifics of the profession and give a real idea of the specialty.

ICT shared to the general and professionally oriented. In the educational process of modern higher education institutions, common ICT (teleconferences, forums, chats, search systems (websites, web directories), online educational environments) have become its integral part. For most modern educators, some of the ICT that have until recently been perceived as innovations are now in the phase of becoming as customary and the everyday learning tools such as e-mail and multimedia presentations. With the help of Moodle in many countries of the world, including Ukraine, thousands of LMS training systems have been created with educational courses sited on them. Lecturers and students from many Ukrainian universities consider in the project system of management education Moodle the wide variety of opportunities to full-fledged implement the online educational process. Iryna M. Naumuk and Natliia I. Korzun describe the experience of introducing a distance learning system in the process of training computer science teachers at Melitopol State Pedagogical University named after Bohdan Khmelnytsky ([17], p. 72). The experience of tutors in this institution of higher education is discussed in the article by Kateryna P. Osadcha “New opportunities for organizing the activities of a distance learning tutor in Moodle 3.2” ([19], p. 30). Iryna S. Mintii in article “Using Learning Content Management System Moodle in Kryvyi Rih State Pedagogical University educational process” describes the experience of implementing blended learning at the Kryvyi Rih State Pedagogical University [15]. Fifteen years of experience in the implementation and operation of the Moodle platform has O.M. Beketov National University of Urban Economy in Kharkiv.

The specificity of each individual specialty has an arsenal of necessary software products, the use of which at the stage of training specialists of a particular specialty ensures the formation of their professional competencies. The functions of manager (administrator, member of administrative staff, organizer, head, and superintendent) can be tentatively divided into 5 sectors: planning, organization, management, control, representation ([5], p. 77).

For the effective solving of professional issues in management sector modern managers need to be able to work with information technologies of office tasks automation, corporate information systems, and reference legal information systems. Therefore, in the basis of the training of managers should be the learning of information technologies of office tasks automation, such as processing of input and output information, collection and analyzing data, creating reports, searching information etc. Microsoft Office is an integrated suite of programs that generally meets the assigned tasks: provides work with a text editor, spreadsheets, database management system, communication tools, and graphical editor. In order to be competitive and demanded at the labor market, a modern manager must have a sufficient level of specialized professional skills: the ability to create and organize effective communications in

the management process; estimate the markets of products and services at the regional, national and international context; to organize and manage business; to make budgets of organizations and to control their implementation, etc. Now in management for automation of operational accounting of financial and economic activity of the enterprise the programs 1C, Galaxy, Parus, Skala are implemented, which in higher education institutions use for formation of information and communication competencies for future managers. Thus, in the 1C set managers are getting know to 1C: Accounting, 1C: Document management and other varieties of the program. But the functional responsibilities of the manager are much broader. Based on the analysis of the functional responsibilities of a modern manager and the list of competencies that a graduate manager should have, we have identified professionally oriented software products, such as MS Project, Teamwork, TeamLab, Open Workbench, GanttProject, dotProject, Outlook, OneNote, EverNote, Nirvana, Wunderlist, Toggl, MS Office, Office 365, Document.Online, AllFusion Process Modeler 7, MS Visio, MS PowerPoint, MS Sway, Libre Office.Impress, FreeMind, Mind42, ViSta, MacANOVA, Matrixer. Also included are special software products for managers of hotels, resorts and tourist services. Their implementation in the process of training managers will be discussed in detail at [2], [7], [11], [21].

The specific software products that manager should be able to use have been divided into five sectors, according to the main functions of the manager. Table 1 shows the correspondence of the manager's functions with professionally oriented software products, the use of which, in our opinion, will contribute to a more efficient performance of functional duties.

Table 1. Manager functions software.

Function	Computer program
Planning	MS Project, Teamwork 2.0, Open Workbench, GanttProject, DotProject, Wunderlist, XMind, Freemind, MindNode, Bubble.us, MindMeister, Mapul, WiseMapping, Mindomo
Organization	TeamLab CRM, OneNote, Evernote, Nirvana, Wunderlist, GitHub, Trello, AllFusion Process Modeler, FreeMind, XMind, Freemind, MindNode, Bubble.us, MindMeister, Mapul, WiseMapping, Mindomo
Management	Nirvana, Google Docs, DotProject
Control	Microsoft Excel, Microsoft Excel Services, DotProject
Presentation	PowerPoint, Prezi, Sway

The capabilities of these computer programs will be analyzed below.

1. Software that helps planning in management gives an opportunity of planning the working hours rationally, the creation of notepads with timer to remind, preparation of business plans, etc. Identifying the types of work and human resources, the distribution of work stages and responsibilities by executors, risk prediction are all invaluable benefits of using computer programs at the planning stage. The ability to use graphs makes the project visual and demonstrative. Equally important is to maintain a dialogue with colleagues.

2. Organization of work (own or collective) – no less important part of the manager’s work. It provides for interaction with colleagues, customers, management, subordinates, and, taking into account the specialization of the manager (for example, sales manager), the organization of specific activities. Most of the presented software products allow forming a united database of clients and contractors contacts, to collect information about them, to coordinate contacts efficiently, and also to control work with each client of each worker.

3. In project management, the manager uses Basecamp, FogBugz, dotProject systems. Using Web2project, which is a variation of dotProject, allows creating an effective, interactive way to manage projects and tasks.

4. It is reasonable to use Excel to control the calculation operations, which allows inputting formulas, constructing diagrams, graphs for reports and presentations.

5. PowerPoint, Prezi, Sway programs allow to fulfil the presentation function. The capabilities of these programs to present visually the information with graphs, diagrams, tables, moving objects (zoom-in and out), involvement video and audio materials will help the manager to present a report, lecture, make a presentation etc.

An analysis of higher education standards, educational and professional training programs for specialists in this specialty showed that the study of the above Microsoft Office software products is provided for by the educational program for training student managers in all universities of Ukraine.

According to the hypothesis of the study, for two years (2017–2019) the introduction of professionally oriented ICT in the educational process will increase the ICT competence of future professionals in the field of tourism and hotel and restaurant service. To form the information and communication competences of 1-3 courses students of the specialty “Management of hotel, resort and tourist service” on the basis of O. M. Beketov National University of Urban Economy in Kharkiv and Alfred Nobel University the pedagogical experiment was carried out. It was attended by 26 teachers involved in the educational process with students of these specialties and 284 students (12 academic groups of students of different courses of three specialties). At the beginning of the pedagogical experiment, a pilot study was carried out, which showed that 24% of 2-3 year students have no experience of working with professionally oriented software products.

Meantime, in the discussions with the lecturers of the disciplines “Information Systems and Technologies”, “Practices on Information and Communication Technologies”, “Statistics”, “Management and Administration”, “Finance, Money and Credit”, “Accounting and Auditing”, “Business Foreign Language”, “Professional Rhetoric”, “Foreign Professional Language”, “PR and Advertising Technologies”, “Business Accounting”, “International Business Management”, “E-Business Information Technologies” on topics and content of disciplines it is clear that within their limits in is the possibility of acquaintance and work with such a special software products as Servio, Ultra-restaurant, Quick Resto, Jowi, Tillypad, R-Keeper, Resti, POS Sector besides the work with 1C, Sail-restaurant products that are provided by educational programs.

At the ascertaining stage of the experiment, the teachers participated in the conversation, the students – in the questionnaire. During the conversation with the teachers of the profile disciplines, they learned the level of their knowledge of ICT, the list of disciplines on which these technologies were implemented, the software products they use in the educational process.

Teachers analyzed the curriculum, identified the disciplines and topics for which the use of professionally-oriented ICT is planned. The components for the formation of ICT-oriented competencies are identified:

1. The target component contains a list of knowledge, skills in working with programs and databases, information services on the Internet and their impact on success in the professional field.
2. The Content Component provides an ICT competency-based curriculum.
3. The technological component contains the technology of formation of ICT competence in the study of disciplines using the ICT technologies of future specialists of the tourism and hotel and restaurant business.
4. Diagnostic component provides diagnostics of the learning process, which allows quick response to deviations in the process of formation of ICT competence.
5. The result component contains the criteria for the formation of ICT competence of specialists.

During the forming part of the pedagogical experiment, measures were taken to develop the ICT competences of students of the specialty “Tourism” and “Hotel and Restaurant Business”. According to the results of the questioning of students, 2 groups were created: EG (experimental) and CG (control). The questions of the questionnaire were aimed at finding out knowledge about professional software products from ICT. The responses to the questionnaire were analyzed. The students received approximately the same answers. There was no special selection in the EG and CG. Under the conditions of the experiment in EG, the classes were conducted using professionally oriented ICT, in the control room – a regular office suite with Microsoft Office applications, which gives the opportunity to work with texts, tables, diagrams and more.

The essence of the pedagogical experiment was to introduce in the process of training of students from the experimental group (hereinafter referred to as EG-1) of specialty “Management of hotel, resort and tourist service” the professionally oriented software products. In the control group (CG-1) acquaintance with professionally oriented software products did not go beyond the bounds of program material.

