Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Preface

To cite this article: 2021 *J. Phys.: Conf. Ser.* **1946** 011001

XIII International Conference on Mathematics, Science and Technology Education

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Abstract. This paper represents a preface to the Proceedings of the XIII International Conference on Mathematics, Science and Technology Education (ICon-MaSTEd 2021) held at the Kryvyi Rih State Pedagogical University, Ukraine, 12–14 May 2021. Background information and the organizational structure of the meeting, paper overview and acknowledgments 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. (see figure 1)

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 [1]. There is urgent general need for principled changes in mathematics, science and technology education elicited by promising theories, models, tools, services, networks and communications.

There were 34 submissions selected. Each submission was reviewed by at least 3, and on the average 3.7, program committee members. The committee decided to accept 23 papers.

The spread of the coronavirus that causes COVID-19 has change conference organization. Therefore, the XIII International Conference on Mathematics, Science and Technology

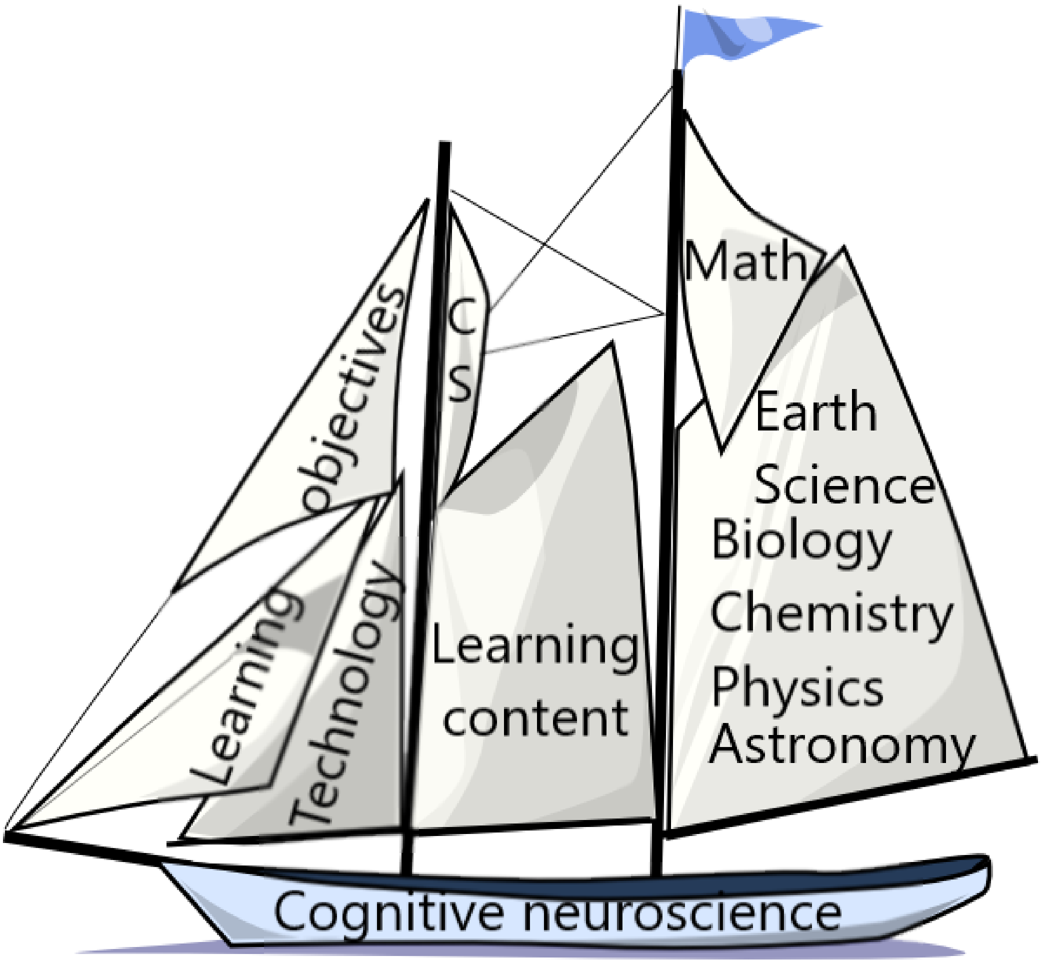

Figure 1. ICon-MaSTEd 2021 logo.

Education (ICon-MaSTEd 2021) took place 12–14 May 2021 at the Kryvyi Rih State Pedagogical University, Ukraine.

More than 100 attendees from 11 countries are joined to ICon-MaSTEd 2021 using Google Meet. The conference featured 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:

- invites 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/SS2021/ where details of the sessions, usually headed by one or more invited presentations.

2. ICon-MaSTEd 2021 program committee

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- *Natalia Zhytienova*, H. S. Skovoroda Kharkiv National Pedagogical University, Ukraine

3. Proceedings structure

- 6 talks were presented in 'Mathematics Education' section: [2], [3], [4], [5], [6] and [7],
- 1 talk was presented in 'Biology Education' section: [8],
- 2 talks were presented in 'Chemistry Education' section: [9] and [10],
- 1 talk was presented in 'Astronomy Education' section: [11],
- 2 talks were presented in 'Computer Science Education' section: [12] and [13],
- 4 talks were presented in 'Technology Education' section: [14], [15], [16] and [17],
- 7 talks were presented in 'Educational Technology' section: [18], [19] and [20], [21], [22], [23] and [24].

4. Conclusion

XIII installment of ICon-MaSTEd was organized 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. Special thanks to session chairs for their work on the conference and its program, excellent and gratefully appreciated conference support.

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 2022. The next meeting in the series is the XIV International Conference on Mathematics, Science and Technology Education, 2022, Kryvyi Rih, Ukraine (https://icon-masted.easyscience.education/2022/).

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Peer review declaration

To cite this article: 2021 *J. Phys.: Conf. Ser.* **1946** 011002

Journal of Physics: Conference Series **1946** (2021) 011002 doi:10.1088/1742-6596/1946/1/011002

Peer review declaration

All papers published in this volume of Journal of Physics: Conference Series have been peer reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review: Single-blind**
- **Conference submission management system:** HotCRP, https://notso.easyscience.education/icon-masted/2021/
- **Number of submissions received: 34**
- **Number of submissions sent for review: 34**
- **Number of submissions accepted: 23**
- **Acceptance Rate (Number of Submissions Accepted / Number of Submissions Received X 100): 67.65**
- **Average number of reviews per paper: 3.7**
- **Total number of reviewers involved: 122**
- **Any additional info on review process:**
- **Contact person for queries:** Serhiy O. Semerikov, Kryvyi Rih State Pedagogical University, semerikov@gmail.com

Journal of Physics: Conference Series

Development of the online course for training master students majoring in mathematics

Development of the online course for training master students majoring in mathematics

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Abstract. This article considers the issue of implementing a model of blended learning to prepare master students majoring in Mathematics (speciality code in Ukrainian educational system “014 Secondary Education. Mathematics”). The research analyses the existing developments of the issue about the use of blended learning while training would-be mathematics teachers. The researchers determined and explained the stages of work on developing the online course “Methods for Teaching Mathematics to Students at Technical Universities”, that is used when students learn methodological subjects of the curriculum. The research describes the development of the theoretical online course model and methodological recommendations on the learning materials and preparing papers for the course. The article offers recommendations related to the course structure. The course developers defined the usability criteria of the educational platforms, determined the stages of course users’ activity, their content, and organization. The research describes the areas of online course activity management, the course tutors’ and moderators’ teamwork is defined as the main condition of its development and support. In order to prove the efficiency of implementing blended learning of the methodological subjects, an experiment was carried out during the assistant practice in technical universities that master students of the specialization “Mathematics” had. The results allowed confirming the efficiency of students’ practical training during blended learning of the methodological subjects that in its turn encouraged the improvement of the assistant practice results.

1. Introduction

The permanent and considerable growth of technological resources generated a new concept of education that uses the blended learning [1–5]. Blended learning is a combination of the personal and online learning experience. The advantage of this multi-methodological approach is that it allows achieving the goals connected with traditional education. Due to this fact the actuality of developing cognitive online environments that ensure a complex training of higher school teachers combining traditional and online education is growing.

In order to confirm the correctness of the chosen approach the analysis of the researches and publications made by [6, 7], dedicated to the development of educational environments, was carried out. The conclusions of the analyzed works proved that the problems of training higher school teachers can be solved by implementing the models of blended learning aimed at the students who can be self-organized and are ready to develop their skills. It was also proven by the scientists [8–11] who explained the conclusions about the global nature of the problem to give practical training to would-be mathematics teachers.

In the mentioned scientific works it is explained that blended learning ensures continuous learning in constantly changing and mobile environments. Besides, according to the research assessment [12–14], the advantages of blended learning include maximum flexibility, efficient and fast delivery of knowledge, and different options of personalization. According to [15], blended learning helps to solve the issues of improving the motivation of students who are involved in online courses [16].

Together with studying the problems in online education, in a range of publications, scientists emphasize the efficiency of using blended learning during mathematics teachers' training. Describing the development of the courses that ensure blended learning [17–19], studied the role of a teacher on high-quality online courses and summarized the students' and teachers' experience of learning online. The same problems interested the researchers [20–22], who pointed out that considerable use of modern Internet technologies while training specialists in different areas requires from higher school mathematics teachers skills to adapt to new conditions, permanently support and renew their knowledge to correspond to the growing demand for online education.

In order to satisfy the growing interest in high-quality online education [23] discuss the development of online systems and describe how to implement the development of a course that ensures the quality and consistency of both things – the content and learning design in university. The scientists recommend the model that ensures the general foundation for all university online courses. In this model, the academic departments choose what courses they want to turn into online courses and give recommendations to the course developers. Also, the scientists suggest a detailed description of the course development process, from concluding a contract to the consultation with the developer who created the instructions and reconsideration of quality standards.

[24] reviewed the literature for studying the problems while carrying online courses and defined three main categories that are connected with online education, instructors, and content development. The scientists described how to solve these problems using the survey among online course participants. Teachers' questions included the change of teachers' role, transfer from personal communication to online, time management, and teaching styles. The content questions included the instructors' role during the content development, multimedia integration into the content, the role of learning strategies during the content development, and suggestions on the content development. Also, in the context of the research, an interesting idea was given by [25, 26], who described how students together with offline classes got consultative online learning support. The results of the experiment proved that students were more motivated in a blended learning environment. The students' satisfaction with blended learning is shown in the researches done by [27–29]. The transforming potential of blended learning in higher education is presented in the research done by [30]. The research by [18] also proved the students' tendency to study more online during blended learning.

Thus, the range of problems that were described in the scientists' researches [18, 27–30] and connected with the implementation of blended learning in universities and online course development encouraged the authors of this article to determine the stages of their work on the development of the online course "Methods for Teaching Mathematics to Students at Technical Universities" [31] to prepare mathematics teachers during blended learning. At the stage of planning aims, the authors of the course were focused on the points of the concept given on the platform "Higher School Mathematics Teacher", developed by authors of [32]. The course developers followed the concept that student's achievement of the goals regularly will motivate them to strive for more. That's why while making the curriculum the attention was focused on the achievable goals that students choose independently. Students' ideas influenced the course structure.

The theoretical analysis of the researches and resources [33, 34], that describes the online course structure and component development, and also the ideas given by the scientists [35], focused on the development of programs for online courses, allowed the authors of the article to include the creation of the course model to the stages of work on its development. At this stage, the attention was concentrated on the research done by the scientists [36,37], who indicated that educational institutions face problems during the model development process. The researchers recommended relying on the survey among the students who represent their expectations from the course for the efficient, high-quality development of the online course model.

The authors of the article also defined such a stage of work on the course development as the organization of their participants' activity and determination of its evaluation criteria. The researchers based their conclusions on the research done by [23, 24, 38] about taking into consideration the wishes of future potential course users.

The course design was determined as one of the stages of its development. While course tutors followed the position given by [39], that interface should be attractive and minimalistic in use [40] and thus, its main objective should be to allow the user to build their learning strategy. Also, during the design development, the principles of instructional design offered by [41], the principles of usability implementation given by [42] and suggestions on online course design and development mentioned by [43] should be taken into consideration.

The analysis of the researches done by the course developers [44, 45], as well as teaching mathematical subjects in technical universities proved the relevance of adding to the stages of online course development the creation of methodological recommendations for learning materials and the organization of course management.

The article aims to determine and explain the stages of the work on the course development for training would-be mathematics teachers during blended learning.

The achievement of the research aim was based on the description of:

(i) The course model creation
(ii) The development of methodological recommendations for learning materials and preparing papers for the course
(iii) The course design
(iv) The organization of course participants' activity and determination of evaluation criteria
(v) The course management
(vi) The experimental confirmation results of the efficiency when implementing blended learning for the subjects of the methodological cycle

2. Method

The authors of the research determined the stages of work on the course development for training mathematics teachers during blended learning: 1) building a course model; 2) development of methodological recommendations for learning materials and preparing papers for the course; 3) course design; 4) organization of the course participants' activity and determination of its evaluation criteria; 5) course management.

We offer to consider the methods that were used during every stage.

2.1. The development of the course model

The development of the theoretical model of the online course "Methods for Teaching Mathematics to Students at Technical Universities" [32] to prepare master students of the specialization "014 Secondary Education. Mathematics" (hereinafter "Mathematics") was the first stage. While creating a model the researchers followed the next principles: system, humanity and professional orientation, flexibility, dynamics, and volatility. At this stage, the researchers created a survey using Google Forms [46] by posting it on the platform "Higher School Mathematics Teacher" in free access and offered it to master students. The survey questions were focused on finding out the future participants' expectations from the course. In particular, it was important for the course tutors to find out the nature of the problems that master students face during their assistant practice, master students' level of awareness about the methodological and technological peculiarities of active mathematics learning; understanding of cloud technologies and systems of computer mathematics while teaching mathematics in technical universities. The analysis of the master students' survey results helped to organize the feedback with the future course participants. Thus, the students were willing to get acquainted with the components of the professional training, get an experience of performing specific types of teacher's activity, and get acquainted with the parameters according to which the internal specialist's readiness for professional activity is evaluated.

Furthermore, the analysis of the respondents' answers allowed us to determine the structural components of the online course model: methodological environment; technologies of the learning environment; the component structure of professional training. In the methodological environment of the model, the course tutors offered the participants to learn the content, methods, forms, and means of learning mathematics in universities. The authors chose the systems of computer mathematics (SCM) [47], cloud technologies [48], and a project method [49] as the semantic filling of the component that ensures the technologies of the learning environment. Connection building between the methodological environment and technologies of the learning environment [50] is carried out using visual, instrumental, integral genesis.

Motivational and value-based, operational and activity-related, controlling, and corrective components during the professional training enable to structure and evaluate the parameters of the internal specialist's readiness for the professional activity. The visual illustration of the theoretical model of the online course "Methods for Teaching Mathematics to Students at Technical Universities" is shown in figure 1.

2.2. The development of the methodological recommendations for learning materials and preparing papers for the course

The second stage of work on creating a course was the development of the methodological recommendations for learning materials and preparing papers for the course. At this stage, the authors of the course used the method of analyzing research [33, 35] and resources [34] that provide recommendations on training, structuring, and development of the online course content. As a result of the analysis the course developers created the recommendations on the course structure, in particular:

1. The course materials should be provided as logical sections (learning "blocks") of the corresponding length for learning during 1–2 hours.
2. It is more appropriate to start every week and every new section with a material review, including structure, learning results, and approximate learning time review.
3. Every section, subsection, and the pages should have clear descriptive headings. It will help the student to plan on which sections they will work and allow them to review the topics that have already been learned.

The course developers suggested the recommendations on handing in the papers for the participants' processing on the course according to the information accessibility features and its quality as well as considering students' needs.

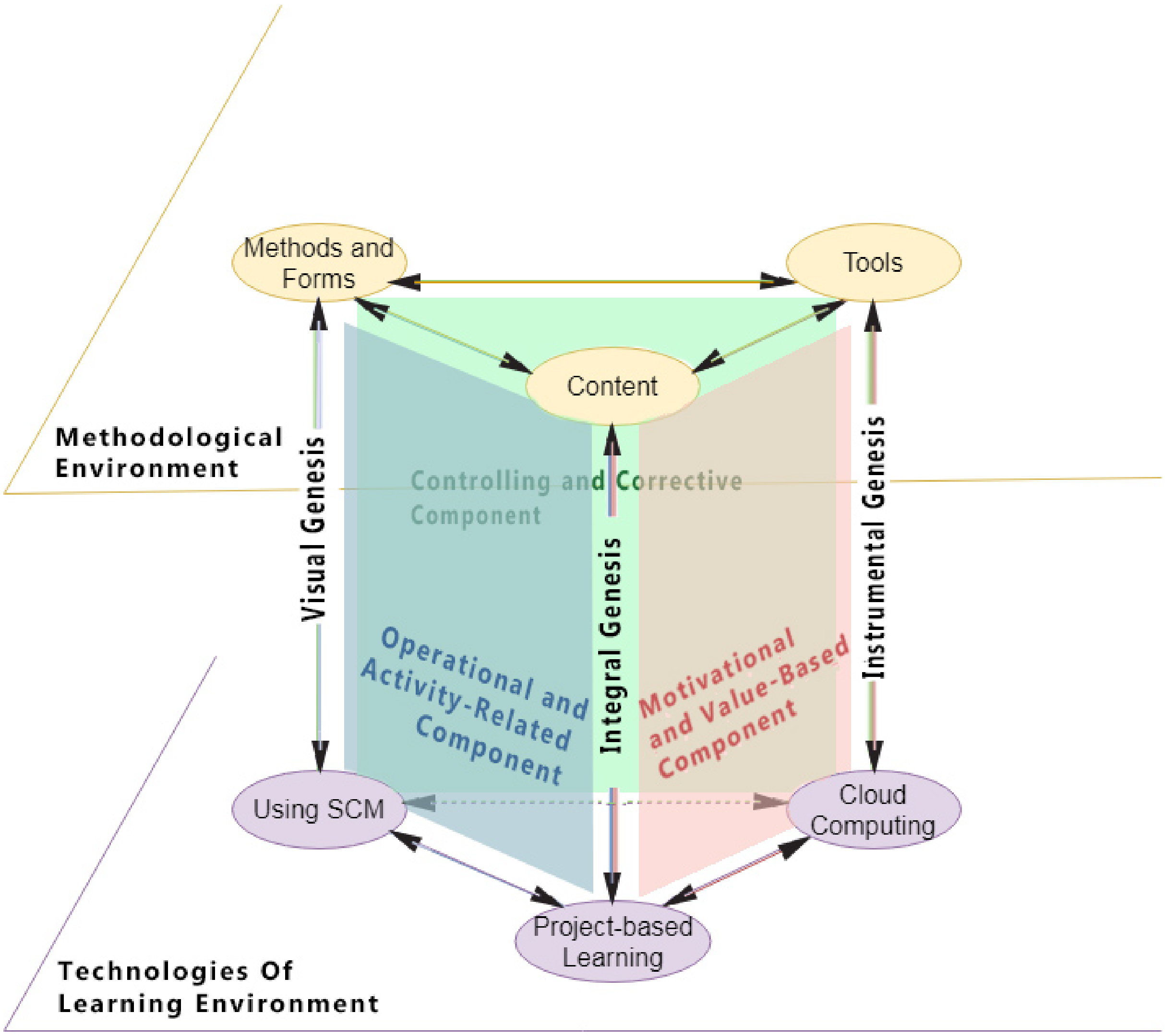

Figure 1. Theoretical model of the online course "Methods for teaching mathematics to students in technical universities".

The materials of lectures and practical tasks, according to the recommendations, can consist of video files, hypertext, demonstrative animation, audio, and video lectures, schemes, pictures, graphics, tables, drawings, information-reference materials, computer simulators. Presentations and other additional materials such as attached files and interactive supplements, resources, given in the reference list, can be also used. The course developers suggest using Camtasia software that can catch the video from the screen in order to create a video lecture of the online course.

Forum use during the course has several functions, that's why the course developers recommend: all the course participants to sign up for the forum to get notifications about new topics and answers on the forum; to use the forum for the participants' communication in the asynchronous mode, in other words, during a long time; to carry out discussions among the participants about their group mates' works using the forum, which is included in one of the course tasks. Moreover, the course developers recommend the participants to visit the forum to share examples of their works with each other and also to ask each other and teachers some questions on the topics that are studied.

The creation of the course content has to be combined with the evaluation of the students who help to evaluate the quality of the developed learning materials and detect minor disadvantages. That's why the course developers recommend improving the course materials using the survey among the respondents who work with the courses. The authors of the course suggest using the surveys created in Google Forms.

2.3. The course design

The course design was determined as the next stage of the work on the course. The researchers defined the interface of the course on the educational platform as one of the factors that impact online learning results.

Using the Inductive Content Analysis Method the course developers carried out the analysis of the structure and principles of creating the most popular international and domestic systems of online education and determined the usability criteria of educational platforms [40]. These parameters were included in the survey among higher school teachers and students, and it was aimed at evaluating the relative importance (weight) for users of the determined usability criteria (Information Quality (IQ), System Learnability (SL), System Navigation, Visual Design, Instructional Assessment, System Interactivity, and Responsiveness). In order to do it, the respondents defined the criterion rating from 1 to 7 depending on its influence on the platform usability (where 1 is the most important). Working on the course design its authors followed the realization of the defined usability criteria on the platform "Higher School Mathematics Teacher" [32]. The ways of following the criteria are represented in table 1.

2.4. The organization of the course participants' activity and determination of evaluation criteria

The organization of the course participants' activity is an important aspect of efficient course learning. The content of every stage organization is represented in table 2.

The authors of the course offered master students a survey using an open online service, posting a survey on the platform "Higher School Mathematics Teacher" [32]. The survey questions were focused on the correction of the course topics and materials. The analysis of the survey results and respondents' suggestions on the forum helped to determine the stages of the participants' activity and the organization of these stages.

The authors determine the main stages of the activity on the course such as the course introduction, its aim, and objectives; weekly learning planning; theoretical data introduction; completing practical tasks; passing tests; communication with the course teachers and participants.

The authors of the course developed the criteria of evaluating the activity of the online course users using the analysis of the programs of university practices [51–54], where master students of the specialization "Mathematics" are prepared. Tutors evaluate the course participants' activity after the course following the next criteria: formed skills to organize the main forms of teaching mathematics in higher schools (scientific-pedagogical activity); formed skills to carry out the methodological analysis of the learning material and prepare learning methodological material for different types of classes (methodological activity); formed skill to choose and use modern technologies and learning methods (integration activity); acquiring experience of teaching activity, moral-ethical qualities that a higher school teacher should have, an individual creative style of the pedagogical activity, necessity of self-education (professional activity).

2.5. The course management

The efficiency of the online course process mostly depends on the organization of the course management. That's why the next stage was to find out about the management of the online

Table 1. Realization of usability criteria on the platform "Higher School Mathematics Teacher".

Criterion name	Criterion function	The conditions of criterion realization on the platform "Higher School Mathematics Teacher"
Information Quality (IQ)	Describes the information correspondence in the system to the learners' needs	The use of programming tools for text formatting, integration of graphic, video and audio information, link, formula, testing, and survey integration
System Learnability (SL)	Describes the learning easiness and speed	
System Navigation	Reflects the quality of navigational tools	Is ensured using the main and additional menus of the platform that are placed in the upper part of the interface and are present on every page, it allows the user to follow the necessary section
Clear sequence	Describes the clear logical consistency of pages	Posting "breadcrumb" navigation on the pages that allows to visually represent the hierarchy of the pages of the upper level and navigate on them
Visual Design	Describes the aesthetics of the learning system visual design	The use of a basic range of colors in RGB coding model (light colors are for the body, dark are for the main content and additional colors are for structural elements and references), that ensures readability and aesthetic design; satisfies the objectives of the platform information value, general structure of the platform interface, that includes a header, footer, sidebar, and content layout elements; the text is ensured by Typography, that includes a stylistic design for headings, subheadings, and the main text
Instructional Assessment	Describes the easiness and efficiency of evaluation tools	Feedback forms, testing subsystems, and file downloads are used
System Interactivity	Rreflects the presence of simple interaction tools between the participants of the learning process	The platform users' forum is used that ensures the interaction of student–teacher, teacher–student, student–student
Responsiveness	Describes the quality of the system image on mobile devices with different resolution	The adapted size of the text, headings and, subheadings, links, buttons, size of the images, and other interface elements are used

course process.

The researchers surveyed master students and mathematics teachers of higher schools. The

Table 2. The organization of the course participants' activity.

Stage of activity	Organization of the stage		
	Tutors' activity	Participants' activity	Method
Course introduction, its aim, and objectives	Formulates the course objectives, defines work terms	Users start studying on the course from the registration point, that's why for every participant the first learning week on the course starts individually, and also according to the learning start, the individual time of finishing the learning week is defined	Video
Weekly learning planning	Formulates the weekly objectives	Users get acquainted with the plans and objectives for the learning week	Video
Theoretical data introduction	Represents the learning topic	Users get acquainted with the theoretical material, work it out at their own pace during the learning week	Text documents, for giving the main theoretical data; videos
Completing practical tasks	Offers resources that allow students to be involved in different types of activity	Users watch the video with the recommendations on the practical task; choose the mathematics section independently for the creation of their product according to the weekly tasks; complete the task; represent the work by posting it on the weekly forum	Video with recommendations on how to make lecture notes or a system of exercises for the practical class; higher mathematics textbooks
Taking tests	Offers the participants a knowledge self-check	Users check the level of the topic assimilation, after taking the test, the topic is counted done if 60% of the answers are correct, the number of taking the test is not limited	Tests
Course participants' cross-checking	Offers to use earlier developed criteria of the task evaluation	Users check the works of two group mates; evaluate them and discuss the works on the forum	Task evaluation criteria
Modern technologies use while learning mathematics in technical universities	Offers to involve modern learning technologies to prepare practical weekly tasks	Users get acquainted with the examples of modern technologies use	Resources to be used: a project method, computer mathematics systems, cloud technologies
Communication with teachers and course participants	Encourages the course participants to take part in weekly forums	Users take part in weekly forums	The forum on the platform that is the main criterion of learning a course

survey for teachers allowed finding out the respondents' attitude to teamwork in creating courses and also the coordination of the team members' activity involved in the platform support. Also, the course developers carried out a theoretical analysis of the researches and resources that implement the recommendations on training, structuring, and developing the content for online courses. The analysis of respondents' answers for the offered questions and studies of the recommendations influence the description of the methodological requirements for the online course structure and content.

The developers structured the course "Methods for Teaching Mathematics to Students at Technical Universities" [31] following weekly planning. The authors introduced the material review at the beginning of every week and every new section, including course participants' introduction to the structure, learning results, and approximate learning time.

The adaptation of the mass production to the requirements of a particular consumer on the educational platform "Higher School Mathematics Teacher" [32] takes place using a partial content change following a definite request, adding extra tasks and materials to the course. The discussions on the forum that are regularly monitored by the course tutors allowed monitoring the content quality, involvement of the potential participants to the material development, creation of the conditions of constant support for the course participants, prompt reaction to their suggestions.

The areas of the online course activity management pointed out by the authors allowed determining the necessary actions concerning management, terms of action, and participants (table 3).

3. Results

The experimental research on the impact of blended learning implementation was held during 2019–2020 while master students of the specialization "Mathematics" learn methodological subjects of the curriculum and during the assistant practice in technical universities.

The experiment hypothesis. The analysis of the theoretical works on the methodology for training master students, the determined theoretical basis of blended learning in the methodological training of future mathematics teachers in technical universities allowed formulating a hypothesis: the efficiency of blended learning during the methodological training of future mathematics teachers in technical universities will be high under the condition of the systematic use of traditional offline learning and online learning of the subjects of the methodological cycle. According to the model of the author's methodology, the use (option A) or non-use (option B) during the assistant practice of the online course "Methods for teaching mathematics to students in technical universities" [31] was determined as the variable. Option A is based on the fact that students during their assistant practice used the materials of the online course [31]. Option B is based on the fact that students during their assistant practice did not use the materials of the online course [31] but used only the offline learning materials that were offered by the teacher following the blended method. Invariable conditions: the number of experiment participants in experimental groups; similar initial students' level in both EG; duration of the learning and assistant practice; using the model of blended learning for the subjects of the methodological cycle where the training for the assistant practice is carried out, evaluation criteria, experimenter.

The selection of the experiment participants. 87 master students of the second training year of Kryvyi Rih State Pedagogical University, Sumy State Pedagogical University named after A. S. Makarenko, National Pedagogical Dragomanov University, Berdyansk State Pedagogical University, Vinnytsia Mikhailo Kotsiubinskyi State Pedagogical University were involved in the experiment, those who had their assistant practice at that time. In order to get equal groups at the beginning of the experiment, the control and experimental groups of students included those who had the same average success rate for the subjects of the methodological cycle. The

Table 3. Management organization on the course.

What is necessary to do?	Who carries it?	When should it be done?
The preparatory stage of the course development		
To work out a survey and spread it among the potential course participants and teachers aimed at finding out the expectations from the course To carry out the theoretical analysis of the researches and resources and make recommendations on the preparation, structuring, and development of the content for online courses To describe methodological requirements for the structure and content of online courses	Course developers	During the course planning
To structure the course on the online platform To develop the course content, forms, and methods of knowledge control	Course developers	During the development of the course content
To support technically the content management during the course creation	Content-manager	
To provide the search for course participants; advertise and promote the course	Client-manager	
Course opening		
To register the users on the course; to provide access to the course	Client–manager	Before the beginning of the course learning
Stage of the course use during the learning period and skills development		
To form the participants' group; to create the course schedule	Client-manager	During participants' learning on the course
To provide the proper efficiency of the course elements during all the time of its use	Content–manager	
To interact with the course participants during individual and group online consultations; to control the learning process	Course tutors	
Finishing learning on the course		
To give a certificate about passing the course	Client–manager	During the last week of the course
Course improvement		
To change partly the content following a particular request; to add extra tasks and materials to the course; to monitor regularly the discussions on the forum; to involve potential participants in the course material development; to react promptly to the course participants' suggestions	Course tutors	Periodically during the course
To support technically the content changes during the course improvement	Content–manager	

students of the experimental group learned the subjects of the methodological cycle: "Methods for Teaching Mathematics in a Specialized School" (MTMSS); "Innovative ICT in Education" (InICT) following the methodology of blended learning. Students of the control group learned the same subjects following the traditional methodology. The same teachers evaluated the pedagogical traineeship in universities (assistant practice) in both groups. During the assistant practice, two experimental groups (EG_1 and EG_2) were created. The students of group EG_1 (19 participants) were offered to sign up for the online course [31] during the practice (option A of the author's methodology model). The students of the experimental group (EG_2 – 21 participants) and of the control group (CG – 47 participants) had their assistant practice without the course implementation (option B of the author's methodology model).

Pre-experimental test. This test was carried out in order to find out the students' success rate for the subjects of the methodological cycle at the beginning of the master's studies. Table 4 represents the average success rate for every subject of the methodological cycle and pedagogical traineeship that the students of the experimental and control groups had during the bachelor's studies. The average success rate is 0.761 in EG_1, 0.804 in EG_2 and 0.761 in CG.

Table 4. The average success rate for the subjects of the methodological cycle during the bachelor' studies.

Subjects	CG	EG_1	EG_2
MTM	0.76	0.758	0.804
ICTT	0.75	0.76	0.814
Pedagogical traineeship (PT)	0.775	0.765	0.795
Average rate	0.761	0.761	0.804

The determination of the success rates took place according to the grading system (table 5).

Table 5. Grading system: national and ECTS and success rates.

Total for all types of learning activities	ECTS estimate	Estimate according to the national grading system	Success rate
90–100	A	Excellent	High
80–89	B	Good	Sufficient
71–79	C		
61–70	D	Satisfactory	Average
50–60	E		
30–49	Fx	Unsatisfactory	Low
0–29	F		

The number of students in EG (in %) at the same success level for every subject of the methodological cycle and practice is represented in table 6.

In order to determine the presence of differences in the success rate, Mann Whitney U–test that is meant for evaluating the difference between two selections following a feature level that is measured by quantity was used. The empirical value of the criterion U reflects the level of the coincidence zone between the sets. The lower $U_{empir.}$ is, the more reliable the difference in results might be. Reliable differences can be observed if $U_{empir.} = U_{cr.}0.05$. "In order to

Table 6. The ratio of the students' number and the success rate (in %).

EG	High level			Sufficient level			Average level			Low
	MTM	ICTT	PT	MTM	ICTT	PT	MTM	ICTT	PT	—
EG_1	15.8	21.1	15.8	52.6	42.1	47.4	31.6	36.8	36.8	—
EG_2	33.3	33.3	28.6	47.6	52.4	52.4	19.1	14.3	19.0	—
CG_2	15.9	20.1	15.2	51.7	41.5	48.1	32.4	38.4	36.7	—

process the data, it is necessary to determine the hypotheses: H_0 and H_1." Hypothesis H_0 is accepted if $U_{empir.} > U_{cr.}0.05$. Hypothesis H_1 is accepted if $U_{empir.} = U_{cr.}0,05$. The comparison of the results of the pre-experimental test in EG_1 and EG_2. The average success rate in CG and EG_1 was 0.761, in EG_2 it was 0.804. CG and EG_1 makes selection 1, EG_2 makes selection 2. H_0 – the level of training in selection 1 is not lower than the level in selection 2. H_1 – the level of training in selection 1 is lower than the level in selection 2. Thus, Mann Whitney U–test use proved that the groups of students with the same initial training level took part in the experiment.

Experimental learning. At the next stage of the research master students' experimental learning, which was held following two options of the author's methodology, was implemented. The first part of the experiment was invariable: the students of the experimental groups (EG_1 and EG_2) learned the subjects of the methodological cycle following the methodology of blended learning. The students of the control group (CG) followed the traditional methodology. The second part was variable: Option A was based on the opportunity given to the students of the experimental group 1 (EG_1) who could sign up for and pass the online course "Methods for teaching mathematics to students in technical universities" [31] during the assistant practice. Option B was based on the opportunity given to the students of the experimental group 2 (EG_2) and control group to pass the assistant practice without any online course involvement.

Post-experimental test. The results after the experimental test are provided in tables 7, 8. In table 7 the average success rates for every subject of the methodological cycle and practice are given, in table 8 the correlation of students' number and the success rate (in %) is determined.

Table 7. The average success rate for the subjects of the methodological cycle during the master's studies.

	Control group	Experimental groups	
Subjects	CG	EG_1	EG_2
MTM in a specialized school (MTMSS)	0.806	0.835	0.863
Innovative ICT in education (InICT)	0.795	0.852	0.871
Pedagogical traineeship in universities (PTU)	0.815	0.842	0.869
Average rate	0.805	0.843	0.876

The growth of the average success rate for the subjects of the methodological cycle and pedagogical traineeship after the experiment is represented in table 9.

The growth is visually represented in figure 2–4.

So, in all the groups in all the subjects, the positive dynamics is recorded, but the growth of the success rate according to option A, when students had online support during the practice is higher than according to option B. That is why it is possible to state about the efficiency of the practical training among students during blended learning of methodological subjects. The

Table 8. The ratio of the students' number and the success rate (in %).

EG	High level			Sufficient level			Average level			Low
	MTMSS	InICT	PTU	MTMSS	InICT	PTU	MTMSS	InICT	PTU	—
EG_1	16.3	21.6	16.9	52.9	42.2	48.4	30.8	36.2	34.7	—
EG_2	36.3	35.8	30.6	48.8	53.9	53.4	14.9	10.3	16.0	—
CG	16.0	21.1	16.3	51.9	41.0	47.6	32.1	37.9	36.7	—

Table 9. The growth of the average success rate (ASR) for the subjects of the methodological cycle according to the experiment results.

	Before the experiment			After the experiment			Growth			
Subjects	CG	EG_1	EG_2	CG	EG_1	EG_2	CG	EG_1	EG_2	Subjects
MTM	0.76	0.758	0.804	0.806	0.835	0.863	+0.046	+0.077	+0.059	MTM in specialized schools
InICT	0.75	0.760	0.814	0.795	0.852	0.871	+0.045	+0.092	+0.057	Innovative ICT in education
Pedagogical traineeship	0.775	0.765	0.795	0.815	0.842	0.869	+0.040	+0.077	+0.074	Pedagogical traineeship in universities
Average rate	0.761	0.761	0.804	0.805	0.843	0.876	+0.044	+0.082	+0.072	Average rate

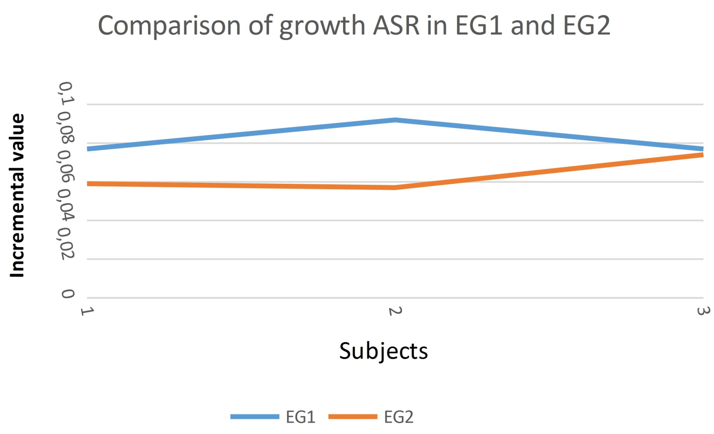

Figure 2. Growth of ASR in groups EG_1 and EG_2.

efficiency of blended learning for methodological subjects also contributes to the improvement of the results of the pedagogical traineeship (assistant practice) in universities.

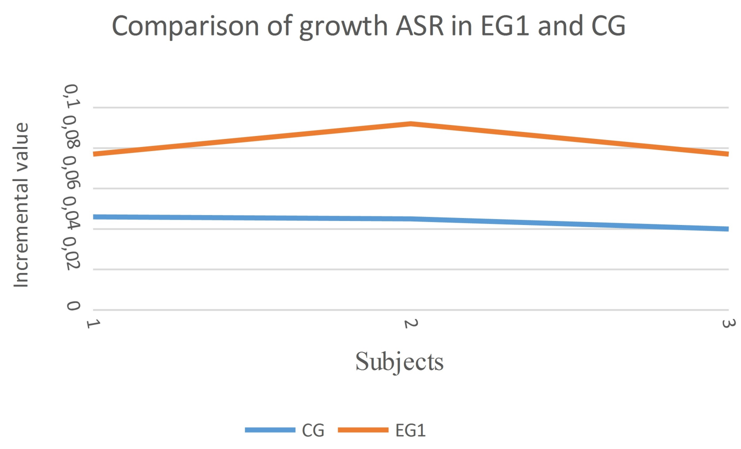

Figure 3. Growth of ASR in groups EG_1 and CG.

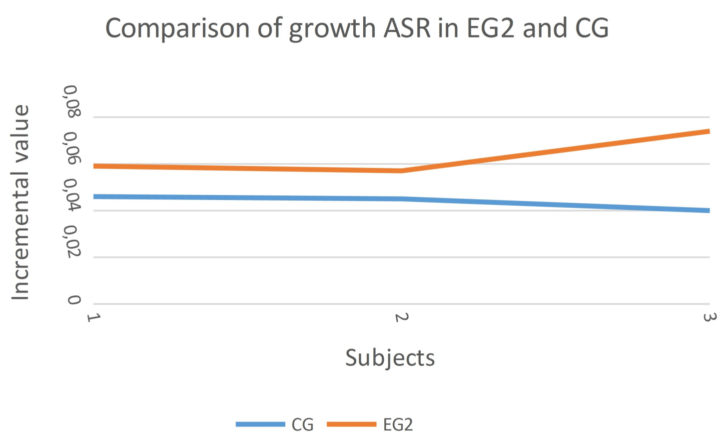

Figure 4. Growth of ASR in groups EG_2 and CG.

4. Discussion

The idea of implementing the models of blended learning for training mathematics teachers in higher schools was proven in the researches by [8–11]. [38], who were focused on the online course use during the development of the environment for blended learning, stated that the model of the online course should help to organize the learning process on the Internet encouraging efficient, integral, and motivated users' practice. During the online course development in order to create such an environment the conclusions of the researches done by [23, 24] were considered, and the necessity to develop a survey aimed at detecting the wishes of the future potential course participants during its development was proven. Taking into account the course participants' ideas and recommendations the scientists helped to develop a model of the online course "Methods for teaching mathematics to students in technical universities" [31]. The selected approach allowed determining the structural components of the online course model: methodological environment; technologies of the learning environment; components of the professional training. The authors of the model based their ideas on the fact that master students' assimilation of the learning material, which was included in the methodical component, encourages their more conscious understanding of the practical implementation of the content, methods, and forms of teaching mathematics in technical universities. The researchers' recommendations, their practical developments, guidance for course tutors enables master students' preparation for offline classes, the development of learning and learning-methodological materials for teaching mathematics. The component functioning of the learning environment technologies is based on using cloud technologies and a project method. The researches done by [55–57] proved the necessity to choose cloud technologies. The scientists stated that due to providing convenient access to the network of computing resources that ensure and release from routine calculations, the use of cloud technologies encourages the intensification of calculations and the attention concentration on more significant questions of the learning process. Selecting the project method, course tutors were concentrated on the works given by [58–60]. The conclusions made by the scientists proved that learning based on projects fosters fast students' personal growth, encourages their self-development and self-management. Visual, instrumental, integral genesis in the model structure helps to set up connections between methodological and technological components of the model learning environment and ensures the efficiency of work with learning materials of these components.

At the stage of developing the methodological recommendations for learning materials and preparing papers for the course the experience of the learning group working on the development of online courses APass (`https://apasseducation.com`) and analysis of the research done by [61, 62] played an important role. Taking into account the recommendations suggested by the scientists, the course developers created the recommendations on the course structure. It is offered to ensure the efficiency of the learning aim on the course using such means as clear aim; matching of the aim and student's expectations; direct correspondence between the learning aims and students' actions during the course and their evaluation; selection of learning materials and technologies that correspond to the learning aims, motivate students and support their results. Moreover, the development of the forum during the course is agreed with the conclusions made by [63], who prove that the forum plays not only an informative role in the participants' communication but also encourages an active participants' role in the discussions on the forum, their tendency to show the highest level of learning the material.

After getting acquainted with the factors that determine the success of the online courses, described in the works of [64,65], we involved experienced experts in teaching mathematics before the preparation and development of high-quality content. The developers, when started creating the course content, supported the idea that the content as the main tool of evaluating the quality of online courses should be followed by the students' estimate. This idea was confirmed in the works of [36, 66, 67].

At the stage of the course design development, the researchers followed the recommendations given by [68] who studied the convenience of using educational websites from the university students' point of view. The course interface on the educational platform was determined as one of the factors that influence the results of online education. The analysis of the recommendations and advice given by [69, 70] helped to describe the organization of the course participants' activity and determine the main stages of the activity: introduction to the course aim and objectives; weekly learning planning; theoretical training; completing practical tasks; taking tests; communication with course teachers and participants.