Teachers actively involved EG students in e-textbooks, electronic correspondence, teleconferences; conducted classes using multimedia systems, computer aided design (CAD) systems, electronic library catalogs, banks and databases. According to the experiment of interactive classes in EG using professionally oriented software products, more than 20% of the total number of class hours were spent than in CG. EG and CG students have studied the technical means (personal computer, peripherals, storage media) and software (word processors, graphic editors, editorial and publishing systems, spreadsheets, information security systems); have learned how to search for information on the WAN, organize their own work using fax, email, teleconferencing, LAN, and more.

During the design experiment, the EG students were additionally familiarized with 22 software products. During the practical classes and during the internship, EG students are given the opportunity to improve their ability to plan, organize and manage the work of the departments, as well as to exercise leadership and representation functions.

Particular attention was paid to the implementation of professionally oriented ICT in teaching the disciplines of the elective part of the educational program: International Business Management, Business Communication, Brand Management, Communication Management. Practical classes were held in specialized computer rooms using modern information and communication equipment, information systems and software products used in management. Each discipline of the curriculum is provided with a teaching methodological complex and a distance course.

All EG students and teachers are registered with Microsoft resources and have corporate accounts. This gives them access to an expanded suite of cloud services, as well as to most Microsoft licensed products (more than 100 items).

During the experiment, EG-1 students were involved in active and interactive forms of studying, one of which was the business game. The simulation of production situations at different stages of work is the basis of the game. As the pedagogical experiment demonstrated, the studying of the disciplines referred above using ICT at the organization of training in the form of business games is more effective, and also contributes to the formation of information and communication competencies of future managers.

In the course of the pedagogical experiment, most of the programs were used with the application of three levels of cloud services: application as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS) [14]. Owing to the using of cloud technologies during the experiment, students received the experience of working with current versions of software products, had unlimited access to the information base, and teachers were able to connect to student bases, control their activity, set the parameters of use of service. That targeted EG-1 students on self-dependence in work.

As a result of the pedagogical experiment, EG-1 students were able to work out mass and individual mailing of advertising information about the institution, personal and corporate invitations to institution events; control of the progress of tasks, stages of its fulfillment; compilation of statistics from different institutions in real time; control over the institution's incomes, fulfillment of functions and assignments by employees, terms of orders execution; connection with payment terminals; automatic adjustment of filling in the contracts and other documents; quality assessment of manager's work through the sites, SMS-polls, automatic voting of the guests of the establishment; video protocols from virtual security cameras; became acquainted with the rules of ensuring the safety of clients and, if necessary, the anonymity of their residence in the institution; programming of backup schedules and getting the reports, as well as data backup, automatic archiving. EG-1 students also had the opportunity to become acquainted with the system of face recognition at the entrance to the hotel and restaurant both as VIP clients and unreliable payers. During the practice lessons, they practiced in ordering goods and services for visitors through the mobile application. Taking into account positive opinions of the restaurateurs,

the cloud-based Poster accounting system was used during the pedagogical experiment. Students had the opportunity to get acquainted with its advantages (access to statistics, structure and finances of the restaurant business; easy installation and usage; independence from the Internet) during the practical and laboratory lessons, as well as during the practical training.

Table 2 presents the criteria for the formation of ICT competencies of students in the experimental and control groups at the ascertaining and control stages of the experiment. It displays the results of a pedagogical experiment in groups.

Table 2. Criteria and indicators of the level of formation of ICT competencies in students of the EG and CG.

Criterion	EG (140 students)		EG (144 students)	
	Statement stage	Control stage	Statement stage	Control stage
The ability to search, collect and analyze professionally important information	108 (77%)	132 (94%)	96 (66%)	113 (78%)
The ability to carry out calculations of indicators to justify management decisions	34 (24%)	96 (68%)	32 (22%)	78 (54%)
The ability to apply management methods (using computer programs and products) to support the organization	42 (30%)	76 (54%)	46 (32%)	62 (43%)
The ability to teamwork, leadership, teamwork	48 (34%)	72 (51%)	40 (28%)	56 (39%)
The ability to analyze production situations using professional software products	23 (16%)	62 (44%)	30 (21%)	44 (31%)
The ability to communicate in various fields of professional activity	74 (53%)	110 (79%)	78 (54%)	92 (64%)
The ability to propose business ideas using computer software products	34 (24%)	56 (40%)	30 (21%)	42 (29%)
The ability to develop business plans using computer software products in Ukrainian and foreign languages	36 (26%)	62 (44%)	34 (24%)	48 (33%)

The criteria and indicators of the formation level of professionally-oriented ICT competencies are based on program learning outcomes: ability to search, collection and analyzing information, calculation the indicators to justify management decisions, to applying management methods to ensure the effectiveness of organization activities, to demonstration interaction skills, leadership, team-work, to substantiation of effective tools of motivation of the personnel of the organization, to the analyzing the situation and implementation of communication in different areas of organization activity, the formulation of business ideas, design and implementation of business plans in Ukrainian and foreign languages using professional-oriented software. Particular attention was paid to the language competence of students, as well as the ability to reason when presenting business projects. The criteria and indicators are based on the main competencies of the future manager, which are indicated in the training and professional program.

It should be emphasized that in the EG and CG students were united on the principle of academic groups.

At the ascertaining stage of the experiment, the students of the EG and the CG showed approximately the same abilities according to the stated criteria.

The difference between the ability to search for any information and information of a professional nature is established. Students of both groups during their studies at school and university look for the necessary information on the Internet and in other sources. They use the information they receive to

prepare for the Seminar classes, exams, practical and laboratory work, and course projects. During their participation in the pedagogical experiment, students from the EG and CG improved their ability to search and use professionally relevant information. The growth of indicators by this criterion in the EG is 17%, in the CG – 12%. It was achieved by introducing such software products into the training of managers: Freemind, MindNode, Google Docs.

The following criteria were obtained for the criterion “Ability to carry out calculation of indicators for substantiating managerial decisions”: at the ascertaining stage, the EG consisted of 34 students (24%), the CG – 32 students (22%). At the control stage, the number of EG students owning this property increased by 44%, in the CG – by 22%, which is also a good result. Introducing Open Workbench software into teaching, XMind, Freemind, Microsoft Excel, Microsoft Excel Services, contributed to the formation of these competencies. A large number of practical classes in accounting, finance, management, and other professionally oriented disciplines in the EG were held in an interactive form using these programs.

According to the criterion “Ability to apply management methods (using computer programs and products) to support the organization” at the beginning of the experiment, we have low formation indicators in both groups. This is due to the narrow specificity of knowledge that students acquire directly at the university. The basis of such knowledge is the beginning of analysis, higher mathematics. But students learn to apply management methods effectively only when becoming acquainted with software products: Process Modeler, Mindomo Nirvana, Google Docs, DotProject. About one third of students at the beginning of the experiment at a sufficient level could carry out managerial activities. At the end of the experiment, we have 54% in the EG and 43% in the CG, which is respectively 24 and 11% higher than at the beginning.

The ability to work in a team, leadership qualities are very important components of the competence of a modern manager. Therefore, during the experiment it was important to track the dynamics of this criterion. In the formation of these qualities, students play a large role in active and interactive forms of conducting classes: didactic games, solving industrial situations, problem learning. Software products that allow the manager to implement the management and control functions of MS Project, Teamwork 2.0, Open Workbench, GanttProject, DotProject, Wunderlist, XMind, Freemind, MindNode, Bubble.us, MindMeister, Mapul, WiseMapping, Mindomo, Microsoft Excel, Microsoft Excel Services, DotProject play a big role. According to this criterion, we have an increase of 17% in the EG and 11% in the CG.

The greatest results were obtained according to the criterion “Ability to analyze production situations using professional software products.” This is explained by the high degree of motivation of students in the study of narrow disciplines. EG students increased their competencies from 23 (16%) to 62 (44%), while the students of the CG showed the results of 30 (21%) at the ascertaining stage and 44 (31%). in the EG the growth was 28%, in the CG - 10%.

According to the criteria “Ability to offer business ideas using computer software products” and “The ability to develop business plans using computer software products in Ukrainian and foreign languages”, students had the opportunity to improve their competencies during the defense of course projects, participation in scientific events (for example, student research contests), work on grants and other commercial projects. By these criteria, not all students can offer business ideas and implement them. But the criteria are important for a successful modern manager. Only 9% of students in the CG were able to increase performance by these criteria. In the EG, this indicator is 18%, which is 2 times more than in the CG.

Generalized indicators of the levels of formation of professionally oriented information and communication competencies of students EG-1 and KG-1 in the specialty “Management of hotel, resort and tourist services” are presented in table 3. The table indicators show a significant decrease in the number of students in the EG and CG with a low level of formation of ICT competencies. It should be emphasized that in the EG after the pedagogical experiment, the number of students with high-level ICT competencies has grown. After the pedagogical experiment, the indicators of ICT formation in the EG increased by approximately 40%. These indicators in the CG increased within 20%.

Table 3. Results of pedagogical experiment.

Level	Control group				Experimental group			
	Stage the experiment							
	Ascertaining		Control		Ascertaining		Control	
	number	%	number	%	number	%	number	%
High	94	66	64	45	96	67,6	84	59
Satisfactory	32	22,5	50	35	28	19,8	37	26
Low	16	11,5	28	20	18	12,6	21	15

5. Discussion and conclusion

The aim of the study was to prove the effectiveness of the implementation of professionally oriented software products based on ICT in the training of managers. According to the hypothesis of our study, the introduction of special professional software products based on ICT into the training of managers of the hotel, restaurant and tourism business contributes to the formation of students at a higher level of professional competencies, in particular, information and communication.