The position expressed by the authors of the article on the necessity of the development management and online platform support is agreed with the researches that describe the solution to the problems that students face during online learning [71, 72]. The areas of online course activity management allowed determining the necessary tutors' actions related to the management, terms of action, and performers at the preparatory stage of the course development, when opening the course, at the stage of using the course during the learning process, and skills development when finishing the learning on the course and course improvement.

5. Conclusions

The authors of the research used the technology of blended learning combined with the use of traditional offline teaching and online teaching for the subjects of the methodological cycle so that master students could succeed during the pedagogical traineeship (assistant practice) in universities.

The stages of work on the development of the online course "Methods for teaching mathematics to students in technical universities" [31] are determined in the research and the objectives of every stage are described.

At the stage of developing a course model, researchers recommend basing the theoretical model of an online course on the idea of blended learning for subjects of an integrated methodological cycle to prepare students for assistant practice. In particular, the course tutors recommend a methodological environment that allows its users to learn the content, methods, forms, and means of teaching mathematics in universities during MTMSS classes and online lectures. The content of the model component that ensures the technologies of the learning environment, according to the recommendations of the course developers allows the efficient subject assimilation and participants' learning of the modern technologies course for teaching mathematics to students in technical universities, such as systems of computer mathematics, cloud technologies, a project method. Link building between the methodological environment and technologies of the learning environment is carried out using visual, instrumental, integral genesis that students get during the assistant practice in universities.

The development of methodical recommendations for educational materials and preparation of papers for the course is defined by researchers as the second stage of work. The researchers recommend building the course content and the process of its learning on the principles of personal orientation, practical realization, flexibility, independence, and voluntary nature. According to the recommendations given by the course authors, the learning materials should correspond to the students' expectations and encourage motivation during the course.

As for the development of course design, at this stage of work researchers recommend creating it following the usability criteria of the educational platforms and minimalism criteria that ensure the easiness of the course material perception, do not overload the users with extra information.

Organizing the activities of course participants and defining the criteria for their evaluation is also an important stage of working with the course. At this stage, the authors of this course have identified areas for managing the activities of the online course, and this in turn allowed to determine the necessary actions for course management, timing, and the team of performers.

In the last stage of working with the course, the researchers identified the issue of the management of the course. In order to ensure the high-quality management of the course, it is recommended in the research to use teamwork at the stage of creating and ensuring the online course functioning.

The results of the experiment show the growth of the average success rate in the subjects of "MTM in the specialized school" and "Innovative ICT in education" and positive results of the pedagogical traineeship in universities among the students of EG compared with CG. Namely, the average rate in the groups CG, EG_1, EG_2, respectively, is +0.044, +0.082, +0.072. Which in turn indicates the positive results of blended learning.

The vector of further research is the development of an online course for learning the discipline of the methodological cycle by master students "MTM in a Specialized School".

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Journal of Physics: Conference Series

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Some applications of the GRAN1 to analyze two-dimensional continuous probability distributions

To cite this article: M I Zhaldak and N P Franchuk 2021 *J. Phys.: Conf. Ser.* **1946** 012002

Some applications of the GRAN1 to analyze two-dimensional continuous probability distributions

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Abstract. The article considers the use of GRAN1 software in the analysis of two-dimensional continuous probability distributions. The learning process can be provided by freely distributable software, through the use of cloud technologies, in particular software from the GRAN package. However, the use of any technology in the educational process, including modern information and communication technologies, as well as the content of education, must be pedagogically balanced, which will avoid any negative consequences for the formation of the future member of society, his mental and physical development. Attention is drawn to the fact that children are increasingly looking for entertainment, using mobile devices, sharing new products with their peers and spending time together, playing a variety of online games, and parents cannot control this process. At the same time, teachers conduct lessons using mobile devices to draw attention to the subject, they are teaching. In the process of using computer technology, students can form a special type of thinking, the so-called "clip consciousness", which leads to fragmentary thinking and the irreversibility of changes in consciousness. Therefore, the problem of excessive use of mobile devices by children requires constant analysis and coverage. The article discusses some examples of using the GRAN1 software to solve problems in probability theory. Examples of approximate calculation of the value of the double integral are given. Tables of values of the corresponding integrals are described. The use of modern information and communication technologies during mathematics lessons is considered.

1. Introduction

Significant spread of the use of modern information and communication, in particular cloud-oriented, technologies (see [1]) in the educational process, in particular in the process of teaching mathematics, requires the development of new computer-based teaching methods focused on the harmonious combination of pedagogical achievements past and present scientific and technical achievements, the pedagogically balanced use of various computer-based learning environments in the learning process, the formation of students primarily scientific worldview, analytical and synthetic, critical and logical, creative thinking, their mental, physical and general cultural development, correct vision of the world, careful attitude to the surrounding world and to people, benevolence, humanity, peace (see [1, 2]).

The purpose of writing this article is to introduce into the course of computational mathematics for students at pedagogical universities analysis of two-dimensional continuous probability distributions as a new fragment.

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 using not very powerful, including mobile Internet devices – smartphones, tablets, etc. [3] 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 to get to the open virtual desktop on a powerful remote computer 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 [4].

On the example of using the resources of a remote server with "cloud" versions of the software package for educational purposes Gran solve several problems.

2. Theoretical background

Children are increasingly looking for entertainment using mobile devices, sharing new products with their peers and spending time together, playing a variety of online games. Be sure to consider the time spent on such devices to prevent getting used to the uncontrolled use of certain applications or due to exposure to unwanted content [5].

Teachers began conducting lessons using mobile devices and computers to draw attention to the subject. It should be understood, that the informatization of education is not a panacea, there are risks of loss of cultural and creative thinking, live communication, and the illusion of accessibility of cognitive actions. In the process of using computer technology, students form a special type of thinking, the so-called "clip consciousness", which leads to fragmentary thinking and the irreversibility of changes in consciousness. This causes a bad mood, irritability, often general malaise, or fatigue. As a result, appetite is reduced, sleep is disturbed, and efficiency is reduced.

The problem of overuse of mobile devices and computers requires constant analysis and coverage. It is clear, that the development, creation and use of software to control the time spent by children on gadgets is one of the urgent needs of parents and teachers to prevent the "collage of modern thinking" of children [6, 7].

However, with a harmonious combination, the educational process improves, because there is always a lively discussion between students. Researchers have shown that children of all ages memorize learning material best while playing. Therefore, motivated use of mobile devices and computers during learning increases student activity [8, 9].

One of the most effective ways to develop analytical, synthetic and logical thinking of students, as we know, is the teaching of mathematics, its various sections – geometry, algebra, mathematical analysis, probability theory, computational mathematics, discrete mathematics, real variable function theory and others [10, 11].

A special place among such sections is occupied by probability theory, its connections with the theory of measure, geometry, mathematical analysis, computational mathematics. Teaching the basics of probability theory to students at school and future teachers at the Pedagogical University is an important basis for the formation of their professional awareness and professional culture [12].

3. Results

Consider some examples of the use of software GRAN1 (see [4, 10, 13]) to solve problems in probability theory, in particular closely related to the corresponding problems in geometry and mathematical analysis [14], relating to the calculation of probabilities of hitting some two-dimensional sets for conditions of two-dimensional distribution of probabilities on the plane, which are reduced to the calculation of double integrals on convex sets, and hence to the calculation of the volumes of the corresponding spatial figures.

For an approximate calculation of the value of the double integral

$$\iint\limits_{G} f\left(x,y\right)\ dx\ dy,$$

where $f\left(x,y\right) \geq 0$ – integral function, G – convex two-dimensional set, divide the set G parallel equidistant lines of view $y{=}y_i$, $i{\in}\overline{1,k}$, on separate strips, and for each y_i define $a(y_i)$ – the smallest value of the abscissa x on the straight $y{=}y_i$ such that the point $\left(a\left(y_i\right), y_i\right)$ is the inner point of the set G, as well as $b\left(y_i\right)$ – the greatest value of the abscissa x on the straight $y{=}y_i$ such that the point $\left(b\left(y_i\right), y_i\right)$ is the inner point of the set G, namely $a(y_i)$ – the leftmost point in the area G on the straight $y{=}y_i$, $b\left(y_i\right)$ – the rightmost point in the area G on the straight $y{=}y_i$. Value y_i, by which points $\left(a\left(y_i\right), y_i\right)$, $\left(b\left(y_i\right), y_i\right)$ are not internal points of the set G, are not included in the consideration. Next will present approximately (see [4])

$$\iint\limits_{G} f\left(x,y\right)\ dx\ dy,$$

through

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

or what is the same, by the formula

$$\sum_{i=1}^{k} h\cdot\frac{1}{2}\left(\int\limits_{a(y_i)}^{b(y_i)} f\left(x,y_{i-1}\right) dx + \int\limits_{a(y_i)}^{b(y_i)} f\left(x,y_i\right) dx\right) \tag{2}$$

where $y{=}y_0$ – the lowest line, that touches the set G,

$y{=}y_k$ – the highest line that touches the set G,

$h{=}y_i{-}y_{i-1}$ – the width of the strip between the lines $y{=}\underline{y_i}$ and $y{=}y_{i-1}$. Note that in the general case, the bands between the lines $y{=}y_i$ and $y{=}y_{i-1}$, $i{\in}\overline{1,k}$, may not be the same width. Then the appearance of the formula will change accordingly (1).

Let on the set $\Omega{=}\left\{\ (x,y)\,|x^2{+}y^2\ \leq 2^2\right\}$ the probability distribution is set due to the density of the probability distribution

$$f\left(x,y\right) = \begin{cases} \frac{3}{8\pi}\left(2-\sqrt{x^2+y^2}\right), & \text{when } (x,y)\in\Omega, \\ 0, & \text{when } (x,y)\,\overline{\in}\Omega. \end{cases}$$

In geometric interpretation through the specified function $f\left(x,y\right)$ describes a straight circular cone with a radius of the base $R = 2$ and height $h{=}\frac{6}{8\pi}$ (see figure 1). It is easy to see the volume of such a cone $V{=}\frac{1}{3}\pi R^2 h{=}\frac{1}{3}\pi\cdot 4\cdot\frac{6}{8\pi}{=}\frac{4\pi}{3}\cdot\frac{6}{8\pi}{=}\ 1$, namely in relation to the specified function $f\left(x,y\right)$ all properties of the density distribution are satisfied (see [15]):

1) $f(x,y) \geq 0$;
2) $\iint_{R^2} f(x,y)\ dx\ dy = 1$.

As is known, in geometric interpretation in case of $f(x,y) \geq 0$

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

is the volume of the body below the surface $z = f(x,y)$ over the area G.

Let for a given probability distribution with density

$$f(x,y) = \begin{cases} \frac{3}{8\pi}\left(2 - \sqrt{x^2+y^2}\right), & \text{when } x^2+y^2 \leq 2^2, \\ 0, & \text{when } x^2+y^2 > 2^2, \end{cases}$$

need to calculate the probability of getting into the square

$$G = [-1;1] \times [-1;1] = \{(x,\ y)\,|x \in [-1;1]\,,\ y \in [-1;1]\ .$$

In the geometric interpretation, this means that it is necessary to calculate the volume of the body, which is obtained as the intersection of two spatial figures – the specified straight circular cone and a straight parallelepiped with a base $G = [-1;1] \times [-1;1]$ and a height not less than the height of the cone. Note that in this case, the intersection of figures means the set of points that are the internal points of both one figure and another (reciprocally to the intersection of sets of points).

In other words, you need to calculate the volume of the body below the surface of the cone above the square $G = [-1;1] \times [-1;1]$, that is, inside the specified parallelepiped (see figure 1).

For an approximate calculation of the probability of hitting a given square $G = [-1;1] \times [-1;1]$ at a given density $f(x,y)$ probability distribution on the set $\Omega = \left\{\ (x,y)\,|x^2+y^2\ \leq 2^2\right)$. first calculate the probability of hitting the area $G\emptyset\ = [0;1] \times [0;1]$ (see figure 2) at the same density $f(x,y)$ probability distribution.

Given formula (1), we choose the step of changing the variable y_i equal $h = 0.1$, and instead of a variable y_i enter a dynamic parameter $p1$, which we will change from the value $p1 = 0$ through the step $h = 0.1$ to value $p1 = 1.0$ and for each parameter value so determined $p1$ we will calculate the integrals

$$\int_0^1 \left(2 - \sqrt{x^2+p1^2}\right) dx,$$

using the relevant services of the program GRAN1 (see figure 3).

As a result, we obtain a table of values of the corresponding integrals (see table 1).

Calculating the sum of the values of the integral thus found and subtracting from it the values multiplied by 0.5 values obtained at $p1 = 0$ and by $p1 = 1.0$ (see formula (1)), and in addition, multiplying the obtained result on the constant $\frac{3}{8\pi}$ and gave on 0.1, we will receive $P(G\emptyset) = 0.1473$.

Thus $P(G) = 4P(G\emptyset) = 0.5892$.

Note that for the calculation of the new value of the integral and for the new value of the parameter $p1$ there is no need to enter the expression of the sub integral function and the limits of integration each time. After increasing the value of the parameter $p1$ on the step h the limits of integration and the expression of the sub integral function change automatically and then the corresponding value of the integral is calculated.

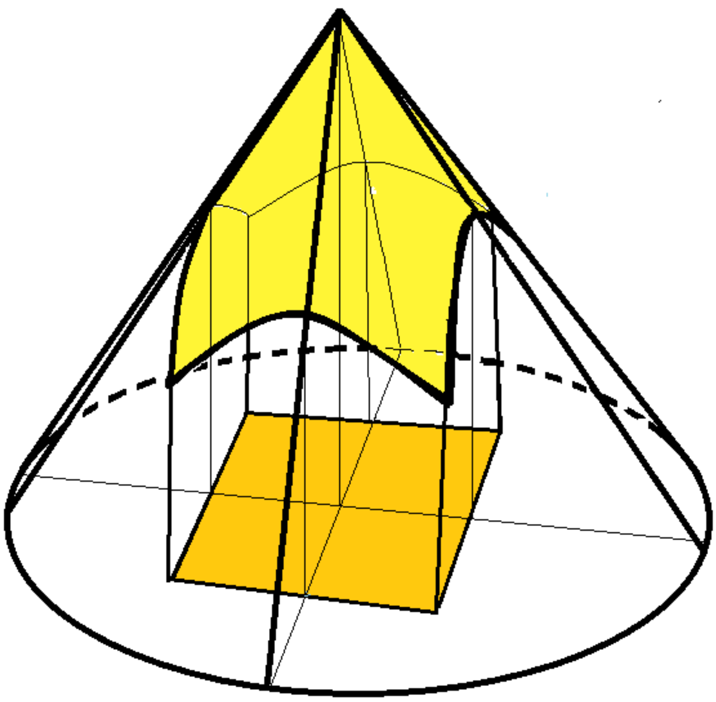

Figure 1. Intersection of two spatial figures.

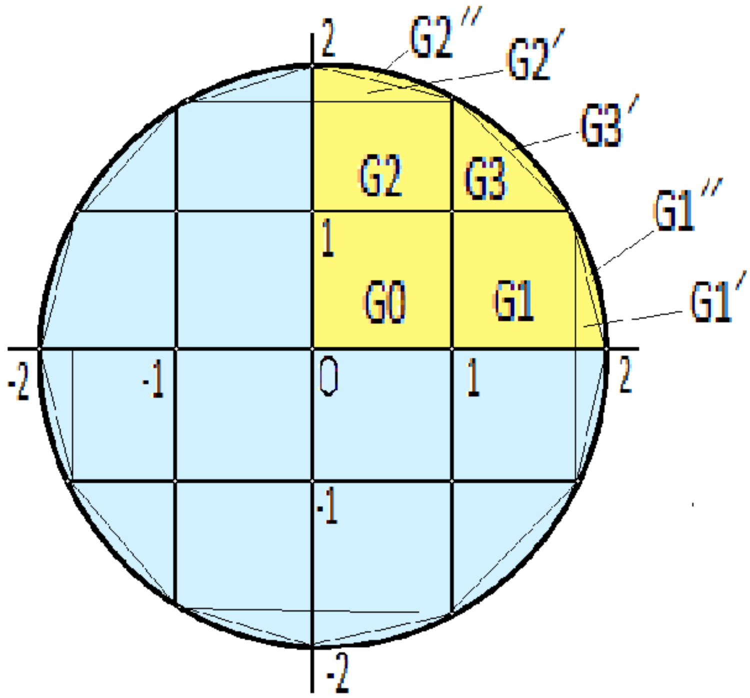

Figure 2. Probability of hitting the area G.

Calculating $P(G1\bigcup G1^{'}\bigcup G1^{''})$, where

$$G1\bigcup G1^{'}\bigcup G1^{''}=\left\{(x,y)\,|x\in[1;2]\,,\,y\in[0;1]\,,\,x^2+y^2\leq 2^2\right\},$$

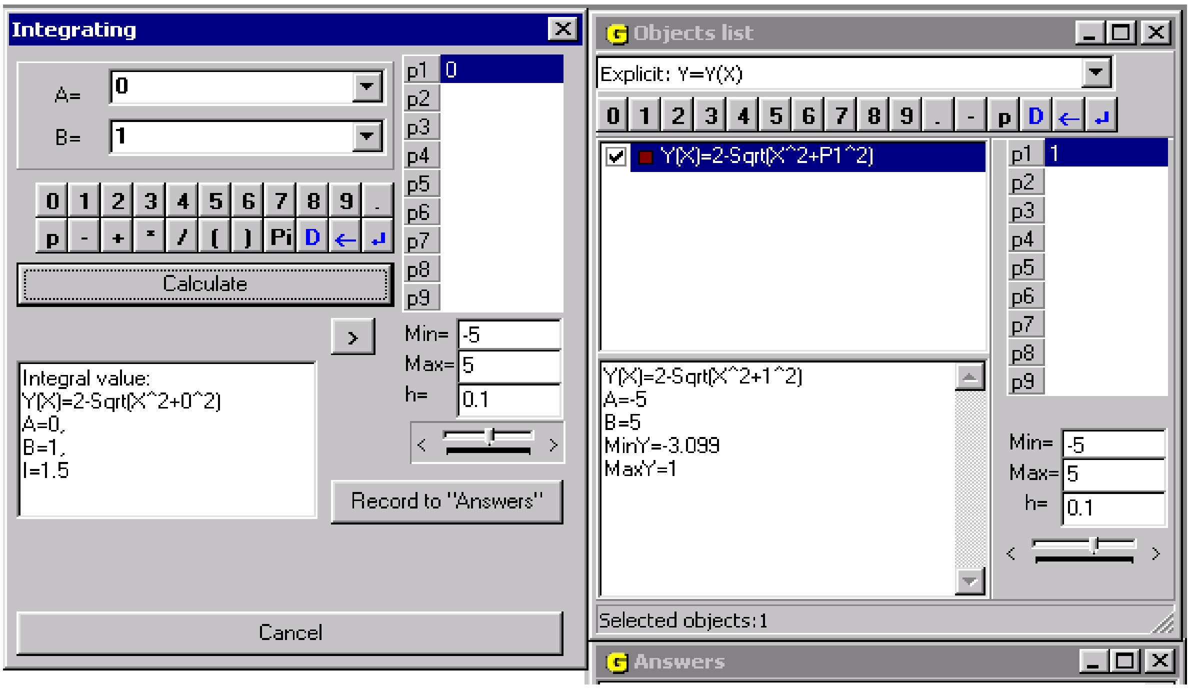

Figure 3. Calculation of integrals in the program.

Table 1. The value of the corresponding integrals.

$p1$	$\int_0^1 \left(2-\sqrt{x^2+p1^2}\right) dx$
0	1.5
0.1	1.483
0.2	1.444
0.3	1.392
0.4	1.33
0.5	1.261
0.6	1.186
0.7	1.107
0.8	1.024
0.9	0.9394
1.0	0,8522

we obtain a table of values of the corresponding integrals (see table 2).

Calculating, as before, the sum of all values found and then subtracting half the sum of the two extreme values (see formula (1)) and multiplying the amount thus obtained first by the constant $\frac{3}{8\pi}$, and then on h= 0.1, we will receive $P\left(G1 \bigcup G1' \bigcup G1''\right) = 0.04753$.

Quite similar in relation $P(G2 \bigcup G2' \bigcup G2'' \bigcup G3 \bigcup G3')$, where

$$G2 \bigcup G2' \bigcup G2'' \bigcup G3 \bigcup G3' = \left\{(x,y) \;\middle|\; x\in \left[0;\sqrt{3}\right], \; y\in[1;2], \; x^2+y^2 \leq 2^2 \right\},$$

Table 2. The value of the corresponding integrals.

$p1$	$\int_1^{\sqrt{4-p1^2}} \left(2-\sqrt{x^2+p1^2}\right) dx$
0	0.5
0.1	0.4965
0.2	0.4863
0.3	0.4694
0.4	0.4465
0.5	0.418
0.6	0.3848
0.7	0.3475
0.8	0.3072
0.9	0.2648
1.0	0.2214

we will receive table of values of the corresponding integrals (see table 3).

Table 3. The value of the corresponding integrals.

$p1$	$\int_0^{\sqrt{4-p1^2}} \left(2-\sqrt{x^2+p1^2}\right) dx$
1.0	1.074
1.1	0.9413
1.2	0.809
1.3	0.6782
1.4	0.5506
1.5	0.4281
1.6	0.3128
1.7	0.2073
1.8	0.115
1.9	0.04142
2.0	0

Calculating the sum of all values found and then subtracting half the sum of the two extreme values and multiplying the result first by $\frac{3}{8\pi}$ and then on 0.1, we will receive

$$P\left(G2\bigcup G2^{'}\bigcup G2^{''}\bigcup G3\bigcup G3^{'}\right) = 0.05502.$$

Folding the obtained probability values $P\left(G\emptyset\right)$, $P\left(G1\bigcup G1^{'}\bigcup G1^{''}\right)$, $P\left(G2\bigcup G2^{'}\bigcup G2^{''}\bigcup G3\bigcup G3^{'}\right)$, we will receive

$$0.1473 + 0.04753 + 0.05502 = 0.2499,$$

that is, the probability of getting into the set $\{(x,y) \mid x{\geq}0,\ y{\geq}0,\ x^2{+}y^2{\leq}2^2\}$ (the upper right quarter of the circle) is approximately equal to 0.2499≈0.25, which indicates a fairly high accuracy of the calculations.

Obviously, in the considered case

$$P\left(G2\bigcup G2^{'}\bigcup G2^{''}\right)=P\left(G1\bigcup G1^{'}\bigcup G1^{''}\right)=0.04753,$$

whence

$$P\left(G3\bigcup G3^{'}\right)=P\left(G2\bigcup G2^{'}\bigcup G2^{''}\bigcup G3\bigcup G3^{'}\right)-P\left(G2\bigcup G2^{'}\bigcup G2^{''}\right)=$$

$$=0.05502-0.04753=0.00749.$$

Because $G3=\{(x,y) \mid x{\in}\left[1;\sqrt{3}\right],\ y{\in}\left[1;\sqrt{3}\right],\ x{+}y{\leq}1{+}\sqrt{3}\}$, then calculating as before, $P(G3)$, we get (see table 4).

Table 4. The value of the corresponding integrals.

$p1$	$\int_1^{1+\sqrt{3}-p1}\left(2-\sqrt{x^2+p1^2}\right)dx$
1.0	0.2214
1.1	0.1775
1.2	0.1343
1.3	0.094
1.4	0.05862
1.5	0.03007
1.6	0.01019
1.7	0.0006251
1.732	0.0000

And further, given formula (1) or (2), we find $P(G3)=0.007353$, whereof

$$P\left(G3^{'}\right)=P\left(G3\bigcup G3^{'}\right)-P(G3)=0.00749-0.007353=0.000137.$$

Concerning $P(G1)$, where $G1=\{(x,y) \mid x{\in}\left[1;\sqrt{3}\right],\ y{\in}[0;1]\}$, we receive (see table 5).

Calculating the sum of all values found and subtracting half the sum of the two extreme values (see formula (1)), multiply the result by the constant $\frac{3}{8\pi}$, and then on 0.1.

As a result, we get $P(G1)=0.04525$, whence

$$P\left(G1^{'}\bigcup G1^{''}\right)=P\left(G1\bigcup G1^{'}\bigcup G1^{''}\right)-P(G1)=0.04753-0.04525=0.00228.$$

Concerning $P\left(G1^{'}\right)$, where

$$G1^{'}=\left\{(x,y)\ \middle|\ x{\in}\left[\sqrt{3};2\right],\ y{\in}[0;1],\ x{+}y(2{-}\sqrt{3}){\leq}2\right\},$$

similarly, to the previous, we receive (see table 6).

Table 5. The value of the corresponding integrals.

$p1$	$\int_1^{\sqrt{3}} \left(2 - \sqrt{x^2 + p1^2}\right) dx$
0	0.4641
0.1	0.4614
0.2	0.4532
0.3	0.4317
0.4	0.4212
0.5	0.3978
0.6	0.3701
0.7	0.3382
0.8	0.3025
0.9	0.2635
1.0	0.2214

Table 6. The value of the corresponding integrals.

$p1$	$\int_{\sqrt{3}}^{2+p1\left(\sqrt{3}-2\right)} \left(2 - \sqrt{x^2 + p1^2}\right) dx$
0	0.0359
0.1	0.03489
0.2	0.03214
0.3	0.02807
0.4	0.02314
0.5	0.01778
0.6	0.01246
0.7	0.007597
0.8	0.003631
0.9	0.0009693
1.0	0.0000...

$P\left(G1^{'}\right) = 0.002132$, whence

$$P\left(G1^{''}\right) = P\left(G1^{'} \bigcup G1^{''}\right) - P\left(G1^{'}\right) = 0.00228 - 0.002132 = 0.000148.$$

Given the symmetry $G2'$ and $G2''$ with respect to $G1'$ and $G1''$ relative to the bisector of each coordinate angle, we get:

$$P\left(G2^{'}\right) = P\left(G1^{'}\right) = 0.002132,$$

$$P\left(G2^{''}\right) = P\left(G1^{''}\right) = 0.000148.$$

Taking into account the symmetry with respect to the coordinate axes and with respect to the bisectors of the first and second coordinate angles, it is possible to calculate the probabilities of hitting any subsets of the set under consideration.

$$\Omega = \{ \ (x;y)\,|x^2+y^2 \ =2^2\},$$

composed of an arbitrary set of subsets G∅, G1, G1′, G1″, G2, G2′, G2″, G3, G3′, and their symmetric mappings with respect to the coordinate axes or bisectors of the second coordinate angle, at a given probability density.

Recall that together with the calculation of the probabilities of getting into different two-dimensional subsets of a two-dimensional set Ω in geometric interpretation the volumes of spatial bodies which surfaces are described through the set functions of a kind are calculated $z=f(x,y)$, where $f(x,y)$ an essential function, by which describes the density probability distribution on the set Ω.

Similarly, calculated probability of falling in convex sets on the plane with a normal two-dimensional probability distribution with the scattering center at a point $(0,0)$ and dispersions along the axes Ox and Oy equal $D_1=\frac{1}{2}$, $D_2=\frac{1}{2}$, the density of which is given in the form $f\,(x,y)=\frac{1}{\pi}e^{-(x^2+y^2)}$, $(x,y)\in R^2$, example

$$\iint\limits_G f\,(x,y)\ \ dx\ dy,$$

where $G=\left\{(x,y)\ \middle|\ (x-1)^2+y^2\le 1\right\}$, $G=\{(x,y)\mid |x+y|\le 1,\ |x-y|\le 1\}$ etc.

4. Conclusions

Analyzing the above, we can conclude that the use of modern information and communication technologies, in particular the program GRAN1, is possible during conducting mathematics lessons, and the choice of means depends not only on the technical support of the educational process in a particular educational institution, but also on the level of teacher and student training to the use of information and communication technologies. The presence of an Internet connection in the educational institution makes it possible, through the use of cloud technologies, to provide the educational process with freely distributable software, including software Services from the package GRAN (which include GRAN1, GRAN2D, GRAN3D) with observance compliance with licensing agreements under applicable law.

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Journal of Physics: Conference Series

PAPER • OPEN ACCESS

A competency-based approach to the systematization of mathematical problems in a specialized school

To cite this article: K V Vlasenko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012003

A competency-based approach to the systematization of mathematical problems in a specialized school

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Abstract. The issue of searching for new methodological approaches to the systematization that will encourage the increase of students motivation to learn mathematics under the competency-based approach is considered in this article. The research analyzes the existing works on the increase in students motivation to learn Mathematics, in particular, the use of cross-curricular connections while forming students competency. Competency-based problems, systematized according to the topic of the 10th grade Functions, their features and graphics, were determined as the tools to measure students competency and a method to form their motivation to learn mathematics. The use of such methods as the initial research and information gathering, systematization and structural analysis of the problems, data processing allowed the authors of the article to systematize the problems for school subjects of the 10th grade that demonstrate cross-curricular connections of Mathematics with other learning subjects and allow showing the advantages of the mathematical modeling in researching real processes. The research shows the realization of cross-curricular connections in time and such connections as parallel learning, perspective connections, use of the mathematical modeling method are shown. An experiment was held in order to prove the efficiency of implementing a system of the problems to demonstrate the use of the function in different tasks of natural subjects. The results proved that the implemented system of problems considerably influences the increase in students motivation to learn mathematics.

1. Introduction

According to the methodological recommendations on developing the components of the state standard for basic and complete general secondary education based on the competency-based approach, the objective to form, develop and improve the complex of the students competencies during the education arises for the system of secondary education. For subject teachers, the transfer to the competency-based approach means improving the system of problems to increase students motivation according to the requirements of learning programs for students of general secondary schools. Mathematics is not an exception, that following the competency-based approach, also implies the research of new methodological approaches and systematization of problems that will encourage the increase of students motivation to learn mathematics. Thats why learning Mathematics should contribute to forming students' key competencies among which there are mathematics competency and main competencies of natural sciences and technologies. One of such approaches is the demonstration of a constant connection between Mathematics and other natural sciences to the students. In order to ensure it, the learning programs include the determination of cross-cutting lines of the key competencies: Environmental security and traditional development, Civil responsibility, Health and security, Entrepreneurship and financial literacy that are focused on forming an ability to use knowledge and skills in real-life situations among students. Thus, while learning Mathematics a need to select and systematize the problems that allow demonstrating the use of Mathematics in other subjects to the students, which will increase their motivation to learn Mathematics, becomes quite urgent.

2. Literature review

The introduction of Mathematics to the compulsory subjects of external testing did not solve the problem of improving students motivation to learn mathematics. The question of searching for ways and approaches to overcome students fear and their difficulties during learning this subject has always interested scientists (Posamentier [1], Abramovich, Grinshpan and Milligan [2], Hernandez-Martinez and Vos [3], Langoban and Tan [4], Williams and Williams [5], Cody [6], Vlasenko et al. [7, 8], and others). For instance, Posamentier [1] distinguishes external and internal motivations. In the internal students motivation during learning Mathematics the scientist sees students understanding why they need to learn mathematics, where this knowledge can be used. The scientist also determines nine methods of improving students motivation to learn mathematics, one of which is the demonstration of the benefits to learn mathematical terms. The researchers Abramovich, Grinshpan, Milligan [2], Lovianova et al. [9] emphasize that Mathematics significantly developed and entered all life areas. Considering Mathematics as a necessary subject, scientists indicate the power of mathematical modeling that should serve as motivation to develop students competencies [10, 11]. Hernandez-Martinez and Vos [3] agree with this idea and say that students motivation can be increased through the demonstration of using Mathematics in the real world. Langoban and Tan [4], Vlasenko et al. [12] believe that the efficiency of teaching Mathematics will increase if students are motivated through the demonstration of the efficiency of using Mathematics in practice. K. C. Williams and C. C. Williams [5] define five components of students motivation to learn mathematics: a student, a teacher, content, method, and environment, and emphasize that mathematical problem have a particular learning content and allow forming and developing internal motivation of students learning activity. Cody [6] sees the increase of students motivation to learn Mathematics through learning activity that is ensured while solving mathematical problems systematized according to a particular approach.

Aimed at increasing students motivation to learn mathematics, we chose an approach the implementation of which requires: 1) arrangement of learning programs in natural subjects in order to enable giving learning material where the use of mathematical concepts is described in parallel; 2) the realization of perspective cross-curricular connections of Mathematics with other learning subjects on condition that it is impossible to provide the material in parallel. The mentioned approach will encourage students understanding of how to use the acquired knowledge in Mathematics in other subjects ensuring both the formation of mathematics modeling skill and increase of student's motivation to learn. While choosing an approach it was also considered that the motivation is internal if it corresponds to the aim of the students activity. The conditions of learning activity, under which learning the content of the subject will be both the motivation and aim, are ensured. It is taken into account that internal motivations are connected with the students cognitive need, their satisfaction that is obtained during the learning period, and as a result, the dominance of internal motivation is characterized by the display of students involvement in the learning activity.

In order to ensure this approach several problems should be systematized. According to Ghanbari [13], Feng, Lu, and Yao [14], Jacome [15] competency-based problems have the greatest potential in this area. In this case, the problems that simulate the actual problems that arise while learning other subjects become the subject of the students learning activity. Niss and Bruder [16], Cai and Hwang [17], Vlasenko et al. [18] propose to consider competency-based problems as specially designed tasks aimed at forming a dynamic combination of knowledge and practical skills, ways of thinking, professional and philosophical qualities that allow to successfully carry out further educational and professional activities. Scientists believe that the tasks of the scientific type can be related to such types of problems.

Considering that one of the main content areas of the course Mathematics in high school is the functional area, the article is aimed at the systematization of competency-based problems following the topic of the 10th grade Functions, their features and graphics. Also, the increase in students motivation to learn Mathematics through the demonstration of the tight connection between Mathematics and other learning subjects is proven.

3. Methods

While choosing the problems that will be included in the system, it was considered that the key message of the topic Functions, their features and graphics should be the modeling of real processes using functions. Since working with diagrams, pictures, graphics is one of the spread types of a persons practical activity, the main objectives of learning a topic include the development of students graphic culture. First of all, it is about reading graphics, in other words, setting the features of some function using its graphics. So, while choosing the system of problems for the 10th grade aimed at revealing cross-curricular connections on the example of the topic: Functions, their features ad graphics with other subjects, the following methods were used:

- primary research and data gathering: analysis of textbooks on different subjects of the 10th grade [19–27]; analysis of mathematics textbooks of the 10th grade [28–32];
- systematization and structural analysis: selected problems on different subjects, the priority was given to competency-based problems;
- data processing: the essence of mathematical modeling to show the use of functions in problems for different learning subjects of the school course was used.

Based on such research methods, the problems for learning subjects of the 10th grade were systematized: physics, economics, chemistry, biology, information technologies, art, environment, geography, civil education, law, homeland defense, history of Ukraine that require the use of students knowledge on the topic Functions, their features and graphics. Lets look at the examples of the problems concerning the developed system (table 1).

Table 1. Problems where students use their knowledge on the topic Functions, their features and graphics.

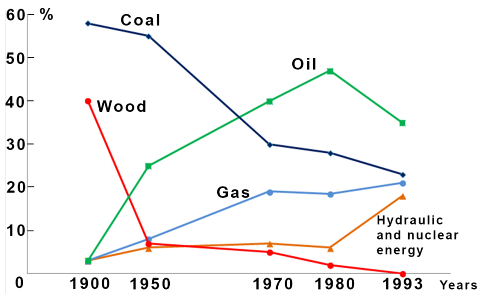
<table>
<tr><th>Subject Topic</th><th>Problem</th></tr>
<tr><td>Economics. Market structure: characteristics of different markets. Capital market. Buyers and sellers of credit resources What influences demand and offer in the capital market</td><td>It is known that the demand for bricklayers is described by the function $LD = 160.06W$, where W is a day salary. One bricklayer is ready to work for no less than 200 UAH/day; two bricklayers are ready to start working for no less than 150 UAH, three bricklayers – no less than 100 UAH, and two others – no less than 120 UAH. Build the demand and offer curve in the bricklayers market. Characterize the balance and its change if housing construction is getting active [19, p. 181].</td></tr>
<tr><td>Biology. Biodiversity. Prokaryotic organism: bacteria</td><td>Bacteria reproduction. Consider the situation when one prokaryotic cell is found in optimal conditions and reproduce without any obstacles. How many cells will be in a model population in ten generations if the cell division takes place every 20 min? Fill in the table and build the graphics of population growth (at the horizontal axis – time, at the vertical axis – cell number). Write the mathematical equation that reflects the pattern of population growth [20, p. 44].
<table>
<tr><th></th><th>0</th><th>20</th><th>40</th><th>60</th><th>80</th><th>100</th><th>120</th><th>140</th></tr>
<tr><td>Time, min</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Number of bacteria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Environment. Technogenesis and economics. Technogenesis – technical progress, economic growth</td><td>The graphics of structure change in consuming fuel and energy resources in the world in the 20th century are represented in the figure 1. Make a conclusion [21, p. 56].


Figure 1. The graphics of structure change in consuming fuel and energy resources in the world in the XXth century.</td></tr>
</table>

Physics. Mechanics. Straight equally accelerated motion	According to the graphics in the figure 2, write the dependency equation $v_x = v_x(t)$ $x = x(t)$. Consider that at the initial stage ($t = 0$) the body is at the beginning of the coordinates ($x = 0$). Build the dependency graphics $x = x(t)$ for every body [22, p. 22].

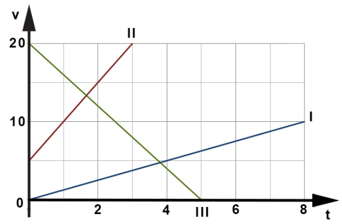


Figure 2. Body motion graphs.

Art. Art trip around European countries. Italian art: the creative boom of humanity	The tower of Pisa is one of the main remarkable architectural monuments of Italy. The external part of every gallery of the tower creates the columns with classical chapiters that lean on the closed arches. The top of the tower has a belfry. The slope of the tower is approximately 10%. Before the repair work, it deviated to the south by 5.5 degrees, now it is deviating by 4 degrees. It is reflected in numbers in the following way: the arch cornice is shifted by 4.5 meters in comparison to the lower one. What function – increasing or decreasing – do you have an association with that is connected with this architectural monument?
Geography. General characteristics of Europe. Natural conditions of Europe	Compare the climate of the cities Reykjavik (Iceland), Rome (Italy), Arkhangelsk (Russia), Kassel (Germany) using climatograms (see the figure 3). Explain the differences [23, pp. 43-44].

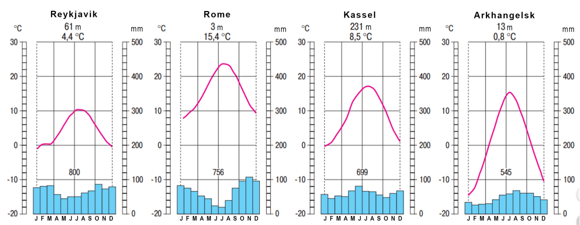


Figure 3. The climate of the cities Reykjavik (Iceland), Rome (Italy), Arkhangelsk (Russia), Kassel (Germany).

<table>
<tr><td>Civil education. Interaction between citizens and the state in order to achieve public welfare Demand and offer, market price, competition</td><td>Using the table, show the curve of offer and demand. Determine the balanced price for bicycle, and also its surplus and deficit. Fill in the blank cells of the table [24, p. 188].
<table>
<tr><th>Price, UAH</th><th>Demand, item</th><th>Offer, item</th><th>Surplus of the offer in comparison to the demand, item</th><th>Type of the market situation: (S – surplus, D – deficit, E – equality)</th></tr>
<tr><td>3500</td><td>0</td><td>130</td><td></td><td></td></tr>
<tr><td>3000</td><td>12</td><td>122</td><td></td><td></td></tr>
<tr><td>2400</td><td>27</td><td>108</td><td></td><td></td></tr>
<tr><td>2000</td><td>38</td><td>97</td><td></td><td></td></tr>
<tr><td>1650</td><td>50</td><td>85</td><td></td><td></td></tr>
<tr><td>1300</td><td>66</td><td>70</td><td></td><td></td></tr>
<tr><td>1150</td><td>60</td><td>60</td><td></td><td></td></tr>
<tr><td>1000</td><td>88</td><td>56</td><td></td><td></td></tr>
<tr><td>750</td><td>120</td><td>42</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Chemistry. Carbohydrate. Alkanes: physical and chemical characteristics.</td><td>Analyze the graphics in the figure 4. According to the melting and boiling temperature, determine the intervals where the data for gas, liquid, and solid alkanes are given. Melting temperature (line A), boiling temperature (line B) of normal alkanes [25, p. 40, 47].</td></tr>
</table>

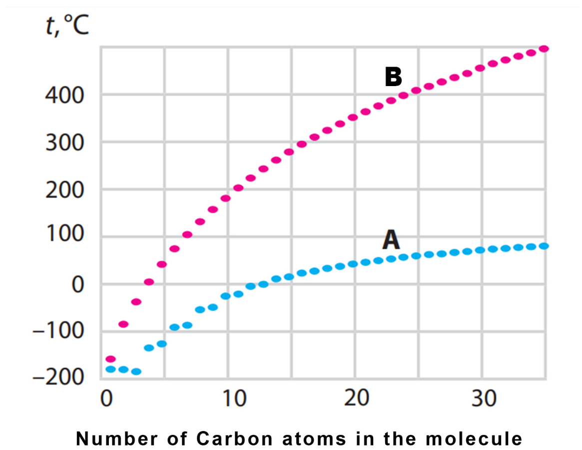


Figure 4. Analysis graphs.

<table>
<tr>
<td>Information technologies. Models and modeling. Data analysis and visualization. Visualization of data trends and ranges. Infographics.</td>
<td>The table represents the number of registered flu and SARS cases for every 10 thousand people in city H:
<table>
<tr><th>No. of weeks</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td>Number of people who fell ill for 10 thousand people</td><td>150</td><td>130</td><td>145</td><td>120</td><td>125</td><td>110</td></tr>
</table>
Based on the table data build a dotted diagram and make a forecast: In how many weeks the epidemiological barrier of flu and SARS cases, which is 50 cases for 10 thousand people, will be exceeded in the city [26, p. 77].</td>
</tr>
<tr>
<td>History of Ukraine. World War I. The end and consequences of the war</td>
<td>Look at the graphics (figure 5, figure 6). What conclusions can you make? [27, p. 44].

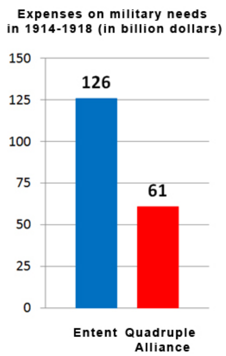


Figure 5. Expenses on military needs in 1914-1918 (in billion dollars).