The conducted pedagogical experiment confirmed the hypothesis of the research. The following conclusions were made:

1. The introduction of licensed software products of Microsoft Corporation into the educational process is not enough for a modern manager of the hotel and restaurant and tourism business to fulfill his functional duties at a high level. Therefore, it is necessary to include special software products in the training of specialists, taking into account the specifics of the future work of students. We consider as such for specialists of the hotel, restaurant and tourism business: MS Project, Teamwork, TeamLab, Open Workbench, GanttProject, dotProject, Outlook, OneNote, EverNote, Nirvana, Wunderlist, Toggl, MS Office, Office 365, Document.Online, AllFusion Process Modeler 7, MS Visio, MS PowerPoint, MS Sway, Libre Office.Impress, FreeMind, Mind42, ViSta, MacANOVA, Matrixer.

2. The list of disciplines, in the study of which it is possible to use professionally oriented ICT and software products, was compiled on the basis of an analysis of educational standards, educational and professional training programs for a particular specialist. Those for the specialty “Hotel and restaurant and tourism business” are “Information systems and technologies”, “Practices of information and communication technologies”, “Statistics”, “Management and administration”, “Finance, money and credit”, “Accounting and audit”. “Business foreign language”, “Professional rhetoric”, “Foreign professional language”, “PR and advertising technologies”, “Business accounting”, “International business management”, “Electronic business information technologies”.

3. Taking into account the conditional division of the main functions of a manager (management, leadership, analysis, control, presentation), it was established that it is advisable to use certain software products and ICTs for the formation of professional competencies in practical classes and in students' independent work.

4. The development of computer technologies requires constant updating of knowledge about them, primarily on the part of teachers. Therefore, teachers involved in the process of training managers should systematically monitor innovations in professionally oriented ICT and constantly improve the educational and methodological support of disciplines, identifying topics, the content of which will contribute to the formation of students' competencies in the field of ICT. The electronic platform Moodle provides great opportunities in this. It allows you to:

- to use elements of cloud technologies;
- provide access to the software for the restaurant business (Servio, Ultra-restaurant, Quick Resto, Jowi, Tillypad, R-Keeper, Resti, POS Sector);
- to introduce simulation technologies, didactic, business and role-playing games in the process of training managers of the restaurant and tourism business in order to form competencies in the field of ICT.

An analysis of the development trends of the tourism and hotel industry recently reveals promising new aspects of scientific research. They relate to economic, social, psychological, pedagogical issues.

For pedagogical science, the study of the professionally important qualities of modern managers remains important and promising. Closely connected with this is the issue of expanding the competencies of future managers during training at the university. Considering that not only developed professional, but also general competencies are important for the manager's personality, promising areas of our further research may be studying the possibilities of introducing software products into the educational process to form the cultural and social competencies of managers.

So, the introduction of software products with ICT in the process of training managers shows positive results in the formation of professionally important competencies. Therefore, after a while there is reason to repeat the experiment, taking into account the expansion of the manager's functions and the emergence of new computer technologies, introducing new software products into the manager's educational process.

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Application of the hierarchy analysis method for the choice of the computer mathematics system for the IT-sphere specialists preparation

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Abstract. Peculiarities of the usage of the hierarchy analysis method for the making decision on the choice of the most efficient computer mathematics system (CMS) used for the preparation of the IT-sphere specialists are in the focus of the research. Eight alternatives were selected for the hierarchy analysis method and seven criteria were considered. The alternative is chosen by means of figuring of the priority vector corresponding to each alternative. The alternative with the highest value is considered the right decision. The scale of impact was used that is the scale of evaluations for the paired comparisons of the advantage of the first object over other with meaning from 1 to 9. The basic criteria for which the alternatives are calculated were described in the course research; their characteristics were chosen, in particular functionalities, studying materials, on-line mode, mobile application, license, language support and an open code. The matrix of the paired comparisons for each criterion was constructed and numerical characteristics of these matrices were calculated – the highest own value, the index of compatibility and the index of the consistency of formulas. Every matrix is composed of the expert evaluations for the alternatives, which are the systems of computer mathematics used in the courses of mathematics. Based on the results of the calculations carried out the impact of the alternative was shown and the system having the highest impact was chosen.

1. Introduction

Nowadays there is a big number of information technologies including computer mathematics systems (CMS) used for teaching mathematics [2]. All of them have a wide-range functional set that is constantly developing and updating [4]. However, every CMS has its drawbacks. Thus, there is a need to choose the right CMS for teaching mathematics to the future IT-specialists [8].

There is no algorithm which can definitely state that every particular task has the most effective CMS [6]. That is why CMS is chosen for every specific context. Accounting for the big number of various systems of computer mathematics it is reasonable to try to automatize the process of choice of such learning tools [7]. To support the choice of the most suitable CMS we propose to use hierarchy analysis method.



The aim of the research is the usage of the hierarchy analysis method for the choice of the most effective CMS, which is used for teaching mathematics in the process of IT-specialists training.

The method is based on the knowledge of experts. And in our case, a specific group of experts preferred CMS for IT-specialists, because the basis of programming is the ability to build a mathematical model, knowledge of efficient algorithms, the process of creating algorithms to solve the problem.

2. Results

The hierarchy analysis method involves decomposition of the problem into the simpler constituents and following pair-wise comparison of the constituents at every next level of the hierarchy. As the result a relatively stable degree of cooperation of the constituents in the hierarchy can be calculated. These statements are expressed numerically. The method includes procedures of synthesis of multiple statements, obtaining of the priority criteria and establishment of the evaluations of the alternative decisions. The hierarchy is being plotted from the top (aim), through the intermediate levels (criteria determining the following levels) and to the lowest level which is a list of the alternatives [5]. The elements of the task in the hierarchy analysis method are compared in pairs with an account of their influence on their common characteristics.

It is showed later in this article the hierarchy analysis method for the choice of the most effective system of computer mathematics consisting of eight alternatives and including seven criteria.

The aim of the research is to choose one of the alternatives on the basis of multiple criteria. The choice of the alternative is carried out by means of the calculating of the elements of the priority vector corresponding to every alternative. The alternative with the highest value of this element is considered a decision made [1].

The hierarchy analysis method uses the scale of the expert evaluations (degree of impact) which are the evaluations for the paired comparisons for the determining of the advantage of the first object over other with meaning from 1 to 9. The general content of these evaluations is set in table 1 [3].

Table 1. Determining of the degrees of impact for the matrix of the paired comparisons.

Degree of impact	Definition	Commentary
1	Equal impact factor	Both object make equal contributions into the achieving of the aim
3	Weak impact factor	Experience and speculations make the first object a little bit advantageous over the other object
5	Significant or strong impact factor	Experience and speculations make the first object much more advantageous over the other object
7	Very strong and obvious impact factor	The advantage of the first object over the other object is very strong. Its advantage is practically obvious.
9	Absolute impact factor	Evidence is in favour of the highly convincing advantage of the first object over the other object.
2, 4, 6, 8	Intermediate values between neighbouring values of the scale	The situation requiring compromise decisions
Reciprocal values of the given valuations	If for the comparison of the object A with the object B one of the given valuations was obtained then, correspondingly, the result of the comparison of the object B with the object A is a reciprocal value	

Based on the results of the analysis of the functionalities of the chosen CMS a multiplicity of the criteria was formed. These criteria should serve as a basis for the choice of the system grounding on the expert evaluations received with the help of the hierarchy analysis method.

The basic criteria for which the alternatives were calculated and their characteristics were chosen received such names:

1. functionalities;
2. studying materials;
3. on-line mode;
4. mobile application;
5. license;
6. language support;
7. open code.

The structure of the task for the decision making with the help of the hierarchy analysis method for the choice of CMS for teaching mathematics to future IT-sphere specialists is shown in figure 1.

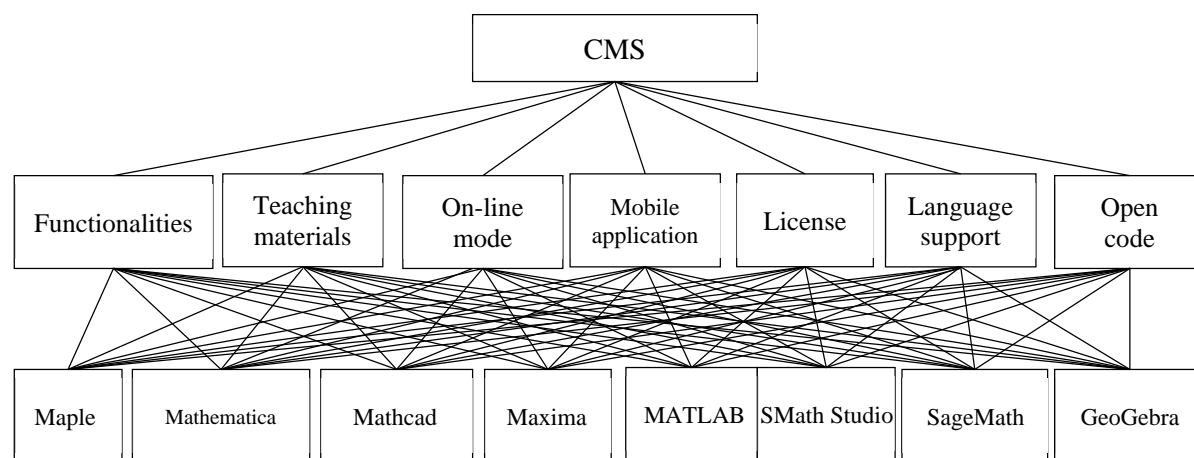


Figure 1. The structure of the task for making of the decision with the help of the hierarchy analysis method for the choice of CMS for teaching mathematics.

To solve the task of the choice of CMS we need to use the hierarchy analysis method. To do this we need to plot matrixes for the paired comparisons for each criterion and calculate new numerical characteristics for these matrixes, namely the highest own value, an index of compatibility and index of the sequence of the correlations. Every matrix consists of the expert evaluations concerning the pairs of the alternatives that are the systems of computer mathematics used for teaching of the mathematics courses.

In case of the application of the hierarchy analysis method as related to the plotting of the matrix of the paired comparisons for every criterion we will provide additional speculations concerning peculiarities of the usage of the system of computer mathematics used for teaching of the IT-specialists.

The criterion “functionality”. This criterion defines an opportunity of solving using a system with a particular range of tasks as the systems significantly differ from each other in their functionality (universal systems and system of the narrow focus). The matrix of the paired comparisons for the choice of the alternative system by the criterion “functionality” is showed in table 2.

Using the matrix (table 2) we can calculate the “impact factor” (priority vector). Speaking the language of mathematics we can interpret it as calculation of the main own vector which upon the normalization becomes a priority vector. To get an analytical evaluation of this vector we can use the algorithm:

1. We calculate the sum of the elements of each column:

$$S_i = a_{1i} + a_{2i} + \dots + a_{ni}.$$

2. We divide all the elements of each column of the matrix to the sum of the elements of the corresponding column: $A_{ij} = \frac{a_{ij}}{S_i}.$

Table 2. The matrix of the paired comparisons for the choice of the alternative system by the criterion “functionality”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	1.00	6.00	2.00	2.00	6.00	3.00	1.00
Mathematica	1.00	1.00	6.00	2.00	2.00	6.00	3.00	1.00
Mathcad	0.17	0.17	1.00	0.25	0.25	1.00	0.33	0.17
Maxima	0.50	0.50	4.00	1.00	1.00	4.00	2.00	0.50
MATLAB	0.50	0.50	4.00	1.00	1.00	4.00	2.00	0.50
SMath Studio	0.17	0.17	1.00	0.25	0.25	1.00	0.33	0.17
SageMath	0.33	0.33	3.00	0.50	0.50	3.00	1.00	0.33
GeoGebra	1.00	1.00	6.00	2.00	2.00	6.00	3.00	1.00
Sum	4.67	4.67	31.00	9.00	9.00	31.00	14.66	4.66

These two operations are called matrix normalizing.

3. Then we add up the elements of each line.

$$S_i = A_{i1} + A_{i2} + \dots + A_{in}.$$

4. And find out the arithmetic mean of each line.

$$w_i = \frac{S_i}{n}.$$

The results are shown in table 3. The last column is a priority vector.

The priority vector is calculated as the evaluation of the main own vector of the matrix of the paired comparisons. The elements of this vector are the impact factors of the alternatives, which were calculated as an algebraic expression of the elements of the corresponding column of the table 3 divided by the general number of the alternatives – number of the elements of the line in table 2.

Table 3. The impact factor of the alternatives by the criterion “functionality”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	Impact factor of the alternatives
Maple	0.214	0.214	0.194	0.222	0.222	0.194	0.205	0.214	1.679	0.210
Mathematica	0.214	0.214	0.194	0.222	0.222	0.194	0.205	0.214	1.679	0.210
Mathcad	0.036	0.036	0.032	0.028	0.028	0.032	0.023	0.036	0.250	0.031
Maxima	0.107	0.107	0.129	0.111	0.111	0.129	0.136	0.107	0.938	0.117
MATLAB	0.107	0.107	0.129	0.111	0.111	0.129	0.136	0.107	0.938	0.117
SMath Studio	0.036	0.036	0.032	0.028	0.028	0.032	0.023	0.036	0.251	0.031
SageMath	0.071	0.071	0.097	0.056	0.056	0.097	0.068	0.071	0.585	0.073
GeoGebra	0.214	0.214	0.194	0.222	0.222	0.194	0.205	0.214	1.679	0.210
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

Thus, by the criterion “functionality” the best alternatives are the three systems Maple, Mathematica and GeoGebra as they have the highest value of the impact factor – 0.210.

Let us calculate such parameters for the matrix of the paired comparisons plotted by the criterion “functionality”:

– the evaluation of the own value calculated: $\lambda_{max} = \sum_{i=1}^n w_i S_i$

where w_i – the impact factor of the alternatives with a number i , S_i – the sum of the elements of the column with a number i of the matrix of the paired comparisons, n – a quantity of alternatives;

– the consistency index: $CI = \frac{\lambda_{max}}{n-1}$;

– the index of ratio sequence: $CR = CI/RI$.

$RI = 1.41$ – random index for $n = 8$, the values of which are equal for the rest of the following calculations of the impact factors of the alternatives.

Upon the calculation of the matrix of the paired comparisons plotted by the criterion “*functionality*”, the stated parameters acquire the following values:

$$\lambda_{max} = 0.21 \cdot 4.67 + 0.21 \cdot 4.67 + 0.031 \cdot 31 + 0.117 \cdot 9 + 0.117 \cdot 9 + 0.031 \cdot 31 + 0.073 \cdot 14.66 + 0.21 \cdot 4.67 = 8.067$$

– the consistency index: $CI = \frac{\lambda_{max}-n}{n-1} = \frac{8.067-8}{8-1} = 0.0097$;

– the index of ratio sequence: $CR = CI/RI = 0.01/1.41 = 0.007$.

As $CR = 0.7\% < 10\%$, then the matrix of the paired comparisons by the criterion “*functionality*” is considered consistent.

By the criterion “*teaching materials*”. In this context we consider the availability of the teaching materials for easy mastering of the work in the system of computer mathematics. Special attention is paid to the instructional guidelines for the work in the system, video lessons, developed applets and algorithms of the tasks solution.

The results of the calculation of the impact factor of the alternatives by the criterion “*teaching materials*” are showed in table 5. The elements of the columns are were obtained as a result of the normalizing of the corresponding elements of table 4. Similar to the criterion “*functionality*” the priority vector is calculated as an evaluation of the own main vector of the matrix of the paired comparisons where the elements are the impact factors of the alternatives. The last were calculated as an algebraic expression of the elements of the corresponding line divided by the general number of the alternatives.

Table 4. The matrix of the paired comparisons of the alternatives by the criterion “teaching materials”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	0.33	3.00	3.00	2.00	0.50	0.50	0.25
Mathematica	3.00	1.00	5.00	5.00	4.00	2.00	2.00	0.50
Mathcad	0.33	0.20	1.00	1.00	0.50	0.25	0.25	0.14
Maxima	0.33	0.20	1.00	1.00	0.50	0.25	0.25	0.14
MATLAB	0.50	0.25	2.00	2.00	1.00	0.33	0.33	0.17
SMath Studio	2.00	0.50	4.00	4.00	3.00	1.00	1.00	0.33
SageMath	2.00	0.50	4.00	4.00	3.00	1.00	1.00	0.33
GeoGebra	4.00	2.00	7.00	7.00	6.00	3.00	3.00	1.00
Sum	13.16	4.98	27.00	27.00	20.00	8.33	8.33	2.86

Thus, by the criterion “teaching materials” the best alternative is the system GeoGebra as it has the highest impact factor – 0.324.

For the matrix of the paired comparisons plotted by the criterion “teaching materials” the following parameters were calculated:

– evaluation of the highest own value: $\lambda_{max} = 8.165$;

– the consistency index: $CI = 0.0236$;

– the index of ratio sequence: $CR = 0.017$.

Table 5. The impact factors of the alternatives by the criterion “teaching materials”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	Impact factor of the alternatives
Maple	0.076	0.066	0.111	0.111	0.100	0.060	0.060	0.087	0.672	0.084
Mathematica	0.228	0.201	0.185	0.185	0.200	0.240	0.240	0.175	1.654	0.207
Mathcad	0.025	0.040	0.037	0.037	0.025	0.030	0.030	0.050	0.274	0.034
Maxima	0.025	0.040	0.037	0.037	0.025	0.030	0.030	0.049	0.273	0.034
MATLAB	0.038	0.050	0.074	0.074	0.050	0.040	0.040	0.058	0.424	0.053
SMath Studio	0.152	0.100	0.148	0.148	0.150	0.120	0.120	0.115	1.054	0.132
SageMath	0.152	0.100	0.148	0.148	0.150	0.120	0.120	0.115	1.054	0.132
GeoGebra	0.304	0.402	0.259	0.259	0.300	0.360	0.360	0.350	2.594	0.324
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

As $CR = 1.7\% < 10\%$, then the matrix of the paired comparisons by the criterion “teaching materials” is considered consistent.

The criterion “on-line mode”. An opportunity to work with CMS online without loading and installation on the computer is considered. Convenience of work in the system is also taken into account.