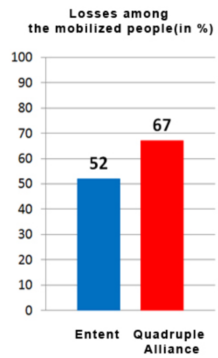


Figure 6. Losses among the mobilized people (in %).</td>
</tr>
<tr>
<td>Law. Structure of the state. A nations form of government.</td>
<td>Study the number of European countries with monarchy and republic forms of government since 1800 and till modern times every 20 years. Fill in the table and build the graphic for every form of government, compare the graphics.</td>
</tr>
<tr>
<td>Homeland defense. Applied physical training. Strength training and overcoming obstacle</td>
<td>Preparing for the route march during one month of every day, running 3 km, mark the time in the table and build a graphic of the dependency between the number of training days and time that is spent on the distance. Make a conclusion.</td>
</tr>
</table>

Besides, the problems from Mathematics [28, 30, 32], algebra, and basics of calculus [29, 31] textbooks of the 10th grade on the topic Functions, their features, and graphics were systematized and they show cross-curricular connections between Mathematics and other learning subjects and enable us to show the advantages of mathematical modeling in the research of real processes (table 2). The focus was on the mathematical problems, the content of which is connected with the above-mentioned subjects such as Physics, Economics, Chemistry, Biology, Informatics, Art, Environment, Geography, Civil education, Law, Homeland defense, History of Ukraine. It was considered that the demonstration of cross-curricular problems during mathematics lessons allows increasing their motivation to learn Mathematics as a versatile language to research the processes known to students while learning other subjects.

Table 2. Cross-curricular connections of Mathematics with other learning subjects.

Mathematical problem	The subject where there is a connection
A skydiver jumps from the plane that is moving at the height of 1020 m above the ground. His way h (in meters), which takes place under condition of free fall, is determined using the formula $h = \frac{gt^2}{2}$, where t is time (in seconds), g is a criterion, $g \approx 10$ m/s^2. The parachute opened at the height of 975 m above the ground. Use a formula to show the dependency of the skydivers free fall time from the mileage, build the graphic of the defined dependency, and find out how much time the skydiver flew during the free fall.	Physics
The Sun weight is approximately $2 \cdot 10^{27}$ t, and the Neptune weight is approximately $1 \cdot 10^{23}$ t. Use this data and also find the data about the weight of other planets and show graphically the dependency of the weight from the planet size in increasing order.	Astronomy
The amount of electricity consumption by a family in the first 6 months of 2012 and 2017 is represented in the table (in kw-h). Build the graphics of electricity consumption in 2012 and 2017 in one coordinate system. Make conclusions.	Economics

	1	2	3	4	5	6
2012	150	130	145	120	125	110
2017	105	100	90	90	95	70

<table>
<tr><td>The table shows the dependency of potassium bromide solubility from the solvent temperature
<table>
<tr><td>$t°$</td><td>0</td><td>20</td><td>40</td><td>60</td><td>80</td><td>100</td></tr>
<tr><td>m</td><td>55.2</td><td>65.1</td><td>75.1</td><td>85.3</td><td>95.2</td><td>104.9</td></tr>
</table>
Build a dependency graphic and find out if this dependency, at least approximately, follows the linear law.</td><td>Chemistry</td></tr>
<tr><td>Paramedics found that a child aged a years old $a \leq 18$ for normal development has to sleep during t hours per 24, where t is determined by the formula $t = 160.5a$. Find $t(16)$, $t(15)$, $t(14)$.</td><td>Biology</td></tr>
<tr><td>Lets suppose that in some big pond the number of water lilies doubles every day. If at the beginning there were five water lilies, how many of them will there be in 1, 2, 3, 5, 10 days? Give a general formula for the number A_n of water lilies in n days. How many would there be in 30, 60 days, if the pond were quite big? Draw a graphic scheme of the function $n \to A_n$.</td><td>Environment</td></tr>
<tr><td>It is considered that while diving under every 30.5 m the inside temperature of the Earth increases to $1°C$. At the depth of 5 m, it is $15°C$. Show the dependency of the temperature t from the depth h. What is the temperature at the depth of 1 km, 3 km?</td><td>Geography</td></tr>
</table>

4. Results

We conducted an experiment in order to determine the efficiency of implementing a system of problems that show the use of functions in different tasks of natural subjects. A survey of learning motivation focus by T. D. Dubovitska was chosen to detect the motivation of the learning activity among students [33]. The methodology detects the focus and motivation level of the learning activity while learning mathematics.

The research basis included secondary schools where master students of the specialization 014 Secondary education (Mathematics) had their pedagogical practice: Kryvyi Rih educational complex No. 81, Kostiantynivka comprehensive school of the I-III levels No. 1, Kostiantynivka educational complex Comprehensive school of the I-III levels – preschool, Kramatorsk educational complex Comprehensive school of the I-III levels No. 6, Kryvyi Rih comprehensive school No. 75 and 122, Piatykhatky comprehensive school No. 3, Zelenodolsk comprehensive school No. 2. Master students who took part in the experiment attended training sessions to get acquainted with its aim and objectives and participated in the development of the system of problems and methods of conducting classes using this system. The teachers were told about the experiment and helped students to carry it out.

The main objectives of the experiment were:

- Analysis of school subjects that are learned in the 10th grade;
- Research of the learning process in algebra and basics of analysis in the 10th grade;
- Development and implementation of the system of competency-based problems on the topic Functions, their features and graphics that show the connection with other subjects;
- carrying out the analysis of the experiment results.

Control (CG) and experimental group (EG) were formed according to the methodology of detecting the focus of learning motivation offered by T. D. Dubovistka [33]. At the beginning and after the end of the experiment, a survey among the students of the 10th grade was held in order to determine their level of motivation to learn Mathematics (table 2). The students read every statement and expressed their attitude to Mathematics using the offered marks: true: +, possibly true: +, possibly false: , false: .

The experiment was held during three weeks (the time spent on the topics Functions, their features and graphics), where 163 students took part: 81 in CG and 82 in EG:

- the control group (CG) included the students of the following schools: Kryvyi Rih educational complex No. 81, Kostiantynivka comprehensive school of the I-III levels No. 1, Kryvyi Rih comprehensive school No. 75, Zelenodolsk comprehensive school No. 2, where teaching algebra is provided using the traditional methodology;
- the experimental group (EG) included the students of the following schools: Kostiantynivka educational complex Comprehensive school of the I-III levels – preschool, Kramatorsk educational complex Comprehensive school of the I-III levels No. 6, Kryvyi Rih comprehensive school No. 122, Piatykhatky comprehensive school No. 3, where teaching algebra was provided using the methodology of demonstrating cross-curricular connections of Mathematics through a system of problems on the topic Functions.

Table 3. The results of the survey among the students of control and experimental groups.

Statement	Number of points			
	CG		EG	
	Before	After	Before	After
1. Learning Mathematics allows me to learn a lot of important information for me, to show the skills	40	55	37	72
2. Mathematics is interesting for me and I want to now as much as possible about this subject	30	51	35	63
3. The knowledge I get during the lessons is enough for me while learning Mathematics	64	60	80	62
4. Mathematics lessons are not interesting for me, I do tasks because the teacher requires it	62	45	63	33
5. Difficulties that arise while learning Mathematics make it even more exciting for me	32	53	29	58
6. I read additional literature except for textbooks and references independently while learning Mathematics	24	43	27	69
7. I reckon that we could skip difficult theoretical questions while learning Mathematics	18	27	20	57

8. If something goes wrong in mathematics, I try to work it our and find a solution	49	61	47	75
9. During mathematics lessons Ive got such a feeling that I dont want to study anything	72	50	78	48
10. I work actively and do the tasks only under the teachers control.	19	36	21	54
11. I discuss with interest the material that is learned during mathematics lessons when I have free time (during the break or at home) with my classmates (friends)	27	43	26	63
12. I try to do the tasks on Mathematics by myself, I dont like when I am given a hint or help	47	50	44	71
13. If possible I try to copy classmates tasks or ask somebody to do the task instead of me	27	23	56	27
14. I believe that all the knowledge in mathematics is valuable and if possible it is necessary to know as much as possible	31	53	33	62
15. The mark I get on Mathematics is more important for me than the knowledge	20	16	55	19
16. If I am badly prepared for the lesson, I am not particularly upset and dont worry	54	45	61	37
17. My interests and hobbies in free time are connected with mathematics	19	22	17	68
18. Mathematics is difficult for me and I have to make myself do the tasks	42	32	47	17
19. If I miss the mathematics lessons due to some illness (or any other reason), I am upset	42	48	41	56
20. If it could be possible, I would exclude Mathematics from the curriculum (the learning plan)	70	63	69	54

Note that the statements in the survey show positive (1, 2, 5, 6, 7, 8, 10, 11, 12, 14, 17, 19) and negative (3, 4, 9, 13, 15, 16, 18, 20) motivation to learn Mathematics. Analyzing the obtained data, we observe that at the beginning of the experiment in both control and experimental groups on such parameters of motivation assessment as 7, 10, 17, 6, 11 the number of points scored does not exceed 30. Data on the same parameters after experimental training showed that in the experimental group the number of points on the studied parameters was in the range from 54 to 69. While in the control group only on parameters 6, 10, 11 the score was in the range from 32 to 43 points, on other parameters the number of points did not exceed 30. Motivation evaluation parameters 2, 14, 5, 1, 19, 12, 8 at the beginning of the experiment were in the range from 30 to 50 points in both control and experimental groups. According to the results obtained after the experiment, we observe that the motivation of students for these parameters increased significantly in both groups. In the experimental group, the number of points increased by 29 on parameters 5 and 14 and by 35 points on parameter 1.

Analysis of the parameters of the manifestation of negative motivation shows that in the control groups, the number of respondents who had positive changes in each parameter ranges from 10 points. As for the experimental group, the changes in points give fluctuations in the positive direction from 15 to 30 points.

In order to determine the internal students motivation level, the following rating is used: 0-5 points – low level of internal motivation; 6-14 points – the average level of internal motivation; 15-20 points – high level of internal motivation. The results of the survey are presented in figure 7.

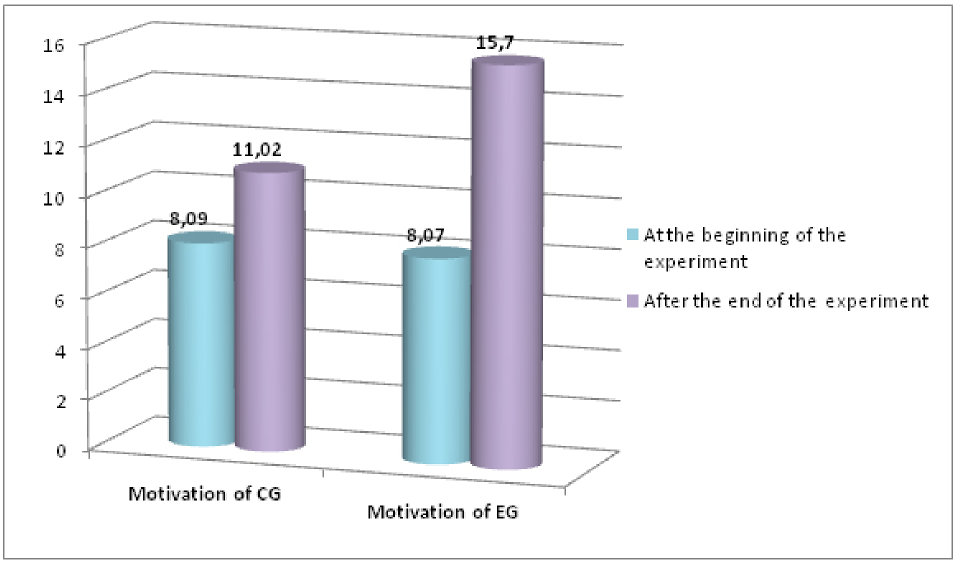


Figure 7. Comparative analysis of motivation levels among the students of CG and EG.

It is clear from the histogram (figure 7) that the motivation level among the students of both groups increased in CG, the GPA became 11.02, and in CG 15.7, but the implemented system of problems influenced more significantly the increase of motivation among the students of EG.

5. Discussion

According to the current programs [34] the topic Functions, their features and graphics is learned in high school which is specialized and students can learn this topic at the basic or specialized level. The actuality of developing cross-curricular problems while learning this topic at every level is determined first of all by the fact that such problems encourage the formation of mathematics competency as the key one [35]. In order to measure the level of students competency Pesakovic, Flogie, Abersek [35] offer to develop the appropriate tools. In our research competency-based mathematical problems that should be selected according to the learning specialization are the tools to determine students competency. For those students who learned Mathematics at the basic level of training, this subject is not specialized, thats why it is very important to motivate students to learn Mathematics by introducing cross-curricular problems that are connected with the students specialization (economic, natural, humanitarian).

For those students who learn Mathematics at the specialized level, it is important to learn how to use a mathematical modeling method that is realized through solving cross-curricular problems. It is necessary to learn mathematical modeling while learning every subject of the natural – mathematical cycle. This idea is proven in the works written by Little [36], Vlasenko et al. [37] who study the formation of connections between Mathematics and science and search for ways so that students of secondary schools do not consider Mathematics inappropriate questioning the use of its learning. The scientist believes that it is a STEM system that will help to connect Mathematics with other school subjects. Rene de Cotret and Susanne Vincent [38] support this idea and consider the use of mathematics knowledge in everyday life, in particular, the integration of the subject knowledge in the project functions which is not in the area of the subject. Arpin supports the realization of cross-curricular connections which is beneficial both for the educational needs of a definite learning specialization and for Mathematics [39].

The analysis of the programs of learning subjects [34] where one can meet the problems connected with the topic Functions, their features, and graphics, encourages the creation of the classification to realize cross-curricular connections in time. Such approach of the authors is supported by the research done by Rivar [40] about setting different forms of relationship between the subjects: interdisciplinarity, multidisciplinarity, transdisciplinarity, and interdisciplinarity in the strict meaning of this word. So, we suggest defining three types of connections in the research. The first of them is parallel learning. This connection takes place when the topic Functions, their features, and graphics in mathematics corresponds to the terms of learning these topics in such subjects as biology, physics, geography, chemistry, information technology that are connected with the functions. It is convenient to carry out students motivation in parallel while learning these subjects offering the same problems while learning the topic Functions, their features and graphics and while learning the topics indicated in table 1. The perspective connections arise during mathematics lessons while considering problems of cross-curricular character (table 2). Motivation improvement takes place because the importance of mathematical knowledge for such subjects as environment, economics, history of Ukraine, law, homeland defense, civil education, and art, which are specialized for students, is shown. At this stage, the use of cross-curricular problems encourages the creation of problematic situations. Such situations cause students' interest to learn Mathematics as a method to research the processes typical for the major (important) subject for the student in the future. The problems that were used during mathematics lessons as perspective connections can be suggested to students during the lessons on major subjects (history of Ukraine, law, homeland defense, civil education, environment, economics, art) according to the program, in the topics where these problems are actual (table 1). In this case, the third type of cross-curricular connections is realized – the use of mathematical modeling method while solving applied problems.

The authors of the research choose an applied problem as the main semantic item of the course. At the same time, we take a problem that is given outside Mathematics as an applied problem and it is solved by mathematical methods and ways. Applied problems can conditionally be divided into such ones where the mathematical problem is included in the problem condition (formalized) and those the solution of which does not imply building a mathematical model (non-formalized). The solution to the first ones is much easier than the solution to non- formalized problems and consequently consists of the following stages:

- analysis of the problem formation;
- search for the solution plan;
- plan fulfillment, checking, and research of the received solution;
- discussion (analysis) of the found method to solve problems aimed at finding out its rationality, ways to solve the problems using some other method or way.

While solving non-formalized problems the above-mentioned stages are supplemented due to the need to build mathematical models. Thats why we refer to the stages of solving non-formalized applied problems the following ones:

- problem setting;
- translation of the problem conditions into the mathematics language;
- creation of the problem mathematical model;

- search for the plan to solve the problem inside the model;
- plan fulfillment, checking, and research of the received solution inside the model;
- interpretation of the received results;
- discussion (analysis) of the found method to solve problems aimed at finding out its rationality, ways to solve the problems using some other method or way.

Such problems enable learning new strategies of solving problems, developing analytical thinking among students that increases their motivation to learn mathematics.

6. Conclusions

Wide and multifaceted cross-curricular connections of Mathematics and other school subjects can become a guide for students to learn other subjects. Following the example of learning the topic Functions, their features and graphics it is demonstrated in the research the systematization of the competency-based problems focused on the increase of students motivation to learn mathematics.

The researchers recommend systematizing the problems of school subjects that are learned in a high specialized school and require the use of students knowledge in the topic Functions, their features, and graphics. Regarding the selection and systematization of cross-curricular problems, the researchers offer to select a system of competency-based problems for the learning subjects where the terms of the selected topic are used. Also, according to the recommendations given by the authors of the article, the formation of mathematical competency as the key one among the senior students takes place through the demonstration of cross-curricular connections of Mathematics and other learning subjects. It allows showing the advantages of mathematical modeling in the research of real processes.

It is recommended to classify the realization of cross-curricular connections in time in order to implement the offered system of problems in learning Mathematics. As a result of such classification, the authors of the article suggest setting three types of connections: parallel learning, perspective connections, use of the mathematical modeling method. Regarding the organization of cross-curricular connections aimed at forming motivation to learn Mathematics, it is suggested to allow the students to solve the selected system of problems independently in order to increase their understanding of using the topic that is learned and develop their skill to model different situations that in its turn increase their motivation to learn a topic. It is recommended to choose an applied problem as the main semantic item of the developed system. According to the recommendations given by the authors, applied problems can be conditionally divided into formalized, when a mathematical model is included in the problem condition and non-formalized that require building a mathematical model.

The positive results of implementing a system of cross-curricular problems in the process of learning Mathematics following the example of learning the topic Functions, their Features and Graphics are proven by the increase of students motivation level recorded during the experiment. Namely, in the experimental group, the positive motivation significantly increased, and the indicators of negative motives in teaching Mathematics decreased. Thus, the level of internal motivation of students increased by 7.63, which corresponds to a high level. However, as in the control group, there is an average level of intrinsic motivation of students.

In the future, the authors of this article plan focused on the development of competency-based teaching methods of such topics of the school course of Algebra as Derivative of a Function, Integral and its Application in a specialized school.

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Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Effectiveness of teaching and learning in technology-supported mathematics education

To cite this article: A Rybak 2021 *J. Phys.: Conf. Ser.* **1946** 012004

Effectiveness of teaching and learning in technology-supported mathematics education

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Abstract. Information and Communication Technologies (ICT tools) are the important teaching resource in modern school. Each new didactic tool is introduced into educational process in order to increase the effectiveness of this process. The paper concerns the research on the efficiency of using ICT in mathematics education. The research on effectiveness of using ICT in average secondary school in Bialystok conducted at the University of Bialystok with using research in action method is described in this paper. It was a preliminary study of what was happening at school in the classroom in the everyday didactic work with using ICT in proper didactic situations and in everyday school circumstances. Progress in using computer for change of style of work during math lesson (from drawing graphs in exercise book to concluding and structuring knowledge) was visible and quite fast. Some students noticed better results of their class tests after lessons with computer. Maybe it is a result of better understanding topics or possibility of solving more exercises instead of drawing graphs by hand. That indicates in some way the change in effectiveness of learning in new circumstances. Connection between using computers in math education and the individual development of the student and his progress in learning mathematics under the influence of using ICT in individual research work and the independent construction of mathematical knowledge will be investigated in the next stages of research.

1. Introduction

Information and Communication Technologies (ICT) mean all technologies that can process, collect and transmit information in electronic form. People should use this power primarily to build and expand their knowledge and solve problems, not just for entertainment purposes. Technology should help in creating new ideas, creating innovative projects, and the ICT potential should function every day, just like pencil and paper used to be, because today technological possibilities are simply at hand. Using ICT in mathematics education becomes more and more popular in Poland. Even if computers on the lessons are used only from time to time, not systematically, teachers observe that such lessons are more attractive for students; students are more active and motivated during these lessons.

Now the following questions are very important: How does using technology influence on effectiveness of educational process (rather – some selected aspects of this effectiveness): understanding mathematical knowledge by students and level of their skills for applying this knowledge in problems solving? What is the meaning of "students' achievements" in computer-supported teaching and learning? How should these achievements be assessed? Already in 2003

Higgins wrote that one of the goals of integrating ICT in education is to enhance teaching and learning practices thereby improving quality of education [1].

What then does "education efficiency" or "education quality" mean and how does it depend on the forms of education and didactic tools used in the process of learning and teaching, in particular on the didactic tool so popular at the moment, such as ICT?

Author of [2] asks the question: Modern technologies in mathematics lessons – benefits or waste of time? And comments this question: "A rich curriculum, a small number of teaching hours, especially when we have to prepare students for end-of-school exams, give some people the impression that using a computer in maths lessons is a waste of time because we could do several tasks at the same time. Information technology can be useful in achieving much greater goals than just automation in displaying and evaluating tasks. Its use may contribute to the student's interest in the subject, better understanding of the issues raised, and to attract the student's attention so much that he will devote much more time to the issue." [2, pp. 29-30]

Currently, during the pandemic, the use of ICT is widespread as learning takes place exclusively through e-learning. We commonly hear opinions that the effectiveness of online education is lower than the effectiveness of traditional education. In Poland, the decrease in this efficiency is considered to be so large that it is planned to reduce the scope of material in this year's state examinations at the end of primary and secondary school.

This paper is about effectiveness of using ICT in traditionally understood mathematics education: during the lessons conducted in the classroom, in the presence of teacher and students. Effectiveness of distance education, especially in such difficult and special circumstances as now, during pandemic, can be separate, very extensive topic for educational research.

2. Effectiveness of education – what does it mean?

Let's start from the aims of school education.

We can say that the aim of education is to enable students to increase the level of their competences, i.e. knowledge and skills by facilitating learning and helping in the learning process, in an atmosphere stimulating independent activity, developing student's aspirations, orienting them towards success and setting more and more difficult tasks for them, i.e. raising the bar (but always within the limits of his abilities) and introducing to critical and creative thinking.

Everyone involved in the educational process (teachers, students, parents) would like education to be as effective as possible, just like all our activities. Colloquially, we understand the "effectiveness" of an action as "a positive result, effectiveness, efficiency". On the other hand, effective teaching means the growth or maintenance of a high level of willingness (i.e. motivation) to learn, both under the guidance of a teacher and independently, and an increase in students' competences.

In pedagogical meaning, effectiveness is considered not only in connection with performance (actions) and tasks, but also in connection with wide educational aims. For many years effectiveness of educational performance in school was interpreted as improving results of teaching and learning, but now it has new meaning and is interpreted as the desired changes in students' knowledge, skills, interests and attitudes that take place under the influence of the educational process. These changes indicate the progress in student's development.

Can the use of ICT help in effective teaching of mathematics?

In order to answer this question, it is necessary to conduct research on the state of knowledge, skills and attitudes of students in ICT-supported mathematical education, but at first let's describe the main features of mathematics education supported by the use of ICT – from the point of view of practices of classroom activities.

3. Characteristics of education supported by the use of ICT

Aims of technology-supported math lesson are interdisciplinary, more complicated than the aims of traditional lesson. The aims regarding mathematical knowledge and skills should be among them as well as the aims concerning the ability of effective use information technology in mathematical problem solving. So we can expect another effectiveness of such lesson than effectiveness of traditional lesson.

Student has to be active during a technology-supported lesson – using software forces new style of work during the lesson. Teacher is not a person that knows everything and brings this completed knowledge to students; she becomes a guide in "knowledge country" that helps to construct new (for student) bits of knowledge. Student is not a "recipient of knowledge" (like during a lecture) but becomes a "constructor of knowledge" – interactive software allows making experiments and simulations, to observe, state hypotheses and verify them. So using technology seems to be the good, natural way to apply the rules of constructivism in math teaching and learning.

So student's activities during technology-supported lesson can be divided into three groups:

- activities related to computing (technological activities),
- activities related to mathematical problem solving (mathematical activities),
- activities related to planning and undertaking – with using proper software – actions that lead to solution of various mathematical problems in creative way.

In this situation, it is clear that student's achievements should be interpreted more widely than in traditional educational process. It is also clear that traditional assessment (based mostly on class tests) of traditionally interpreted student's achievements is not proper in teaching in new style. Traditional assessment leaves out of range many achievements that are formed in technology-supported math education. If student is an active "constructor of knowledge", active member of educational process, so his/her performance (especially performance with using technology) should be assessed.

Let's come back to the meaning of "effectiveness of education interpreted as the desired changes in students' knowledge, skills, interests and attitudes and consider what role can ICT play in creating effective mathematics education.

What role can ICT play in enhancing students' knowledge?

- Using interactive learning software means student's research work on solving well-defined problems leading to the construction of new knowledge.
- Searching for information in various sources is a creative way to make collections, comparisons and making conclusions – that is, to creating new knowledge.
- Using simulation software enables verifying hypotheses by students, that is very important part of creating new knowledge.

What role can ICT play in developing students' skills?

- ICT can play supportive role in skills development (e.g. facilitating task comprehension by visualizing content).
- Can enable students to solve tasks in various ways (without a computer and with a computer).
- Can play verifying role in the process of developing skills (for example solving exercises and problems).
- Can increase the attractiveness of performing exercises with the use of ICT.

How can ICT help in shaping proper students' attitudes in educational process and social life?

- Can help in shaping independence in constructing knowledge.
- Can develop creative thinking.
- Can develop critical thinking.
- Can help in shaping openness to learning with the use of ICT (not only for entertainment).

Now let's pay attention to increasing motivation students to learn that is a very important part of students' attitudes. How can using ICT help in increasing students' motivation to learn mathematics?

- Students like to work with the computer in lessons, but the teacher must remember that the computer is only a teaching resource and its use is not an end in itself.
- According to students, computer lessons are more interesting, but the teacher should remember that such lessons should provide an opportunity to satisfy cognitive curiosity, not only a curiosity about a new tool or situation.
- Using ICT makes provided content more attractive, but the teacher should remember that it should be used according to the age of students, didactic situation and the function of used tool.

4. Review of research on the effectiveness of ICT-supported education

Many different investigations on many aspects of using technology in education were and still are executed in almost all world. These investigations concern many phenomena: students' attitude to new method, their motivation for learning, change in self-confidence level, change in abilities for problem solving, sometimes investigations concern change in knowledge, understanding knowledge and skills for applying knowledge. The results of the PISA study from 2012 showed that all depends on the way new technologies are used. They are effective in shaping creativity and logical thinking, learning by creating and solving problems, also in supporting activities and in cooperation with others [3, pp. 32-34]. Research on level of knowledge and its durability in most cases were conducted as a strict experiment. Research on forming or understanding mathematical concepts are often conducted with use of very special software and/or method of case study.

Carried out research can be divided for the following groups:

(a) research on the effectiveness of the use of specific software (e.g., GeoGebra), usually conducted in the form of an experiment;
(b) research on the efficiency of using specific devices (laptops, iPads), specially created learning environments or ICT as a whole (i.e. different devices and/or different software);
(c) research on effectiveness of distance education (blended learning, e-learning).

References to selected research reports are provided below.

Ad (a)

Generally conclusions from the research on on the effectiveness of the use of specific software are positive.

The results of study on the effectiveness of Geometer's Sketchpad, a Dynamic Geometrical Software (GSP), in facilitating the teaching and learning of Mathematics, among technical schools students, described in [4] shown that the empirical tests have indicated the effectiveness of GSP in the teaching of mathematics through the substantial performance differences in favour of the experimental (taught with using of GSP) group. The results also shown that GSP has helped the students to better retained the knowledge taught.

The results of study on effectiveness of using GeoGebra software on mathematics learning among 62 students in Malaysia, described in [5], shown that students have positive perception towards learning and have better learning achievements using GeoGebra.

In [6] long three-year investigation on effects of using GeoGebra in fifth grade of rural school in Hungary is described. GeoGebra was used there in teaching of some topics from geometry and also for basic operations with integers and fractions. What is interesting: results of experiment showed that in case of using GeoGebra for operations on integer and fractions the results of experimental group have been shifted towards the positive direction, but not in so large scale as in the case of geometry. It means that in case of specific software its using should be very carefully planned according didactic situation.

Investigation from India is described in [7]. The aim of this study was to examine the impact of using the free educational software GeoGebra on 9th grade students' mathematics achievement in learning geometry. A total of 50 students were selected from a government school located in the eastern part of India. The experimental group (25) was taught theorem on circles using GeoGebra while the control group (25) was taught utilizing traditional teaching methods. At the end of the treatment, students' mathematics achievements were measured using a post - test. The result indicated that GeoGebra is an effective tool for teaching and learning geometry in middle school.

Ad (b)

Here results are not so obviously positive.

In [8] author writes: "Results showed that students who used laptops in class spent considerable time multitasking and that the laptop use posed a significant distraction to both users and fellow students. Most importantly, the level of laptop use was negatively related to several measures of student learning, including self-reported understanding of course material and overall course performance."

In [9] authors describe the experiment conducted with virtual space world (ANIPPO environment created for solving problems from 3-dimensional geometry) in teaching geometry in fifth grade. The results are the following: "ANIPPO world seems to be an obstacle to solve the problems. Technical problems have disturbed the experimentation (domination of technic on didactic). Experimental group had not sufficient time to appropriate ANIPPO world and it is a too complex appropriation. Complexity of inter-registers treatment in ANIPPO world: long text written in natural langages on the screen, complex keyboard manipulations to move in the ANIPPO world, confused oral exchanges between pupils. ANIPPO world with avatar plays more a distractor role than a motivating role." Also authors highlights difficulties of problems interpretation : space geometry is not enough taught in primary school, problems were too difficult, Protocol of pre-experimentation was disturbed by technical problems. What does this study say to us, teachers? Our conclusion is that not always modern, specially created learning environments are the best solution for students.

New technological gadgets, like iPads, smartphones etc. appeared in educational space and of course some investigations on their effectiveness as didactic tools were conducted. In [10] very interesting research on innovative approach to exploring student interaction with iPad apps is described. It focuses specifically on design and content features of apps selected by an experienced teacher to enhance literacy, numeracy and problem-solving capabilities of her 5 year old students. Findings reveal a complex matrix of influencing factors. These include the effect of embedded pedagogical scaffolds (eg., modelling, reflection time), corrective and formative feedback, text-to-speech functionality, imposed interaction parameters, impediments (eg., web links, advertisements, buying content) and the entertainment/education balance. Arguments are made for researchers, teachers and developers to work together and adopt methodologies such as that introduced in this article, to gather data to radically improve the design of apps used by young students for learning.

Very interesting experimental course called "iTrust: Centralized, Distributed, and Mobile Search" is described in [11]. In this course, 22 high-school students needed to understand the differences between centralized and distributed search engine, identify their trade-offs, explore the iTrust gadgets (desktop, cell phones, and tablets), in order to understand simple statistical equations. As the conclusion the author writes: "My pedagogy allows my students to become more active in the class, to obtain more learning knowledge, to increase their learning motivations, to pay greater attention in my class, and ultimately to simulate their interests in learning inside and outside of the class. As a result, it encourages students to engage more actively in the class and lead to greater learning in the classroom. In addition, once the students become engaged, instructors will become more motivated toward teaching."

Case study of developed a computer-aided instruction utilizing the Scratch program, which is a programming tool, and a mathematics curriculum with Scratch program, and applied the developed curriculum to teach mathematics as a recipe of a practical instruction for the 21st century skills and positive attitude toward mathematics is described in [12]. The result of this case study shown that this intervention has a great possibility as an alternative way to teach mathematics in ways that stimulate learners' various abilities, such as creativity, problem solving, logical thinking and the like, as well as that build a positive attitude toward mathematics.

A Meta-analysis of the Effects of Computer Technology on School Students' Mathematics Learning is described in [13]. This study examines the impact of computer technology (CT) on mathematics education in K-12 classrooms through a systematic review of existing literature. A meta-analysis of 85 independent effect sizes extracted from 46 primary studies involving a total of 36,793 learners indicated statistically significant positive effects of CT on mathematics achievement. In addition, several characteristics of primary studies were identified as having effects. For example, CT showed advantage in promoting mathematics achievement of elementary over secondary school students. As well, CT showed larger effects on the mathematics achievement of special need students than that of general education students, the positive effect of CT was greater when combined with a constructivist approach to teaching than with a traditional approach to teaching, and studies that used non-standardized tests as measures of mathematics achievement reported larger effects of CT than studies that used standardized tests.

Ad (c)

Research on effectiveness of distance education outpaced the really extensive use of e-learning in education – pandemic in 2020 forced almost all countries to change the form of education from stationary to distant. Probably very serious research on effectiveness of such form of education will start now, so here only few examples of investigations from the previous years.

Blended Learning: Does it help students in understanding mathematical concepts? - the author of [14] asks. This experimental research aimed to investigate the effectiveness of learning mathematics delivered through blended learning. In particular, this study compared the effectiveness of blended learning using Moodle and traditional one in relation to students' conceptual understanding. The data was gathered through written test and interview. 127 students of grade eight secondary school were involved. The data shows that students who learn in blended learning approach have better conceptual understanding rather than their counterparts. The students claim that they can access learning material and revisit some difficult material in their convenience time. Nevertheless, there are some obstacles faced by students related to maintaining their motivation to learn independently and keeping distraction off to access other website when they learn online.

What drives a successful e-Learning? – the author of [15] asks. Study reported in the article developed an integrated model with six dimensions: learners, instructors, courses, technology, design, and environment. A survey was conducted to investigate the critical factors affecting learners' satisfaction in e-Learning. The results revealed that learner computer anxiety, instructor attitude toward e-Learning, e-Learning course flexibility, e-Learning course quality, perceived usefulness, perceived ease of use, and diversity in assessments are the critical factors affecting learners' perceived satisfaction. Study did not concern only mathematics education, but its results (although not very new) are very important now, in the days of forced universal e-learning.

At the end of this research review, it is worth quoting the conclusions and recommendations of systematic review and literature survey of research conducted from 1985 until 2015 described in [16]: "Based on the summary of almost 30 years of research, this study provides important conclusions related to the effectiveness and moderators of technology integration in mathematics classrooms. In conclusion, the results of this systematic review indicate that technology integration supports mathematics achievement across prior meta-analytic research. (. . .) Based on these results, the researchers recommend that teachers and researchers continue to implement technology in the mathematics classroom, but emphasize optimizing the effects grade level, role of technology, and duration. (. . .) In addition, more research is necessary to capture the unique influences of teachers on the effects of technology integration in the mathematics classroom."

5. Example of research on the effectiveness of ICT-supported education conducted at the University of Bialystok

Presented reports from research show that there is small number of research works on effectiveness of teaching and learning with using computers conducted in regular, systematic work with a whole class, not in experimental conditions, but in everyday school circumstances.

In this situation at the University of Bialystok was made decision to start with such research because:

- Computers (with proper educational software) should become – and in many cases become – a didactic tool not only for individual work, but also for a common work in a classroom.
- All students – working in normal school circumstances – should profit from using computers in their learning, so research on results of using this tool in the whole math education, with all obstacles that school reality brings, should be done.
- During technology-supported math lesson students have opportunity to develop some special abilities, so the ways of assessment should take into consideration this change in students' achievements.

5.1. Obstacles

There were a few difficulties in planning and conducting research of above-mentioned kind:

- Small number of math lessons per week; in some types of schools there are two hours of mathematics per week, so teachers very often have to make hard decision: to devote lesson for practice in doing traditional exercises or to devote lesson for using computer (that is in mind of many people considered rather as a play).
- Not easy access to computer laboratory; there are many lessons of ICT in the schools, so labs are occupied, but in many schools situation becomes better because of the second multimedia lab that schools are given just for using technology in teaching all school subjects.
- Teachers' abilities to use technology in their work with students; many teachers (not all, but many) don't trust themselves, their abilities.
- There is a paradox in Polish educational reality: In the national curriculum it is written: "The most important skills developed in general primary education are: (. . .) creative problem solving in various fields with the conscious use of methods and tools derived from computer science" [17]; "The most important skills acquired by a student during general education in general secondary school and technical secondary school include: (. . .) creative problem solving in various fields with the conscious use of methods and tools derived from computer science, (. . .) the ability to efficiently use modern information and communication technologies." [18], but using all technological tools is forbidden during the exams (except of the simplest calculator during the exam after secondary school). Results of the exams are "the gate" to school of higher level, so teachers are expected (at first and most important) to

prepare students for exams. The conclusion for many teachers is simple: if technology is not used during the exams, so why am I to waste time, waste lessons for going to computer lab? But I must say that many teachers try to save time on the lessons for practice for exams and, in the same time, try to use additional hours for work in the laboratory. Teachers that teach ICT and mathematics are in better situation: they can teach bits of mathematics with computers on ICT lessons.

Very important remark: The use of multimedia textbooks by displaying them on the multimedia board and using the multimedia board for writing instead of the usual blackboard is not considered to be using ICT in math lessons. We took into consideration only the use of computer as the tool for investigative work of students.

5.2. Aims of the study

The main aims of the study were:

- introducing the elements of assessment of students' work on the computers to technology-supported math education,
- making research on the influence that using technology and assessing students' work on computers have on some aspects of effectiveness of teaching and learning process,
- recognition students' and teachers' opinions about the effectiveness of using systematic use of computers as the tools of constructing knowledge by students and about new way of assessing in math education.

From among problems that are included into the idea of "effectiveness of educational process" the following ones have been chosen to investigation:

- taking up by students active and creative position in technology-supported learning,
- the range of students' own work on problem solving with the use of technology (work at home and everywhere outside classroom is included),
- taking up by students position of responsibility for the results of their learning and development: their own planning and consistent accomplishment of their educational objectives,
- formation (structuring) knowledge by students based on the results of their work with computers.

5.3. Research problems

The following main research problem has been formulated: **What kind of influence has introducing the alternative assessment into technology-supported math education on effectiveness of math teaching and learning?**

The main problem has been divided into the following detailed problems:

- What is the influence of introducing assessing abilities to use technology in learning on students' creative activity?
- Does introducing assessing abilities to use technology in learning cause changes in students' attitude toward their learning?
- How does the constructing knowledge by students in technology-supported math education progress?

5.4. Research methods, techniques and tools

Action research method and an exploratory probing have been chosen as the methods of investigation. Questionnaire and document analysis has been chosen as research techniques. As investigation tools questionnaires for teachers or students and a number of special form of homework after the lessons in which computers were used. Also all students' documents – in paper or electronic form – created during the lessons or outside classroom are collected in portfolios and used as documents for analysis.

No hypotheses were formulated. This is a result of choice of action research as a main research method [19]. Researchers choose this method when they want to investigate particular phenomenon in the reality, in the full context and get to know them just as they are, not find that they fit to our notion about them. This method allows taking up for investigation problems that are almost unknown, such problems that researcher rather has some intuition than knows something about them, so it is difficult to formulate hypotheses. In case of considered research, the effectiveness of math teaching and learning in context of using technology and assessing the results of students' work with computers. Of course, we would like to observe the positive influence of these elements on effectiveness of educational process in many respects, but we cannot assume this. At the beginning of the research we don't know what school reality will bring. So researcher rather wants to observe and describe changes in students' development than try to fit the results of investigation to my assumptions and expectations.

5.5. Procedure of investigation

Investigation started in two classes (totally 56 students) in second grade of secondary economical school in Bialystok. There were two math lessons per week in each class, so it was clear from the beginning that it would be impossible to have many lessons with use of computers during a school year. In these classes mathematics was taught on basic level. Students from selected classes did not work with computers on math lessons before the beginning of the project.

Before the beginning of school year we (author of this paper and math teachers from selected classes) have looked at the plan of lessons for the whole year and chose the topics that could be supported by using computers and proper software. We realized that most of topics (accordingly to curriculum) regard functions, so we chose program *Graphic Calculus* (authors: Piet van Blokland and Carel van de Giessen from VuSoft, Netherlands [20]) as software for selected lessons. During the first math lesson in the computer laboratory students learned the program, then they could make copies for their home computers.

During all school year it was possible to have THREE technology-supported math lessons in computer lab with each class. Math teachers of these classes cooperated with each other in preparation materials for the lessons. All students from two classes had to make the same homework after each lesson.

5.5.1. First lesson (In case of this first lesson the entire plan is given here, in the next cases I will give the short descriptions)

Topic: Graphs of polynomial functions

(Note: This lesson comes after the lesson on topic: Polynomial equations *and precedes the lesson on topic:* Polynomials inequalities. *Students can already find zeros of polynomials – solve the equation* $a_nx^n+a_{n-1}x^{n-1}+a_{n-2}x^{n-2}+...+a_1x+a_0=0$. *In each lesson about polynomials we use the formula of polynomial like in previous sentence. We teach solving polynomial inequalities by finding zeros of polynomial, drafting a simplistic graph and reading the signs of polynomial values from this graph.)*

Age of students: 17

Duration of the lesson: 45 minutes.

Aims:

- general:
  - to improve the ability of using Graphic Calculus,
  - to enlarge knowledge about polynomials,
  - to form a positive attitude to solving problems and inquiring,
  - to facilitate accurate, logical and critical thinking,
- detailed – after the lesson students can:
  - describe how the graph of polynomial function depends on its zeros,
  - describe how the degree of polynomial and the sign of coefficient a_n influence the polynomial values in infinity ($-\infty$ and $+\infty$),
  - draft a graph of polynomial knowing its zeros and sign of coefficient a_n.

Methods: discussion, brain storming session, work with computers, problem solving method.
Forms of work: plenary session and work in pairs (with computers).
Procedure of the lesson:

- Introductory part:
  Students revise:
  - the idea of "zero of polynomial function",
  - the connection of the zero of any function with its graph,
  - the rules of using *Graphic Calculus*, especially needed on the lesson option *Draw Graphs*.
- Main part:
  Students work with computers in pairs. Before working with computers students are given their task: they have to observe what the influence of degree of polynomial, multiple of zeros and sign of coefficient a_n on different attributes of its graph is.
  They use GC: draw and watch graphs of polynomials:
  $y = (x-1)(x-2)(x-3)$ – *three single zeros, odd degree of polynomial,* $a_3 > 0$
  $y = -3(x-1)(x-2)(x-3)$ – *three single zeros, odd degree of polynomial,* $a_3 < 0$
  $y = (x-1)^2(x+3)$ – *one single zero, one double zero, odd degree of polynomial,* $a + 3 > 0$
  $y = -2(x-1)^2(x+3)$ – *one single zero, one double zero, odd degree of polynomial,* $a_3 < 0$
  $y = -2(x+3)^3(x-2)^2$ – *one triple zero, one double zero, odd degree of polynomial* $a_5 < 0$
  (Note: The teacher or students can build other examples of polynomials. The form of these polynomials saves time needed to find zeros and help to observe the connection between zeros and graph.)
  We hope that after watching the graphs students will conclude:
  - The polynomial's graph is a curve, which intersects the X-axis in points $(x_i, 0)$ if x_i is a zero of odd multiple, and reflects on the X-axis in points $(x_j, 0)$ if x_j is a zero of even multiple.
  - If $a_n > 0$ then polynomial values in infinity (when $x \to \infty$) are positive.
  - If $a_n < 0$ then polynomial values in infinity (when $x \to \infty$) are negative.

  These conclusions will help students to draft the graphs of polynomials when solving polynomial inequalities.
  Students should write down their conclusions in their exercise books and try to draft the graphs of the following polynomials by themselves:
  $y = 2(x-1)(x-2)^2(x-3)$
  $y = -3(x-1)^2(x+2)^3(x-3)$.
- Final part:
  1. Short recapitulation of the lesson.

2. Getting the feedback from the students by asking questions: Is everything clear? What was the main difficulty?
3. Setting the homework.

Many years ago author of this paper created the special form of homework after lessons with computer. This homework consists of two parts: first part plays role of feedback, second part contain exercises for practice related to topic of the lesson. Students like this form of homework, because they know that their opinion about the lesson is important for teacher and they feel responsibility for some part of math education.

After first lesson with computers students received the following form:

Name: ________________ Date: ________________

Homework after the lesson on topic: Graphs of polynomial functions
Answer the following questions:

1. What was the lesson about?
2. What were you doing during the lesson? Describe your activities.
3. Was using computer during this lesson useful? Justify your answer.
4. What was good about the lesson?
5. What was bad about the lesson?

Draft the graphs of following functions:

- $f(x) = -2x(x-3)^3(x-5)^2$,
- $f(x) = 4(x+5)(x+4)(x+3)(x+2)(x+1)$

Results of first lesson
All students wrote that using computer had been useful because graphs of functions had been made correctly, precisely and fast.
The table 1 shows students' answers questions No 4. and 5.
Some conclusions from homework:

- Many students wrote: **"It was possible to understand the topic faster and easier"**. In the same time about 80% students did not solve exercises (did not draft two graphs) correctly. Conclusion is: students' knowledge after the lesson was very weak; they learnt almost nothing about the connection between zeros and graph of polynomial. The short-term effectiveness of this lesson was very low.
- Many students wrote: **"Computer did all work for us"**, and assessed this as the wrong part of the lesson. Conclusion is: Students consider math activities only as manual actions, like drawing graphs.
- Also they wrote: **"We had to conclude from graphs by ourselves"** and, mostly, assessed this as the wrong part of the lesson. Conclusion is: Students are not used to put hypotheses and make conclusions. They are not used to construct knowledge. They are a little bit lost when computer does all "manual work" and leaves them thinking.
- Some students copied their homework from each other.

It became clear that students were the beginners in using computers for learning and structuring knowledge, so we (I and math teachers) decided to take the results of first lesson as a point of reference and observe a progress just from this level.

Table 1. Students' opinions about good and bad sides of the lesson.

Good sides of the lesson	Bad sides of the lesson
A graph has been made immediately after typing a formula.	**I could not learn too much because computer did all work for me.**
Cooperation.	**It was necessary to commit myself very much.**
Easy examples.	Not enough number of computers in the lab.
New experiences.	**It was difficult to determine properties of function.**
Learning computing.	**It was difficult to conclude from graphs.**
It was possible to understand the topic faster and easier.	**We had to conclude from graphs by ourselves.**
Mathematics with computers is more interesting.	**Lack of skills in making conclusions.**
Lesson was quite different from typical math lessons.	**Computer did all work for us (we had only to type formulas).**
Fast pace and precision of work.	
It was like a play.	
We were mobilized to conclude from graphs.	
It was possible to compare a few graphs in the same coordinates system.	
Computer did work for us.	

5.5.2. Second lesson Topic: Graphs and properties of functions $y = \sin x$ and $y = \cos x$

Procedure of the lesson:

Students were working with program *Graphic Calculus*, options *Trigonometric Functions* and *Draw Graphs*. They created graphs of functions $y = \sin x$ and $y = \cos x$, discussed the main properties of these functions. Then, in groups, students had to solve the following exercises:

Exercise 1.

Create (using software) graph of function $y = \sin x$ and read from the graph:

a) range of function values,
b) zeros of function,
c) intervals in which values of the function are positive,
d) arguments for which value of the function equals 1,
e) arguments for which value of the function equals –1,
f) intervals in which function is decreasing.

Exercise 2.

Create (using software) graph of function $y = \cos x$ and read from the graph:

a) the lowest and the highest value of the function,
b) range of function values,
c) zeros of function,

d) intervals in which function is increasing and intervals in which function is decreasing,
e) line of symmetry of the graph,
f) arguments for which $\cos x = 1, \cos x = 0, \cos x = -1, \cos x = 0.5, \cos x < 0, \cos x > 0$.

Write down results of your work in your exercise book.

Homework after this lesson:

Name: ________________ Date: ________________

Homework after the lesson on topic: Graphs and properties of functions $y = \sin x$ and $y = \cos x$

Answer the following questions:

- What was the lesson about?
- Was using computer during this lesson useful? Justify your answer.
- What was good about the lesson?
- What was bad about the lesson?

On this sheet draft (by hand) graphs of functions:

1. $y = \cos x$,
2. $y = \sin x$.

and write down answers the questions:

....

(Questions were similar to questions from the lesson)

Some conclusions from homework:

- Only one student wrote that using computer on this lesson was not useful, many other students noticed two good things: possibility of observation the process of rising graphs and possibility of work with radians and degrees. Conclusion is: students want to understand the processes, not only the results.
- Two students wrote: "Computer did all work for me, it was bad in the lesson". Conclusion: Still some students do not count thinking, reading from the graph, concluding, discussing etc. as the mathematical activities.
- All students made exercises, although some of them made mistakes. Conclusion: the effectiveness of the lesson was better than in case of first lesson with computer.

5.5.3. Third lesson Topic: Transformations of graphs of trigonometric functions

Procedure of the lesson:

Students were working in pairs with program *Graphic Calculus*, option *Draw Graphs*. They had to create the proper graphs and fill in the table with the results.

Example of the task:

Basic function: $y = \sin x$. Formula of function after transformation: $y = (x - \pi/3)$ – task for students: to create graphs of both functions, to describe the transformation and to give the domain and range of values of function after transformation.

After work with computers students formulated the conclusion about the connection between the kind of transformation (the direction and distance of translation) of graph and the formula of obtained function.

Homework after this lesson contained the questions about the lesson and two exercises that had to be solved on the sheet of homework:

Exercise 1

Draft graphs of functions: $y = \cos(x - \pi/4) + 1$, $y = \tan(x + \pi/3)\check{}2$ (and some others)

Exercise 2

Write down the formula of function that you obtain after translation the graph of function y=cos x four units down

(and a few similar examples)

Conclusions from homework:

- Students are used to work with the program. They do not complain that concluding is hard, but are happy that computer allows comparing graphs and helps – by visualization – to remember the mathematical rules.
- Students solve exercises (sometimes with mistakes) by themselves.

6. Assessment

During all lessons students had opportunity to be given good mark for active participation in the lesson. Homework was not assessed in marks.

After third lesson eager students had opportunity to take additional tasks (related to the topics) for their own work – for good mark. Only 14 students from one class and nobody from the other class decided to do this additional work.

All homework, sheets with tables completed during the lessons and additional works became a parts of students' portfolios.

7. Questionnaires

At the end of school year students completed the questionnaires. They were asked for answering some questions related using computers in math education. Only 38 students from two classes have completed the questionnaires (it is only 68% of all students involved in investigation), so in the results presented bellow $n = 38$.

The answers to the questions from the survey are presented below.

- Question: What results of using computers in math education do you observe in yourself? – *Students could choose and mark items from the list.*
- Question: Is it necessary to keep the results of students work with computers in any form (notes, printouts, files on hard disk)?
  Answers:
  Yes – 28 students, 73.7%
  No – 7 students, 18.4%
  No answer – 3 students, 7.9%
- Question: Should students' work on computers during math lessons be assessed?
  Answers:
  Yes – 21 students, 55.3%
  No – 14 students, 36.8%
  No answer – 3 students, 7.9%

Some conclusions from the questionnaires:

Most of participating in the survey students indicated that it is easier for them to understand topic with using software in learning, but only few of them noticed connection between using ICT and better results of tests.

Table 2. Results of using computers in math education observed by students in themselves.

Item from the list	Number of students	Percent of choices
Bigger motivation for learning	13	34.2
Bigger activity	12	31.6
Easier understanding the topic	30	78.9
Bigger abilities to problem solving	24	63.2
Easier concluding, structuring knowledge	19	50.0
Better results of class tests	9	23.7
Other		

More than 50% of participating in the survey students believe that their work with computer should be assessed, but only few of them used occasion to receive good mark for additional task with computer.

What does it mean? It is big question for teachers. Also it is some hint what direction of further work should be.

8. Conclusions and directions of further work

The first stage of introducing new didactic tool to math education in two classes from average secondary school in Bialystok has been described in this paper. Even this not-too-big experience was very informative for us (author of the paper and math teachers), especially as for progress in using computers for structuring the knowledge and students' attitude towards giving marks for the results of work with computers.

Let's remain research problems and conclude what answers these problems the results of the research gave:

- What is the influence of introducing assessing abilities to use technology in learning on students' creative activity? – Answer: 63% of responding students said in the survey that using ICT gave them bigger abilities to problem solving, 50% of responding students said that concluding and structuring knowledge was easier with computer. It is not too big number, but it is necessary to take into consideration that the period of shaping these students' abilities was not too long (only three lessons).
- Does introducing assessing abilities to use technology in learning cause changes in students' attitude toward their learning? – Answer: It is difficult to answer definitely, especially that most of students did not use occasion to do additional task even for good mark.
- How does the constructing knowledge by students in technology-supported math education progress? – Answer: here situation is rather clear: students were better in constructing knowledge at each subsequent lesson – it was visible from their homework.

Only partial answers the research problems were received, but we do not worry because the research was introductory research on this what is going on in the classroom in the everyday didactic work with using ICT in proper didactic situations and in everyday school circumstances. The most important for us was the following:

- Students accepted computer and software not only as a tool that can increase attractiveness of lesson, but also as a tool for learning.
- Progress in using computer for change of style of work during math lesson (from drawing graphs in exercise book to concluding and structuring knowledge) was visible and quite fast.

- Many students understand that the results of their work with computer should be saved somewhere in some form; they accepted the portfolio idea.
- About 50% of responding students agree that the results of their work with computer should be assessed in school mark and this mark should influence the final grade. But, in the same time, the opportunity to receive good mark used only several students.
- Some students noticed better results of their class tests after lessons with computer. Maybe it is result of better understanding topics or possibility of solving more exercises instead of drawing graphs by hand. That indicates in some way the change in effectiveness of learning in new circumstances. Connection between using computers in math education and results of class tests and exams will be investigated in the next stages of research. It is hard task; special tools should be constructed.
- Math teachers from selected classes' notices that shy students became more self-confident after introducing computers into learning process. Possibility of work at home with computer on homework assignments and possibility of good, creative preparing homework was very encouraging for students, especially if students' skill for computing were better that for math.
- One more result of introducing technology into math education appeared: cooperation between students and ICT teacher and cooperation between math teachers and other subjects' teachers (statistics, economics, ICT). We did not expect this result and now we are very pleased.

Students want more math lessons with computers. Research that has been started will be continued in the future, after coming back to normal work in schools after pandemic – we hope that it will be possible next school year; three lessons are not enough to answer the research problems. Maybe investigation will be expanded because number of math teachers from other schools would like to join this research. We will focus on the individual development of the student and his progress in learning mathematics under the influence of using ICT in individual research work and the independent construction of mathematical knowledge.

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[17] 2017 Rozporządzenie Ministra Edukacji Narodowej z dnia 14 lutego 2017 r.w sprawie podstawy programowej wychowania przedszkolnego oraz podstawy programowej kształcenia ogólnego dla szkoły podstawowej, w tym dla uczniów z niepełnosprawnością intelektualną w stopniu umiarkowanym lub znacznym, kształcenia ogólnego dla branżowej szkoły I stopnia, kształcenia ogólnego dla szkoły specjalnej przysposabiającej do pracy oraz kształcenia ogólnego dla szkoły policealnej URL `https://podstawaprogramowa.pl/files/D2017000035601.pdf`
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Hyperbolic geometry in general education: comprehending the incomprehensible

To cite this article: I Lénárt 2021 *J. Phys.: Conf. Ser.* **1946** 012005

Hyperbolic geometry in general education: comprehending the incomprehensible

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Abstract. This paper is a self-independent continuation of my article on Comparative geometry between the plane and the sphere that was presented at the previous edition of ICon-MaSTEd Conference 2020. Below I discuss the possibility of adding a third geometry to the plane and the sphere, namely, the hyperbolic geometry on the hemisphere. I describe my own path to the subject, then the content of the syllabus which contains basic concepts of hyperbolic geometry for future preschool, elementary school, and secondary school teachers. Finally, I give reasons to introduce the subject into primary and secondary schools, not just for the "talented" but also for the "average" students.

1. Introduction

In the 2020 edition of ICon-MaSTEd Conference (XII International Conference on Mathematics, Science and Technology Education) I described the Comparative Geometry project, its underlying ideas and my experiences applying it in distance education [1].

The fundamental idea of the project is to teach and learn two (or later more) different systems of geometry simultaneously for a wide range of age groups. Students compare and contrast concepts and theorems in two or more different worlds of geometry, as suggested, for example, in the book of Henderson and Taimina for university students [2], or my book for the upper elementary and secondary school [3], or science popularization books like Van Brummelen's work [4].

Instead of a Euclidean monologue, we use a drama-play between different geometric systems. It is the drama, the comparison and contrast that make geometry interesting. It gives the student the opportunity to build his own geometry and live through the torment and beauty of creation.

In last year's article [1], the two systems I compared were the geometry of the planar surface and the spherical surface. The essence of the present article is to deal with the basics of a third system in the classroom, but only after the introduction of the first two systems. The third system is the hyperbolic, Gauss-Bolyai-Lobachevskian geometry. In the conclusions I summarize my reasons for this proposal. Detailed description of comparing the three geometries in education is found in the book of Rybak and Lénárt [5].

I do not describe a planned and analytically evaluated experiment, but an action research, a set of experiences I gained during decades of teaching comparative geometry.

As I mentioned in my presentation last year (and repeat here to make the background and conditions clear) I have been giving college and university courses in comparative geometry since 1990, mainly for prospective kindergarten teachers, elementary school teachers, and high school teachers, occasionally future mathematicians and geographers too.

The mathematical knowledge of the target audience has been extremely diverse. For quite a few students, basic concepts of plane geometry are only (vaguely) memorized but not interiorized. In contrast, other students have profound competence up to calculus and higher algebra. Spherical geometry was practically unknown for most of them. Several times I have come across students who are familiar with calculus or set theory but do not know how to draw a straight line on the sphere.

Hyperbolic geometry was completely unknown to the vast majority of students. Even the few who heard of the subject remembered it with sacred horror much more than enthusiasm.

In the first decade of my teaching about comparative geometry, I only dealt with plane geometry versus spherical geometry in the courses. For a long time, I didn't consider hyperbolic geometry as part of the material. It seemed much more difficult and formidable than spherical geometry. Besides, I did not feel my own pedagogical and demonstrational tools or even my mathematical competences adequate for the task.

It was not until around 2000 that I started incorporating hyperbolic geometry into the syllabus. Some groups completed the original syllabus earlier than others. There were still a few hours left to deal with a new topic, a third system of geometry.

However, it was not at all easy, even for high-performing groups, to keep up with the new concepts. Major goals like creating interest or removing inferiority complexes have often been hampered by the acceptance of a very new, very different approach to geometry.

For that reason, I gradually changed my strategy. The new material about hyperbolic geometry was sporadically inserted into the main syllabus about the plane and the sphere. From time to time I hinted at the third option beyond plane geometry and spherical geometry. This method proved to be more effective, less tiring, and more suitable for arousing interest in the students.

When we still have time at the end of the semester and the students are curious about the topic, we sketch the basic concepts of hyperbolic geometry in 3-4 consecutive lessons, referring to the related concepts of planar geometry and spherical geometry all the time.

2. My way to hyperbolic geometry

I was fully empathetic to my students' problems because my own path to hyperbolic geometry was also far from smooth.

My first attempt to get acquainted with the subject was the booklet "Scientia Spatii" (The Science of Space) [6], the classical work of the Hungarian János Bolyai, one of the discoverers of hyperbolic geometry. To my great disappointment, I found it incomprehensible at first reading. Whenever I came across the word "obvious", I suspected that a statement would follow which was far beyond my competence.

I add that Bolyai's work became understandable and fascinating later on, by the hemispherical model. I could even use some parts of it with my students in the classroom.

I read excellent references on the subject including Greenberg [7], Szőkefalvi-Nagy [8], and others who applied some versions of the flat disc model, or the half-plane model of Poincaré [9]. I understood more or less what they were saying but I didn't like the subject.

Some other sources discussed the topic on a purely algebraic basis which I could grasp, but could not imagine how a human being came to axioms so far from my perception and common sense.

Later on, I looked into outstanding software materials that also dealt with the flat disk model of hyperbolic geometry, like Cinderella [10], dynamic geometry of Szilassi on Geogebra [11] or

Non-Euclid [12]. These software materials were very useful, but, again, only after grasping the basic concepts on the hemispherical model, or when I tried to prove or refute the validity of an assumption in hyperbolic geometry.

It was Poincaré's hemispherical model in Horváth's book [13] that opened up the path of hyperbolic geometry. Concepts that could not be understood on other models became clear and illustrative in this way. My previous experience with spherical geometry has been of great help in exploring new hyperbolic concepts.

Even so, I kept on drawing and constructing on palpable hemispheres. The hemispherical model gave the inspiration and self-confidence to teach the material and even start my own research on hyperbolic geometry.

3. Summary of the content of the syllabus

Below I describe the main topics, illustrations and wordings by which I tried to make the basic concepts accessible to my students.

In order to illustrate the constructions, I use round-shaped goods (fruits, ball, globes, etc.) and spherical construction materials [14, 15]. Round-shaped commodities come in handy in distance education.

3.1. Surface and basic elements:

Planar geometry is built on the surface of the infinite plane, and spherical geometry on the finite sphere. What kind of surface could be used to create a third type of geometry that admits points, straight lines, polygons, circles, etc., but differs in many respects from plane geometry or spherical geometry?

There are several models on different surfaces on which the new geometry can be built. In what follows, I mainly use the surface of an open hemisphere whose equator does not belong to the model.

The simplest element of this geometry is the point, just as in plane geometry or spherical geometry.

Figure 1. Points on the hemisphere.

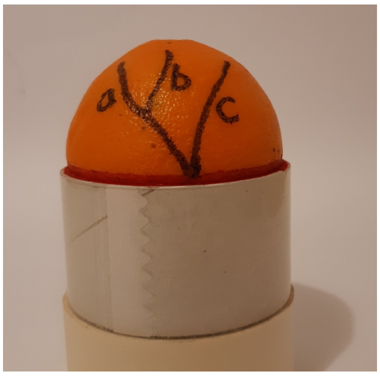

Figure 2. Intersecting vs. non-intersecting curves.

Figure 1 shows points as basic elements of hyperbolic geometry on the open hemisphere. Curves a and b on figure 2 cross in a hyperbolic point, but curves a and c do not, since the point of intersection is on the bordering equator which does not belong to the model.

What to choose for the simplest line, the hyperbolic straight line? The Euclidean straight line is out of question, because it has only one point in common with the hemisphere. The spherical great circle fits on the surface, but this choice would take back to the well-known system of spherical geometry.

Instead, choose the spherical semi-circles which are perpendicular to the omitted equator.

Figure 3. Straight line on the plane.

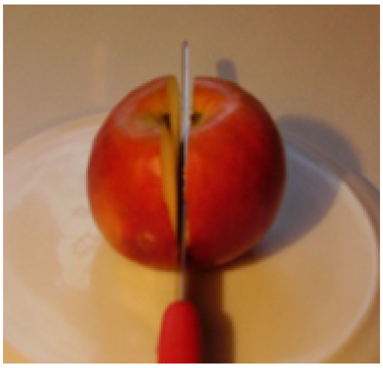

Figure 4. Straight line on the sphere.

Figure 5. Straight line on the hemisphere.

The straight lines on different surfaces can be illustrated in several ways, as with a planar ruler on figure 3, the cutting line of a halved apple on 4, or of a sliced onion on 5.

My experience is that the most difficult transition in comparative geometry is the change from the planar straight line to the spherical straight line or great circle and especially from the planar and spherical straight lines to their hyperbolic counterpart.

For that reason, it is very useful to invent exercises for distinguishing hyperbolic straight lines from other hyperbolic lines, especially those lines which correspond to certain spherical circles.

- All lines on figure 6 are hyperbolic straight lines.
- No line is hyperbolic straight line on figure 7.
- Only the longitudes are hyperbolic straight lines or segments on figure 8.
- On figure 9 all latitudes are hyperbolic straight lines, plus one longitude through the pole point at the top of the hemisphere.

Following are some fundamental properties of the hyperbolic straight line which are extremely hard to grasp from the Euclidean or spherical perspective:

- Each straight line is infinite, because the endpoints are on the omitted equator, that is, the straight line has no endpoint within the open hemisphere.
- Any two are always congruent with each other, even if they seem ‘large’ or ‘small’ circles in spherical geometry.
- Each straight line divides the surface into two congruent halves, even if the two regions seem very different in size from the spherical perspective.

3.2. Lines through two points

- On the plane, two points share one straight line that passes through them.
- On the sphere, if two points are not opposite, they have exactly one straight line / great circle through them. If they are opposite, there are infinitely many straight lines through them.
- On the hemisphere, any two points have always one straight line passing through them, just as with the plane. (At this initial stage, I am not confusing students with saying that one or even both points could be on the omitted equator. In other words, the statement remains valid if we include ideal points on the equator.)

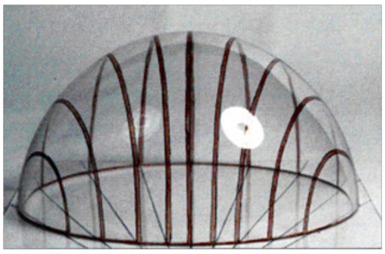

Figure 6. Are they hyperbolic straight lines?

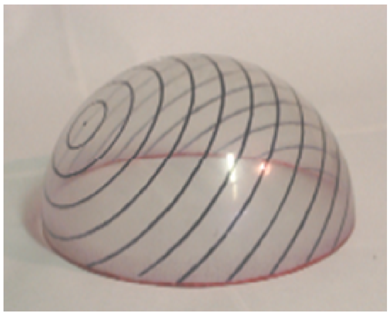

Figure 7. Are they hyperbolic straight lines?

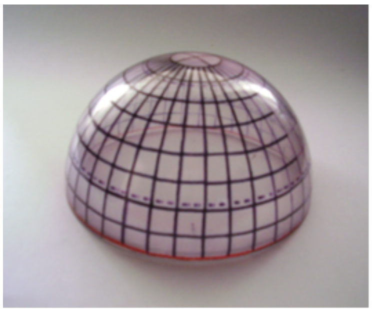

Figure 8. Are they hyperbolic straight lines?

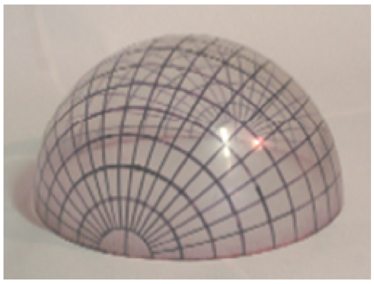

Figure 9. Are they hyperbolic straight lines?

3.3. Common points of two lines

- On the plane, two straight lines share one common point if they are intersecting, or no common point, if they are parallel.
- On the sphere, two straight lines / great circles always intersect in two opposite points. Parallel straight lines / great circles do not exist on the sphere.
- On the hemisphere, the picture is different from the plane or the sphere. Two straight lines may or may not intersect. If they are intersecting, they have one point in common. If they are not intersecting, they may or may not meet at the same point of the omitted equator. We agree that we call two hyperbolic straight lines parallel lines (also called asymptotic lines) if they meet at a point of the omitted equator, that is, in an ideal point. In all other cases of non-intersecting hyperbolic straight lines, we call them skew straight lines. This latter case cannot happen on the plane or on the sphere where skew straight lines do not exist.
- Figure 10 shows two intersecting lines.
- Figure 11 shows two parallel (asymptotic) straight lines.
- Figure 12 shows two skew lines.
- Figure 13 also shows skew straight lines. One is tempted to call them parallels from the spherical perspective, but these lines do not meet at the same ideal point.

3.4. Pencils of straight lines

On the plane, there are two types of pencils of straight lines:

- All straight lines passing through a point.
- All straight lines parallel with each other.

Figure 10. Intersecting hyperbolic straight lines.

Figure 11. Parallel hyperbolic straight lines.

Figure 12. Skew hyperbolic straight lines.

Figure 13. Skew hyperbolic straight lines.

On the sphere, there is only one type of pencils:

- All great circles through two opposite points, like the longitudes through the North and South Poles.

On the hemisphere, there are in fact three types of pencils, but we only consider two types, because the third one is too alien for the beginner:

- All the straight lines passing through a point.
- All the straight lines parallel with each other, that is, passing through the same point of the omitted equator.

An example of a hyperbolic pencil passing through a point is all the longitudes on the Northern Hemisphere passing through the North Pole. However, if we mark a point not on the top of the hemisphere, we get a very unusual shape of a pencil, reminding of a spider's web. In the second case, we get a pencil of parallel lines, which, in turn, reminds me of a fountain. (These childish analogies make easier to grasp and remember the concept.)

These two types of pencils are apparently different from the spherical perspective, but are indistinguishable from the hyperbolic point of view. This is another trait that is very far from what we are used to on the plane or on the sphere, so I do not bother my students with it.

Figure 14. Pencil of hyperbolic straight line through the pole point.

Figure 15. Pencil of hyperbolic straight lines through a point off the pole.

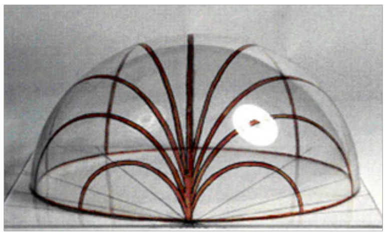

Figure 16. Pencil of parallel hyperbolic straight lines through an ideal point on the equator.

3.5. The Parallel Postulate

Consider a pencil of straight lines, and another straight line L that does not belong to the pencil. How many straight lines of the pencil do not intersect straight line L?

- On the plane, there are infinitely many intersecting straight lines, and only one non-intersecting line in the pencil.
- On the sphere, there are infinitely many intersecting straight lines, and no non-intersecting line in the pencil.
- On the hemisphere, the picture is far more complex. There are infinitely many intersecting straight lines, and also infinitely many non-intersecting straight lines in the pencil. The two sets of lines are separated from each other by two "guards", two non-intersecting lines which are called parallel or asymptotic lines.

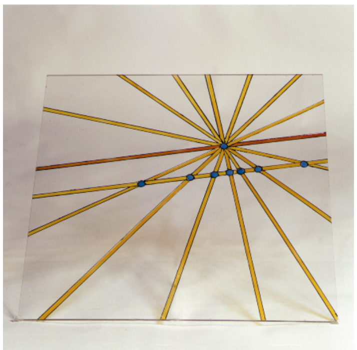

Figure 17. On the plane: one parallel line.

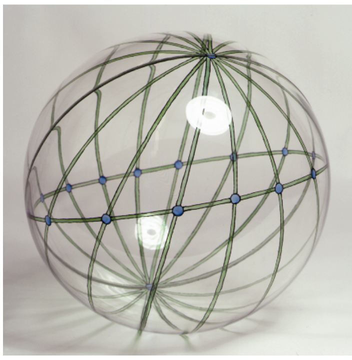

Figure 18. On the sphere: no parallel line.

Figure 19. On the hemisphere: infinitely many parallel lines.

It is interesting to mention how Bolyai himself came up with the basic idea. He was unaware of the hyperbolic models described in this article, so he imagined the scene on a flat sheet as the lines of the pencil were rotating around the common point of intersection. One of the rotating lines in a certain position bounces off the outer line, and the rotation continues until another rotating line intersects the outer line again. On the Euclidean plane, the bouncing-off line is the same as the bouncing-back line, but what if we assume that there are infinitely many non-intersecting lines between the two?

These detours are very important and instructive. The learner's main concern is how he or she would have come to the same idea. The spark of thought that led Bolyai to his discovery makes the seemingly superhuman achievement understandable for the learner.

3.6. Measuring hyperbolic distance

I usually omit this topic, because it is too complex for the beginner. I only try to explain the gist of the problem when students specifically ask for an explanation. The following is a summary of my interpretation when it is explicitly required by the students.

The problem is that the points on the equator of the hemispherical model are out of reach of our measurement, because these points do not belong to the hyperbolic surface. As we move forward along a straight line from an inside point to an ideal point (a point on the equator), our steps appear shorter and shorter for an outer observer.

Another problem is that all hyperbolic straight lines are congruent, although they may appear different in size from the spherical perspective. If we want to make a scale of measurement of hyperbolic distance (that is, to create a hyperbolic ruler), it has to fit any hyperbolic straight line.

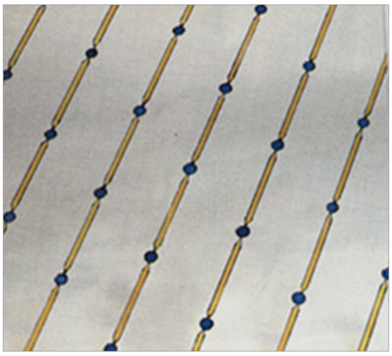

Figure 20. On the plane, equal units seem equal for the outer observer.

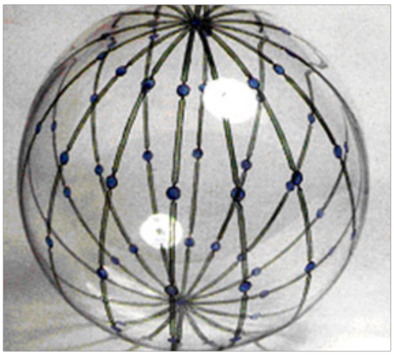

Figure 21. On the sphere, equal units seem equal for the outer observer.

Figure 22. On the hemisphere, equal units seem shorter when approaching the equator.

Still another problem is that we would like to define hyperbolic distance and angle so that the wonderful concord between the sides and angles of the isosceles triangle remains valid on the hemispherical model. Equal sides subtend to equal angles, and conversely ("Pons Asinorum").

The proper definition of distance involves the concept of cross-ratio. It is not too hard, but too lengthy for the beginner. Figure 23 and figure 24 show a possible scale for the purpose, but, again, I usually omit it altogether from the introduction.

3.7. Measuring hyperbolic angle

The situation is much simpler than measuring distance. If two angles appear to be the same in the hemispherical model, they are in fact the same. In contrast to distance measurement, we can trust our eyes when measuring the angle.

Measuring angle on the plane and on the sphere does not need explanation.

On the hemisphere, construct two tangential spherical straight lines through the vertex of the hyperbolic angle. The spherical angle of the two spherical straight lines can be taken for the measure of hyperbolic angle of the two hyperbolic straight lines.

Figure 23. An option of scaling the hyperbolic ruler.

Figure 24. Measuring the hyperbolic distance of two points along the scale.

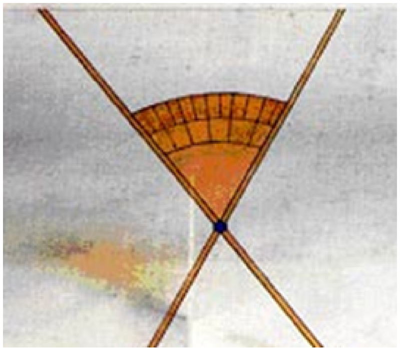

Figure 25. Measuring angle on the plane.

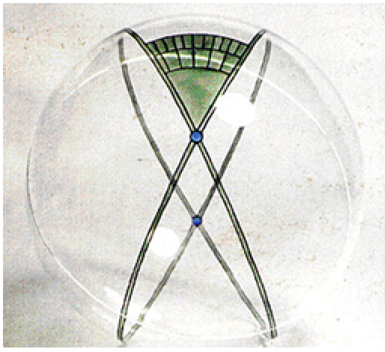

Figure 26. Measuring angle on the sphere.

Figure 27. Measuring angle on the hemisphere.

A striking consequence of the definition:

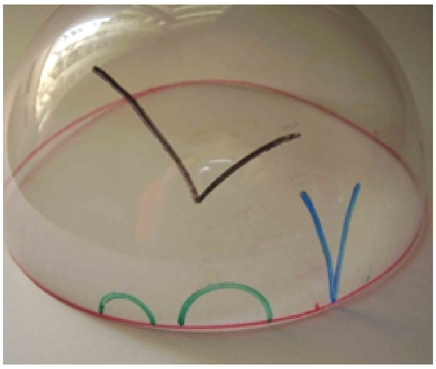

Figure 28. Different cases of arranging two hyperbolic straight lines.

The angle of two parallel lines as a limit of non-parallel lines can be defined as equal to 0. However, the angle of two skew lines (which do not share real or ideal points) cannot be defined!

3.8. Sum of interior angles in a hyperbolic triangle

- On the plane (figure 29): The sum of interior angles of any triangle is 180°.

Figure 29. Regular triangles on the plane.

Figure 30. Regular triangles on the sphere.

Figure 31. Regular triangles on the hemisphere.

- On the sphere (figure 30): The smaller the spherical triangle, the closer to the plane. Therefore, the sum of interior angles changes from the smallest possible 180° (the point) to 540° in the greatest possible triangle with three vertices on the equator.
- On the hemisphere (figure 31): The smaller the hyperbolic triangle, the closer to the plane. Therefore, the sum of the interior angles changes from 180° in the smallest possible triangle (the point) to 0° in the largest possible triangle with three ideal points on the omitted equator. This triangle is also known as the triply asymptotic triangle. (Any two sides of this triangle are parallel to each other according to the definition of parallels on the hyperbolic surface. Another notable difference to the plane or the sphere: a triangle with parallel sides!)

3.9. Khayyam-Saccheri quadrilateral
This was one of the first problems leading to the discovery of hyperbolic geometry.

For a given segment, erect two perpendiculars at two endpoints, measure two equal distances on the perpendiculars and connect the new endpoints. Due to the symmetry of the figure, the two top angles are congruent; but how big will they be?

On the plane (figure 32), each will be a right angle; on the sphere (figure 33), always bigger than that; on the hemisphere (figure 34), always smaller than that.

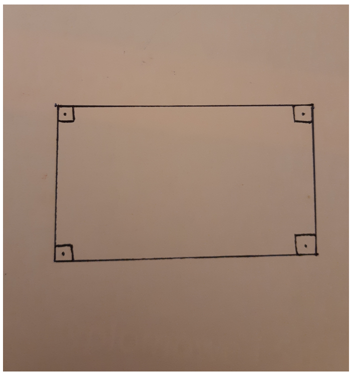

Figure 32. Planar rectangle.

Figure 33. Spherical Khayyam-Saccheri quadrilateral.

Figure 34. Hyperbolic Khayyam-Saccheri quadrilateral.

3.10. Lambert quadrilateral

This is another problem that probably would have led Lambert to the discovery of hyperbolic geometry before Gauss, Bolyai and Lobachevsky had he not died at the age of 49: Given a quadrilateral with three right angles, how big is the fourth angle?

On the plane (figure 35) each will be a right angle; on the sphere (figure 36) always bigger than that; on the hemisphere (figure 37) always smaller than that.

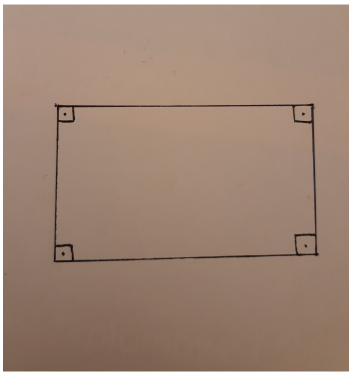

Figure 35. Planar rectangle.

Figure 36. Spherical Lambert quadrilateral.

Figure 37. Hyperbolic Lambert quadrilateral.

3.11. Napier shape

Create a chain of five consecutive perpendicular segments. Can the fifth segment be perpendicular to the first one? In other words, can you close the chain of perpendiculars into a cycle?

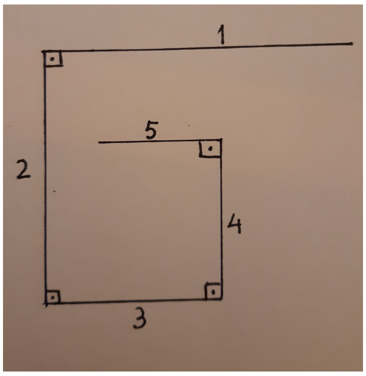

Figure 38. Chain of five perpendiculars on the plane.

Figure 39. Spherical Napier pentagram.

Figure 40. Hyperbolic Napier pentagon.

On the plane (figure 38) it is not possible, since the fifth segment is parallel with the first one. On the sphere (figure 39) the chain is closed to form a cycle called a Napier pentagram ("Pentagramma Mirificum"). On the hemisphere (figure 40) the chain is closed in a cycle which can be called a Napier pentagon because it is a convex polygon.

The Napier pentagram is 400 years old, but – to the best of my knowledge – the Napier pentagon is a new invention [16].

4. Conclusions

4.1. Concepts

The above material presents the basic concepts of hyperbolic geometry versus the corresponding concepts of planar and spherical geometry in the order and style that I have used in my courses.

There are many other mathematically and historically interesting and important concepts that can be added to this material, such as the equidistant line (the set of points equidistant from a line), the classification of circles and cycles, or the measurement of area.

All these topics do not require trigonometry of any kind which is an extremely important and beautiful topic. However, it requires a different approach, a different mathematical language, so it is not included into this introductory material.

4.2. Why and to whom is it worth teaching?

The real question is, why and to whom is it worth teaching? What goals can a teacher set in teaching this new, unusual material?

At first glance, the idea of including hyperbolic geometry in general education seems too bold, far from the current curriculum. The eminent Russian scholar Alexandrov [17] 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".

Alexandrov's opinion is also supported by the history of science. Plane geometry and spherical geometry evolved more than two thousand years ago. In contrast, the basic works of hyperbolic geometry are only two hundred years old, although preliminary research had begun much earlier.

4.3. Why do I still recommend using hyperbolic geometry as part of comparative geometry in general education?

- If the learner has already dealt with comparative geometry of the plane and the sphere, he has become more or less free from the shackles of purely Euclidean approach. As a result, the transition to a third geometry becomes much easier.
- The hemispherical model of hyperbolic geometry gives the student the opportunity to apply his / her prior knowledge in spherical geometry.
- The hemispherical model makes many new concepts in hyperbolic geometry easier to visualize and understand, such as the concept of straight line, angle measurement, properties of polygons, classification of circles and cycles, etc. Conversely, the hyperbolic model proves to be very helpful in understanding the deeper meaning of many concepts and theorems in plane and spherical geometry, for example, the circle with infinite radius, or the isosceles triangle theorem.
- Hyperbolic geometry is a vital part of modern geometry, mathematics, physics (for example the theory of relativity), or the philosophy of science. It is becoming increasingly important in other disciplines, and even in the fine arts and architecture.
- Hyperbolic geometry often provides a stark counterexample to certain concepts of plane geometry and spherical geometry.
- The futile attempts over two millennia to refute the existence of a third geometry, then the successful construction of hyperbolic geometry two hundred years ago, and finally its general acceptance and utilization belong to the most exciting chapters in the history of science. Ancient Greek geometers, medieval Arabic and Persian scholars, Italian, German, Russian, Swiss, Hungarian, and other European researchers worked on the development of the new discipline. Hence, the history of hyperbolic geometry is extremely challenging and instructive not only from the mathematical point of view, but also in the general history

of human culture. It can readily be used as a bridge between the humanities and natural sciences.

- Beyond all this, I consider another aspect very important. The axioms of hyperbolic geometry are very unusual from the Euclidean perspective. For most learners, this geometry is an archetype of a discipline that is inaccessible for the “average” student. Only the selected few, the geniuses are able to grasp it. Thus, for many people (who have heard of it at all), hyperbolic geometry reveals the limitations of their comprehension. One of the main purposes of the paper and project is to show that the foundations of hyperbolic geometry are not harder than the geometry of the plane or the sphere, just require a different approach which becomes understandable or even enjoyable by appropriate learning and teaching methods and models.

4.4. My students at ELTE University, Faculty of Preschool and Primary Education

Students of any grade could apply to the elective course Ball Geometry. No prerequisite knowledge of any type of non-Euclidean geometry is expected from the applicants.

For many years, I had only one course of this type in the Hungarian language at the Faculty. In the last twelve years, I opened an English course for Erasmus students with the same syllabus. At the end of the 2017/18 semester, 15 Hungarian students who had already completed Ball Geometry I, asked me to open Ball Geometry II as the continuation of the first semester. Because of administrative reasons, this could not happen in the spring semester, only the next fall semester.

I emphasize again that these students were future kindergarten and elementary school teachers. Their mathematics curriculum did not include non-Euclidean geometries, apart from the formulas of measuring surface, volume and components of the three-dimensional sphere, and the geographic coordinate system on the globe.

I described in the preliminary prospectus for the students that the aim of the course was to compare different geometric systems, to contrast planar geometric concepts with the corresponding concepts of other geometries. I was expecting that this information would scare many students away from the course, yet I did not want to cause any disappointment to them with an unexpectedly difficult material.

To my pleasant surprise, this was not the case, as shown in the table 1.

Table 1. Number of students in the last five years:

Semester	Ball Geometry I	Ball Geometry II	Erasmus students
2015/16 Fall	19		1
2015/16 Spring	21		4
2016/17 Fall	20		5
2016/17 Spring	22		1
2017/19 Fall	56		2
2017/18 Spring	30		2
2018/19 Fall	29	8	
2018/19 Spring	36	6	2
2019/20 Fall	53	16	13
2019/20 Spring	16	9	5
2020/21 Fall	58	21	4
2020/21 Spring	62	15	5

Following the favourable reception of the Ball Geometry course and the support of several cooperating colleagues, certain elements of comparative geometry have become part of the compulsory examination.

At the beginning of each semester, I asked my students why they applied for the course. The answers could be broken down into four main types, with roughly equal proportions:

- An acquaintance who took the course recommended that it was worth attending.
- The title "Ball Geometry" sounded appealing.
- Mathematics in general, and geometry in particular, did not belong to his/her favourites in the secondary school, and he/she expected a positive turn from math phobia.
- In contrast, math memories from secondary school were positive, and he/she was eager for topics and exercises which were more challenging than the material required in kindergarten or elementary school.

Of course, participants in an elective course do not represent the average level of students. Nevertheless, my experiences during three decades of teaching have shown that prospective kindergarten and primary teachers are open and eager for mathematics that arouses their interest and provides a way to develop their competences.