The results of the calculation of the impact factor by the criterion “online mode” is showed in table 7. The elements of the columns were obtained through normalizing of the corresponding elements of table 6.

Table 6. The matrix of the paired comparisons of the alternatives by the criterion “online mode”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	0.25	7.00	7.00	1.00	3.00	3.00	0.25
Mathematica	4.00	1.00	9.00	9.00	4.00	5.00	5.00	1.00
Mathcad	0.14	0.11	1.00	1.00	0.14	0.20	0.20	0.11
Maxima	0.14	0.11	1.00	1.00	0.14	0.20	0.20	0.11
MATLAB	1.00	0.25	7.00	7.00	1.00	3.00	3.00	0.20
SMath Studio	0.33	0.20	5.00	5.00	0.33	1.00	1.00	0.17
SageMath	0.33	0.20	5.00	5.00	0.33	1.00	1.00	0.17
GeoGebra	4.00	1.00	9.00	9.00	5.00	6.00	6.00	1.00
Sum	10.94	3.12	44.00	44.00	11.94	19.40	19.40	3.01

Thus, the system GeoGebra is the best alternative by the criterion “online mode” as it has the highest impact factor – 0.308.

For the matrix of the paired comparisons plotted by the criterion “online mode” the following criteria were calculated:

- evaluation of the highest own value: $\lambda_{max} = 8.811$;
- the consistency index: $CI = 0.1159$;
- the index of ratio sequence: $CR = 0.082$.

As $CR = 8.2\% < 10\%$, then the matrix of the paired comparisons by the criterion “online mode” is considered consistent.

Table 7. The impact factors of the alternatives by the criterion “online mode”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	Impact factor of the alternatives
Maple	0.091	0.080	0.159	0.159	0.084	0.155	0.155	0.083	0.966	0.121
Mathematica	0.366	0.320	0.205	0.205	0.335	0.258	0.258	0.332	2.278	0.285
Mathcad	0.013	0.035	0.023	0.023	0.012	0.010	0.010	0.037	0.163	0.020
Maxima	0.013	0.036	0.023	0.023	0.012	0.010	0.010	0.037	0.163	0.020
MATLAB	0.091	0.080	0.159	0.159	0.084	0.155	0.155	0.066	0.949	0.119
SMath Studio	0.030	0.064	0.114	0.114	0.028	0.052	0.052	0.055	0.508	0.063
SageMath	0.030	0.064	0.114	0.114	0.028	0.052	0.052	0.057	0.509	0.064
GeoGebra	0.366	0.320	0.205	0.205	0.419	0.309	0.309	0.332	2.465	0.308
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

The criterion “mobile application”. An opportunity of loading of CMS into the mobile device as well as opportunities to work in this mobile application are analyzed.

The results of the calculations of the impact factor of the alternatives by the criterion “mobile application” are showed in table 9. The elements of the columns were obtained through normalizing of the corresponding elements of table 8.

Table 8. The matrix of the paired comparisons of the alternatives by the criterion “mobile application”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	0.13	1.00	0.33	0.17	0.17	1.00	0.11
Mathematica	8.00	1.00	8.00	5.00	2.00	2.00	8.00	0.50
Mathcad	1.00	0.13	1.00	0.33	0.17	0.17	1.00	0.11
Maxima	3.00	0.20	3.00	1.00	0.33	0.33	3.00	0.17
MATLAB	6.00	0.50	6.00	3.00	1.00	1.00	6.00	0.25
SMath Studio	6.00	0.50	6.00	3.00	1.00	1.00	6.00	0.25
SageMath	1.00	0.13	1.00	0.33	0.17	0.17	1.00	0.11
GeoGebra	9.00	2.00	9.00	6.00	4.00	4.00	9.00	1.00
Sum	35.00	4.58	35.00	18.99	8.83	8.84	35.00	2.50

Thus, the system GeoGebra is the best alternative by the criterion “mobile application” as it has the highest impact factor – 0.354.

For the matrix of the paired comparisons plotted by the criterion “mobile application” the following criteria were calculated:

- evaluation of the highest own value: $\lambda_{max} = 8.347$;
- the consistency index: $CI = 0.0496$;
- the index of ratio sequence: $CR = 0.035$.

As $CR = 3.5\% < 10\%$, then the matrix of the paired comparisons by the criterion “mobile application” is considered consistent.

Table 9. The impact factor of the alternatives by the criterion “mobile application”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	Impact factor of the alternatives
Maple	0.029	0.027	0.029	0.017	0.019	0.019	0.029	0.044	0.213	0.027
Mathematica	0.229	0.218	0.229	0.263	0.226	0.226	0.229	0.200	1.820	0.228
Mathcad	0.029	0.028	0.029	0.017	0.019	0.019	0.029	0.044	0.214	0.027
Maxima	0.086	0.044	0.086	0.053	0.037	0.037	0.086	0.067	0.495	0.062
MATLAB	0.171	0.109	0.171	0.158	0.113	0.113	0.171	0.100	1.108	0.138
SMath Studio	0.171	0.109	0.171	0.158	0.113	0.113	0.171	0.100	1.108	0.138
SageMath	0.029	0.027	0.029	0.017	0.019	0.019	0.029	0.044	0.213	0.027
GeoGebra	0.257	0.437	0.257	0.316	0.453	0.452	0.257	0.400	2.830	0.354
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

The criterion “license”. This criterion allows analyzing of the opportunities of application of CMS as the main drawback of the systems is that they are commercial that is one needs to get a license to use them. This fact significantly complicates the usage of such systems in the teaching process. The situation is quite different when the usual systems of computer mathematics are used.

The results of the calculations of the impact factor of the alternatives by the criterion “license” are showed in table 11. The elements of the columns were obtained through normalizing of the corresponding elements of table 10.

Table 10. The matrix of the paired comparisons of the alternatives by the criterion “license”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	0.33	0.20	0.14	0.50	0.14	0.14	0.14
Mathematica	3.00	1.00	0.25	0.14	0.00	0.14	0.14	0.14
Mathcad	5.00	4.00	1.00	0.14	5.00	0.14	0.14	0.14
Maxima	7.00	7.00	7.00	1.00	7.00	1.00	1.00	1.00
MATLAB	2.00	0.33	0.20	0.14	1.00	0.14	0.14	0.14
SMath Studio	7.00	7.00	7.00	1.00	7.00	1.00	1.00	1.00
SageMath	7.00	7.00	7.00	1.00	7.00	1.00	1.00	1.00
GeoGebra	7.00	7.00	7.00	1.00	7.00	1.00	1.00	1.00
Sum	39.00	33.66	29.65	4.56	34.50	4.56	4.56	4.56

Thus, the three systems Maxima, SageMath, SMath Studio, GeoGebra are the best by the criterion “license” as they have the same highest value of the impact factor – 0.213.

For the matrix of the paired comparisons plotted by the criterion “license”, the following criteria were calculated:

- evaluation of the highest own value: $\lambda_{max} = 8.743$;
- the consistency index: $CI = 0.1061$;
- the index of ratio sequence: $CR = 0.075$.

As $CR = 7.5\% < 10\%$, then the matrix of the paired comparisons by the criterion “license” is considered consistent.

Table 11. The impact factor of the alternatives by the criterion “license”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	Impact factor of the alternatives
Maple	0.026	0.010	0.007	0.031	0.014	0.031	0.031	0.031	0.180	0.023
Mathematica	0.077	0.030	0.008	0.031	0.000	0.031	0.031	0.031	0.238	0.030
Mathcad	0.128	0.119	0.034	0.031	0.145	0.031	0.031	0.031	0.548	0.069
Maxima	0.179	0.208	0.236	0.219	0.203	0.219	0.219	0.219	1.703	0.213
MATLAB	0.051	0.010	0.007	0.031	0.029	0.031	0.031	0.031	0.220	0.027
SMath Studio	0.179	0.208	0.236	0.219	0.203	0.219	0.219	0.219	1.703	0.213
SageMath	0.179	0.208	0.236	0.219	0.203	0.219	0.219	0.219	1.703	0.213
GeoGebra	0.179	0.208	0.236	0.219	0.203	0.219	0.219	0.219	1.703	0.213
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

The criterion “language support”. This criterion allows analyzing in which languages a particular system can function; an issue of Ukrainian-language and Russian-language interface of the system is in the focus of attention.

The results of the calculations of the impact factor of the alternatives by the criterion “language support” are showed in table 13. The elements of the columns were obtained through normalizing of the corresponding elements of table 12.

Table 12. The matrix of the paired comparisons of the alternatives by the criterion “language support”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	0.33	0.25	0.33	1.00	0.14	1.00	0.11
Mathematica	3.00	1.00	0.33	2.00	3.00	0.20	3.00	0.14
Mathcad	4.00	3.00	1.00	4.00	4.00	0.33	4.00	0.33
Maxima	3.00	0.50	0.25	1.00	3.00	0.25	3.00	0.14
MATLAB	1.00	0.33	0.25	0.33	1.00	0.14	1.00	0.11
SMath Studio	7.00	5.00	3.00	4.00	7.00	1.00	7.00	0.50
SageMath	1.00	0.33	0.25	0.33	1.00	0.14	1.00	0.11
GeoGebra	9.00	7.00	3.00	7.00	9.00	2.00	9.00	1.00
Sum	29.00	17.49	8.33	18.99	29.00	4.21	29.00	2.44

Thus, the system GeoGebra is the best alternative by the criterion “language support” as it has the highest impact factor – 0.368.