I find it ridiculous and unfair to trace all the problems of secondary and tertiary education back to preschool and primary teachers. Even if such problems do exist, they can be traced back at least as much to the shortcomings of teacher training as to indifference of the students.

4.5. Does comparative geometry help in writing a test paper or an exam?

The answer depends on what the test or exam requires of the student: ready-made knowledge, routine exercises, or problem-solving thinking?

In fact, comparative geometry is more of an obstacle than an advantage in the first two cases. If the student is expected to answer as many questions as possible within the shortest possible time, he / she will lose valuable time pondering too much over an example.

Learning about comparative geometry is of real advantage if the teacher requires independent, problem-solving thinking from the student and rewards this attitude accordingly.

4.6. Direct vs. ICT experimentation

The widest possible use of ICT technology is essential and should be developed by the practicing teacher and educator as well [18]. This is especially true in the historical era of distance education, which, although not caused, was dramatically accelerated by the onset of the pandemic.

With all this in mind, I still consider direct, hands-on experimentation in geometry to be essential for grasping the basic concepts and developing them further. Hands-on experimentation and ICT research are not mutually exclusive but complementary factors for development. To quote a classic, "Men will always deceive themselves by abandoning experience to follow imaginary systems" [19].

For a long time, hyperbolic geometry presented itself as a very abstract mathematical theory, very distant from practical use. In the last hundred years, it has been widely accepted through its application in the natural sciences and has become an important part of mathematical theory and physical experimentation. As such, it well deserves some introductory lessons as part of comparative geometry in general education.

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Journal of Physics: Conference Series

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Construction of cubic splines for interpolating functional dependencies and processing the results of experimental studies

Construction of cubic splines for interpolating functional dependencies and processing the results of experimental studies

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Abstract. Algorithms for constructing cubic splines with different boundary conditions have been developed: 1. The second derivative takes arbitrary values at the ends of the spline. A special case is the "natural spline", when the second derivative at its ends is equal to zero. 2. At one end of the spline, the first derivative is given, and at the opposite end – the second derivative. 3. The first derivative is given at the two ends of the spline without any restrictions on the second derivatives. The proposed methods were tested on the example of interpolation of the function $10x \sin xe^{-x}$ for the interval $[0, 1]$. The relative calculation error for the number of nodes $n = 10$ was about 10^{-2}. With an increase in the number of nodes to 1000 and 10000, the error increases, respectively, to 10^{-6} and $10^{-7} - 10^{-8}$. It is shown that a number of problems with other boundary conditions can be solved using the proposed methods. The considered algorithms can be used for interpolating functional dependencies and processing the results of experimental studies, represented as a discrete set of pairs of numbers.

1. Introduction

Restoring functional dependence on the basis of a discrete set of numbers is one of the important issues of computational mathematics. In the simplest case, this set is specified in the form of a table with two variables $(x_k, y_k), k = 0, 1, 2, \dots, n$, belonging to the interval $[a, b]$. Identification of the dependence $y(x)$ for large n using interpolation polynomials, like the Lagrange polynomial, encounters insuperable difficulties that can be avoided using splines. The theory of polynomial splines was developed in the works [1–9] and others. First of all, it expanded the possibilities of interpolating functional dependencies [10, 11].

Later, the field of application of spline functions covered many sections in the theory of differential equations, mathematical modeling [12], in the design of various profiles [13], in computer graphics [14–16], when processing experimental data [17–19]. Using splines, it is possible to describe the trajectories of moving objects, a change in the distribution of temperature and electromagnetic fields, diffusion processes in multilayer systems [8], they can also be used when solving other problems of applied mathematics and geometry [3]. The most widespread is the cubic spline, which is distinguished by its simplicity and ease of implementation when solving a wide range of problems [20, 21]. Most often, the so-called "natural spline" is used, which corresponds to the assumption that its second derivatives at the boundaries of the interval $[a, b]$ are equal to zero [3]. The use of "natural spline" guarantees a sufficiently high accuracy of interpolation of continuous functions with continuous first and second derivatives. In many cases, there is a need to use other boundary conditions. In particular, these include the following tasks:

- finding profiles of various types with given boundary conditions,
- constructing the lines on a closed contour,
- processing the results of experimental studies on the dependence of one factor on another with the selected boundary conditions.

This work is devoted to the creation of algorithms that provide the construction of cubic splines of this type.

2. Research work objectives

Supposing on the interval $[a, b]$ there is a continuous function $F(x)$ with continuous derivatives up to the third order. Imagine that at the nodal points $x_0 = a, x_1, x_2, ..., x_n = b$, this function takes known values equal, respectively, to $y_0, y_1, y_2...y_n$. Let us consider the possibility of recovering this function for the entire interval $[a, b]$ with a certain accuracy δF. Theoretically, the use of well-known interpolation polynomials makes it possible to obtain a solution to the problem posed with an arbitrarily high accuracy. However, the accumulation of computational errors for sufficiently large values of n does not allow achieving the desired results. In this case, the spline interpolation method can be used. Cubic splines are polynomials of the least degree that have continuous second derivatives. The most widespread is the cubic spline $S(x)$, given by polynomials not higher than the third order [3].

$$f_k(x) = a_k + b_k(x - x_k) + c_k(x - x_k)^2 + d_k(x - x_k)^3, k = [1, \dots, n], x_{k-1} <= x <= x_k, \quad (1)$$

A great advantage of cubic splines is the simplicity of the algorithms for their construction, which ensures their wide use in many applied problems with a relatively small error. To ensure the continuity of the spline, it is necessary to require that the value of the spline at the nodal points $S(x_k)$ has to be equal to $f_k(x_k) = y_k$ and $f_k(x_{k-1}) = f_k - 1(x_{k-1})$. In this case, the constants in the polynomial ak are equal to y_k. Let us emphasize the differences between neighboring coordinates of nodes and the values of functions at these nodes by $\delta x_k = x_k - x_k - 1$, $\delta y_k = y_k - y_k - 1$, $k = [1, ..., n]$. The condition of the spline continuity implies that the equalities are fulfilled as follows

$$g_k = b_k - c_k \delta x_k + d_k \delta x_k^2, k = [1, ..., n], \quad (2)$$

where $g_k = \delta y_k / \delta x_k$.

The polynomials (1) obtained in this way restore the function $F(x)$ on the entire interval $[a, b]$. To ensure the smoothness of the spline, it is necessary to require the continuity of the derivatives of the spline at the nodal points. Let's take $f'_{k-1}(x_{k-1}) = b_k - 1, f''_k - 1(x_{k-1}) = c_{k-1}$ where, taking into account the formula (1), it follows that

$$b_k = b_{k-1} + 2c_k \delta x_k - 3d_k \delta x_k^2, k = [2, ..., n], \quad (3)$$

$$d_k = (c_k - c_{k-1},)/(3\delta x_k), k = [2, ..., n], \quad (4)$$

After the substitution of $d_k \delta x_k$ from (4) into formulas (2), (3) we will get

$$b_k = g_k + c_k \delta x_k/2 + c_{k-1} \delta x_k/3, k = [2, \dots, n], \quad (5)$$

$$b_k - b_{k-1} - c_k \delta x_k - c_{k-1} \delta x_k = 0, k = [2, ..., n], \quad (6)$$

From formula (5) it follows that $b_{k-1} = c_{k-1} \delta x_{k-1}/2 + c_{k-2} \delta x_{k-1}/3 + g_{k-1}, k = [3, ..., n]$.

Substituting the obtained result and formula (5) into (6), we will get

$$2\delta x_k c_{k-1} + (4\delta x_{k+1} + 3\delta x_k)c_k + 3\delta x_{k+1}c_{k+1} + 1 = 6h_{k+1}, k = [2, ..., n-1], \tag{7}$$

where $h_k = g_k - g_{k-1}$.

The solution of the system of equations (7) makes it possible to identify the coefficients of the spline dk and bk by formulas (4), (5) and, thus, to ensure the restoration of the function. $F(x)$ using polynomials (1). Thus, the main problem is reduced to solving a system of $n-2$ linear algebraic equations (7), which contains n unknowns c_k, $k = [1, ..., n]$. For its numerical solution, it is necessary to take two additional relations. In many applications, they are set by the conditions for the second derivatives at the ends of the interval $[a, b]$ in the form of $S''(a) = 0, S''(b) = 0$ [9].

The *purpose* of the work is to develop an algorithm for constructing cubic splines with different boundary conditions.

3. Work outcomes

3.1. General solution of the problem

Let us write down the equations (7) in the form

$$A_k c_{k-1} - B_k c_k + C_k c_{k+1} = D_k, k = [2, \ldots, n-1], \tag{8}$$

or in matrix form

$$\begin{array}{cccccccc}
A_2 & -B_2 & C_2 & D_2 & & & & \\
 & A_3 & -B_3 & C_3 & D_3 & & & \\
 & & . & . & . & . & & \\
 & & & A_k & -B_k & C_k & D_k & \\
 & & & & . & . & . & . \\
 & & & & & A_{n-1} & -B_{n-1} & C_{n-1} \quad D_{n-1}
\end{array}$$

where

$$A_k = 2\delta x_k, B_k = -(4\delta x_{k+1} + 3\delta x_k), C_k = 3\delta x_{k+1}, Dk = 6h_{k+1}, k = [2, \ldots, n-1]. \tag{9}$$

To solve system (8) of $n-2$ equations with respect to unknowns c_k, we “extend” it to n equations by including two relations,

$$c_0 = \alpha_0 c_1 + \beta_0, c_{n-1} = \alpha_{n-1}c_n + \beta_{n-1}. \tag{10}$$

Coefficients $\alpha_0, \beta_0, \alpha_n, \beta_n$will be later specified taking into account the selected boundary conditions.

Substitute the expression for c_0 from (10) into formula (9), which gives

$$A_1(\alpha_0 c_1 + \beta_0) - B_1 c_1 + C_1 c_2 = D_1, \tag{11}$$

where follows the dependence of the first radical c_1 on the second radical c_2

$$c_1 = \alpha_1 c_2 + \beta_1, \tag{12}$$

where $\alpha_1 = C_1/(B_1 - A_1\alpha_0), \beta_1 = (A_1\beta_0 - D_1)/(B_1 - A_1\alpha_0)$.

Similarly, substituting c_1 from (12) into formula (11), we obtain an expression from which we can identify $c_2 = \alpha_2 c_3 + \beta_2$. Next, using the induction method, we find the k radical

$$c_k = \alpha_k c_{k+1} + \beta_k, k = [1, ..., n-1], \tag{13}$$

with known coefficients

$$\alpha_k = C_k/(B_k - A_k\alpha_{k-1}), \beta_k = (A_k\alpha_{k-1} - D_k)/(B_k - A_k\alpha_{k-1}), k = [1, ..., n-1]. \quad (14)$$

After substituting the coefficients of equation (9) A_k, B_k, C_k, D_k into expressions (14), we find

$$\alpha_k = -3\delta x_{k+1}/(4\delta x_{k+1} + 3\delta x_{k+2}\delta x_k\alpha_{k-1})k = [1, ..n-1], \quad (15)$$

$$\beta_k = (-2\delta x_k\beta_{k-1} + 6h_{k+1})/(4\delta x_{k+1} + 3\delta x_k + \alpha_{k-1}2\delta x_k), k = [1, ..., n-1]. \quad (16)$$

To identify the first coefficients α_1, β_1 and the last radical c_n, additional information is needed on the behavior of the spline on its boundaries.

3.2. Algorithms for constructing splines with different boundary conditions

Let's consider the following cases which can be encountered while analyzing the applied problems:

1. The second derivatives of the spline at the ends of the interval $[a, b]$ are determined by the conditions
$$S''(a) = s_1, S''(b) = s_2. \quad (17)$$
2. At one end of the interval $[a, b]$, the first derivative of the spline $S'(a) = s_3$, is specified, at the opposite end – the second derivative $S''(b) = s_2$.
3. On the boundaries of the interval $[a, b]$, the first derivatives are set: $S'(a) = s_3, S'(b) = s_2$.
4. It provides a link between the values of the spline and its first derivative at the boundaries of the area: $f_1(a) = f_n(b), f'_1(a) = f'_n(b)$.

Case 1. Construction of a spline under condition (17).

The second derivative at the nodal point $x_n = b$ is equal to $2c_n$; therefore, condition (17) implies the equality $c_n = s_2$. From the second condition at the nodal point $x_1 = a$ it follows that $c_1 - 3d_1\delta x_1 = s_1$, which makes it possible to expand the possibility of using formula (4) to the interval $k = [1, ..., n]$ by introducing an additional constant $c_0 = s_1$. The first coefficient α_1 is obtained from formula (14) by setting the value of α_0 in (10) equal to zero

$$\alpha_1 = -3\delta x_2/(4\delta x_2 + 3\delta x_1). \quad (18)$$

Taking the value β_0 in (10) equal to zero, we identify the coefficient β_1 from the formula (16)

$$\beta_1 = 6h_2/(4\delta x_2 + 3\delta x_1). \quad (19)$$

The numerical algorithm for constructing a spline is as follows:

Step 1. Calculation of the coefficients of the tridiagonal matrix $A_k, B_k, C_k, D_k, k = [1, \ldots, n-1]$, by formulas (9).

Step 2. Identification of the sweep coefficients α_k, β_k using recursion relations (15), (16). The first values α_1, β_1 are calculated for $\alpha_1 = 0, \beta_0 = 0$.

Step 3. Calculation of coefficients c_k in polynomials (1) using recursion formula (13).

Step 4. Finding the coefficients dk, bk by formulas (4), (5).

Step 5. Identification of the value of the spline at a given point belonging to the interval $[a, b]$ using formula (1).

Table 1. Results of testing the interpolation of the function $10x\sin(x)e^{-x}$ $(n = 100)$.

	x	$f(x)$	$Spline(x)$
0	0.980000	3.054610	3.054570
1	0.981000	3.056718	3.056657
2	0.982000	3.058820	3.058746
3	0.983000	3.060915	3.060838
4	0.984000	3.063005	3.062930
5	0.985000	3.065088	3.065021

The solution of this problem in a particular case with zero conditions for the second derivatives $s_1 = s_2 = 0$ is described in many publications [9]. These splines are called "natural". The proposed algorithm was tested on the example of interpolating the function $10x\sin xe^{-x}$ for the interval $[0, 1]$. The relative calculation error for the number of nodes $n = 10$ was about 10^{-2}. Table 1 shows comparative data in the case of testing at $n = 100$.

According to the table 1, the relative interpolation error is about $3 \cdot 10^{-5}$. An increase in the number of nodes to 10^3 provides a calculation accuracy of up to $3 \cdot 10^{-8}$.

Case 2. Construction of a spline under conditions

$$S'(a) = s_3, S''(b) = s_2. \tag{20}$$

As the spline value $S(a)$ is equal to y_0, so according to (1) we have

$$g_1 - b_1 + c_1\delta x_1 - d_1\delta_{x_1^2} = 0. \tag{21}$$

The value of the first derivate with $x = a$ is equal to

$$f'(a) = b_1 - 2c_1\delta x_1 + 3d_1\delta x_1^2 = s_3. \tag{22}$$

From (21) and (22) we can identify the coefficient

$$b_1 = (-s_3 + 3g_1 + c_1\delta x_1)/2. \tag{23}$$

The algorithm for constructing a spline under conditions (20) will change and become as follows:

Step 1. Calculation of the coefficients of the tridiagonal matrix $A_k, B_k, C_k, D_k, k = [1, \ldots, n-1]$ and identification of the sweep coefficients α_k, β_k by formulas (9), (15) and (16). The first values α_1, β_1 are calculated for $\alpha_1 = 0, \beta_0 = 0$.

Step 2. Calculation of coefficients c_k in polynomials (1) using the recursion formula (13), while the value c_n is taken equal to s_2.

Step 3. Identification of the coefficient b_1 using the formula (23). The rest of the coefficients for b_k are calculated by formula (5).

Step 4. Finding the coefficients d_k by formula (4)

Step 5. Identification of the value of the spline at a given point belonging to the interval $[a, b]$ using formula (1).

Case 3. Construction of a spline under conditions

$$S'(a) = s_3, S'(b) = s_4. \tag{24}$$

The uniqueness of the solution of the problem provides the opportunity to calculate all parameters related to the spline with conditions (24). Let's calculate the coefficients of spline at terms

$$a_n = y_n, b_n = s_4, d_n = 0. \tag{25}$$

In this case

$$c_n = (s_4 - g_n)/\delta x_n. \tag{26}$$

The algorithm for constructing a spline with conditions (24) will be as follows:

Step 1. Calculation of the coefficients of the tridiagonal matrix $A_k, B_k, C_k, D_k.k = 1, \ldots, n-1$ under conditions $S'(a) = s_3, S''(b) = 0$ and identification of sweep coefficients α_k, β_k by formulas (9), (15) and (16). The first values α_1, β_1 are calculated for $\alpha_1 = 0, \beta_0 = 0$.

Step 2. Calculation of coefficients c_k in polynomials (1) using the recursion formula (13), while the value cn is taken equal to zero.

Step 3. Identification of the coefficient b_1 by the formula (23). The rest of the coefficients for b_k are calculated by formula (5).

Step 4. Calculation of c_n according to formula (26).

Step 5. Construction of a spline under conditions (20) for $s_2 = c_n$.

Step 6. Identification of the value of the spline at a given point belonging to the interval $[a, b]$ using formula (1).

The solution of a number of problems with other boundary conditions can be obtained using previously considered methods. Let's dwell on a few examples. Let the conditions be given that are mirror-like with respect to formulas (20), $S'(b) = s_3, S''(a) = s_2$.

In this case, it is sufficient to consider the problem in the interval $[b, a]$. In applications, there is a situation when the beginning of the spline is closed at its end using the conditions $S(a) = S(b) = y_0, S'(a) = S'(b) = s_3$.

A similar problem is solved using the algorithm related to the third case.

3.3. Discussion of results

The relative simplicity of cubic splines construction made them an effective tool for solving various problems. There are two main directions of using splines. The first one is associated with the interpolation of functional dependencies, especially in the applied mathematics and computing. In this group of tasks there exist high requirements for the accuracy of calculations. The second group includes tasks where the most important things are necessary smoothness of lines, identification of the direction of the process development, presentation of the results of processing the experimental data in the form of approximate dependencies (approximation problems), etc.

The "natural spline" with boundary conditions (17) at $s_1 = 0, s_2 = 0$ is well suited for interpolating functions. In the case of continuous functions with continuous derivatives of the first and second order, it provides high accuracy. It is known that the relative error of interpolation of functions with the same step δx is about $\Delta_{Theory} = 5/(2\delta x^3 f'''_{max})$, where f'''_{max} is the maximum value of the third derivative in the interpolation interval $[a, b]$. Table 2 shows the data on the theoretical accuracy of the Δ_{Theory} method and the accuracy of $\triangle\ \Delta_{Test}$, obtained during testing on the example of interpolating the function $f(x) = 10x \sin(x)e^{-x}$ depending on

Table 2. Dependence of the theoretical accuracy Δ_{Theory} and the accuracy of interpolation obtained in test experiments with the function $10x\sin(x)e^{-x}$) in the interval $[0,1]$.

N, number of steps	10	100	1000
Δx	10^{-1}	10^{-2}	10^{-3}
Δ_{Theory}	$5\cdot 10^{-2}$	$5\cdot 10^{-5}$	$5\cdot 10^{-8}$
Δ_{Test}	$3\cdot 10^{-3}$	$3\cdot 10^{-5}$	$3\cdot 10^{-8}$

the step δx in the interval $[0,1]$. The maximum f'''_{max} for this function is approximately equal to 56.

High accuracy of interpolation, confirmed by the data shown in table 1 and table 2, is not a compulsory condition for using splines in many application tasks. In some of them, it is more important to ensure the required curvature of the line [22] or the fulfillment of special conditions at the borders. The results, obtained in this work, do not exhaust all cases of the possibility of constructing splines with different boundary conditions. It can be seen from formulas (25), (26) that the fulfillment of condition (24) presupposes the replacement of the third degree polynomial by a parabola at the last step. A solution of such a problem can be obtained in another way, for example, by replacing it with a fourth-degree polynomial of the following type

$$f_n(x) = a_n + b_n(x-x_n) + c_n(x-x_n)^2 + d_n(x-x_n)^3 + e_n(x-x_n)^4, x_{n-1} <= x <= x_n. \quad (27)$$

Let's emphasize one important circumstance. The fulfillment of the boundary conditions (20) or (24), when using the proposed algorithms, is reflected only in the first and last intervals adjacent to the boundaries of the interval $[a,b]$. Table 3 shows the results of calculations of $Spline2(x)$ with modified boundary conditions and the "natural spline" $Spline1(x)$ on the example of the function $10\sin x$ for the interval $[0,\pi]$.

Table 3. Results of calculations based on $Spline2(x)$ with modified boundary conditions and the "natural spline" $Spline1(x)$ for the function $10\sin x$ in the interval $[0,\pi]$.

i, number of the node	Number of the point between the nodes	x	$10\sin x$	$Spline1(x)$	$Spline2(x)$
	3(99)	3.09761	0.43968	0.43965	0.43965
	4(99)	3.10389	0.37690	0.37688	0.37688
99	5(99)	3.11018	0.31411	0.31419	0.31419
	1(100)	3.11646	0.25130	0.25134	$0.24\underline{730}$
	2(100)	3.12274	0.18848	0.18849	$0.1\underline{6438}$
	3(100)	3.12903	0.12566	0.12566	$0.0\underline{7139}$
	4(100)	3.13531	0.06283	0.06283	$-0.\underline{00150}$
100	5(100)	3.14159	−0.00000	−0.00000	−0.00000

The information presented in Table 3, reflects the results of calculations for $n = 100$ at nodal points numbered 99, 100 and at several points between nodes with indices 3(99), 4(99), ..., 4(100), 5(100). In the case of the "natural spline" $Spline1(x)$, there were no restrictions on the function at the boundaries of the interval $[0,\pi]$, while the first derivates at the nodes $x_0 = 0$ and

$x_{100} = 0$ turned out to be equal to 10 and -10 respectively. It can be seen from table 3 that the interpolation results differ from the exact value of the $\sin(x)$ function in the fifth decimal place.

$Spline2(x)$ meets boundary conditions (24) for $s_3 = 10, s_4 = 10$. In this case, all the formulas used to construct the spline $Spline1(x)$, except for the last polynomial, which was represented by formula (27), have been preserved. Table 3 shows that the calculation results were reflected only for those values of x with indices 1(100), 2(100), ..., 5(100), which were located in the half-interval $[x_{99}, x_{100}]$ after the prelist node with number 99. All values of the spline $Spline2(x)$ to the left of the x coordinate remained unchanged. Similar results were obtained for a spline with modified boundary conditions at zero node x_0. Replacing the boundary condition $s_3 = 10$, corresponding to the "natural spline", by any other value led to a change in the calculated data only in the half-interval $[x_0, x_1]$.

The data obtained can be used while training specialists in the field of applied mathematics and computing. At the first stage, it is recommended for students to study the dependence of the accuracy of extrapolation of a known function on the number of nodal points for a fixed interval of its variation within the interpolation interval $[a, b]$. At the second stage, it is desirable to investigate the dependence of the accuracy on the form of the function, in particular, when using oscillating functions. At the third stage, it is useful to offer students to construct approximating type splines, which are often used to process the results of experimental studies.

4. Conclusions

The algorithms for constructing cubic splines with various boundary conditions have been developed:

1. The second derivative takes arbitrary values at the ends of the spline. A special case is the "natural spline", when the second derivative at spline ends is equal to zero.
2. At one end of the spline, the first derivative is given, and at the opposite end there is the second derivative.
3. The first derivative is given at two ends of the spline without any restrictions on the second derivatives.

It is shown that a number of problems with other boundary conditions can be solved using the proposed methods. The considered algorithms are recommended to use while interpolating functional dependencies and processing the results of experimental studies, represented as a discrete set of pairs of numbers.

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Identification of “Primorsk-1” wind power plant impact on the ecological situation connected with the behavior of ornithofauna on the Azov Sea coast

Identification of "Primorsk-1" wind power plant impact on the ecological situation connected with the behavior of ornithofauna on the Azov Sea coast

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Abstract. The results of ornithocomplexes monitoring in the territory of the wind power plant (WPP) "Primorsk-1" in 2017 and 2018 are presented. The research was conducted by two methods: observations made according to the recommendations of the Scottish Natural Heritage Fund (SNH) and route accounting method (RAM). The distribution of birds by seasons, direction of migration and flight altitudes has been identified. The number of birds, registered in 2017 by the SNH method, was 5923 specimens of 45 species: 3795 specimens of 33 species were flying in transit, 2,113 specimens of 40 species belonged to the forage group, 15 birds of four species belonged to the demonstration type. Most of the birds (64.2%) were flying in transit. The greatest activity of birds was observed in spring (36.3%) and autumn (35.0%) seasons of migration, when the share of the transit group accounted for 75.5% of all annual transit flights. At an altitude of up to 10 m 5086 (86.2%) birds were registered, in the range of altitudes (11÷25) m – 697 (11.8%), in the range of altitudes (26÷50) m – 53 (0.7%). No birds were found at an altitude above 180 m. In the risk zone of interaction with turbines, there were 72 birds of four species: Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo. The total number of birds, registered by the RAM method in 2018, was 8927 specimens of 72 species: 802 specimens of 11 species were flying in transit, 2511 specimens of 32 species belonged to the forage group, 5614 specimens of 60 species belonged to the terrestrial group. The greatest activity of birds was registered in autumn (70.0%) and spring (15.2%) seasons of migration, and the share of the transit group in these seasons accounted for 93.4% of all annual transit flights. The predominant directions of migration were western, north-eastern and south-western. At an altitude of up to 10 m – 2369 (71.5%) birds were registered, in the range of altitudes (11÷25) m – 371 (11.2%), in the range of altitudes (26÷50) m – 367 (11.2%). At an altitude above 51 m – 202 birds (6.1%) were registered. Comparison of the results, obtained by different monitoring methods, was carried out by bringing the number of birds to 1 hour of observation in an area of 1 km^2. The total bird density in the case of the RAM method was 3.3 times higher. The density of transit type birds according to different methods was within the admissible statistical dispersion of 10.2÷12.7 specimens/hour·km^2. However, the density of forage type birds, registered by the RAM method, was 7.1 times higher than the density, identified by the SNH method. The average number of all the birds flying over the wind park territory at each moment of time according to various counting methods was within the statistical scatter (1.15÷1.28) specimen/(hour·km^2). The size of the transit group in the case of the SNH method use was 3 times larger than that calculated by the RAM method, while the size of the forage group, on the contrary, was 2.5 times less. The anticipated number of collisions during one year of the wind power plant functioning, calculated by the SNH and RAM methods, was in the range of 5.6÷6.7 (about 0.6 specimens per turbine for one year of its functioning, or 0.2 specimen/1 MW/year). The number of collisions was about 6.9^{-4}% of the total number of transit and forage type birds in the wind park territory, 3.3-3% of the number of the considered species specimens present at all altitudes, and 0.25% of all birds in a risk zone. The data obtained indicate an insignificant impact of the “Primorsk-1” wind power plant on the ornithofauna of the Azov sea coast.

1. Introduction

Research of the wind power plants (WPPs) impact on the environmental situation is becoming especially urgent. The issue of bird interaction with turbines is particularly relevant one [1–4] and it is also important to take measures to minimize the consequences of their collisions with turbines [5–7].

The energy strategy of Ukraine envisages producing at least 30% of renewable energy sources from all generated electricity by 2030 [8–10]. A significant part of wind power plants (WPPs) will be located on the Azov Sea coast. The natural territories of the Azov and Black Sea coasts of Ukraine are the reserves of unique biodiversity. They contain steppe plant communities and support numerous populations of birds migrating across Eurasia. This fact imposes significant responsibilities on the specialists responsible for anticipating environmental changes. Therefore, the formation of a system for monitoring, assessing and anticipating the state of bird communities in this region is extremely important.

The algorithm of a systematic approach to predictive assessment of the wind energy impact on birds is described in a number of scientific works [11]. It allows the researchers to choose the most optimal observation methods. The bird complexes monitoring in the territory of wind parks and adjacent zones is usually carried out in two ways. One of them, proposed by the Scottish Natural Heritage Foundation [12], is based on the study of individual sites belonging to the wind park. The Foundation Method (SNH) has gained widespread acceptance in the scientific community and has practically become a reference method. Another method uses the results of observations made by the route accounting method (RAM), adapted to the monitoring conditions of the wind power plant [11]. Each of these methods of obtaining necessary information has its own advantages and disadvantages. The SNH method provides data on the birds’ activity parameter $k_j = n_j t_j$ in the risk zone (RZ) of their interaction with the rotors, where $k_j = n_j t_j$ is the number of birds of the $_j$-species registered in RZ, t_j is the time of their stay in this zone. The value $k_j = n_j t_j$ is used in mathematical models to estimate the number of bird collisions with turbines [13]. The disadvantage of this method is a need to extrapolate the data obtained from the observation sites (the area which, as a rule, does not exceed 20% of the total area of the wind power park) to the territory of the entire park. The RAM method covers the study of the area occupied by 70÷80% of the wind power plant territory. In addition, the implementation of route accounting method is more convenient from the point of view of organizing observations and is more profitable in terms of economy and time. One of the RAM method disadvantages is its inaccuracy in identifying the birds’ activity parameter k_j.

There appears a question – which of the considered methods of studying the wind turbines impact on the ecological situation connected with the behavior of ornithofauna in the territory of wind parks and adjacent areas is better. So, this question remains unanswered. In this work, both methods are used to study the interaction of birds with turbines, which allows obtaining more reliable information. The work was performed on the basis of observations of the “Primorsk-1” wind park territory. This WPP is a typical representative of a series of wind turbines that are functioning on the Azov Sea coast or are being designed to bring new capacities into operation in the coming years.

2. Research aim and objectives

The aim of the research work was to analyze the results of ornithofauna monitoring in the wind power plant territory, obtained in two ways – by the route accounting method (RAM) and using the recommendations of the Scottish Natural Heritage Fund (SNH). To achieve the aim, it was necessary to organize seasonal observations of bird complexes in the "Primorsk-1" wind park territory and accomplish the following objectives:

- to identify the distribution of birds in different seasons, as well as according to different directions of migration and altitude flight characteristics,
- to choose a method for anticipating the possibility of bird interactions with turbines and, based on the results of monitoring the "Primorsk-1" wind park territory by the RAM and SNH methods, estimate the number of their collisions with turbines,
- to carry out a comparative analysis of data on the behavior of birds in the wind park territory, obtained by means of various observation methods.

In accordance with accumulated experience of studying ornithocomplexes on the Azov Sea coast, migration processes monitoring should be carried out in different seasons at least 4 times a year for up to three or four days of observations at counting sites or route sections. An important moment is the measurement and processing of data using modern equipment and appropriate software, which largely determines the reliability of the results.

Ornithological monitoring should cover the main periods of the bird life cycle, namely: spring migration period, nesting period, autumn migration period, wintering. The results of long-term studies [11] indicate that the nesting period falls on the first and third decades of March, as well as the first ten days of April. The first nesting counting usually takes place at the end of April, from 25.04 to 28.04, and the second – at the end of May, from 25.05 to 28.05. The exact observation terms may vary slightly. The correct terms of observations allow researchers to take into account early and late nesting bird species. Autumn monitoring should cover the second decade of September, the first and second decades of October and the first decade of November. It is advisable to carry out additional counting in November. The terms of registration the winter season should be divided into two stages: during the prevailing wintering periods (usually the second decade of January) and during the end of wintering periods (usually the second decade of February).

2.1. Bird monitoring methods in the "Primorsk-1" wind power plant territory

2.1.1. General foundations of the observation organization. The research was carried out in accordance with the requirements of national legislation. The coordinates of the registered birds, observation sites and wind park territory were linked to a Google map, which made it possible to identify the direction of flight and a number of parameters necessary to describe the behavior of birds in the wind park territory. The mapping of flora and fauna was carried out using previously developed AutoCAD program, which facilitated the discussion of the results obtained, taking into account the design layout of the integrated planning infrastructure of the wind park site [11].

During the observations, the following equipment was used: NIVA 2121 car, Etherna, Bushnell binoculars, optical tubes OPTOLYTH 20-60x80, VIXEN 20-60x100-1, VIXEN Geoma 20-60x80, NICON Forestry 550 laser device for altitude identification, GARMIN GPS MAP 78s device for identifying coordinates. Identification of species, sex, age of birds, as well as characteristics of winter and transitional outfits was carried out using the identifier of birds of Europe (Collins Bird guide/Second edition, 2009). The mapping of the places of birds' accumulation, as well as the spatial characteristics of movements along the route, was carried out using the GARMIN GPS MAP 78s navigator. The linear dimensions between the objects and the flight altitude of the birds were measured using a NICON Forestry 550 laser altimeter. Meteorological data were recorded using a compact LeCrosse 1700 weather station.

Observation sites were selected in accordance with the recommendations of the SNH Foundation [12]. In particular, the following requirements were taken into account:

- monitoring sites corresponded to natural areas of the wind park and buffer zones,
- a number of monitoring sites did not exceed the possibility of their examination within 1-2 days,
- observer's field of view at the observation point (OP) did not exceed 180° for each section.

Using the route accounting method of observation (RAM), observer was moving on foot or by car. The mapping, available for bird registration, was about 0.5±0.1 km along the route, as well as to the left and right of its direction. The observation area was approximately 1 km^2. The size of the area, covered by the route accounting method, was about 75% of the entire wind power plant territory.

2.1.2. Conducting observations at stationary sites by the SNH method. Monitoring of seasonal ornithological situation at three observation points (OP) belonging to the "Primorsk-1" WPP territory was carried out during 2017. The sizes of the OP1, OP2 and PO3 sites were 0.50 km^2, 0.86 km^2 and 1.23 km^2 respectively with a total area of 2.59 km^2. It is represented in figure 1. In terms of their landscape and biotopic parameters, the OPs were close to those of the entire WPP territory with an area of 10.1 km^2. The OPs were chosen in such a way that not a single point belonging to the wind park was at a distance of more than 2 km from the OP borders. Experience shows that in this case the impact of the observer on the behavior of birds will be a minimal one. Physical characteristics of OP within the study area are presented in table 1 and figures 1-4.

Figure 1. Layout of observation points within the project area of the WPP site.

Table 1. Physical characteristics of observation points (OP) and coordinates of observation points, S – area in km^2.

OP	Coordinates N	Coordinates E	A, km	B, km	C, km	D, km	S, km^2
1	46.733790	36.424918	0.69	0.71	0.74	0.69	0.50
2	46.759229	36.469566	0.65	1.4	0.7	1.19	0.86
3	46.758907	36.509302	0.92	1.3	0.9	1.4	1.23
Total							2.59

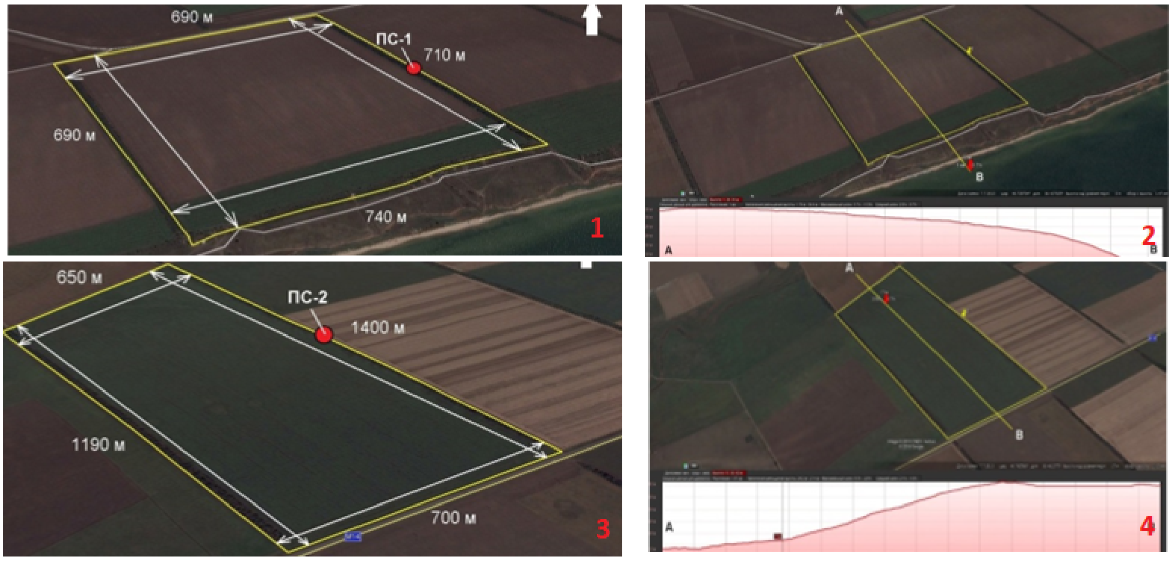

Figure 2. Characteristics of observation point OP1 (1 – Physical-geographical situational plan, 2 – Geomorphological profile in the line A-C, 3 – Physical-geographical situational plan, 4 – Geomorphological profile in the line A-C).

Figure 3. Characteristics of observation point OP2 and the layout of its central part.

The accounting scheme was as follows. The expedition car transported three observers, one to each point, to carry out morning measurements during the period of three hours. The duration of evening observations was also three hours at each site. The observations were made in a clear weather with a visibility on the ground of at least 2 km. In rare cases, if the rains were not too frequent and prolonged, observations were allowed on rainy days. The bird's trajectory was tracked until it stopped flying or disappeared from the sight. The flight altitude was identified at the first moment of bird registration and then repeated with 15 seconds intervals. The altitude value was classified according to five zones: below 10 m, in the range of 11÷25 m, in the range of 26÷50 m, in the risk zone of interaction with turbines from 51 m to 174 m and more than 174 m. Sitting birds (terrestrial type of stay in the territory site) were registered only once at the beginning of observation. The observation results were entered into forms, samples are shown in tables 2-4.

Observations were carried out in the morning and in the evening for 3 hours each. The

Figure 4. Layout of south-eastern part of OP3.

Table 2. Summary table of observation results at OP in 2017, T1 and T2 – time of start and end of observations, ΔT – duration of observations in hours, coordinates: SW – south-east, SE – south-east, E – east.

Date	Observer	OP	T1	T2	ΔT	Weather
20.09	Serdiuk	1	08:00	11:00	3	Partly cloudy, south-western wind, good visibility
21.09	Petrik	2	09:00	12:00	3	Partly cloudy, south-western wind, good visibility
10.10.	Kosach	1	08:00	11:00	3	Dry, sunny, eastern wind

Table 3. Observation results: n – number of birds, t – time of stay at the site, nt - reproduction of the number of birds n by the time of their stay t at the observation site of OP (The flight of the birds of target species at observation sites in 2017).

Species	Date	OP	n	Type and direction of flight, age of a bird	t, sec	nt, sec
Sandpiper	12.03.13	1	1	Demonstrational flight	30	30
Sandpiper	14.04.13	2	30	Direction: north-western	15	450
Circus cyaneus	15.04.13	1	1	Adult specimen. Demonstrational flight	25	25

monitoring time was chosen in such a way as to cover all periods of bird life. In 2017, observations were carried out for 24 days: winter periods: 2017.01.21, 2017.01.22, 2017.02.12, 2017.02.13; spring migration periods: 2017.03.13, 2017.03.14, 2017.03.25, 2017.04.02, 2017.04.03, 2017.04.04, 2017.04.25; nesting periods: 2017.05.13, 2017.05.14, 2017.05.15, 2017.05.16, 2017.05.17, 2017.05.18; autumn migration season: 2017.09.12, 2017.09.13, 2017.09.14, 2017.10.16, 2017.10.17, 2017.10.18, 2017.11.10.

The dependence of the observation duration T and the length of life cycle phases T_{lcp} of birds on the registration season as applied to the annual cycle of the "Primorsk-1" wind park functioning is given in table 5. The T_{lc} value is calculated on the basis of conditionally light 12.5

Table 4. Displaying the migration pattern at the OP for each hour of observation in the AutoCAD program: n – number of birds, h – flight altitude, coordinates: NE – north-east, S – south, N – north.

Layer 1						
1	9:00	Anser albifrons	22	Transit	400	NE
2		Turdus merula	3	Transit	5	S
3		Sturnus vulgaris	18	Forage	10	N
4		Emberiza calandra	22	Transit	5	N
Layer 2						
5	....	.....	...	...	...	...
Total 12 species			258			

hours per day in spring and summer periods, 10 hours – in autumn and 8 hours – in winter.

Table 5. Duration of observations T by the SNH method in 2017 and the phase of the annual life cycle of birds T_{lcp}.

Cycle of observation	Duration of observation T (OP1), hours	Duration of observation T (OP2), hours	Duration of observation T (OP3), hours	$\sum T$	T_{lcp}, days	T_{lcp}, hours
Spring migration	36	36	36	72	85	1062,5
Nesting	42	42	42	126	90	1125
Autumn migration	42	42	42	126	100	1000
Winter period	24	24	24	72	90	720
Total	144	144	144	432	365	3907,5

2.1.3. Route accounting method (RAM). During the monitoring process, all bird species that were observed along the route were registered. The accounting was carried out in 2018 in the morning and evening hours, lasting approximately 3 hours. The observation days were chosen in such a way as to cover all periods of bird life: winter season: 2018.01.25, 2018.02.16, spring migration season: 2018.03.10, 2018.03.20, 2018.04.11, nesting period: 2018.05.05, 2018.05.23, autumn migration season: 2018.09.15, 2018.09.29, 2018.10.13. The duration of observations was 63 hours: 13 hours in winter, 22 hours in the spring migration season, 15 hours during the nesting period, 13 hours in the autumn migration season.

During the period of seasonal migrations, almost the same route was used with minor changes. The accounting width was differentiated depending on the following conditions:

- features of movement (on foot, by car),
- ability to view the biotope (open biotopes, wood line),
- features of species biology (secretive, living in open biotopes),
- size of specimens,
- lighting (clear, cloudy),
- season (nesting, migration, winter).

During the territory monitoring, the observation date, time of the day, bird coordinates, type of registration (on foot, by car), impact of weather on the quality of registration (interferes, does not interfere), route length in each biotope, and total number of each species were registered. The compulsory parameters of the data taken into account included the following characteristics of ornithocomplexes:

- number and species characteristics of birds,
- altitude and direction of flight,
- behavioral characteristics of birds during migration period in the wind power plant territory,
- trophic migrations and the degree of use of biotopes as forage sites,
- impact of anthropogenic and natural factors on the state of birds of seasonal ornithocomplexes.

Cartographic work was carried out using the AutoCAD program in accordance with the tables of records and registration of migrants. Each route had its own schematic map, where the layer-by-layer (hourly) results of registration and migration of transit and forage groups birds were registered separately. The results of the route observation were entered into the tables of registration (table 6) and migration movements (table 7). Based on these tables, two maps were created in the AutoCAD program.