For the matrix of the paired comparisons plotted by the criterion “language support” the following criteria were calculated:

- evaluation of the highest own value: $\lambda_{max} = 8.477$;
- the consistency index: $CI = 0.0681$;
- the index of ratio sequence: $CR = 0.048$.

As $CR = 4.8\% < 10\%$, then the matrix of the paired comparisons by the criterion “language support” is considered consistent.

Table 13. The impact factor of the alternatives by the criterion “language support”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	Impact factor of the alternatives
Maple	0.034	0.019	0.030	0.017	0.034	0.034	0.034	0.045	0.249	0.031
Mathematica	0.103	0.057	0.040	0.105	0.103	0.048	0.103	0.057	0.618	0.077
Mathcad	0.138	0.172	0.120	0.211	0.138	0.078	0.138	0.135	1.129	0.141
Maxima	0.103	0.029	0.030	0.053	0.103	0.059	0.103	0.057	0.538	0.067
MATLAB	0.034	0.019	0.030	0.017	0.034	0.034	0.034	0.045	0.249	0.031
SMath Studio	0.241	0.286	0.360	0.211	0.241	0.238	0.241	0.205	2.023	0.253
SageMath	0.034	0.019	0.030	0.017	0.034	0.034	0.034	0.045	0.249	0.031
GeoGebra	0.310	0.400	0.360	0.369	0.310	0.475	0.310	0.409	2.944	0.368
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

The criterion “open code”. This criterion allows analyzing an opportunity of improvement of CMS by means of additional functionality. An availability of open code for the developers is checked.

The results of the calculations of the impact factor of the alternatives by the criterion “open code” are showed in table 15. The elements of the columns were obtained through normalizing of the corresponding elements of table 14.

Table 14. The matrix of the paired comparisons of the alternatives by the criterion “open code”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra
Maple	1.00	1.00	1.00	0.11	1.00	1.00	0.17	0.11
Mathematica	1.00	1.00	1.00	0.11	1.00	1.00	0.17	0.11
Mathcad	1.00	1.00	1.00	0.11	1.00	1.00	0.17	0.11
Maxima	9.00	9.00	9.00	1.00	9.00	9.00	3.00	1.00
MATLAB	1.00	1.00	1.00	0.11	1.00	1.00	0.17	0.11
SMath Studio	1.00	1.00	1.00	0.11	1.00	1.00	0.17	0.11
SageMath	6.00	6.00	6.00	0.33	6.00	6.00	1.00	0.33
GeoGebra	9.00	9.00	9.00	1.00	9.00	9.00	3.00	1.00
Sum	29.00	29.00	29.00	2.88	29.00	29.00	7.85	2.88

Thus, the systems Maxima and GeoGebra are the best two alternatives by the criterion “open code” as they have the highest impact factor – 0.329.

For the matrix of the paired comparisons plotted by the criterion “open code” the following criteria were calculated:

- evaluation of the highest own value: $\lambda_{max} = 8.159$;
- the consistency index: $CI = 0.0227$;
- the index of ratio sequence: $CR = 0.016$.

As $CR = 1.6\% < 10\%$, then the matrix of the paired comparisons by the criterion “open code” is considered consistent.

All the criteria have indexes of compatibility significantly lower than 10%. It means that the matrixes of the paired comparisons are compatible.

Table 15. The impact factor of the alternatives by the criterion “open code”.

Alternatives	Maple	Mathematica	Mathcad	Maxima	MATLAB	SMath Studio	SageMath	GeoGebra	Sum	The impact factor of the alternatives
Maple	0.034	0.034	0.034	0.039	0.034	0.034	0.021	0.038	0.270	0.034
Mathematica	0.034	0.034	0.034	0.038	0.034	0.034	0.022	0.038	0.270	0.034
Mathcad	0.034	0.034	0.034	0.038	0.034	0.034	0.022	0.038	0.270	0.034
Maxima	0.310	0.310	0.310	0.347	0.310	0.310	0.382	0.347	2.628	0.329
MATLAB	0.034	0.034	0.034	0.038	0.034	0.034	0.022	0.038	0.270	0.034
SMath Studio	0.034	0.034	0.034	0.038	0.034	0.034	0.022	0.038	0.270	0.034
SageMath	0.207	0.207	0.207	0.115	0.207	0.207	0.127	0.115	1.391	0.174
GeoGebra	0.310	0.310	0.310	0.347	0.310	0.310	0.382	0.347	2.628	0.329
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.000	1.000

To determine the impact factor we need to evaluate the degrees of importance of the criteria using the method of paired comparisons. To simplify any further speculations we will consider all the criteria equally important; in this case all the boxes of the matrix will have the same values equal to one.

In this case, the column “total impact factor” in table 16 the alternative is calculated as an arithmetical average of all the impact factors by all the criteria. Grounding on the results of the presented calculations the impact factors of the alternatives are provided and on the basis the system with the highest impact factor is chosen. The analysis of the results of table 16 demonstrated that the system of the dynamic mathematics GeoGebra has the highest total impact factor.

Table 16. The results of evaluation of the impact factors of the alternatives.

	Functionality	Teaching materials	Online mode	Mobile application	License	Language support	Open code	Total value
Maple	0.2099	0.0840	0.1207	0.0266	0.0225	0.0311	0.0338	0.0755
Mathematica	0.2099	0.2068	0.2847	0.2275	0.0297	0.0772	0.0338	0.1528
Mathcad	0.0314	0.0343	0.0204	0.0267	0.0686	0.1412	0.0338	0.0509
Maxima	0.1173	0.0342	0.0204	0.0619	0.2129	0.0673	0.3285	0.1203
MATLAB	0.1173	0.0530	0.1186	0.1385	0.0275	0.0311	0.0338	0.0743
SMath Studio	0.0314	0.1318	0.0635	0.1385	0.2129	0.2529	0.0338	0.1235
SageMath	0.0731	0.1318	0.0636	0.0266	0.2129	0.0311	0.1739	0.1019
GeoGebra	0.2099	0.3243	0.3081	0.3537	0.2129	0.3680	0.3285	0.3008
Index of compatibility	0.0097	0.0236	0.1159	0.0496	0.1061	0.0681	0.0227	0.0565
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Thus, according to the expert evaluations obtained with the help of the hierarchy analysis method of CMS, GeoGebra is defined as the most effective to use in the process of IT-sphere specialists preparation.

It is advisable to evaluate an arithmetic average on hierarchies’ compatibility by means of summing up all the levels by the valued index of the sequence of the correlations:

$$\overline{RC} = \frac{0.0565}{1.41} = 0.0401 < 0.1.$$

In the course of the calculations, it was evaluated that the index of the sequence of correlations equals to zero if all the elements of the matrix of the paired comparisons are equal to zero. The obtained result testifies to the compatibility of all the hierarchies. The stated conclusions were drawn on the basis of the calculations and provided in figure 2 and table 17.

Table 17. The impact factors of the alternatives of the systems of computer mathematics.

Alternative	Priority
Maple	0.0755
Mathematica	0.1528
Mathcad	0.0509
Maxima	0.1203
MATLAB	0.0743
SMath Studio	0.1235
SageMath	0.1019
GeoGebra	0.3008

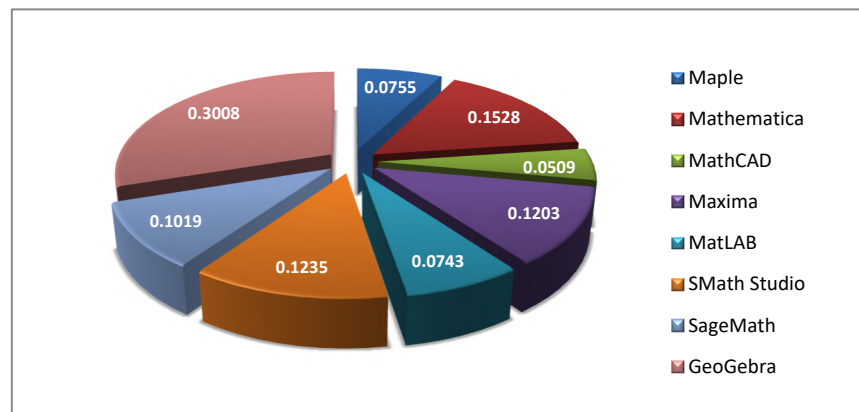


Figure 2. The diagram of distribution of the impact factor indexes of the alternative CMS for teaching mathematics.

3. Conclusions

In conclusion, in the course of the research, we analyzed eight alternatives and accounted for seven criteria for taking decision on the choice of the most efficient CMS used for teaching mathematics to the future IT-sphere specialists. The choice of the alternative is made by means of calculating of the elements of the priority vector corresponding to each alternative. The basic criteria for which the alternatives were calculated were their characteristics, namely the following: functionality; teaching materials; an online mode; a mobile application; a license; language support; and an open code. The matrix of the paired comparisons by each criterion was plotted and numerical characteristics of these matrixes, namely the highest own value, an index of compatibility and an index of the sequence of correlations, were calculated. Every matrix consists of the expert evaluations of the pairs of alternatives, which are the systems of computer mathematics used for teaching of the courses on mathematics. Grounding on the results of the provided calculations impact factors of the alternatives were showed and on the basis a system of dynamic mathematics GeoGebra with the highest impact factor was chosen. Thus, according the expert evaluations obtained using hierarchy analysis method it is the CMS GeoGebra that is best for usage for teaching mathematics in the process of preparation of future IT-sphere specialists.

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Method for assessing the information content of factors forming the cognitive independence of students

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Abstract. The article describes the problem of awakening the cognitive activity of students, arising due to revolutionary transformations in teaching technologies. It shows the need to study the factors that affect cognitive activity and assesses the information content of those factors. Based on the method of pair comparisons, a technology for ranking the factors affecting cognitive activity has been developed. A mathematical model of the formation and processing of expert assessment results and an example of calculations are given, and the feasibility of including the subsystem for evaluating factors affecting cognitive activity in the computer control system of the university is shown. The structure of an adaptive e-learning system based on the technology of taking into account the factors that form the cognitive independence of students is described. Experiments carried out in 3 universities of Ukraine have shown that the use of the developed mathematical model and information technology allows to increase significantly academic performance and to decrease the frequency of refusals from independent work of students using the e-learning environment.

1. Introduction

The current revolution in education ([6], [8]), the e-learning technology ([13], [26]) that has received a surge (also due to the problem of COVID-19 [4], [10], [30], [32], [33]), as well as the concept of lifelong learning ([1], [38]) exacerbated the problems of

- the quality of e-learning environment ([34], [36]),
- adaptive learning ([3], [17], [22], [25], [27]),
- activation of cognitive independence ([7], [15], [18], [28], [35]).

In the complex of problems of pedagogy of electronic society, the problem of such a personality quality as “cognitive independence” comes out on top ([6], [40]).

2. Problem statement

Various aspects of the problems of cognitive independence are considered in a huge number of scientific studies ([23], [40]), including general issues ([31], [39]), the structure of cognitive independence ([9]), various methods of activating cognitive independence ([9], [24], [31], [39]), etc. are being studied.



However, in general terms, the task of optimizing cognitive independence in the conditions of the modern stage of e-learning throughout life, unfortunately, has not been solved.

There is not even a single universally accepted definition for cognitive independence.

In this study, we use the definition of [21]: “Cognitive independence of students is an integrative quality of the personality, based on cognitive activity associated with the initiative and the search for various ways to solve educational and cognitive problems without the participation of a teacher (the teacher prepares a system of tasks), which ensures self-development of personality”.

Identification of factors of cognitive independence is the main prerequisite (first stage) of activation of cognitive independence, as shown in [23], [31].

A significant number of cognitive independence factors have been identified [21].

The problem is that the degree of manifestation of those factors varies depending on the particular educational environment and tends to change rapidly ([6], [23], [40]).

The question of the degree of manifestation of each factor in the general structure of cognitive independence is of interest to many researchers ([9], [21], [23], [24], [31], [39]). Unfortunately, there is no universal method for solving this problem. In this regard, we define the purpose of this work as follows:

“Develop a computer-based method for assessing the information content of cognitive independence factors and their ranking (in terms of pedagogical value for managing cognitive independence in the system of lifelong learning), using the structure of cognitive independence as an explicit concept.”

3. Results

3.1. Method for assessing the information content of cognitive independence factors

Informational content of the factor ([12], [29]) – the ability of this factor to contain information about the degree of its influence on the subject of research [14], [41] (in our case, on cognitive independence).

Unfortunately, due to the specifics of the research object, we cannot use instrumental and imitation methods for assessing skills [21] to determine the degree of influence of any factor on the development of cognitive independence.

It has been proven ([2], [11], [21]) that expert methods based on subjective assessments of experts are the most appropriate methods for this purpose.

Among the expert methods used in pedagogical research, we distinguish the following ones: the method of rank order, the method of predetermined scoring, the method of free scoring, the method of coefficient estimation of the level of assimilation, and the method of pair comparisons ([12], [21], [29]).

Our experiments with teachers ([21]), who were invited to use various technologies of expert assessment, showed that the method of pair comparisons can be considered the most convenient.

In this regard, the following assessment technology has been developed:

Stage 1. Formation of the questionnaire.

To determine the degree of influence of factors on the development of cognitive independence of a student, we form a special questionnaire in which expert educators are invited to evaluate the degree of joint manifestation of the main characteristics (factors) of cognitive independence. To do this, they fill out a table to record the characteristics (factors) of cognitive independence

- a) from top to bottom in the first column of the table,
- b) from right to left in the same order.

The compiled table is scanned from left to right: each column element is compared with each row element. If, according to the expert, the element located in the left column of the table is less common than the element placed in the top row, then “1” is written in the cell at the intersection of the column and row. If the element located in the top row of the table is more common than in the left column, then “0” is put in the numerator. In the case of equal manifestation frequencies, a value of 0.5 is set in the cell. The experts do not fill out last two columns for R and P.

Stage 2. Processing questionnaires.

As a result of filling out the questionnaire by experts, one can calculate the degree of manifestation of the components of cognitive independence. Further, the obtained information is processed as follows: first, line-by-line summation of the contents of the cells is performed. The result of this summation is the rank R of each factor in the structure of cognitive independence. It is written to the corresponding “rank R ” column of the table. The factor with the highest rank is assigned a degree equal to 1.

Then, the degree of manifestation P_i of each factor is calculated by the formula:

$$P_i = \frac{P_{max}R_i}{R_{max}}, \tag{1}$$

where $P_{max} = 1$ – the degree of manifestation of the factor that has the highest rank;

R_i is the rank of the factor;

R_{max} is the highest rank.

The results are entered in the column “Degree of P manifestation”. This is how all data provided by each expert is processed.

Then a table is filled in, where the results of the questionnaires are summarized.

The results of calculating the degrees of P_{ni} from each questionnaire of the n -th expert for each i -th factor are transferred to this table, i.e., column P_1 , is filled in for the 1st expert, column P_2 – for the 2nd expert, ..., and column P_n – for the n -th expert.

The averaged values of the degrees of manifestation of factors in the structure of cognitive independence are calculated based on the obtained P_i data:

$$P_{i,av} = \frac{\sum_{j=1}^n P_{ij}}{n}, \tag{2}$$

where n – the number of experts, j – the expert’s number; i – factor number. These values serve as a measure of the informative value of the factor.

Further, the variance S_i of expert estimates for each factor is determined, which is calculated by the formula (for a small sample, an unbiased variance estimate is used):

$$S_i = \sqrt{\frac{\sum_{j=1}^n (P_{i,j} - P_{i,av})^2}{n-1}}, \tag{3}$$

where n – the number of experts, $P_{i,j}$ – the degree of manifestation of the i -th factor in the structure of cognitive independence according to the j -th expert. The value of $n-1$ indicates the number of degrees of freedom.

Then, a confidence interval of values for each component of cognitive independence is determined by the formulas:

$$v_i = t_\phi * \frac{S_i}{\sqrt{n}}; \quad P_i^u = P_{i,av} + v_i; \quad P_i^l = P_{i,av} - v_i, \tag{4}$$

where v_i is the confidence interval; t_ϕ is the confidence probability; P_i^u (P_i^l) – the upper (lower) confidence boundary of the values of information content of factors of cognitive independence.

3.2. An example of assessing the information content of cognitive independence factors

Consider an example developed as an experiment in the Center of Distance Education of the Sumy National Agrarian University, when studying the cognitive independence of students (economic specialties) who are trained at the Department of Cybernetics and Informatics (Department Head Svetlana Agadzhanova). The number of experts is 16 (teachers of the department and employees of the Distance Education Center).

The working group identified the following main factors, affecting cognitive independence (in the study of the disciplines of the computer and cybernetic cycle):

1. The need and desire to acquire knowledge and methods of activity;
2. Cognitive motive and interest;

3. Interest in the results of their independent cognitive activities;
4. Interest in a future profession;
5. Initiative;
6. Basic knowledge (owned by the individual);
7. Basic skills, computer skills and previously learned software tools;
8. Acquired knowledge of the studied disciplines of the computer cycle;
9. Acquired skills in the studied disciplines of the computer cycle, computer skills and learned software;
10. Use of scientific and methodological literature, communications, the Internet;
11. Attentiveness;
12. Strong-willed efforts;
13. Purposefulness;
14. Persistence;
15. Contact with the teacher during the performance of independent cognitive activities in order to obtain information;
16. Contact with other students during the performance of independent cognitive activities in order to obtain information;
17. The ability to set and achieve goals of cognitive activities;
18. The ability to plan their cognitive activities;
19. The ability to assess their potential in the performance of cognitive activities;
20. The ability to evaluate the results of their cognitive activities.

The calculation results, ranked by the upper confidence interval, are presented in table 1.

In a study with a reliability level of 95% (for all components) and a number of degrees of freedom equal to 16, the confidence probability (Student's coefficient) is $t_{\varphi} = 2.1314$.

Table 1 and figure 1 show the results of calculating the confidence intervals of the information content for each of the 20 factors of cognitive independence.

Table 1. The ranking results of the factors that form the cognitive independence of students (Sumy National Agrarian University, Ukraine).