Table 6. Sample route accounting of birds in the wind park territory on September 25, 2018: No. – a number of the bird locations on the schematic map, n – a number of birds counted.

No	Time	Seсies	Type of biotope	n
1	08.00	*Turdus merula*	Wood line	6
2		*Buteo buteo*	Field	2
3	09.00	*Accipiter nisus*	Field	3
...	...	...	...	...
Total		29 species		208

2.1.4. Methods for processing the results of bird observation in the territory of wind park. The primary processing of the results of bird monitoring at three observation points by the SNH method was carried out using the "BIRDS1" database [3]. This program is designed to obtain information on the dependence of the number of registered birds on the time and season of observation, direction of flight, type of migration, flight altitude at various sites. To ensure the analysis of information based on the results of monitoring the wind park territory by the RAM

Table 7. Results of registration of migratory movements of birds in the wind park territory on September 25, 2017, n – a number of birds, coordinates: NE – north-east, S – south, N – north.

No	Time	Species	n	Type of migration	Altitude, m	Coordinates
1	09.00	*Anser albifrons*	22	Transit	400	NE
2		*Turdus merula*	3	Transit	5	S
3		*Sturnus vulgaris*	18	Forage	10	N
...	...	...	...	...		
Total		12 species	258			

method, the information system "BIRDS2" was used, which provided storage and processing of the initial data. In response to a user's request, the program makes it possible to receive information on the following parameters: an identifier that binds the coordinates of a registered bird to a point on a Google map, time of the day, month of registration, duration of observation, altitude and flight speed, average number of birds in flight over the wind power plant territory at a given time and other data.

Comparison of quantitative parameters that characterize the behavior of birds in the territories with different areas S during an unequal time interval T is incorrect; therefore, in a number of cases, normalized data were used. Some of them (n_s) referred to an area of 1 km^2, others (n_{ST}) – to an area of 1 km^2 per 1 hour of observation:

$$n_S = \frac{N}{S}, n_{ST} = \frac{N}{ST}. \quad (1)$$

For example, the average number of birds, which corresponds to the results of registration at three observation points by the SNH method per 1 km^2, was calculated by the formula:

$$n_S = \frac{N_1 + N_2 + N_3}{S_{Sum}}, \quad (2)$$

where N_1, N_2, N_3 are the numbers of birds registered, respectively, at three observation points with an area of S_1, S_2, S_3, $S_{Sum} = (S_1 + S_2 + S_3)$ – total area of observation sites.

When using the RAM method, the average value was calculated by the formula

$$n_{S0} = \frac{N}{S_0}, \quad (3)$$

where N is a number of counted birds on this route, S_0, – available view area for bird registration, which is approximately equal to 1 km^2.

In the research work, the parameter N_0, was introduced, which identifies the number of flying birds over the territory of the wind park at each moment of time. The N_0 value can be obtained by photographing the wind park territory from a flying vehicle. Based on the results of photographing, m, images were obtained, where M_0, of flying birds were registered. In this case, the parameter N_0, is equal to

$$N_0 = \frac{M_0}{m}, \quad (4)$$

The information obtained during the wind park monitoring contains data on the time $t_{ij}^{(k)}$ of the stay of birds of k-species in the number $n_{ij}^{(k)}$ at each of three observation sites (i=1,2,3). In this case, the value of $N_0^{(k)}$ can be calculated by the formula

$$N_0^k = \frac{S\sum\left(\sum K_{ij}^{(k)}\right)}{S_{sum}T}, \tag{5}$$

where S – area of the wind park, S_{sum} – total area of observation sites, T – observation time, during which $n_{ij}^{(k)}$ birds were registered in the j-group, which have flown through the given area during time $t_{ij}^{(k)}$, $K_{ij}^{(k)}$ – parameter that determines the activity of birds of k-species at i-observation site in j-group, $n_{ij}^{(k)}$ – a number of specimens in j-group of birds that have flown through i-section during time t_{ij}. The activity coefficient of birds for one j-group in the number of n_{ij}, that have flown through the i-segment during time $t_{ij}^{(k)}$ is calculated by the formula $K_{ij}^{(k)} = n_{ij}^{(k)} \cdot t_{ij}^{(k)}$, and the sum of these coefficients at i-section – by the formula

$$K_i^{(k)} = \sum K_{ij}^{(k)} = \sum n_{ij}^{(k)} t_{ij}^{(k)}, \tag{6}$$

When using the RAM method, the observers have at their disposal only one section with the area S_0. In its center there is an observer. If the SNH method provides for the registration of the flight time and the number of registered birds over each observation point, but the results of the territory monitoring by the RAM method provide information only about the altitude and direction of flight. In this case to estimate the activity coefficient, we represent the shape of the observation site as a circle with radius r with area $S_0 = \pi r^2$, in the center of which the observer is located. The value of S_0 is about 1.0 km^2, which corresponds to the viewing radius $r = \sqrt{S_0/\pi} = 560$ m. It can be shown that the average statistical length of the flight path for birds flying over a similar area is approximately equal to $l \approx 880$ m. According to the RAM method coefficient of activity of several groups of birds, each of which consists of $n_j^{(k)}$ of j-specimens of k-species, which have flown by with a speed $v_j^{(k)}$ during the entire observation time, will be equal to

$$K_0^{(k)} = l\sum \frac{n_j^{(k)}}{v_j^{(k)}}. \tag{7}$$

Using formulas (6) and (7) makes it possible to transform formula (5) to a form that can be used to identify the average number of birds flying over the territory of the wind park at each moment of time based on the results of monitoring by the RAM method

$$N_0^{(k)} = lS\frac{\sum \frac{n_j^{(k)}}{v_j^{(k)}}}{TS_{RAM}} = \frac{SK_0^{(k)}}{TS_{RAM}}, \tag{8}$$

where S_{RAM} is the total area along the route where birds are registered during one day of observation. The calculation of the probability of a bird collision p_j with the blades of a wind wheel when it is in the danger zone of a wind park (DZ) was first proposed in [13,14]. DZ refers to the portion of the territory above the wind power plant occupied by rotating turbines. Let's consider the possibility of a bird collision with turbines in the territory of the "Primorsk-1" wind power plant. The amount of the danger zone DZ is

$$VDZ = M\pi R2dcos(\gamma), \tag{9}$$

where $M = 26$ – a number of turbines in the territory of WPP, $R = 68$ m – radius of the wind wheel, $d = 4.1$ m – width of the wind wheel blade, $\gamma = 300$ – blade wedge angle between its chord and the plane of rotation of the propeller.

The value of probability P_j is calculated by the formula [3]

$$P_j = [\pi R_0 + 6(R - R_0)L^{(k)}2/\pi + 3(R - R_0)d + 3(R - R_0)2\varphi t^{(k)}/2]/(\pi R_2), \tag{10}$$

where $L_2^{(k)}$ – wingspan of the bird, $\varphi = 14$ rpm – angular speed of turbine rotation, r_0 – radius of the rotor sleeve on which the blade is attached, $t^{(k)}$ – time of bird's flight of k-species through the rotor with a speed $v^{(k)}$.

The time of flight is calculated by the formula

$$t^{(k)} = \frac{d\sin(\gamma) + L_l^{(k)}}{v^{(k)}}, \tag{11}$$

where $L_l^{(k)}$ – length of a bird.

Following the research work [14], let's introduce the concept of a risk zone of possible collision of birds with turbines RZ. It refers to the part of the space in the altitude interval $\delta H = H_2 - H_1$ between the lower H_1 and upper H_2 levels of the turbine wind wheel above the observation sites of the area S. Distance from the ground to the lower part of the rotor $H_1 = 48$ m, to the upper part – $H_2 = 182$ m. The amount RZ is

$$VRZ = \delta HS, \tag{12}$$

The number of collisions of birds of k-species with turbine blades in i-section in one of m-seasons (m=1÷4) is calculated by the formula [3]

$$n_{im}^{(k)} = \frac{M\pi R^2 \cos(\gamma) v^{(k)} dT_{Lc} f P^{(k)}}{T_{im}\delta HS_i} K_{im}^{(k)}, \tag{13}$$

where f is the coefficient of evasion, which determines the bird's ability to change the direction of flight near the wind wheel and, thus, avoid collision with it. The most probable value of the coefficient f is in the range of 0.05÷0.005 [6, 15], T_{Lc} – duration of the life cycle of birds for one year of wind park functioning for one year, $K_{im}^{(k)}$ – activity coefficient of birds of k-species registered in the RZ at i-site with an area of $K_{im}^{(k)}$ during the monitoring period T in m-season, T_{im} – duration of observations at i-site with an area of S_i in m-season.

Formula (13) was derived to anticipate the interaction of birds with turbines based on the results of monitoring the observation sites by the SNH method. It can be shown that when using information on the behavior of birds in the territory of a wind park using the RAM method, it is necessary to use the same formula after replacing the activity coefficient $K_{im}^{(k)}$ in it by the parameter $K_0^{(k)}$ calculated by formula (7), and the value S by an area S_0, which is available for registration of birds by the route counting method.

3. Results of work

3.1. General analysis of the number of birds in the "Primorsk-1" wind park territory

Ornithocomplexes at the observation points OP1, OP2 and OP3 were monitored using SNH recommendations in 2017. The total number of registered birds was 5923 specimens of 45 species: 3795 specimens of 33 species have flown in transit, 2113 specimens of 40 species belonged to the forage type, 15 birds of four species – to the demonstration type. The number of demonstration group did not exceed 0.3% of the total number of registered birds, therefore, in the future, the analysis will be carried out only for the birds of the transit and forage groups in the amount of 5908 specimens.

In 2008 in the process of monitoring the territory by the RAM method, birds sitting on the ground, wires, trees and bushes were additionally registered and included in the group called "terrestrial". The total number of registered birds on the routes was 8927 specimens of 72 species: 802 specimens of 11 species have flown in transit, 2511 specimens of 32 species belonged to the forage type, 5614 specimens of 60 species – to the terrestrial type.

Quantitative characteristics of transit and forage type birds in different seasons are given in table 8.

Table 8. Distribution of birds by season, registered by the SNH method in 2017 (1) and by the RAM method in 2018 (2).

Type of migration	Winter season	Spring migration	Nesting season	Autumn migration	Total according to the type
Transit	547(1) 0(2)	1237(1) 128(2)	381(1) 53(2)	1630(1) 621(2)	3795(1) 802(2)
Forage	345(1) 277(2)	907(1) 375(2)	420(1) 162(2)	441(1) 1697(2)	2113(1) 2511(2)
Total	892(1) 277(2)	2144(1) 503(2)	801(1) 215(2)	2071(1) 2318(2)	5908(1) 3313(2)

According to monitoring data, in 2017 (64%) birds have flown in transit. The greatest bird activity was observed in spring (36%) and autumn (35%) seasons of migration, when the transit group accounted for 76% of all annual transit flights. The predominant directions of migration were east (27%) and southeast (19%). At an altitude of up to 10 m, 5086 (86%) birds were registered, in the range of altitudes (11÷25) m – 697 (12%), in the range of altitudes (26÷50) m – 53 (0.7%). No birds were observed at an altitude above 180 m. In the RZ zone there were 72 (1.3%) birds of four species:

(i) *Larus ridibundus* in the amount of 43 specimens of the transit group: 30 birds have flown during the spring migration, 13 – during the autumn migration. 1011 birds of this species were registered at all altitudes: 978 birds have flown in transit, 33 belonged to the forage group.

(ii) *Merops apiaster* in the amount of 15 specimens have flown in transit during the spring migration. At all altitudes, 45 birds of this species were registered: 39 birds belonged to the transit group, 6 – to the forage group.

(iii) *Circus aeruginosus* in the amount of 9 specimens (7 – of transit group, 2 – of forage group). Six birds were registered during the spring migration and three during the autumn migration. At all altitudes, 45 birds of this species were registered: 25 birds have flown in transit, 20 belonged to the forage group.

(iv) *Buteo buteo* in the amount of 5 specimens have flown in transit in autumn. 26 birds of this species were registered at all altitudes: 13 birds have flown in transit, 13 belonged to the forage group.

The results of monitoring by the RAM method in 2018 also showed that the greatest migration activity of birds is observed in autumn (70%) and spring (15%), and the share of the transit group in these seasons accounted for 93% of all annual transit flights. The predominant directions of flight were west and north-east. At an altitude of up to 10 m, 2369 (72%) birds were calculated, in the altitude interval (11÷25) m – 371 (11%), in the altitude interval (26÷50) m – 367 (11%). At an altitude of over 51 m, 202 birds (6%) were registered. The RZ contained 4 specimens of the species *Buteo buteo* (less than 1%): two birds of forage type were registered in the spring migration period at an altitude of 100 m, two birds have flown in autumn at an altitude of 150 m.

Observation by the RAM method more fully reveals the forage group, the number of which is 3.1 times higher than the number of transit birds. In addition, the RAM method makes it possible to register terrestrial birds, the number of which was 1.7 times higher than the total number of transit and forage birds. It is recommended to carry out the comparison of data on other parameters after bringing the monitoring results to one hour of registration per 1 km^2 of the observation site area using formulas (1)÷(4).

3.2. Distribution of birds by observation seasons, flight altitude and direction of migration
The number of birds and their species largely depend on the season. The total number of birds registered in the winter season: 2017.01.21, 2017.01.22, 2017.02.12, 2017.02.13 by the SNH method was 892 specimens of 14 species: 547 (61%) specimens of twelve species have flown in transit, 345 (39%) specimens of thirteen species belonged to the forage group. Using the RAM method in the period of 2018.01.25, 2018.02.16, 277 specimens of seven species were identified. All of them belonged only to the forage group. The distribution of birds by direction is presented in table 9.

Table 9. Distribution of migratory birds by directions in winter: N – north, NE – north-east, E – east, SE – south-east, S – south, SW – south-west, W – west, NW – north-west, (1) – SNH method, (2) – RAM method.

Direction	N	NE	E	SE	S	SW	W	NW
Transit	1%(1) 0%(2)	1%(1) 0%(2)	41%(1) 0%(2)	28%(1) 0%(2)	13%(1) 0%(2)	2%(1) 0%(2)	8%(1) 0%(2)	7%(1) 0%(2)
Forage	7%(1) 1%(2)	23%(1) 47%(2)	26%(1) 0%(2)	19%(1) 1%(2)	13%(1) 1%(2)	6,4(1) 52%(2)	4,2(1) 0%(2)	1,4(1) 0%(2)

SNH method. In winter period of 2017 the main directions of flight for the transit group were eastern (41%), southeastern (28%) and southern (13%), and for the forage group – eastern (26%), north-eastern (23%) and southeastern (19%). All birds were registered at an altitude up to 51 m: 89% of them at altitude up to 10 m, 10% in the range of altitudes (11÷25) m, 1% in the range of altitudes (26÷50) m.

RAM method. A completely different distribution was observed in 2018. The birds did not fly by in transit. Half of the birds from the prey group (52%) moved south-westward, and the other half (47%) moved north-eastward. All birds were registered at an altitude up to 51 m: 66% up to 10 m, 32% – in the range of altitudes (11÷25) m, 2% – in the range of altitudes (26 ÷ 50) m.

The spring migration period was characterized by a higher diversity of species. The total number of birds registered in the periods of 2017.03.13, 2017.03.14, 2017.03.25, 2017.04.02, 2017.04.03, 2017.04.04, 2017.04.25 by the SNH method was 2144 specimens of 20 species: 1237 (60%) specimens of 16 species have flown in transit, 907 (40%) specimens of 14 species belonged to the forage type. 51 (2.4%) bird was found in the RZ zone. In the range of altitudes (26÷0) m 17 birds (<2%) were observed, in the range of altitudes (11÷25) m – 250 (12%) birds, the remaining 1822 (85%) specimens were at an altitude of up to 10 m.

Observations by the RAM method, carried out in the periods of 2018.03.10, 2018.03.22, 2018.04.11 have identified 503 specimens of 26 species. In the forage group 375 birds (75%) were counted, in the transit group – 128 birds (25%). In RZ, at an altitude of 100 m, two forage-type *Buteo buteo* birds were observed. Most of the birds were registered at an altitude of up to 10 m. In the range of altitudes (26÷50) m one bird was observed, in the range of altitudes (11÷25) m – 40 (8%) birds.

Distribution of birds by direction during the spring migration is presented in table 10.

Table 10. Distribution of birds by direction in spring migration season: N – north, NE – north-east, E – east, SE – south-east, S – south, SW – south-west, W – west, NW – north-west, (1) – 2017, (2) – 2018.

Direction	N	NE	E	SE	S	SW	W	NW
Transit	13%(1) 0%(2)	12%(1) 75%(2)	20%(1) 0,8%(2)	14%(1) 21%(2)	7%(1) 3,2%(2)	7%(1) 0%(2)	8%(1) 0%(2)	19%(1) 0%(2)
Forage	22%(1) 32%(2)	6%(1) 45%(2)	24%(1) 8%(2)	6%(1) 15%(2)	11%(1) 1%(2)	7(1) 22%(2)	7(1) 5%(2)	17(1) 1%(2)

SNH method. During the spring migration in 2017, the predominant transit routes were eastern (20%) and northwestern (19%). In the northern, north-eastern and southeastern directions, 12% to 14% of the specimens have flown. The main directions of flight of forage type birds were eastern (24%), northern (22%) and south-western (17%).

RAM method. The main directions of birds in transit during spring migration were north-eastern (75%) and southeastern (21%). Most of them (98%) were registered at an altitude of up to 10 m, two birds (about 2%) have flown in the range of altitudes (11÷25) m. There were no birds at an altitude above 26 m.

By the nesting period, the activity of birds sharply decreased. The total number of birds registered in the periods of 2017.05.13, 2017.05.14, 2017.05.15, 2017.05.16, 2017.05.03, 2017.05.17, 2017.05.18 by the SNH method was 801 specimen of 37 species: 381 (48%) specimen of 20 species have flown in transit, 420 (52%) specimens of 30 species belonged to the forage type. In the range of altitudes (11÷25) m 55 (8%) birds were found, the remaining 746 (62%) specimens were at an altitude of up to 10 m. No birds were observed at an altitude above 26 m.

In the periods of 2018.05.05, 2018.05.23, 215 specimens of 11 species were identified by the RAM method (162 birds have flown in transit, 53 birds belonged to the forage group). At an altitude of up to 10 m there were 134 (62%) birds, 40 (8%) specimens were observed in an altitude interval (11÷25) m, 11 (32.5%) birds were registered in the altitude interval (26÷50) m. In RZ and above it the birds were not observed.

Distribution of birds by direction is presented in table 11.

SNH method. The main directions of transit flights during the nesting period in 2017 were: south-western (28%), north-eastern (26%) and northern (15%). At an altitude of up to 10 m, 85% of birds were registered, in the range of altitudes (11÷25) m – 15%. The main directions of flight of forage type birds were northern (26%), north-eastern (21%) and south-western (16%). At an altitude of up to 10 m, 97% of birds were observed, in the range of altitudes (11÷25) m – 3%. No birds were found at an altitude over 26 m.

RAM method. In 2018 the main direction of transit migration during the nesting period was north-eastern – 70%. About 15% have flown in the eastern and south-western directions each. At an altitude of up to 10 m, 7.5% were registered, in the interval (11÷25) m 75.5% of specimens were observed, in the interval (26÷50) – 17%. The main directions of flight of forage type birds

Table 11. Distribution of migratory birds by direction in the autumn season: N – north, NE – north-east, E – east, SE – southeast, S – south, SW – south-west, W – west, NW – north-west, (1) – 2017, (2) – 2018.

Direction	N	NE	E	SE	S	SW	W	NW
Transit	15%(1) 0%(2)	26%(1) 70%(2)	13%(1) 13%(2)	7%(1) 0%(2)	3%(1) 0%(2)	28%(1) 17%(2)	3%(1) 0%(2)	5%(1) 0%(2)
Forage	26%(1) 2%(2)	21%(1) 62%(2)	13%(1) 4%(2)	14%(1) 0%(2)	1%(1) 2%(2)	16(1) 27%(2)	5(1) 2%(2)	5(1) 1%(2)

were north-eastern (62%) and south-western (27%). In the range of altitudes (26÷50) m one bird was registered, in the range of altitudes (11÷25) m – 40 (8%) birds, the remaining 460 (91%) specimens were observed at an altitude of up to 10 m. There were no birds at an altitude above 50 m.

Monitoring during the autumn migration periods of 2017.09.12, 2017.09.13, 2017.09.14, 2017.10.16, 2017.10.17, 2017.10.18, 2017.11.10 by the SNH method has identified 2071 bird of sixteen species. Most of them (1630 specimens) have flown in transit, the rest (441 specimens) belonged to the forage group.

The use of the RAM method in the periods of 2018.09.15, 2018.09.25, 2018.10.13 made it possible to register 2318 birds of 26 species, of which 621 have flown in transit, and 1691 belonged to the forage group.

Distribution of birds in the autumn season by direction is given in table 12.

Table 12. Distribution of migratory birds by direction in the autumn season: N – north, NE – north-east, E – east, SE – southeast, S – south, SW – south-west, W – west, NW – north-west, (1) – 2017, (2) – 2018.

Direction	N	NE	E	SE	S	SW	W	NW
Transit	1%(1) 0%(2)	5%(1) 8%(2)	37%(1) 4%(2)	32%(1) 0%(2)	12%(1) 44%(2)	3%(1) 2%(2)	6%(1) 34%(2)	5%(1) 8%(2)
Forage	21%(1) 1%(2)	5%(1) 10%(2)	23%(1) 1%(2)	8%(1) 3%(2)	29%(1) 1%(2)	8(1) 7%(2)	6(1) 75%(2)	9(1) 2%(2)

SNH method. Most of the birds in the autumn season of 2017 have flown in transit in the eastern (37%) and southeastern (32%) directions. The main directions of flight of forage type birds were southern (29%), eastern (23%) and northern (21%). At an altitude of up to 10 m, 1723 (82%) birds were registered, in the range of altitudes (11÷25) m – 297 (15%), in the range of altitudes (26÷50) m – 30 (2%) specimens. 21 (1%) bird was observed in the risk zone of interaction with turbines.

RAM method. Birds of only one species, *Larus Cachinaris*, in the amount of (45%) specimens have flown in the southern direction. In the western direction (34%) specimens of two species *Merops apiaster* and *Motacilla alba* were observed. 10% of birds were registered at an altitude of up to 10 m. In the range of altitudes (11 ÷25) m there was 4% of birds, in the range of altitudes (26÷50) m – 54% of birds, 32% of birds have flown above 150 m.

The main direction of flight of forage type birds was western – 75%. The north-eastern and south-western directions accounted for 10% and 7%, respectively. At an altitude of up to 10 m, 90% of specimens were registered, 9% of birds were observed in the range of altitudes (10÷25) m. In the range of altitudes (25÷50) m – 1% of birds was observed. Two forage type *Buteo buteo* birds were found in the risk zone at an altitude of 100 m.

3.3. Identification of the number of birds in the wind park territory and the number of their collisions with turbines

The calculation of the number of bird collisions with turbines was carried by the formula (13) using the results of monitoring of the wind park territory by the RAM method in 2018. In the risk zone of interaction with turbines (RZ), 4 specimens belonging to the species *Buteo buteo* were observed. Two birds, demonstrating feeding behavior, were registered at an altitude of 100 m in the spring migration period, two birds have flown in transit in autumn at an altitude of 150 m. The length of the bird's flight path at the observation site was 880 m, the flight speed was 11.6 m/s [16], period of each bird's stay was 75.9 s.

In the calculations, the following values of WPP parameters and flight characteristics of birds were used: maximum blade width $d = 4.1$ m, maximum angular rotation speed of the wind wheel $\varphi = 14$ rpm, radius of the wind wheel $R = 67$ m, radius of the wind wheel hub $R_0 = 3$ m, angle between the chord of the section of the blade and the plane of the wind wheel $\gamma = 300$, length of the bird m, wingspan of its wings $L_{2j} = 1.2$ m. The probability of collision, calculated by the formula (10) for a bird flying perpendicular to the plane in which the wind wheel is located, is equal to 0.19.

To anticipate the interaction of birds with turbines, there are two calculation schemes.

First case. In the RZ zone birds were observed only in the spring and autumn seasons. The value of the phase of the life cycle T_{Lc} in different seasons in relation to one year of the wind park "Primorsk-1" functioning is presented in table 13. When calculating T_{Lc}, the duration of a conditionally light day per day ΔT was taken equal to 12.5 hours for the spring migration and autumn migration seasons, 10 hours in the autumn period and 8 hours in the winter period.

Table 13. Duration of observations T by the RAM method, the number of conditionally light days ΔT in the season and phases of the life cycle of birds T_{Lc}.

Cycle of observation	T, hour	ΔT, hour	T_{Lc}, days	T_{Lc}, hour
Spring migration	13	12,5	85	1062,5
Nesting	22	12,5	90	1125
Autumn migration	15	10	100	1000
Winter period	13	8	90	720
Total	63	43	365	3907,5

The number of collisions during one year of the WPP functioning, calculated by the formula (13) for the collision probability $P_j = 0.19$, taking into account the data in table 14 is equal to 3.7 for the spring and 3.0 for the autumn migration season. The total number of collisions was 6.7 specimens per year.

Second case. The total number of *Buteo buteo* birds that were observed in the territory of the wind park at all altitudes was 16. One bird was registered outside the RZ in winter, seven – during the spring migration period (2 in the RZ and 5 outside it), three – during the nesting season and five – in autumn (2 in RZ and 3 outside it). It can be assumed that, theoretically, birds could appear in the risk zone not only in spring or autumn, but also in winter and during nesting periods. Therefore, the registered number of birds can be equally attributed to any season. In this case, the same formula (13) is valid, but due to different duration of the life cycle of birds P_j and duration of monitoring time T, the results will not be the same. The calculated number of collisions during one year of WPP functioning turned out to be 5.6 specimens, which practically coincides with the calculated value in the first case.

Combining the latest data with the previously obtained results and taking into account seasonal differences, it can be assumed that the valid anticipation of a number of collisions is the range of values 5.6÷6.7. It is interesting to compare the obtained data on the interaction of birds with turbines with the research done on the basis of monitoring the "Primorsk-1" wind park territory in 2017 [3]. In this research work, 72 birds of four species were registered at stationary observation sites of a larger size (2.59 km^2) in the RZ: *Larus ridibundus* (43 specimens), *Merops apiaster* (15 specimens), *Buteo buteo* and *Circus aeruginosus*, respectively, 5 and 9 specimens. In this research work, birds of the species Circus aeruginosus were not found in the WPP territory. Two species *Larus ridibundus* (29 specimens) and *Merops apiaster* (246 specimens) represented a fairly large group, but were observed outside zone of interaction with wind wheels. Some of them belonged to the forage group and were at an altitude of 50 m, while the others were flying above the turbines. The anticipated number of collisions during one year of WPP functioning, according to the cited work, was about 6.5 birds.

The results of the analysis of the observation sites monitoring using the recommendations of the Scottish Natural Heritage Fund in 2017 and the route accounting method in 2018 are shown in table 15. The first value with index (1) in each cell of the table characterizes information about birds of the transit and forage groups obtained by the SNH method in 2017 at all observation sites, the second value with index (2) corresponds to the results of route accounting method in 2018. The parameters of the first line of the table refer to birds of all species registered at the WPP in all seasons:

N – total number of birds of all species registered at the observation sites,

n_0 – number of birds registered during one hour in an area of 1 km^2,

K – coefficient of bird activity in the observation area,

K_0 – coefficient of bird activity in the area calculated by formulas (6), (7), and reduced to one hour of observation per 1 km^2,

N_0 – number of birds in the wind park territory in a state of flight at each moment of time, calculated by formulas (5) and (8). The speed of birds of various species was in the range (11÷19) m/s. When calculating the activity coefficient K, the speed value was taken equal to 15 m/s. The flight speed of each bird species registered in the RZ was taken from the literary sources,

N_1 – extrapolated value of the total number of transit and forage birds that have flown over the wind park territory during one year.

Similar information on transit and forage groups of birds is separately presented in the second and third lines. The fourth line contains data only for birds that were found in the RZ zone at an altitude from 51 m to 174 m: 72 birds of the four species Larus ridibundus, Merops apiaster, Buteo buteo and Circus aeruginosus in 2017 and 4 birds of the same species Buteo buteo in 2018. The listed species constitute a risk group that was observed at all altitudes.

The last line of the table 14 contains information on the risk group of birds. Four species from this group (*Larus ridibundus*, *Merops apiaster*, *Buteo buteo*, and *Circus aeruginosus*) were registered at all altitudes in 2017, and three species (*Larus ridibundus*, *Merops apiaster*, *Buteo buteo*) – in 2018.

Comparative analysis of observations carried out by two different methods using the information given in the first column of Table 14 would not be correct for two reasons. Firstly, according to SNH method the area of three points is 2.6 times larger than the area of the site that

Table 14. Results of the analysis of the ornithocomplexes observations in the "Primorsk-1" wind park territory by the SNH monitoring method in 2017 (1) and the RAM method in 2018 (2): N – number of birds counted, n_0 – number of birds registered for 1 hour per 1 km^2, K – coefficient of bird activity, K_0 – coefficient of bird activity per hour per 1 km^2, N_0 – number of birds in the WPP territory in a state of flight at each moment of time, N_1 – number of birds that have flown through the WPP during 1 year.

	N	n_0, (hour · km^2)$^{-1}$	K. s	K_0, s/hour·km^{-2}	N_0	N_1
All birds	5908(1) 3313(2)	15.8(1) 52.6(2)	170000(1) 190000(2)	460(1) 3100(2)	1.28(1) 1.15(2)	620000(1) 2080000(2)
Transit	3795(1) 802(2)	10.2(1) 12.7(2)	110000(1) 47000(2)	300(1) 750(2)	0.83(1) 0.28(2)	400000(1) 500000(2)
Forage	2113(1) 2511(2)	5.6(1) 39.9(2)	59000(1) 150000(2)	160(1) 2300(2)	0.44(1) 1.11(2)	220000(1) 1580000(2)
Birds in the risk zone RZ	72(1) 4(2)	0.19(1) 0.06(2)	2400(1) 240(2)	6.5(1) 4.8(2)	0.018(1) 0.0018(2)	7500(1) 2400(2)
Birds of risk group	1127(1) 291(2)	3.0(1) 4.6(2)	40000(1) 17000(2)	110(1) 270(2)	0.30(1) 0.13(2)	120000(1) 180000(2)

is available for observation and registration of birds by the RAM method. Secondly, the total observation time in 2017, which is 144 hours, was 2.3 times longer than the monitoring time in 2018. Consequently, the quantitative indicators of bird behavior characteristics in the case of the same informativeness of the considered methods should differ by about 6 times. This distinction is more or less characteristic for transit birds and birds belonging to the group of specimens of the four species *Larus ridibundus, Merops apiaster, Buteo buteo*, and *Circus aeruginosus*, which have flown into the zone of risk of interaction with turbines. As for the forage type, there is a strong discrepancy. Instead of the expected 6 times increase in the number of forage type birds registered by the SNH method compared to the RAM method, a 1.2 times decrease in this indicator was observed.

The data of the second column, where all parameters are reduced to 1 hour of observation in the territory of 1 km^2, allow us to make a more correct comparison of the same parameters. The number of birds from the transit group observed by different methods is within the admissible statistical dispersion of 10.2÷12.7. However, the bird density, which is equal to 39.9, registered by the RAM method, is 7.1 times higher than the value found by the SNH method. Such a difference cannot be caused by statistical scatter, and is more likely related to the specifics of monitoring. It can be assumed that the movement of the observer along the route leads to frightening of sitting birds and, thereby, to an increase in the number of forage groups.

A sharp increase in the forage component affects the rest of the indicators characterizing the behavior of birds in the WPP territory. This circumstance affects the activity coefficients, which identify the number of bird collisions with turbines and the number of birds N_0 in the WPP territory in a state of flight at each moment of time. The density of the activity coefficient K_0 of birds of various categories correlates well with the density of birds n_0.

The average number of all birds in the wind park territory in a state of flight at each moment of time, calculated by various methods, is within the statistical scatter (1.15÷1.28). However, the size of the transit group in the case of the SNH method is 3 times higher compared to the RAM method, while the size of the forage group, on the contrary, is 2.5 times less. The number of birds *Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo* in the risk zone of interaction with turbines and the total number of birds of the listed species at all altitudes, identified by the SNH method, are also several times higher than that done by the RAM method.

The last column of N_1 of table 14 contains extrapolation values of parameters characterizing the behavior of birds in the WPP territory as a whole. The total number of birds of transit and forage types, registered by different observation methods, is within (0.62÷2.08) 106. The transit group of specimens that have flown over the territory of the wind park was about (4.0÷5.0)1 05 birds. There were about (2.4÷7.5) 103 specimens of four species *Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo* in the risk zone of collisions with rotors. Representatives of these species are present at all altitudes in the amount of (1.2÷1.8) 105 birds.

In conclusion, let us compare the parameters of all birds from the risk group *Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo*, which were found in the area of possible collision with turbines. According to our research and research work [3], the anticipated number of collisions is in the range (5.6÷6.7), i.e., about 0.6 specimens per turbine during one year of its functioning or 0.2 specimen/1 MW/year. Thus, the number of collisions is:

6.9-4% of the total number of transit and forage type birds in the territory of wind park,

3.3-3% of the number of specimens of the considered species present at all altitudes,

0.25% of all birds of the specified species that are in a risk zone.

The data obtained in order of magnitude correlate with the literature sources known to us. For example, the mortality rate of forage type birds in the wind park territory in Andalusia (Spain) was 0.03 specimens per year per turbine [17]. At another station with 256 turbines, the figure was 0.4 [18]. In the research work by Polish scientists [19], they analyzed data on the registered deaths of birds at 109 functioning wind parks in Europe and North America. It turned out that the average number of dead birds is at the level of 0.1 specimen/1 MW/year.

The main error in the calculated data is associated with the choice of the coefficient f in the formula (13). This factor takes into account the ability of the bird to change direction of flight near the wind wheel and, thus, avoid collision with it. In this research work, the value of f is equal to 0.05. There is every reason to believe that f value is actually much lower [15, 20]. Therefore, it can be assumed that high-power turbines are dangerous, mainly in poor visibility, as well as for sick or weakened birds after a long flight.

4. Conclusions

The article presents the results of the ornithofauna monitoring in the "Primorsk-1" wind park territory by the SNH method in 2017 and the RAM method in 2018. The distribution of birds by season, direction of migration and flight altitude has been identified. An algorithm for calculating the number of birds in the wind power plant territory and their death due to collisions with turbines has been described. A comparative analysis of the data obtained by various methods has been carried out.

The total number of birds for 24 days of observation by the SNH method was 5923 specimens of 45 species: 3,795 specimens of 33 species have flown in transit, 2,113 specimens of 40 species belonged to the forage type, 15 birds of four species – to the demonstration type. Most of the birds (64.2%) have flown in transit. The greatest activity of birds was observed in spring (36.3%) and autumn (35.0%) seasons of migration, when the transit group accounted for 75.5% of all annual transit flights. The predominant directions of migration were northern, north-east, eastern, western and northwestern. At an altitude of up to 10 m there were 5086 (86.2%) birds, in the range of altitudes (11÷25) m – 697 (11.8%), in the range of altitudes (26÷50) m – 53 (0.7%). No birds were found at an ltitude above 180 m. In the risk zone of interaction with turbines, 72 birds of four species were observed: *Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo.*

When monitoring the territory by the RAM method in 2018, birds of the terrestrial group, sitting on the ground, wires, trees and bushes, were additionally registered. The total number of registered birds was 8927 specimens of 72 species: 802 specimens of 11 species have flown in transit, 2511 specimens of 32 species belonged to the forage type, 5614 specimens of 60 species belonged to the terrestrial type. The greatest activity of birds was observed in autumn (70.0%) and spring (15.2%) seasons of migration, and the share of the transit group in these seasons accounted for 93.4% of all annual transit flights. The predominant directions of migration were western, north-eastern and south-western. At an altitude of up to 10 m, 2369 (71.5%) birds were observed, in the range of altitudes (11÷25) *m* – 371 (11.2%), in the range of altitudes (26÷50) m – 367 (11.2%). There were 202 birds (6.1%) above 50 m. There were 4 specimens of the species Buteo buteo in the RZ zone. Monitoring of the territory by the route accounting method more fully reveals the forage group, the number of which was 3.1 times higher than the number of transit birds.

Comparison of the results was carried out on the basis of data reduced to 1 hour of observation over an area of 1 km^2. The number of birds of the transit group, identified by different monitoring methods, was within the admissible statistical spread of 10.2÷12.7 specimens/(hour·km^2). However, the density of birds registered by the RAM method is 7.1 times higher than the density found by the SNH method. Such a difference cannot be caused by statistical scatter, and is more likely related to the specifics of monitoring. It can be assumed that the movement of the observer along the route leads to frightening of the sitting birds and, thereby, to an increase in the number of forage group birds.

The average number of all birds in the wind park territory in a state of flight at each moment of time, calculated by various methods, was within the statistical scatter (1.15÷1.28) specimens/(hour·km^2). However, the size of the transit group in the case of the SNH method is 3 times higher compared to the RAM method, while the size of the forage group, on the contrary, is 2.5 times less. The number of birds *Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo* in the risk zone of interaction with turbines and the total number of birds of the listed species at all altitudes, identified by the SNH method, are also several times higher than that done by the RAM method.

The total anticipated number of transit and forage type birds in the wind park territory during one year of its functioning, according to different methods, is (0.62÷2.08) 106. The number of birds that will be flying in transit over the wind power plant territory during this time is (4.0÷5.0) 105. The number of birds in the risk zone of collisions with rotors is estimated at (2.4÷7.5) 103 specimens of four species *Larus ridibundus, Merops apiaster, Circus aeruginosus, Buteo buteo.* It is anticipated that representatives of these species will be present at all altitudes in the amount of (1.2÷1.8) 105.

The calculated number of bird collisions with turbines during one year is in the range of 5.6÷6.7 (about 0.6 specimens per turbine during one year of its functioning, or 0.2 specimens/1 MW/year). Such a frequency of collisions can be considered rather low and quite acceptable during the "Primorsk-1" wind park functioning. It is about 6.9-4% of the total number of birds of the transit and forage type in the wind power plant territory, 3.3-3% of the number of specimens of the considered species present at all altitudes, and 0.25% of all birds in the risk zone of interaction with turbines. The data obtained agree in order of magnitude with the literature sources known to us. For example, in accordance with the analysis of the bird interaction with turbines at 109 functioning wind power plants in Europe and North America, the average number of dead birds is 0.1 bird/1 MW/year [19].

In our opinion, the study of the wind power plant impact on birds should not be limited to assessing the possibility of bird collisions with turbines. The development of the wind energy component in providing modern civilization with new energy sources might have a significant impact on the environmental situation in general. In particular, the construction of a large number of wind power plants can lead to a redistribution of the existing balance between predators and victims in the ornithofauna, a change in the habitats and feeding of birds, a change in the direction of migration flows and other negative phenomena. The statistical data, accumulated in many countries, makes it possible to approach the understanding of the wind energy impact on the ecological situation in a broader aspect. Research in this direction is of theoretical and practical interest.

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Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Experience in teaching analytical chemistry in a joint English-language educational project of Chinese and Ukrainian universities

To cite this article: I M Gryshchenko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012008

Experience in teaching analytical chemistry in a joint English-language educational project of Chinese and Ukrainian universities

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Abstract. The paper was aimed to study the problems that may arise when Chinese students learn an analytical chemistry course in English, read by teachers from Ukraine. In particular, the reasons for the possible excessive increase in cognitive load were investigated. The comparative analysis of the existing learning styles was carried out to achieve the goal of the study. For this purpose, the indicators were compared for respondents studying in similar chemical specialities at the Kyiv College of the Qilu University of Technology in China and Kyiv National University of Technologies and Design in Ukraine. Some students from China demonstrate more pronounced reflective, verbal and intuitive learning styles. In contrast, a decisive advantage towards active, visual and sensing styles is characteristic of Ukraine students. The structure of the lecture course was analysed from the viewpoint of e-resources used. The optimal application of different electronic resources for students with varying learning preferences was established based on the results of experiments by the method of dual-task. The difference in educational priorities should be reflected in the various forms and methods used in the teaching of chemical disciplines. Recommendations for the development of appropriate learning resources are given.

1. Introduction

Introducing information and communication technologies (ICT) into the educational process has led to the emergence of many electronic resources (e-resources) for teachers that were previously unknown and inaccessible [1–3]. These tools cover entirely different areas of educational activities. For example, it can be electronic resources to assess student knowledge, such as testing programs and test shells [4–6]. Other resources are informational [7, 8]. They help informally fill the course being read. Among them, there are static and dynamic visualisations, e-books, media libraries, educational software, simulators, tutorials and academic databases [9–12]. Also, resources can be used to organise communication and data retrieval. Another class of e-resources is software for computer modelling and packages of professional applied programs [13–18].

Lectures remain the dominant form of organising training, especially for teaching basic disciplines. Conservative by nature, however, the lectures did not remain unchanged [19–22]. Now it is almost impossible to imagine lecture talks without multimedia support. The most common example is lectures accompanied by a slide deck. When preparing presentations, electronic resources can also be used, which are very diverse.

It should be noted that the widespread use of ICT does not automatically benefit training [23, 24]. Using e-resources can be effective only if several conditions are met. Probably two aspects are critical [25, 26]. They select teaching methods and educational e-resources, considering the audience's characteristics and the cognitive load that these resources cause.

Individual perception of educational e-resources, materials and information is often described in terms of "learning styles" or "preferences of learning styles" [27–31]. This aspect concerns both teachers and students. Also, a conflict of styles can emerge between teachers and students. On the one hand, the knowledge of student preferences is essential to avoid a possible conflict of styles. On the other hand, it is imperative and advisable to study the preferred learning styles for student groups. Based on this knowledge, it is possible to optimise various aspects of the presentation of materials, including optimising the e-resources used [25, 32, 33].

For successful learning, one needs to control students' level of cognitive load [34–38]. Overloading often causes a misunderstanding, while underloading leads to a loss of attention. In both cases, the perception of the material can deteriorate

Optimising cognitive load is exacerbated when teaching is not in the native language [39, 40]. The cognitive load increases as students need additional time and mental efforts to translate/understand words and compare them with illustrations and actions. The presence of too complicated effects in presentations, the use of a wide range of techniques and e-resources can easily overload a student when teaching in a foreign language [41, 42].

Suppose a foreign teacher conducts teaching in a foreign language. An additional problem may arise that affects both the effectiveness of e-resources and the cognitive load. Evidently, foreign teachers use the same styles and formats that are accepted in their country. The question remains open and unexplored to what extent the approaches used are acceptable and understandable for international students. Do they create additional difficulties, both at the cognitive level and the level of mere perception?