<i>ParameterNo.</i>	P_{cp}	S_i	n_i	P_i^u	P_i^l	P_i^u rank
16	0.6929	0.3413	0.1892	0.8821	0.5036	1
8	0.7312	0.1435	0.0796	0.8108	0.6516	2
20	0.6626	0.2429	0.1347	0.7973	0.5279	3
15	0.6276	0.2927	0.1623	0.79	0.4653	4
9	0.7135	0.1136	0.063	0.7765	0.6505	5
6	0.663	0.1126	0.0625	0.7255	0.6006	6
7	0.6251	0.1293	0.0717	0.6968	0.5534	7
19	0.514	0.3156	0.175	0.689	0.339	8
12	0.5855	0.148	0.082	0.6675	0.5034	9
10	0.6273	0.0661	0.0367	0.664	0.5906	10
14	0.4967	0.1912	0.106	0.6027	0.3906	11
11	0.5594	0.0658	0.0365	0.5958	0.5229	12
18	0.4512	0.2475	0.1372	0.5885	0.314	13
13	0.5063	0.1373	0.0761	0.5824	0.4302	14
4	0.5455	0.0418	0.0232	0.5686	0.5223	15
1	0.5142	0.0623	0.0345	0.5488	0.4797	16
3	0.4576	0.1272	0.0706	0.5281	0.387	17
2	0.4965	0.0257	0.0143	0.5107	0.4822	18
5	0.4407	0.0691	0.0383	0.479	0.4024	19
17	0.3684	0.1662	0.0922	0.4605	0.2762	20

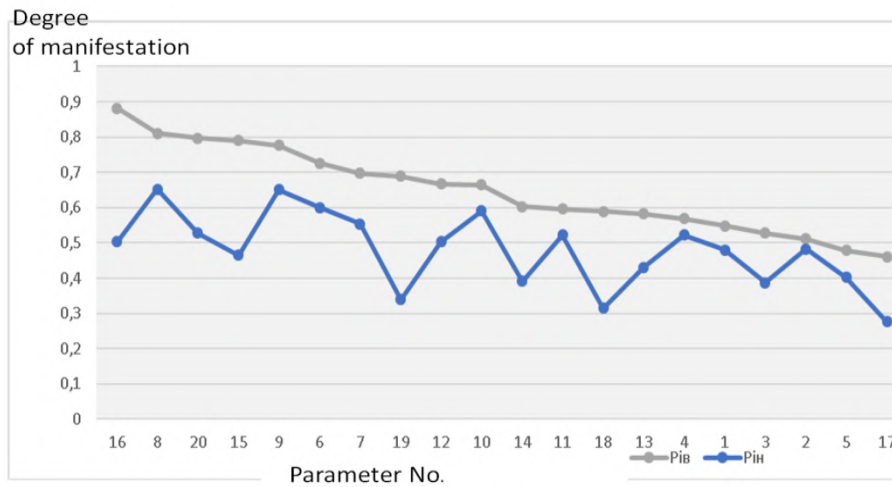


Figure 1. Confidence intervals of the degree of manifestation of personal qualities in the structure of cognitive independence (P_{ib} , P_{ih} – upper and lower confidence limits).

3.3. Improving educational technologies using the results of assessment of the information content of cognitive independence factors. An example.

Using the results of assessment of factors allows each university to find those “pain points” that need special attention when improving educational technologies ([3], [2], [11], [16], [20], [37]).

Based on the result of the experiment described above, a special technology (figure 2) was developed (information environment for e-learning) with special advanced features ([5], [19], [21], [20]), including:

- Communication between students in the process of independent work (factor 16, rating 1);
- Self-control of the learning process (factor 20, rating 3);
- Prompt communication with the teacher (factor 15, rating 4).

The use of a new educational information environment in the groups of faculties of management, food technology, agricultural mechanization, veterinary and agronomy of the Sumy National Agrarian University (data obtained as a result of the experiment [5], [19]) allowed them

- to increase significantly academic performance from 72.3 to 81.4 (by 100 point scale);
- to decrease the frequency of refusals from independent work of students using the e-learning environment from 24.8% to 7.3%.

The use of the system of adaptive e-learning based on an intelligent agent-manager made it possible to reduce the percentage of refusals from the use of e-learning (the quality of training, according to teachers’ estimates, has increased, but the statistics have not been properly processed):

- Sumy State University (disciplines “Data Mining”, “Decision Theory”, “Ergonomics”, “Methodology of Scientific Research”; teachers – Prof. E. A. Lavrov and Prof. E. G. Kuznetsov) from 30.1 to 8.3;
- Taras Shevchenko National University of Kyiv (discipline “Discrete mathematics”; teacher – Prof. O. E. Siryk) from 17.9 to 5.1.

4. Conclusions

Cognitive independence is an integrative quality of a person, based on cognitive activity associated with the initiative and the search for various ways to solve educational and cognitive tasks, ensuring self-development of a person.

The technology of questioning and processing the opinions of experts (teachers), based on the method of pair comparisons, is a convenient means of identifying the degree of influence of various factors.

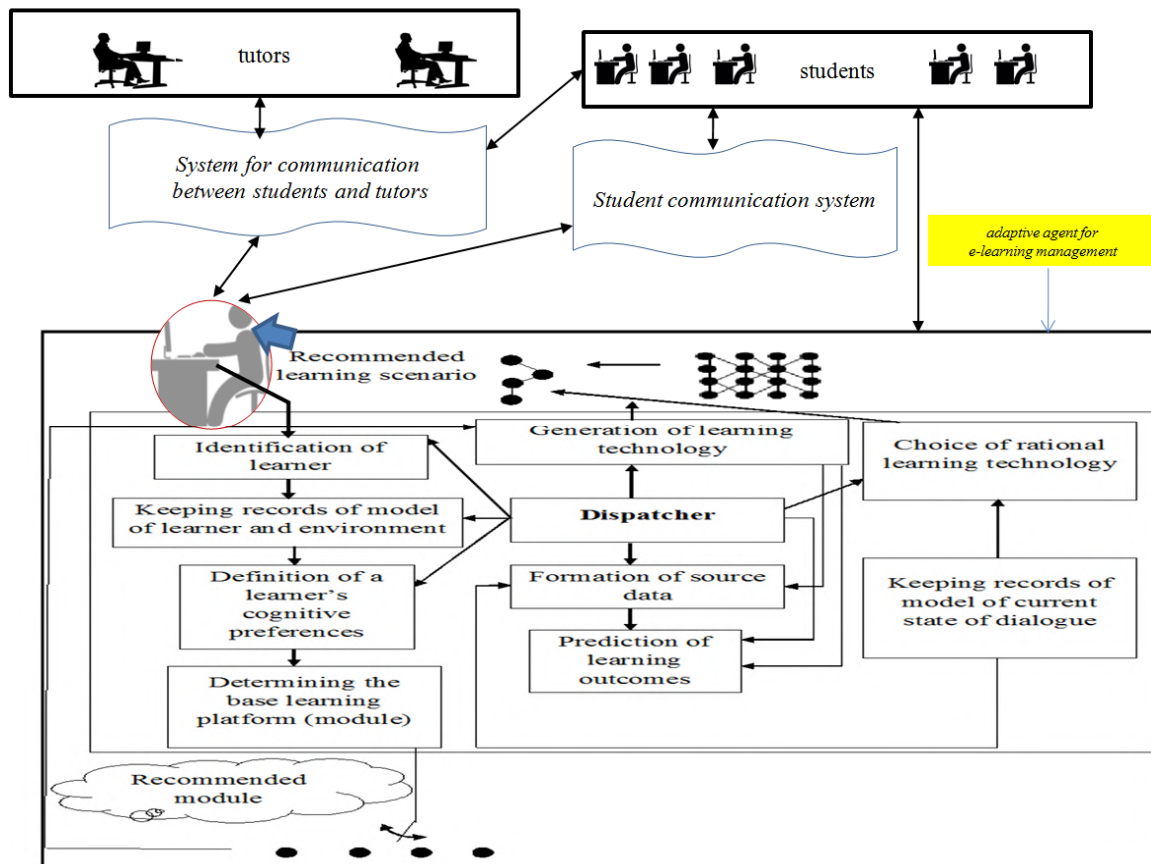


Figure 2. System of adaptive e-learning based on intelligent agent-manager.

Due to the rapid change in teaching technologies and the psychological characteristics of students, an assessment of the degree of influence of factors on cognitive independence should be carried out regularly.

Embedding a subsystem for assessing the influence of factors in the learning management system is a convenient means for assessing.

Assessing the importance of factors affecting cognitive independence is a necessary step in improving the educational process, including the electronic educational environment.

The experiments carried out confirmed the constructiveness of the method and the possibility of significant improvements in the quality of the educational process, based on a systematic study of factors affecting cognitive independence.

The use of the developed mathematical model and information technology allows to increase significantly academic performance and to decrease the frequency of refusals from independent work of students using the e-learning environment.

The capabilities of modern educational environments should constantly expand on the basis of research on factors affecting the cognitive independence of students (including taking into account the requirements of adaptability, communication between students in the learning process, self-control of the learning process, quick communication with the teacher, etc.).

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The authors dedicate this article to the memory of their teacher, Doctor of Technical Sciences, Professor Akiva Tovievich Asherov (1938-2011), who first formulated the ideas that formed the basis of the study.

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