The work aimed to study the problems that may arise when Chinese students learn an analytical chemistry course in English, read by teachers from Ukraine. Analytical chemistry is one of the key disciplines for future specialists in chemical engineering. It involves the separation, identification, and quantification of matter. Analytical chemistry plays a crucial role in various chemical industry branches, such as in the production of synthetic and herbal medicines, industrial process control, environmental monitoring, medical diagnostics, food production, etc. [43–45]. A comparative analysis of Chinese students' learning styles and students from Ukraine of similar specialities was carried out to achieve the study's goal. The structure of the lecture course is analysed from the viewpoint of e-resources used. Some estimates are made of possible correlations between English language proficiency and student achievement.

2. Experimental

The experiment was carried out while teaching a course in analytical chemistry at the Qilu University of Technology, Jinan, Shandong province, People's Republic of China.

The indicators of a group of first-year students of the Kyiv College at the Qilu University of Technology (KCQUT) were studied. Methods of polling and testing were used, and the results of surveys, tests and exams of a student group were analysed. The group comprised 75 people majoring in light chemical engineering. The students in this college are Chinese. Teaching is conducted in English. Teaching in various disciplines is undertaken by both Chinese and Ukrainian teachers. In particular, analytical chemistry is read by Kyiv National University of Technologies and Design (KNUTD) teachers.

The course of analytical chemistry consisted of 32 lecture hours, namely 16 lectures of 90 minutes each. There were two midterm tests, an oral and written final exam. Besides chemical knowledge, the oral exam allowed one to assess the students' ability to understand, interpret, and use spoken English to solve professionally-oriented problems (terminology, classification of chemical compounds, fundamental laws, etc.). Students completed three independent homework assignments and individually performed laboratory work using computer modelling.

The ChemLab English-language program was used for modelling [46]. Before completing the assignments, the teacher explained the technology of work in ChemLab for 45 minutes. Students recorded their work on video and sent them for verification, which the teacher carried out offline.

During independent work with ChemLab, the cognitive load was reduced. The students worked each at their own pace and had sufficient time to comprehend each performed action. This type of work was considered a first step of testing the influence of cognitive load on student learning effectiveness.

The ChemLab program has an intuitive, user-friendly interface and tools for adapting work to each user's requirements. It includes:

- the ability to turn on and off the hint mode and labels on each object,
- the text of instructions for performing work,
- changing the design of the working window of the program, and
- at least three possible options for manipulating modelling objects using the mouse or the context menu.

A similar course of analytical chemistry was also read to first-third-year students of KNUTD. The experiment involved 161 people. The students majored in chemical and pharmaceutical technology at the Faculty of Chemical and Biopharmaceutical Technologies. Lectures were delivered in their native Ukrainian language.

The content of the lecture course was identical for both QUT and KNUTD universities. A comparison was made between the learning styles of Ukrainian and Chinese students who participated in the experiment.

In both cases, profiles of student learning preferences were identified by R. Felder-B. Soloman method. The instrument, known as the Index of Learning Style [47, 48], was used. All respondents answered 44 questions. The processing of responses allowed one 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 type of data processing. Understanding of information took place by using a sequential (seq) or global (glo) approach. In other words, each of the four dimensions consists of a pair of a style and antistyle or two contrasting styles. An 11-point scale was used to quantify students' preferences for each of four dimensions.

An individual style was predominant when the calculated score in the person's answers ranged from 6 to 11 points. The preferred learning styles for a group of students were assessed in two ways. In the first case, the shares of students that scored 6 to 11 and 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 (Method 1) illustrated the distribution of student preferences between style and antistyle for each of the four dimensions.

The first approach did not reflect the strength of the existing preference within a pair of styles. Another approach (Method 2) implies calculating the average score of learning preferences in a group instead of the relative number of students in a group. The average score reflected the relative number of students with individual preferences and depended on the preference strength. If the average score was 0-3 points for a style, it was considered that there was no preference. The style preference was weak if the average score was 4-7 points and strong for 8-9 points. The preference was rated as very strong, with an average between 10 and 11 points.

The level of cognitive load of students was measured by the method of dual-task using the developed software. Students mastered the study material prepared with the help of various multimedia resources. The secondary task was to press the button on the screen when the button colour had changed. The time between changing the colour and pressing the button was fixed. It allowed an experimenter to record the change in students' reaction time (t) to the visual signal. It was believed that the response time increases with increasing cognitive load.

In total, 34 Ukrainian students took part in the experiment. Each of them performed six tasks. Each task was repeated 5-6 times to get statistically significant results. When performing the tasks, respondents read the text of two levels of difficulty (tasks 1 and 2), animated text (3), watched videos with audio (4), as well as videos with audio, which contained intense distractions (5). For example, such distraction effects were explosions or flashes. The reaction time (t_n, where n is the number of the experiment) was measured for all five experiments.

A blank experiment was conducted to consider the individuality of the respondents. In such cases, the response time to colour change (t_0) was measured in the absence of a learning task. The periods spent in experiments 1-5 were normalised to the blank investigation time in the future. All calculations and comparisons were made for the relative values $R_n \equiv t_n/t_0$.

As the Kolmogorov-Smirnov test showed [49], the obtained results are subject to normal distribution. Therefore, statistical processing of the obtained results was performed using the T-test for paired dependent samples. First, the differences between the results of the two experiments under comparison were calculated for each respondent. Then, it was checked whether the average of these differences differs from zero. The level of significance was taken as $\alpha \equiv 0.05$.

The materials of the published course for analytical chemistry were used to analyse a slide deck structure. The slide deck is divided into 18 parts, delivered in 16 lectures, and contains 1275 slides. Except for slides with titles and lecture contents (49 slides), an analysis of the content was carried out for the remaining informational 1226 slides. Twelve key elements, which compose slides, were defined. They are titles and contents of sections, flowcharts, classification schemes, stage schemes of a process, procedure schemes, tables, graphs and tasks to solve. Besides, some slides were 100% covered by text, while text coverage varied between 25% and 75% in other transparencies. Also, illustrations for displaying chemical processes at the micro, macro and symbolic levels are highlighted. The analysis carried out included the frequency of using certain elements combined with varying degrees of student preferences for specific resources.

3. Results

3.1. Preferred learning styles

Preferences in learning styles for students of KCQUT and KNUTD calculated by Method 1 are presented in figure 1.

The results represent the proportion of students from the total number, and qualitatively they look similar. In both cases, students are prone to act, sen, vis and seq learning styles. Both experimental curves are shifted to the right and compared to the circular balance curve (50%).

However, a significant difference is seen between Ukrainian and Chinese students in the degree of existing preferences in three of the four dimensions. Both teams show virtually the same results only in the seq-glo dimension. For all other styles, a relatively more significant imbalance between style and antistyle characterises Ukraine students. Conversely, China student preferences look relatively more balanced. For example, almost 87% of Ukraine students show a tendency to the sen style. In comparison, this figure is only 64% among students from China.

The difference in the proportion of students between a particular style and antistyle is not statistically significant. However, this is primarily because individual indicators range from 0 to 11 points. Accordingly, the average data for the group as a whole gives only a qualitative picture.

The learning preferences were assessed according to Method 2 to obtain additional information on the differences between students from different educational institutions. As already mentioned, Method 2 estimates the relative number of students who exhibit preferences

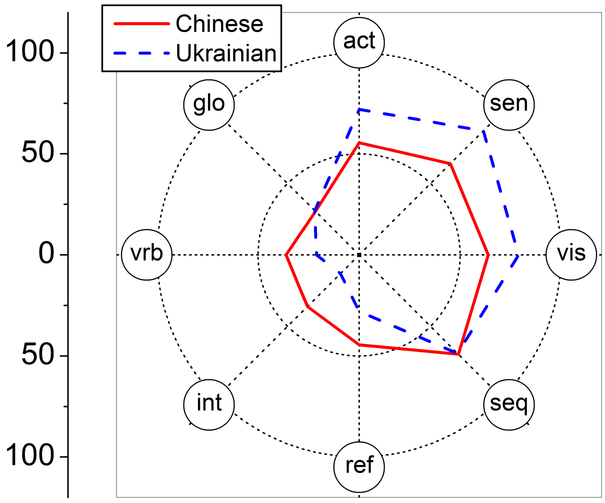

Figure 1. The relative number of students of KNUTD (dotted line) and KCQUT (solid) with different learning preferences.

of different strengths relative to a particular learning style. Relative values, normalised to the total number of students in the sample, were used to level the impact of different numbers of students in the samples. According to the strength of preference, the division of all students into four groups was considered: group 1 – where there is no preference for a particular style or style and antistyle are balanced; group 2 – style has an advantage over antistyle of moderate strength; group 3 – there is a strong advantage; group 0 represents students with the benefit of antistyle of any power over style.

As can be seen from figure 1, the difference in educational preferences can be expected in three dimensions: act-ref, sen-int, and vis-vrb. The results of calculations by Method 2 are shown in figure 2 for these dimensions. In figure 2, the values of act, sen and vis antistyles are shown in addition to the styles of ref, int and vrb. For them, the picture is significantly different.

For each of the dimensions ref, int, vrb, groups of maximum number (up to 50-60% of the total number of students) demonstrate moderate strength. Groups with a balanced style and antistyle occupy 25-40% in number. Groups with other types of learning preferences (groups 0 and 3) are the smallest in number. Together they number from 5 to 10%. The advantage of the respective antistyle or the balance between style and antistyle is typical for 90-100% of Ukrainian students.

Ukrainian students primarily demonstrate either a moderate propensity for these styles or a balance of styles and antistyles. The moderate tendency to these styles of Chinese students is less pronounced. The largest group consists of students with balanced preferences. A relatively large (about 17%) group comprises Chinese students with a strong preference for the styles of act, vis and sen. To some extent, this is abnormal behaviour, as groups with strong preferences are usually small.

3.2. Cognitive load

One can assume that a foreign language increases cognitive load and thus complicates learning. The workload of Chinese students studying in English was increased compared to the workload of, for example, Ukrainian students studying in their native language. After the course of analytical chemistry, the final exam was divided into parts, oral and written, to confirm the assumption about the influence of the language of instruction. The written exam was organised

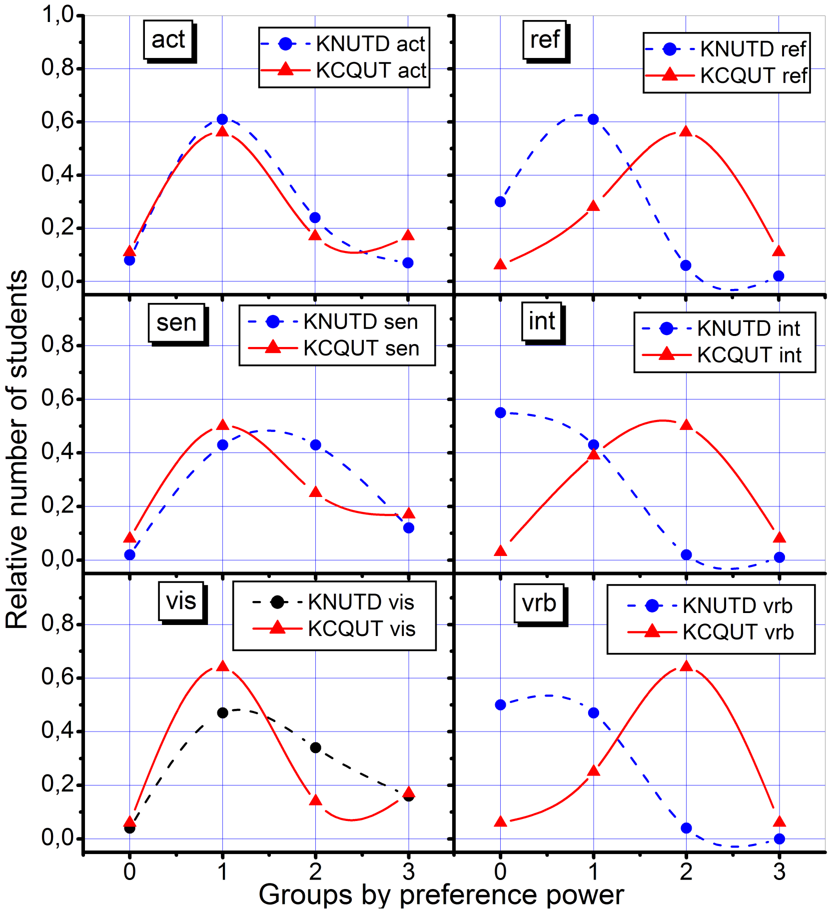

Figure 2. The relative number of students in groups 0-3 who have a learning preference of a particular style: 0 – antistyle prevails, 1 – the balance between style and antistyle, 2 – moderate style advantage, 3 – strong style advantage.

traditionally, and its primary purpose was to test the gained chemical knowledge. During the oral exam, an attempt was made to assess students' necessary level of understanding in English simultaneously with fundamental chemical knowledge. During the exam, students were asked simple questions about chemical terminology and basic chemical laws. They were forced to understand quickly and then answer questions impromptu, demonstrating the level of basic knowledge in both Chemistry and English. The answers were scored on a 10-point scale.

Figure 3 shows a strong linear correlation ($R^2 \equiv 0.89$) between the final mark in analytical chemistry and the language exam mark. The final mark was based on the results of two intermediate tests, the completion of three homework assignments, laboratory work on computer simulations, and the final written exam results. The most straightforward and most logical explanation for the invented fact is that the lack of knowledge of the language of instruction significantly increases students' cognitive load. The increased load thus critically increases the time required to understand and perform tasks.

Suppose students can choose the pace, which is acceptable for performing tasks and understanding the results. Such conditions will help to reduce cognitive load and improve the level of mastery of educational material. ChemLab software provides such an opportunity. This program contains tools for slower or faster execution of the experiment. Also, work is possible with or without prompts. By performing their laboratory works with the help of

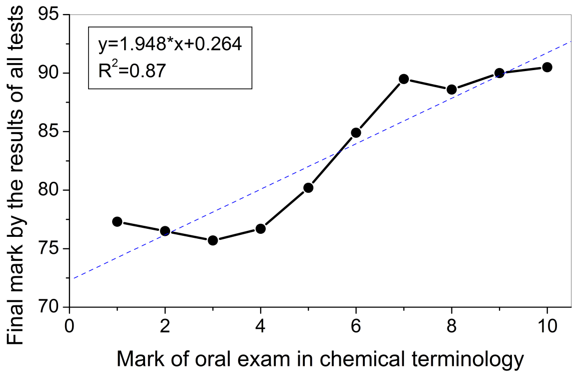

Figure 3. Correlation between the final mark in analytical chemistry, based on all home and laboratory works, exams and tests, and the oral language exam mark. The oral exam used to test students' ability to understand and use chemical nomenclature.

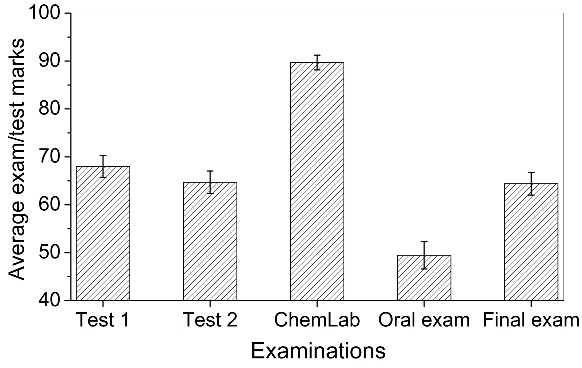

Figure 4. The average results of all exams of the group of students KCQUT in studying analytical chemistry. For comparison, the results are reduced to values on a 100-point scale.

ChemLab, students could create the most favourable environment, thereby reducing cognitive load. As a result, the average score of the group according to the results of laboratory work in ChemLab significantly exceeded the figures obtained by the same students in passing tests or exams (figure 4). Only 2 out of 75 students failed this lab.

Thus, the increased cognitive load when learning a foreign language is an essential factor that must be taken into account when developing a lecture course. On the one hand, the development of multimedia technologies creates a wide range of e-resources that can be implemented in the lecture course. The simultaneous use of many resources can increase the cognitive load in the learning process. To clarify this issue, the influence of using different educational resources, including simultaneous, on the level of a cognitive load of KNUTD students was studied using the dual-task method. The cognitive load level was assessed by measuring the time required to perform a secondary task in the learning process using different multimedia resources. The results of the study are given in table 1.

Table 1. The results of the measurement of cognitive load by secondary task method.

Task No	Respondent reaction rates were measured under the following conditions:	t_n, ms	$R_n = t_n/t_0$
0	The absence of an educational task (blank run)	530.4	1
1	Simple text reading	777.2	1.41
2	Complex text reading	904.1	1.81
3	Text reading concurrently with animation viewing	835.8	1.70
4	Video viewing together with audio listening	658.9	1.38
5	Video viewing together with audio listening, if demonstration contains distracting effects (explosions, flashes etc.)	1511.3	3.21

The statistical analysis shows that the difference in the relative time R_n is observed for five pairs of experiments out of 10. For example, the differences between the response time R_1 when reading plain text and the values of R_2 (complex text) and R_3 (text with animation) are statistically significant at $\alpha_{12} \equiv 0.011$ and $\alpha_{13} \equiv 0.049$. For experiment 4, the time differences are substantial for experiments 2, 3 and 5 ($\alpha_{24} \equiv 0.038$, $\alpha_{34} \equiv 0.01$, $\alpha_{45} \equiv 0.028$).

For each of these cases, the addition of a second, more sophisticated resource significantly increases the cognitive load. The obtained results show the potential danger of increasing cognitive load when using many different e-resources. As already mentioned, teaching in a foreign language exacerbates the problem of student overload. Therefore, when preparing lecture material, an excessive complication of illustrations should be avoided. Care should be taken to ensure that the slides used are simple in content and stuffing various multimedia resources.

3.3. Lecture structure

As mentioned above, the lecture course has 1275 slides distributed between 18 sections. Of these, 49 slides contain only the names and contents of sections and their subsections. Therefore, they are excluded from further analysis. The remaining 1226 slides are informative.

All 18 sections of the course were combined into five parts according to their content to simplify the analysis. Table 2 illustrates the main characteristics of parts of the course, namely the number of parts and slides in them and the saturation of slides with multimedia elements.

Table 2. The number of slides per lecture part and the average number of multimedia elements per slide.

Lecture parts	Section No	No of informational slides	No of slides with titles	No of multimedia elements per slide
Introductory	1-3	228	23	1.44
Equations & equilibrium	4-5	128	2	1.68
Classic methods	6-9	167	4	1.67
Instrumental methods	10-17	598	19	1.78
Chromatography	18	105	1	2.13
Total	1-18	1226	49	1.72

As is seen, the density of multimedia elements increases from the first lectures to the last one. Typically, each slide contains only two elements and less than 1.5 elements at the beginning of the lecture course. This approach seems appropriate because students are gradually getting used to the methods of conveying the material.

About a third of the total number of informative slides consists of full-text slides. This indicator is maximum in the introductory part because introductory lectures contain many definitions, wording, etc.

It gradually decreases with the transition to other parts of the lecture course. Schemes for various purposes can be seen on average on 20% of slides. On the contrary, this figure increases from the beginning of the lecture course to its completion. Information as graphs and tables is typical of about 22% of informative slides.

Table 3 contains more detailed information on the distribution of multimedia elements between different parts of the course.

About 50% of the total number of informative slides contain illustrations of chemical processes at different representation levels. Such illustrations are hardly appropriate on slides with tasks, full-text slides, and slides containing classification schemes. Excluding such unappropriated slides, there are 816 slides left throughout the course. More than 70% have illustrations of chemical processes at different representation levels (table 4).

The most challenging task is to form an understanding of the transitions between different levels of representation of chemical knowledge [50–52]. However, according to the analysis, there are very few slides (less than 10%) with such illustrations.

Table 3. The number of lecture slides with distinct elements.

Lecture parts	Total	Text 25-75%	Text 100%	Classification	Flow chart	Stage scheme	Procedure scheme	Table	Graph	Task
Introductory	251	92	99	22	3		2	12	28	6
Equations, equilibrium	130	77	27	1				7	2	12
Classic methods	171	74	48	3	1	3	5	20	17	7
Instrumental	617	307	175	18	133	18	10	47	95	11
Chromatography	106	85	14		19			16	33	2
Total	1275	635	363	44	156	21	17	102	175	38

Table 4. The number of slides with illustrations of chemical knowledge at different levels of representation, transitions between these levels and the share of such slides in the slide deck.

Number of slides	Symbol	Micro	Macro	Macro-symbol	Symbol-micro	Micro-macro	Ternary micro-macro-symbol
816	304	94	193	33	14	19	2
Part, %	37.3%	11.5%	23.7%	4.0%	1.7%	2.3%	0.2%

4. Discussion

As is known [25, 53, 54], learning styles can significantly differ for students of different fields of study. Students of related specialities have similar learning profiles. This paper compares the learning styles of students of similar specialities. However, students of distinct groups received secondary education in different countries; higher education was conducted in their native and foreign languages. The obtained results (figure 1) indicate a significant difference in learning preferences between students of KNUTD and KCQUT.

Students from Ukraine demonstrate a clear advantage in the act, vis and sen styles of study. In each dimension, 72% to 89% of students have the benefits mentioned above. In contrast, Chinese students are significantly more verbal (36% verbal students versus 64% visual) than Ukrainian students (21% verbal vs 79% visual). They are good at perceiving linguistic and textual elements, getting more information from words in both written and oral explanations.

They are also a bit more reflective and intuitive: 44% and 36% of Chinese students at Kyiv College are reflective and intuitive, respectively. The same results for Ukrainian students are 28% for reflective and 13% for intuitive style. Almost half of Chinese students prefer reflection and observation. They like to work alone and work well with the text. A third of Chinese students are innovators, being more resourceful and intuitive in information perception. They like to work with abstract problems, concept formulations and mathematical dependencies and readily accept complications. In contrast, they hate monotonous work and repetition, are bored studying the details and do not like courses that contain much material for memorisation and routine calculations,

In dimension seq-glo, the measured difference between Chinese and Ukrainian students is minimal; it never exceeds 1%. Convergent thinking prevails in all students who participated in the survey. They achieve understanding in the step-by-step study when each new step logically follows from the previous one. Traditional technical education is mostly sequential. The coincidence of the characteristics of students from different countries in this aspect possibly results from the influence of the chosen field, namely technical education.

In general, students who studied at KCQUT exhibit a more balanced profile of learning preferences compared to students of KNUTD. However, as shown in figure 2, Chinese students are characterised by a limited group of students who have pronounced learning advantages, often simultaneously for three styles – act, sen and vis. The relative number of such students (up to 17% of the total) is even higher than among KNUTD students (usually 7-12%). The learning advantages of the other 80-83% of students from China show even more balanced profiles than follows from the averages in figure 1. From a practical point of view, the identified difference in learning preferences must be taken into account, particularly when developing educational materials and organising the English-language training for students of China.

The effectiveness of learning is influenced by both the quantitative and qualitative composition of the learning preferences. All four available dimensions are essential for a complete description of the student's learning profiles. Therefore, the analysis is ineffective if the impact of some individual styles on the progress in studies is considered [25, 53].

Students who have different combinations of learning styles experience cognitive loads differently when using e-resources. A detailed analysis of the impact of the qualitative composition of a mix of styles on academic progress has shown that active or sequential styles are necessarily present in learning profiles of well-progressing Ukrainian students. In a broader sense, it is possible to say that the best progress is made by students who have typical advantages for this field of study [53]. In contrast, atypical advantages are undesirable. One can assume that the content of the disciplines being taught, the teaching methods used, and the teaching resources, including e-resources, create a more comfortable learning environment for students with typical learning preferences. Thus, all these factors contribute to a better understanding of chemical knowledge. Therefore, to increase the effectiveness of educational activities, lecturers must analyse the composition of groups and optimise methods, forms and resources for teaching in concord with established groups' profiles.

For both universities, the combination of act-sen-vis-seq styles prevails, but the degree of preference differs significantly. The number of Ukrainian students with the above mix of styles (group A) is approximately 72-89% of the total number. Among Chinese students, only 55-64% belong to group A. In other words, 36% to 45% of students from China have learning preferences (group B) that contrast with the dominant combination in three of the four dimensions. Only the structure of priorities in the seq-glo dimension remains unchanged for groups A and B. Group B contains much less Ukrainian students (11-28% of students).

The vast majority of Ukrainian students receive educational material taught using optimal teaching methods. Therefore, the focus on the specific learning preferences of group A is reasonable and appropriate when teaching students in Ukraine. With KCQUT students, this approach may be one-sided, as it does not consider the existing preferences of 36-45% of Chinese students. For students with different learning profiles, the ways of mastering and assimilating information, as well as the information channels involved, significantly differ. As a result, the perception, as well as the effectiveness of different teaching methods, diverges.

Table 5 illustrates the perception of teaching methods by students of groups A and B separately. A plus marks optimal teaching methods for a particular learning style. Four teaching methods fit nicely with three of four learning preferences in group A. Another five methods are agreed only with two of four learning preferences. Such procedures should be used with caution, as a significant proportion of students do not perceive them.

For group B, the situation looks worse. None of the methods is simultaneously acceptable for all four available preferences. Only one method fits with three of the four available student benefits. The other eight methods are only proper for two learning styles at a time. The obtained result formulates the problem of finding optimal teaching methods for students of group B, which currently has no solution and needs further study. It is also apparent that this problem is acute primarily for KCQUT students, as it may affect 36-45% of existing students.

A separate factor of academic success is language proficiency in learning in a foreign language environment. According to all tests and exams, students with limited language proficiency

Table 5. Optimal teaching methods for students with different learning profiles: a) - profile act-sen-vis-seq and b) - profile ref-int-vrb-seq. Suitable methods for a given learning style are marked with a plus. (* PBL and PjBL – problem-based learning and project-based learning)

a) Teaching methods – profile	act	sen	vis	seq	b) Teaching methods – profile	ref	int	vrb	seq
PBL and PjBL*	+	+	+	+	Question-answer method	+		+	+
Modelling	+	+	+	+	Modelling		+		+
Practical	+	+	+		Verbal			+	+
Visual		+	+	+	Visual			+	+
Experiment		+	+		Independ.work with text	+		+	
Games & simulations	+		+		Case method	+	+		
Verbal	+		+		PBL and PjBL*			+	+
Question-answer method		+		+	Discussion panel		+	+	
Performing exercises		+		+	Performing exercises			+	+

showed worse outcomes than those who speak a foreign language better. On average, for students who received 1-5 points in the language exam, the results of their progress in the study of analytical chemistry are 77.3 points. Those who took 6-10 points in English had an average of 88.7 in analytical chemistry in all exams. The reasons for different levels of English proficiency may be various. As evidenced by the literature [55, 56], one of them may be the difference in learning styles, using teaching methods that are not optimal for some learning styles. It affects the effectiveness of foreign language learning.

Students with limited language skills experience an additional mental workload. If they use favourable resources and reduce the load to some extent, the results improve. Such a statement is evidenced by the results of laboratory work using ChemLab. This program's extensive capabilities to adapt the interface and tools to individual needs (enable/disable hint mode, additional labels on objects, use of online instructions, etc.) led to an increase in the average score obtained by the group for laboratory work. The laboratory work results are by 31- 38% better than the results of other tests of the same students (figure 4).

As proven in dual-task experiments, the simultaneous use of multiple e-resources can complicate learning. The negative effect of distraction can outweigh the positive impact of using simultaneous multiple communication channels. Conversely, the selection of optimal e-resources, both in quantity and quality, reduces cognitive load and promotes learning (table 1). The importance of the optimal choice of educational resources determines the approach to creating lecture presentations for international students. On the one hand, such presentations should be relatively simple and do not contain many e-resources. However, simplifying slides can have negative consequences.

The slide deck analysis showed that insufficient attention was paid to the formation and assimilation of transitions between different levels of representation of chemical knowledge. A serious problem is the inability of many students to create virtual connections between different expression levels of chemical knowledge. As is known, these levels are microscopic (atomic-molecular world, including ideas about the structure of the atom), macroscopic (phenomena of the material world) and symbolic (apparatus of mathematical methods and symbolic description of chemical processes). The inability to establish and use links between the different levels is a severe obstacle to students' development of chemical knowledge [57, 58].

Chemical knowledge is formed in the correct conceptual structures when all the above levels of understanding of processes and phenomena are included. Students quickly make imaginary transitions from one level of knowledge to another. Ideally, such changes should proceed between three levels - micro, macro and symbolic [51].

Unfortunately, virtually no slides illustrating transitions between representations levels are present in the slide deck. As follows from table 4, 11% to 37% of the slides contain illustrations of chemical processes at one of the three mentioned representation levels. Examples of transitions between levels are ten times less. The number of slides with double transitions does not exceed 4% at best, and the figure is only 0.2% for triple links. As a result, teachers are forced to stretch their visualisation in time and space, e.g., by using different neighbouring slides to realise the need to master the triple transitions. Under such conditions, students are forced to combine knowledge at different levels independently. For example, recall information from a previous slide and integrate data with current or subsequent images.

Obviously, when preparing each illustration in the educational presentation, it is necessary not to forget about forming chemical knowledge. If this goal, e. g., is understanding the triple transitions between levels of chemical knowledge, it needs to place all the essential elements on a single slide. In this case, the design of slides should follow Mayer's multimedia principles [19,20] and not overload them, creating conditions for an optimal cognitive load of students.

5. Conclusions

(i) Chinese and Ukrainian students of related specialities demonstrate qualitatively similar preferences in learning styles. Following the Felder - Soloman method, the dominance of act, sen, vis and seq is characteristic of both student groups. However, a significant quantitative difference is observed in learning profiles. Thus, 36% to 44% of students from China demonstrate reflective, verbal and intuitive learning styles. A decisive advantage in the opposite direction, namely act, vis and sen, is characteristic of Ukraine students. From 72% to 87% of Ukrainian students have such advantages. The difference in these learning preferences should be reflected in the different forms and methods used in teaching academic disciplines.

(ii) The influence of the simultaneous use of different e-resources on students' cognitive load was investigated by the method of dual-task. Concurrent use of over two resources can lead to students' mental overload and impair their perception of information. Simultaneous use of different e-resources can activate the simultaneous exchange of information through several channels of perception. However, the danger of mental overload concurrently increases. Then the negative effect of overload outweighs the positive impact of using several channels of information perception. Teaching in a foreign language enhances the mental load on students. It is evidenced by the data obtained on the correlation between students' knowledge of the language of instruction and their academic achievements. If learning conditions help reduce cognitive load, academic achievements increase even among students with poor language skills.

(iii) Studies of the structure of the presentations accompanying analytical chemistry have shown that a slide deck's design cannot be overly complicated. Virtually all course slides involve 1.5 to 2.4 e-resources per slide. However, attempts to simplify the structure of slides have led to a lack of attention to the formation of mental transitions between microscopic, macroscopic and symbolic levels of representation of chemical knowledge. The construction of such transitions is one of the most important and, at the same time, the most challenging task in teaching chemistry courses. An insufficient number of slides (up to 4% of the total) with illustrations of transitions between different levels reduces the teacher's ability to explain these issues.

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Journal of Physics: Conference Series

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Augmented reality as a part of STEM lessons

To cite this article: L Ya Midak *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012009

Augmented reality as a part of STEM lessons

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Abstract. Modern teachers and the managers of educational establishments have big challenge – to organize the lectures and the study process so that the students are provided with the necessary skills and to meet their educational needs, as well as their parents' expectations. An integrated lesson that is developed with a synthesis of information on different educational subjects stimulates the students' analytic thinking, which in exchange boosts the integral perception of the reality. That is why STEM lessons are becoming more and more popular among the educators, as far as the specifics of this approach can really solve a lot of tasks. Modern IT-developments are an appropriate T – component during STEM lessons and while developing STEM projects. One of these up-to-date trends is called Augmented Reality (AR), which allows visualizing the study material and improves its reception and memorizing. The purpose of the research is development of a mobile app (on Android) for STEM lessons, designed for visualization of the chemical structure of organic, biologically active substances, which can be used by the teacher and students in order to carry out integrated lessons of biochemical area; revealing key specifics of using STEM technologies while studying natural sciences.

1. Introduction

1.1. The problem statement

Nowadays, it is pretty obvious that if the problems are solved with ancient methods, a new level of education quality cannot be reached. New strategies, new up-to-date pedagogic technologies are a must-have [1–3].

An integrated lesson is one of the innovations of the modern methodology [4, 5]. This technology is becoming a part of school courses with ambitious confidence and connects subjects, incompatible at glimpse. The "Chemistry" subject is integrated by definition (a priori) [6]. It is overfilled with inter-subject connections and, along with other natural disciplines, offers the students wide knowledge in many fields of science, art, culture and the daily routine.

An integrated lesson that is developed with a synthesis of information on different educational subjects stimulates the students' analytic thinking, which in exchange boosts the integral perception of the reality [4, 5]. Integrated lessons can solve information, communication, educational and theoretic issues. Editions and choices on the structure of integrated lessons are widely different. Two or more subjects can be integrated. Information, communication, valuable and semantic competencies (responsibilities) are formed during these lessons [4, 5].

The nowadays pedagogic science claims that "in order to have the student receive the knowledge efficiently and to promote their intellectual development, it is vitally important to set-up wide connections not only with different units of the study course, but also with numerous disciplines overall" (Inbound and internal subject integration) [1]. The experience shows that with the integrated education, which is updated and repeated by other fields of study, provides extremely better results in comparison with classic study of the disciplines [1, 4, 5, 7]. The integrated approach accelerates establishment of the knowledge system, develops the abilities to transfer these into different branches.

1.2. The purpose of the research

The purpose of the research is development of a mobile app (on Android) for STEM lessons, designed for visualization of the chemical structure of organic, biologically active substances, which can be used by the teacher and students in order to carry out integrated lessons of biochemical area; revealing key specifics of using STEM technologies while studying natural sciences.

2. Discussion and results

The result of the integrating natural and mathematical sciences with elements of technology and engineering is STEM education (STEM = Science + Technology + Engineering + Mathematics; STEAM = Science + Technology + Engineering + Arts + Mathematics; STREAM = Science + Technology + Reading+wRiting + Engineering + Arts + Mathematics) [8–12].

Nowadays, the teachers and the managers of educational establishments have big challenge – to organize the lectures and the study process so that the students are provided with the necessary skills and to meet their educational needs, as well as their parents' expectations [13].

That is why STEM lessons are becoming more and more popular among the educators, as far as the specifics of this approach can really solve a lot of tasks. Contemporary graduates – the upcoming disrupts and innovators need to receive the basic knowledge in natural and technical sciences, combined with 21st Century skills, like the communication ability, teamwork ability as well as the power to solve problems in the light of innovation opportunities and demands of the society [8, 13, 14].

During a STEM lesson every single activity is clear for the students, the lab equipment, robotics are directly involved into the structure of the lecture.

Modern IT-developments are an appropriate T – component during STEM lessons and while developing STEM projects. One of these up-to-date trends is called Augmented Reality (AR), which allows visualizing the study material and improves its reception and memorizing [15–18].

Establishing study system, involving AR technologies, can obviously make it easier for the students to understand the theory, as far as they have the capability to reinforce it in practice (to make virtual models in real time) [18–29]. Due to implementing innovations into the education system, especially virtual educational tools (3D modelling, augmented reality) the efficiency of study is improving overall.

The competitive approach requires a motivated selection of the integrated lessons, applying the results in daily routine. From this perspective, there are a couple of spicy biochemical subjects: Chemistry of Love, Chemistry of Happiness, Chemistry of Smell etc., which give the ability to understand the chemical processes, going on inside a human body. In the modern era, in most of the study plans of the course "General education (chemistry)", the discipline "Biochemistry" is one of the optional disciplines. Studying this subject will definitely help the upcoming chemistry teachers to explain biological processes of the human body, give examples during the chemistry lectures, perform integrated lessons and apply the knowledge, gained, in order to intensify the students' education curiosity.

A mobile application LiCo.School, capable of visualizing the study material was designed to image the molecules of bio-organic compounds. It can be downloaded with the QR-code (figure 1). Formulae of organic compounds, provided in this paper, are markers for this mobile app.

Figure 1. QR-code to uploaded the LiCo.School mobile application.

At the first stage, 3D pictures of molecules were developed for this mobile app. For the purpose of applying AR, augmented reality markers were developed [30] on the Vuforia platform; 3D objects were modeled in 3ds Max, augmented reality objects were realized with the multi-platform tool for developing two- and three-dimensional mobile applications Unity 3D.

The natural science courses involve a lot of subjects, which are absolutely impossible without integration. For example, an integrated lesson can be performed in the 8^{th} grade in order to study the "Metabolism and energy transformation in the human body" topic. According to the study program, the student must operate with the definitions (metabolism, energetic needs, and vitamins), give examples of vitamins, describe the ingredients of nutrition products, food as a source of energy, the metabolism and energy transformation in the human body, nutritional and energetic needs of a human, explain the functional value of the proteins, fats, carbohydrates, vitamins, water and mineral substances for the human body. Supplying this knowledge is only possible with integration of physics, chemistry and biology. Also, this subject can be reviewed in the context of exotic fruits, which became popular in the shops, in order to make the lesson up-to-date.

For the majority of people, the most popular fruit is mango. Mango is occupied by vitamins, minerals and antioxidants, and furthermore, like all other fruits, they contain minimum proteins and fats. Mango provides with a huge amount of tryptophan (figure 2) – the ferment which is the precursor of serotonin – "the hormone of happiness".

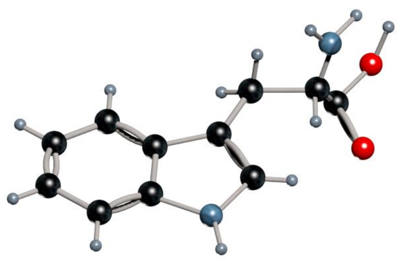

Figure 2. Tryptophan.

Mango is one of the top champions in containing the Vitamin C – ascorbine acid (figure 3). This water-soluble vitamin needs to be supplied to the organism, as far as it does not accumulate or store inside the cells [31, 32]

Mango is also full of folic acid – vitamin B_9 (figure 4). This substance is taken by the organism while building proteins and DNA, and they build new cells [31, 32].

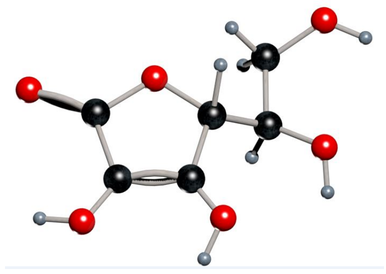

Figure 3. Vitamin C (ascorbine acid).

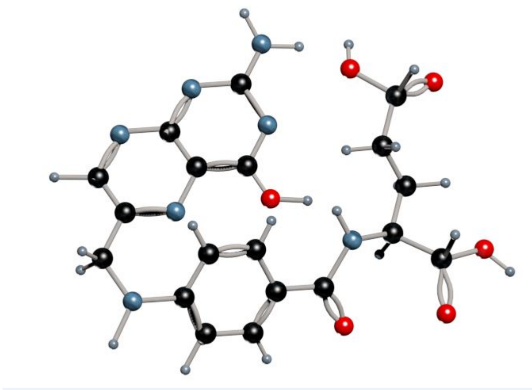

Figure 4. Vitamin B_9 (folic acid).

Vitamin E (figure 5), also contained in mango is fat-soluble. It supports the immune function and is a vital antioxidant.

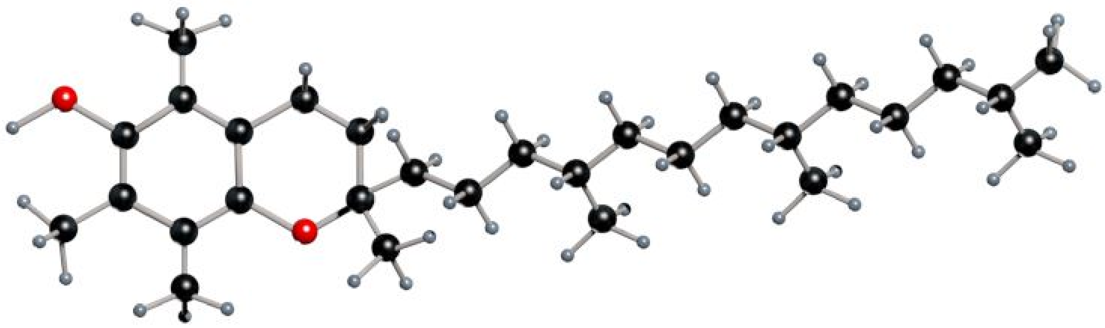

Figure 5. Vitamin E (α-tocopherole).

Mango does also involve vitamin A (figure 6), crucial for eyesight, osseous tissue growth and for reproduction health.

As far as we can see, a brief description of only one fruit gives the opportunity to learn a few vitamin formulas. But, as far as this topic is reviewed by 8^{th} grade students, and vitamins are organic compounds, studying which does only begin during the 9^{th} grade chemistry lessons, it is reasonable to simplify the material, visualizing it with augmented reality. In this way, every

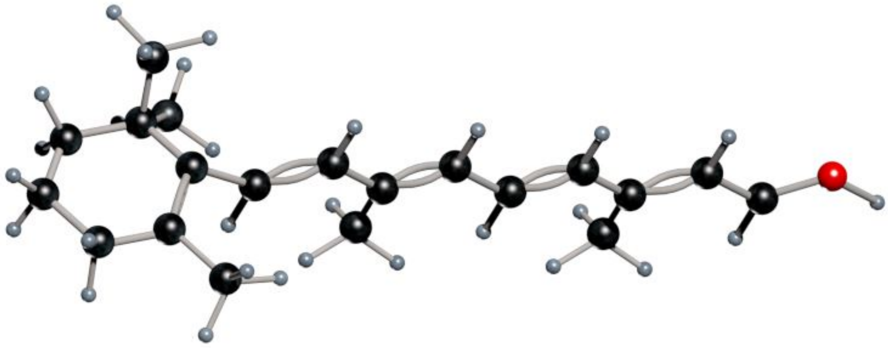

Figure 6. Vitamin A (retinol).

student can view this material on their smartphone or tablet, to "hold" the molecule of vitamin in their hands, which makes the lesson significantly interesting. This approach will help the students analyze the situation, boost their critical thinking and help them make the reasonable conclusions about the value of nutrition products, and the knowledge, received at the lesson will be useful in the grown-up routine.

The augmented reality can be implemented while investigating, for example, the chemistry of happiness. It is a fact that the nature of our happiness is chemical [33]. The happiness is defined as a psycho-emotional state of a total life satisfaction, the feeling of deep comfort and endless joy. The feeling of endless satisfaction is nothing, but a sophisticated chain of biochemical processes, driven by special hormones – "the hormones of happines", produced by the brain [33].

Dopamine, serotonin and the endorphins (figure 7) are considered to be the three hormones of happiness. All of them are produced in the human body and depend on its vital activities, the division of physical and mental stresses, nutrition and health.

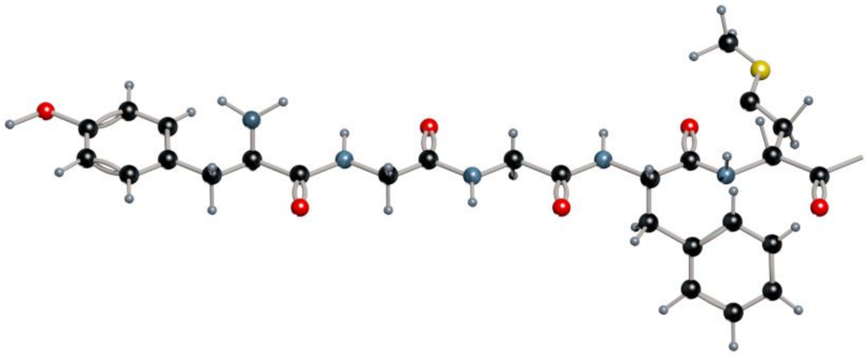

Figure 7. A part of endorphin.

Endorphins are probably the most famous hormones of happiness and satisfaction. Endorphins are a group of poly-peptide chemical compounds, which are produced by neurons of the cerebrum (the brain), similar to opiates in their structure. Endorphins develop inside the neurons of the brain from a substance, produced by the hypophysis – betalipotropin [33].

Serotonin (figure 8) is the hormone, connected with seasonal rhythms [33]. Its production depends on the daylight duration. Serotonin (5-hydroxy-tryptamine) is a neurotransmitter. A biogenic amine, the precursor of which is hydroxylated tryptophan (5-hydroxy-triptophane), which is to be processed with decarboxylizing pyricoxal phosphate dependant decarboxylase and building a biologically active amine. Serotonin is metabolised in the human body in moments of extasy, its amount is increasing with euphoria and decreasing with depression. 5-10% of serotonin is syntethized by the pineal gland from the vitally important tryptophan amino acid. The sunshine is a must-have for its production, that is why we feel so good during the sunny days [33].

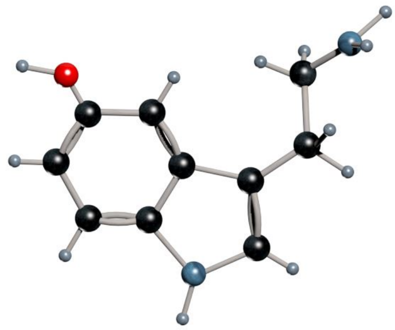

Figure 8. Serotonin.

Dopamine (figure 9) is the hormone of joy and satisfaction, it is also defined as the hormone of motivation, metabolizing in the organism at the beginning of love feeling. It is also the antagonist of PRL (mammotropic hormone) – the hormone of stress and nervousness.

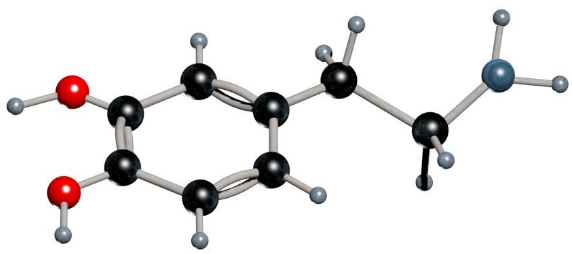

Figure 9. Dopamine.

Dopamine appears like an award for a completed act: the person feels an energy boost, satisfaction from what they have done. That is why this hormone is being connected with motivation. It encourages realization of interesting projects, personal achievements, heroic acts etc [33].

The chemistry of fear is as fascinating. The adrenaline (figure 10) effect (the hormone of fear) on the vascular system is represented by the hormone speeding up the heartbeat, increasing the blood pressure, but at the same time it dilates blood vessels of heart, the muscles and the internals. Operating through the vessel system, adrenaline can touch almost all the functions of all the viscera, and as a result the forces of defending the organism against stressful situations are involved. Nor-adrenaline (figure 11) is the hormone of happiness and relief. This hormone manages the relaxation, relief and normalization of post stress processes. Noradrenaline neutralizes Adrenaline [33].

While explaining the material above, the students attention can be attracted with the right daily routine, analyze they nutrition, discuss about leisure, hobby etc. This approach will allow to learn more about every student, set up an individual approach, simplify the teacher's work during next lessons.

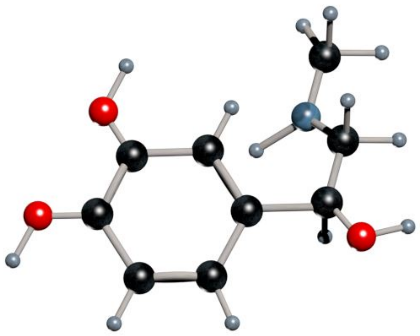

Figure 10. Adrenaline.

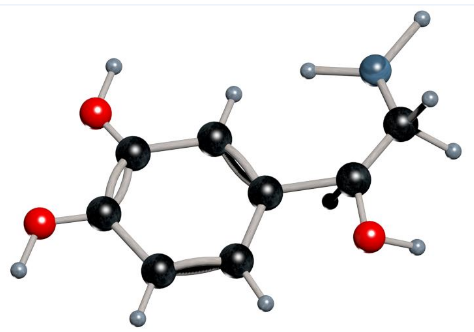

Figure 11. Noradrenaline.

Discussing these everyday, real-life problems, activates the student's semantic activity, motivates for study, develops critical thinking, etc. For example, everybody is familiar with the feeling of pain, which means everyone can share certain opinions, experience. That is why this subject can easily be taken to explain the structure of organic compounds, their features, existing area, effects on the human body. These knowledge are extremely necessary in order to form professional qualities of the upcoming chemistry teachers, as far as in chemistry lab, students and the teacher are permanently exposed to dangerous chemical substances. A careless performance of a practical work or a laboratory experiment, inappropriate safety regulations management can be a result of a critical situation during the lesson. In this case, the knowledge of toxicological chemistry will help the teacher act hard-and-fast to deal with the situation.

The pain system of a human body works with different chemical substances, the structure of which can be viewed in 3D. One of the substances, causing pain is bradykinin (figure 12) – a peptide, that dilates the blood vessels and decreases the blood pressure.

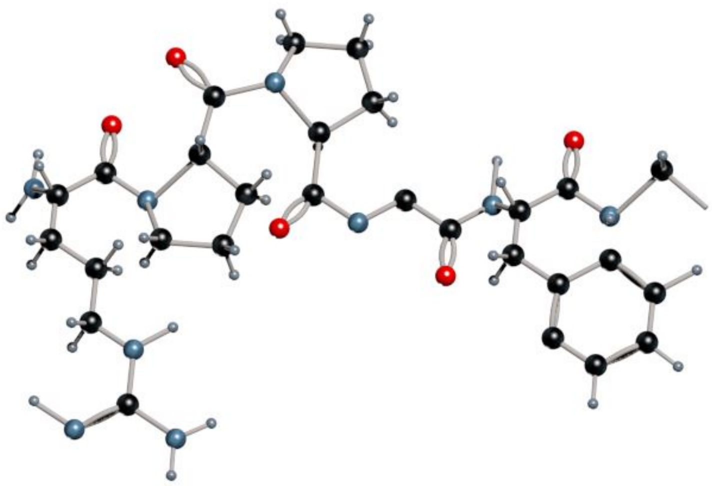

Figure 12. A part of bradykinin.

A 0,5 μ gram of bradykinin causes severe pain [31, 32]. This substance is metabolizes in tissues while they are damaged, or in the blood plasma during the coagulation process.

Histamine (figure 13) is a biogenic substance, that is produced as a result of decarboxylizing the histidine amino acid in the organism [31,32]. Normally, in an organism, histamine is mostly inactive and bound. During different pathological processes (anaphylactic episode, heat injury, freezing, hay fever, urticaria fever and other allergic diseases), the amount of released histamine increases.

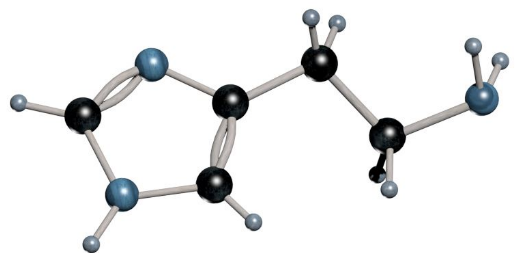

Figure 13. Histamine.

Prostaglandines (figure 14) cause contractions of the unstriped muscles (especially the womb muscles), they have influence on the blood pressure, vascular glands, water-salt metabolism, etc. They are widely used to alleviate the child birth pain, artificial abortion, etc.

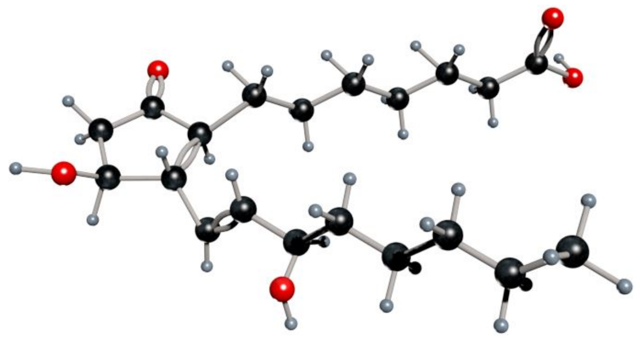

Figure 14. Prostaglandine.

These and many other examples can be used by the teachers during STEM lessons, because the data, given, integrates a couple of subjects in it and includes information and communication technologies. Visualization of the study material makes its reception and memorizing easier. A properly selected demonstration material helps better understand various processes and phenomena, going on in the human body, the structure of chemical compounds and mechanisms of their correlation.

The augmented reality can also be used while studying the nature of bioactive substances, such as chemistry of smell, and also while developing and stand up for a project (Subject 3. Oxygen-containing organic substances: “ethers and esters in cosmetics”).

The smell is a specific feeling of certain volatile substances, present in the air, carried by chemical receptor units of scent (chemo-reception), and located in the nasal cavity of humans or animals. We perceive the smells through our sophisticated nasal sense system. The nasal system – is the least investigated system of the human body. Even nowadays, the scientists are still trying to define all the physical specifics of the nasal sense mechanism.

It is known, that the human can only perceive five main smells – mint, camphor, floral, ethereal and musky. All the others are received by combining the main ones.

Osmophores are molecules, which have a smell and are defined by the following features: volatility, low water solubility, good solubility in organic solvents.

Nowadays, the tight interconnection between the molecular structure and the smell of the substance is not established, only particular trending characteristics were noticed.

Fragrant substances with a pleasant smell, usually are representing the following classes of organic compounds: terpenoids, ketones, aldehydes, esters, heterocyclic ring substances (figure 15, 16, 17, 18).

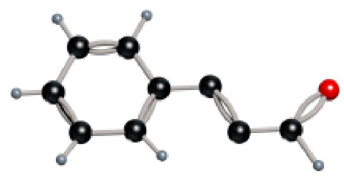

Figure 15. Cinnamic aldehyde.

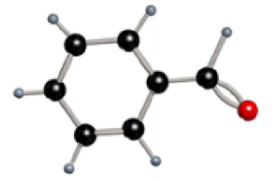

Figure 16. Benzole aldehyde.

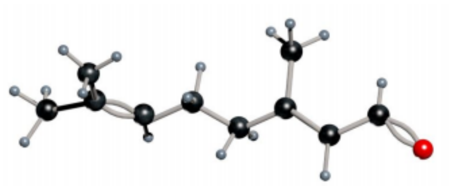

Figure 17. Citral.

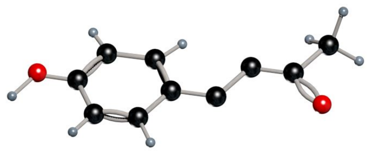

Figure 18. Raspberry ketone.

Depending on which acid and alcohole are involved into the esters, their smells vary.

Isoamyl formiate (figure 19) is the gey component of the plum smell, and isoamyl acetate (figure 20) has the duchess pear flavour.

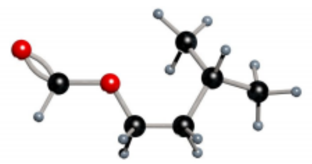

Figure 19. Isoamyl formiate.

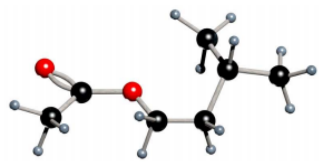

Figure 20. Isoamyl acetate.

Isoamyl valerate (figure 21) and butyl buterate are responsible for the flavours of fresh apple, banana and pineapple.

In this way, mixing and varying the acid and alcohole component of ester, different fruit smells can be modeled. This is the task of Chemistry of Aromatic Substances.

Furthermore, the smell can be consequenced by heteronuclear compounds. In this way, 2-acetylpiridine (figure 22) has the popcorn flavour, 2-methyl-4-methoxypyrazine (figure 23) – the fresht bread crust flavour.

Indole (figure 24) smells like jessamine flowers, maltol (3-hydroxy-2-methyl-4H-pyran-4on) (figure 25) has a fruit-caramel odon.

Unpleasant smells are investigated much less, but for the plants, they do the same task, as the pleasant ones – they attract the insects for pollination. There is a wide-spread belief that the human is more sensitive to unpleasant smells.

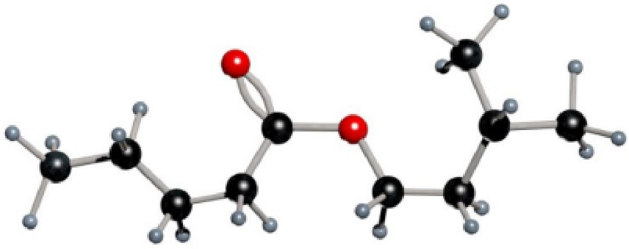

Figure 21. Isoamyl valerate.

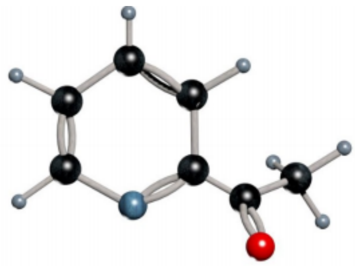

Figure 22. 2-acetylpiridine.

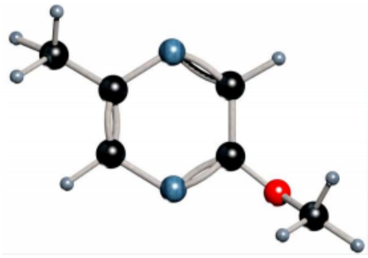

Figure 23. 2-methyl-4-methoxypyrazine.

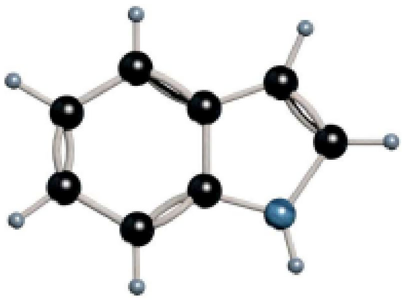

Figure 24. Indole.

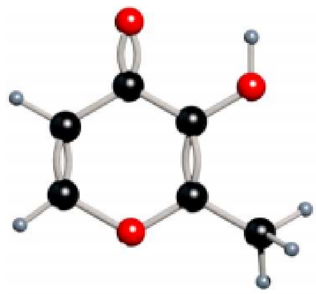

Figure 25. Maltol.

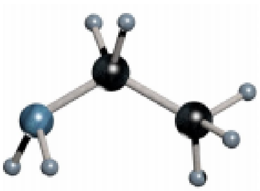

Figure 26. Ethanamine.

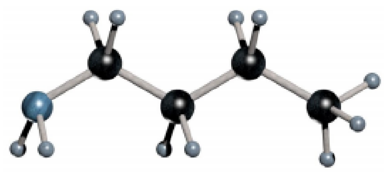

Figure 27. Butane-1-amine.

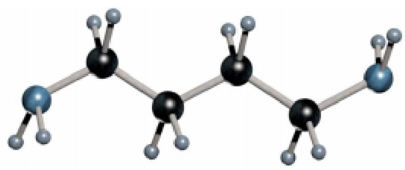

Figure 28. Putrescine.

The major part of the unpleasant flavour among plants is provided by amines (fish smells) (figure 26, 27, 28).

Sulphur-containing compounds (figure 29, 30), like thiols and disulphides have extremely unpleasant, strong smells. Isoamyl mercaptan gives the smell of skunk secretion. Cases are known, when people fainted, breathing in the emissions of these animals.

Disulphides are responsible for the strong smell of some plants, for example garlic and onion. The animals themselves do not have these compounds, but when an onion or garlic is cut, the

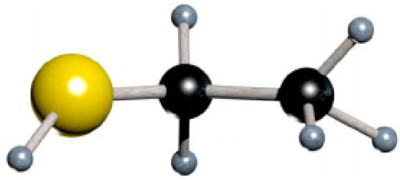

Figure 29. Ethyl mercaptan.

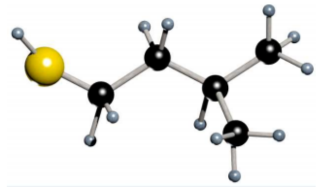

Figure 30. Isoamyl mercaptan.

amino acid cysteine, containing the –SH group, under the influence of ferments is transforming into disulphides with a smell.

While explaining the material above, the students' attention can be attracted on the influence of the structure of chemical substances on smell: the carbon chain length, the nature and quantity of functional groups, the specifics of spatial structure of molecules and the nature of substituting groups in the benzene nucleus; the ability to model different fruit smells (mixing and varying the alcohol and acid components of ester).

As far as the investigated substances are organic, the STEM lessons in the subject, being offered, are suitable for 9^{th}-10^{th} grade students, in order to boost interest while studying organic chemistry. The mobile application, developed, was tested by 9^{th} grade 99 students, and was given positive reviews by 90% of those surveyed.

3. Conclusions

The integrated lessons fascinate with innovation, with capability to involve alternative ideas and original approaches into the school course. The experience proves that the extensive use of information and communication technologies has benefits in achieving the general aims of education, building communication values: the ability to collect facts, contrast them, organize information work, express own thoughts on paper and verbally, think logically, listen and understand the written and verbal language, discover something new, make choices and decisions.

Applying new information technologies in study allows differentiating the study process, taking to consideration their individual features, gives the creative teacher the ability to spread the spectrum of study data presentation methods, allows performing a flexible management of study process, is sociably valuable and up-to-date.

Augmented reality gives the opportunity to visualize the object to the limits, meaning convert 2D images into 3D, and "make it alive". Applying this ICT tool while studying new material gives the students an opportunity to improve their imagination (spatial awareness), "to see" and bring a deeper understanding of the theory, heard, which upgrades its perception and builds certain practical skills, furthermore, it is working on a cellphone, which is an advantage of AR.

Integrated lessons with augmented reality are powerful boosters of the intellectual work of a child. The efficiency of these lessons is higher, comparing with the regular ones, as far as during the study process, the students carry on creative, investigational work, receiving high-quality visualization of study material. This provokes a solid curiosity to the subjects, develops perception activity of the students and is a part of STEM education.

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Journal of Physics: Conference Series

Mobile technologies providing educational activity during classes

To cite this article: S L Malchenko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012010

Mobile technologies providing educational activity during classes

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Abstract. Modern mobile technologies have become widespread in our lives. All of us use them every day. The use of mobile phones in education is a topical issue too. This paper presents the methodological features of the use of mobile technologies in the astronomy's class. Modern methods offer a lot of techniques and innovative forms of teaching methods in order to improve students' knowledge. These innovations are aimed to increase using activity-based and person-centered approaches to learning and also, they will help to intensify students' training activities therefore. The including mobile technology in education process will be engage and productive. We used mobile technologies for the organization of practical tasks from astronomy, as well as the possibility of individualization of education is shown. The such tasks help to increase students' cognitive activity. It is presented in the article, as an example for astronomy studying, there is example of mobile phone using for the Moon research.

1. Introduction

Nowadays informatization tendency of society and digital technologies development have an impact on the educational process [1]. Due to the conception of new Ukrainian school [2], a new type of education must be implemented at secondary educational institutions. This type of education, in general, aims at studying and supporting the civilization achievements, form a person being able to implement new innovational changes, to solve the problems which a person faces as well as a society. If earlier students used their computers at home or at informatics lessons, now the most students have a mobile phone, a tablet or an e-book. So, the use of education and development information materials with the use of these devices is a significant pedagogical reserve. Heading the interest in mobile technologies to education, students' cognitive activity may be significantly increased. Such education supposes constant students' involvement into active educational and cognitive activity. This encourages them to initiative, creative approach and active position in all kinds of the mentioned activity; it supposes not only getting but also gaining knowledge and skills, projecting their own world view, student's formation of the key competences, so that increasing the result of educational process [3]. It heads educational skills for the whole life.

Astronomy is the science about the Universe and its development, and the main goal of studying astronomy in secondary educational institutions is the end of formation of world natural and science picture [4, 5]. In the most modern secondary educational institutions astronomy is studied in 11^{th} grade, consequently a paradox appears: students are interested in space and the Universe but they have low motivation to study the astronomy school course. For better students' understanding and absorbing of the material a teacher constantly has to use various visualization aids, using photo, animation, video, schemes, 3D models demonstration. The use of non-standard forms and technologies increases motivation of astronomy studying. The use of interactive tools, multimedia boards, computers or mobile apps in combination with books, as well as combination of educational material with known and interesting information can attract student's attention, also it will stimulate him to more serious and responsible attitude to the subject. So, with the help of the mobile apps they can study starry sky, the Solar system, star building and evolution, as well as observe different astronomical phenomena [6, 7]. The quantity of astronomy apps increases but the methods of their use at astronomy lessons are not enough described. Therefore, the relevance of the paper is in the necessity of working out the manuals for implementing the mobile apps use at astronomy lessons for practical classes organization.

2. Problem overview

Increasing devices quantity and their interference into people's life encourage to overthinking the significance and opportunity to get information in different spheres of activity including education. Modern "digital society" has a new thinking type (clip thinking). That's why a teacher must build educational process in a new way and use actively mobile education technologies.

Increasing tendency of mobile phones use in educational aims is observed throughout the world. Students and teachers use these devices in most cases for exchanging the information, consultations with dictionaries and thesauruses [8].

The foundations of mobile learning is still under development [9–11]. Due to the definition [12] mobile learning is a type of distance education and an opportunity of getting and giving educational content on individual mobile tools such as pocket computers, smartphones, tablets, e-books, mobile phones, etc. Educational content is included into digital educational actives which, therefore, include any form of content or media available on an individual mobile device.

Mobile technologies are a wide spectrum of digital and fully portable mobile tools (smartphones, tablets, e-books etc.) that allow to operate with information getting, processing and spreading [13–16]. Mobile technologies improve methods and ways of access to information and its presenting so that leads to the creation of new or improving existing forms of material processing [17, 18]. In general, education becomes personalized, accessible and non-restricted by time measures [19]. The main peculiarity of mobile learning differentiating it among other educational technologies is its mobility [20]. Considering the above mentioned pros of mobile learning, it can never substitute traditional education but its proper use can significantly increase the meaning of existing educational styles [21].

Kong in her research [22] studied lecturers' experience in educational mobile systems use. His conclusions defined five topics among which there are (a) lecturers' perception of mobile learning, (b) motivation to use mobile learning, (c) behaviour standards in the mobile learning use, (d) problems with the accepting of mobile learning and (e) advantages of the mobile learning use. Gan and Balakrishnan [23] studies the factors which impact on the mobile learning perception and can improve the interrelation of a lecturer and students during a lecture, in particular, the use easiness, self-effectiveness and satisfaction. In the research devoted to the college lecturers in Kentucky and Tennessee Thomas et al defined the determinants of accepting the mobile learning including Internet access, educational programmes, calculators and calendars. Potential obstacles include students' cheating, inappropriate information in the Internet, threatening in the Internet and failure. Mobile learning in the developing country is studies in the research [24]. The results show opportunity of complex education through knowledge exchange, academic societies development and immediate communication. Recommended mobile learning can create common educational environments that consequently may broaden active educational opportunities [21].

The theoretical aspects of mobile learning were researched by K. L. Buhaichuk [25], V. Yu. Bykov [26], Y. O. Modlo [18], N. V. Rashevska [27], S. O. Semerikov [28], S. V. Shokaliuk [29], K. I. Slovak [9], A. M. Striuk [30], I. O. Teplytskyi [31], V. V. Tkachuk [32] and others.

V. Yu. Bykov [26] researched criteria of mobile learning in the educational process, the use of mobile devices of all types and also their purpose and role in education whereas K. L. Buhaichuk [25] paid attention to didactic opportunities of mobile apps. N. V. Rashevska [27] studied advantages and disadvantages of mobile devices use in the students' educational process of higher educational institutions. M. Oprea and K. Miron also pay attention to mobile learning [33]. There are works devoted to the problems of implementation and use of mobile devices via physics teaching. J. Trucksler and M. Oprea [34] emphasize that mobile devices broaden the diapason of time measures of information perception.

The disadvantage of mobile phones use is emphasized in the researches [35] due to their negative impact in children's behaviour. The other researches describe the average and middle level of teachers and students being ready to follow as well as general research tendency [24, 36, 37]. Mobile phones use in the educational process improves cowork between students and lecturers, provides immediate communication, strengthens students' participation and interrelation, encourages authentical education and reflexive practice, also it broadens opportunities for educational societies and changes in lecturers' approaches [8].

The research [8] deals with the lack of being ready to use mobile technologies in the educational process, low experience of mobile devices use is mentioned. So, to get more positive result of mobile technologies implementation in the educational process it is necessary to develop skills and culture of mobile telephones use.

3. Results and discussion

3.1. Information

Nowadays different educational mobile systems, video connection systems, distant courses, mobile apps, electronic publications, lessons, projects, students' progress registers, test schemes, social networks, e-mail are created [38–41]. General recommendations for computer and mobile apps implementation in to the educational process are worked out.

For example, such programmes for teaching different disciplines are used:

- English Platinum 2000, Triple Play Please [40] for teaching foreign languages;
- Multiplication table, Pythagor, Formulas, Math Board, Math Helper [23], Mathway, Algebra Touch [8] for teaching mathematics;
- Geography, Compass for Android for teaching geography;
- Chemistry, Mendeleiev periodic table Android, Merck PTE HD for teaching chemistry;
- Power of Minus Ten – Cells and Genetics, Sleep as Android for teaching biology;
- 3D Anatomy for teaching anatomy;
- Audacity, Test Tone Generator, Angle Meter, Smart Measure, Android Speedometer [42], Constant Table, Learn Physics, Serious Physics, Physics at school, Physics. Formulas 7-11, Physics, Physical calculator for teaching physics.

The articles [42–49] considered the issues of mobile phones use at school physics lessons.

The use of computer and mobile apps in astronomy are offered by Iryna Pakhomova on her website [50], also the examples of getting data from apps to solve the astronomy tasks are presented in the work [51]. There are websites where the use of astronomy mobile apps is described.

The most scientists define some important positive moments that significantly increases teaching effectiveness:

- personalized education,
- immediate feedback,
- effective use of educational time at lessons,
- continuity of the educational process,
- qualitative new level of educational process management.

Mobile devices are usually students' possession and that's why students can use them the whole day and not only at the lessons. Therefor mobile technologies allow to individualize more particular student's education, to create conditions in respect to which a student will have his own tasks that take into account his skills and inclinations, interests and experience. A student will be able to use his mobile device for tasks fulfillment (task solution, text reading, watching the content having educational content etc.) in convenient time for him. At the same time "personalization" has also another meaning which is related to collecting information about mobile technologies users. Different users prefer different ways and forms of information watching and perception (tables, diagrams, texts etc.). So, personalized technologies development will allow students to choose the form of information reading in future.

One more important aspect of personalized education is different tempo of educational material absorbing for students with not equal abilities. The use of traditional methods of teaching and information and communication technologies, connected with desktop computers, allowed only partially to differentiate new information presenting and absorbing for the students with different educational abilities. The use of mobile devices significantly broadens the measures of educational material presenting and absorbing. It is connected with the opportunity of their use out classrooms. In such a way, mobile technologies correspond person-oriented approach to education and increase it to the qualitative new level.

Astronomy due to its meaning is a visual science and has certain practical direction, in particular, it is presented in the ground navigation due to the position of celestial bodies, geographical position determination, time measurement, gaining skills of the use of angle-measuring and optical instruments, task solving with the use of formulas of astronomical calendar and map of starry sky. Students' knowledge and practical skills in astronomy must be tightly connected with modern state of science and manufacture, correlate with demands of new high-tech society.

Computer and mobile phone use broadens opportunities also in teaching astronomy. These are computer and mobile planetariums, astronomical database, 3D models, animations, atlases of space objects images, in particular, images of planets and their satellites got with the help of rocket and space tools, simulators, computer tests and self-control of knowledge. Interactive apps due to their didactic purpose may be divided into:

- demonstrative,
- educational,
- controlling,
- trainers,
- imitative (simulators).

The programmes that are included to the first group demonstrate astronomical phenomena, processes etc. Such programmes can be used for new material demonstration and illustration. Models made for calculation celestial bodies coordinates, also they can be used for holding practical and laboratory classes, demonstrating the methods of task solving, experimental task fulfilling, for control and self-control. Programme-trainers and imitating models (simulators) may be used at laboratory and research works. Immediate feedback is reached with the help of the use of mobile programmes or platforms (aimed to be used on mobile devices or computers) having a goal to assess training results faster and to monitor gained results by students.

To automize the process of gathering, analysis and defining transcripts about students' training success on the classes we can use the platform Plickers for mobile phones [14]. The assessment of students' answers arises immediately and a teacher can see the information on his screen, in particular, about the quantity of right and false answers with mentioned students' surnames, diagram of general quantity of answers. This allows teacher to predict further steps at the lesson in choosing the educational material (which was absorbed by students not thoroughly) for re-review.

A big quantity of other mobile apps, platforms and resources exist (Google Forms, Survey Monkey, Kahoot!, Socrative etc.), with the help of which a teacher has an opportunity quickly to assess students; knowledge and skills. As a rule, these programmes can work on different operational systems (Windows, Linux, macOS, Android, iOS), so that a student can answer on control questions or take a test on his own mobile device, not from a desktop computer of an educational institution.

Mobile apps are better to use not on the certain astronomy lessons but during the whole educational process. At first, students get acquainted with an app, get skills how to use it, and then during learning of peculiar topics students accomplish different tasks of practical character, get new knowledge and reinforce the old one. As experience shows, at the beginning students are interested in the use of apps and spend a lot of time for studying possibilities of any app, but sooner or later with teacher's clear instructions students quickly accomplish tasks. Not to waste the time it is recommended to give practical tasks with the use of mobile apps as a hometask.

There are a lot of mobile apps of educational aim and, as a rule, they have different purposes:

- guides or encyclopedias,
- quizzes or tests,
- e-books,
- star maps,
- virtual travellings,
- 3D models.

To learn the building and celestial bodies of the Solar system except the use of photos, maquettes and video we can use special apps like planetariums that allow not only virtually to travel throughout the Solar system but also to study the characteristics of planets, satellites, comets and asteroids. With the help of planets 3D models students can study the type and size of planets. There are a lot of such apps and most of them have similar structure and opportunities: Solar System Scope, Solar Walk 2, Amazing Space Journey etc. (description and opportunities of their use are presented in [52]).

There are such mobile planetariums like Stellarium, Sky Map, Google Sky Map, SkySafari, Star Chart, Star Walk, Star Walk2 and Solar Walk, etc. Descriptions of work with these programmes are presented in the Internet. Using these apps we can study observable motion of the Sun, observable motions of planets, their building and physical characteristics and also other planets of the Solar system. Kepler's laws. Accomplishing such tasks students have their spherical imagination developed, they understand astronomical phenomena and terms well, they can easily orientate on the ground with the help of position of the Sun and other celestial bodies.

3.2. Experiment

Holding astronomy classes with the help of information and communication technologies, in particular, mobile apps provides students' gaining not only subject competences but also it creates additional opportunities for laboratory experiments in the conditions of virtual reality existence. Person-oriented education, fast access to information, easy form of checking knowledge are provided during this process. The use of mobile apps was offered to the students of the faculty of physics and mathematics and 11th form students. There were no serious problems except those that were described in the previous works (Internet access, storage volume, battery charge, mobile phone quality). School students occurred to be less ready to use mobile phones for practical tasks accomplishment. However, when computer analogues to mobile apps were offered, they preferred to use mobile ones. This can be explained with the fact that mobile phones are all the time available and they can be used any time, also all the students have mobile phones of batter or worse quality, and a home computer may be used by some family members.

Here is one of the tasks offered to students: the research of motion of the Moon and the study of Moon surface.

The programme Moon Globe may be used for the study of Moon surface (figure 1). The detailed Moon map allows to study lunar craters, mares and mountains. The app defines user's place and shows Moon location. Also, you can turn on another regime and turn the Earth satellite to any side in order to see everything thoroughly. To study Moon landscape students can be offered to use this app or some similar and to accomplish such tasks:

- Find on the Moon surface seas; Sea of Crises, Sea of Tranquility, Sea of Nectar, Sea of Cold, Sea of Showers, Sea of Cleverness, Sea of Clouds, Sea of Moisture, and Ocean of Storms; craters: Ptolemy, Alphonsus, Copernicus, Kepler, Aristarchus, Herodotus; mountains: Teneriffe, Montes Recti, Montes Alpes, Montes Caucasus, Montes Apenninus, Montes Taurus; Piton, Pico.
- Write down 5 names of seas, craters and mountains that are the largest.
- Find craters which are called after famous people.
- Compare observable Moon side with non-observable one (that can't be seen form Earth).

Observable Moon motion with stars backside shows the real Moon motion around Earth which is followed by the changes of our satellite appearance. We can study Moon motion and its phases with the help of mobile apps Moon Phases (figure 2). This app is designed by M2Catalyst for Android, it is free and has Ukrainian language interface. The app contains the information about Moon rise and set, lunar phase, distance to Earth and the constellation of stars the Moon is in. You can get the information for any date, it is enough to turn Moon image.

This app can be offered for students to study motion and conditions of Moon observance: Moon motion on celestial sphere during a month; synodic and sidereal Moon; lunar phases, attribution of Moon position on the starry sky in different phases; Moon position relatively to the horizon in different spheres. To accomplish this task we offer student to fulfill such a table 1 based on data for the straight month.

Table 1. Example of task for student.

Data	Day in lunar calendar	Time of rise	Time of set	Phase (lighting)	Location on the stellarium

Here is the example (table 2) of such task accomplishment.

Figure 1. Interface of Moon globe.

Having fulfilled the table students are to analyze the data and make conclusions about:

- Time during which the Moon changes its phase (synodic period).
- Time during which the Moon makes Earth revolution (sidereal period). To do this a student must analyze the time when the Moon returns to the same constellation of stars.
- How the Moon moves on the starry sky. Pay attention that the Moon goes through all of the zodiac constellation of stars m so that Moon motion as Sun motion is projected on the ecliptic.
- The time of Moon location over the horizon.
- Pay attention at dates of lunar phases, interval between young Moon (new moon. 0%), first quarter (25%), third quarter (25%), full moon (100%).
- The best observance conditions. It may be difficult for students to do this independently, so a teacher asking additional questions can help to get their own conclusions. To accomplish this it is necessary to analyze the time of Moon rise and set and lunar phase. If the phase is 0%, the Moon is over the horizon at noon and it cannot be observed. Moreover to observe Moon with the help of telescope during the light part of the day is irrational as craters and mares on the Moon surface are not distinct.

Figure 2. Interface of Moon Phases.

Table 2. Example of task for student (completed).

Day in lunar calendar	Time of rise	Time of set	Phase (lighting)	Location on the stellarium
0	6:59	17:01	0	Aquarius → Pisces
1	7:23	18:05	1	Pisces
2	7:44	19:01	4	Pisces → Aries
3	8:03	20:11	8	Aries
4	8:22	21:14	15	Aries
5	8:41	22:17	22	Aries → Taurus
6	9:01	23:22	31	Taurus
7	9:26	0:27	40	Aries → Taurus
8	9:55	1:34	50	Gemini
9	10:30	2:39	60	Gemini
10	11:15	3:39	70	Gemini → Cancer
11	12:11	4:32	80	Cancer
12	13:19	5:17	87	Cancer → Leo
13	14:35	5:54	94	Leo
14	15:57	6:26	98	Leo → Virgo
15	17:20	6:53	100	Virgo
16	18:43	7:19	99	Virgo → Libra
17	20:06	7:45	94	Libra
18	21:28	8:11	87	Libra → Scorpio
19	22:37	8:36	81	Scorpio
20	23:47	9:02	71	Scorpio → Sagittarian
21	0:04	9:26	61	Sagittarian
22	1:15	9:57	50	Sagittarian → Capricorn
23	2:19	10:46	40	Capricorn
24	3:13	11:42	30	Capricorn
25	3:58	12:43	21	Capricorn → Aquarius
26	4:34	13:47	14	Aquarius
27	5:03	14:52	8	Aquarius → Pisces
28	5:28	15:56	4	Pisces
29	5:50	17:00	1	Aquarius → Pisces

After the full moon it rises very later, in the third quarter, the Moon can be observed in the second half of night and in the morning so to organize school Moon observance during this period will be difficult. That's why a teacher together with students must conclude that the best period to study Moon surface is the first quarter (the Moon can be observed in the evening and in the first part of night).

Such task accomplishment is exciting for students, it has problem character and the conclusion made by students (with a teacher) are similar to their own scientific research. Students can easily remember this knowledge.

Such type of practical class was offered to university students and they demonstrated research traits, also they conducted the observance with great interest and made their own conclusions. The main result was that after such a task they could easily define if the Moon was observable in the sky, when (which date to choose) they need to organize evening Moon observance with the help of telescope (i.e. the Moon will be over the horizon in the evening and first part of night), got to know relief details of the lunar surface.

4. Conclusions

The practice of telling school students about the Universe apparition or about black holes with the use of an ordinary textbook or in simple terms is not effective. Abstract data hardly can impress someone. The use of visual materials is far another idea, especially, added with 3D images and the use of mobile apps to organize practical classes. There are really a lot of relevant resources in astronomy. Some apps are really familiar to the students but they do not use them for study.

The approbation of mobile apps use showed that students are ready to use them during the educational process even though it demanded more detailed instruction of app use, also it increased students' interest in the accomplishment of these tasks. Moreover, such tasks change education from explaining and illustrative to partly studying and even research method which provides much higher level of cognitive activity activization.

The analysis of methodic peculiarities of mobile technologies use in the educational process in astronomy makes the base to make such conclusions:

- the formation of students' information and digital competence as a key oine in modern world supposes a wide use of information and communication technologies in the educational process, especially the mobile technologies use in the educational process;
- mobile learning at secondary educational establishments has more advantages in comparison to the traditional use of information and communication technologies in education. It can be explained with rapid spreading of mobile devices and apps as well as their accessibility. But a significant need of implementing mobile learning is methodic working out of methods and ways of mobile devices and apps use in different didactic situations;
- school students even senior ones are not ready enough to implementing mobile technologies into the educational activity, even though they master enough mobile devices and some apps and services. Unfortunately, students and teachers are not ready to use educational potential of many mobile apps. That points at the fact that implementation of mobile learning demands purposeful training both students and teachers for such educational activity, particularly, to use the way of highlighting methodic peculiarities of the use of mobile learning techniques in the educational practice.

It should be pointed also problems and difficulties that take place during mobile technologies implementation:

- the students may have mobile devices with different technical characteristics (or different operational systems) that can make impossible to install certain apps and therefor effective devices use at the lesson;
- students' mobile devices may have low battery charge (or its low power) and therefor quickly discharge during the lesson;
- poor mobile Internet (absent Wi-Fi) may take place at school location and therefor it can be an obstacle for the use of online resources;
- children may feel jealous to the classmates who have devices with better parameters (newer, more power-ful);
- it is difficult to organize educational process in such a way that students will not distract at unwanted apps or Internet-services and also if an educator does not know about the opportunities to use mobile devices for his subject study.

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The use of MOOCs as additional tools for teaching NoSQL in blended and distance learning mode

To cite this article: I S Zinovieva *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012011

The use of MOOCs as additional tools for teaching NoSQL in blended and distance learning mode

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Abstract. Today there is a significant demand for improving the quality of the educational process in higher education institutions, in particular, through the improvement of principles and methods of teaching various sciences by enhancing the practical skills of students and graduate students. The implementation of this task is particularly difficult in the context of distance learning (for full-time and part-time) and blended learning. This study corresponds to the current direction, as it concerns the study of the possibilities and feasibility of using additional tools for teaching disciplines within NoSQL. Paper's focus is on the justification of the use as an additional tool of a number of massive open online courses (MOOC) distance learning platforms, a comparative analysis of a number of platforms for their compliance with the established criteria. Examples of using MOOC MongoDB University within the discipline "Organization of NoSQL databases" are given. To confirm the facts of the expediency of using MOOC as an additional tool in blended learning and distance learning mode, the data of the survey of students are presented.

1. Introduction

Modern university science in Ukraine is aimed at training highly professional specialists in various fields, developing the scientific potential of the country through the formation of relevant competencies of applicants at I–III levels of higher education, creating conditions to ensure the possibility of "lifelong learning" for effective self-realization. The basis of the modern paradigm of higher education is the need to form a culture of intellectual activity, which, among other things, involves: the acquisition of skills and abilities to adapt to the external environment and the changes that occur in it; development of the innovative type of thinking; the desire to learn. The above is relevant for both applicants for higher education and institutions that provide educational services.

The reality of recent years is that the need to transform the ways and methods of organizing the educational process has become a challenge for all, without exception, higher education institutions (HEIs) around the world. The transition to distance learning [1–3], and later – blended learning [4, 5], has given impetus to the active development in the market of various educational platforms, software for organizing conferences, platforms for storing educational content and video hosting, etc. In addition, it became clear that the organization of the educational process in distance mode or blended form requires not only the availability of appropriate software and hardware resources but also requires consideration of the specifics of training higher education, including specialties and educational qualifications, specifics of educational-professional (educational and scientific) programs, the profile of HEIs, the expected learning outcomes.

The study of databases (DB) is a mandatory component of the training of specialists in various specialties and fields of knowledge in the context of the concept of Industry 4.0. Databases are part of a number of digital technologies, such as mobile applications [6], GIS [7], multimedia [8], Grid and Smart technologies [9], Artificial Intelligence [10], etc. According to Complete Ranking, prepared by DB-Engines [11], in December 2020 the most common DB in the world were (by rating's place): 1) Oracle, 2) MySQL, 3) Microsoft SQL Server, 4) PostgreSQL, 5) MongoDB, 6) IBM Db2, 7) Redis, 8) Elasticsearch, 9) SQLite, 10) Cassandra. From the presented list 6 objects belong to the Relational DB class, and 4 – NoSQL (MongoDB, Redis, Elasticsearch, Cassandra), and NoSQL databases show the upward dynamics of popularity for the last few years in a row, as shown in figure 1.

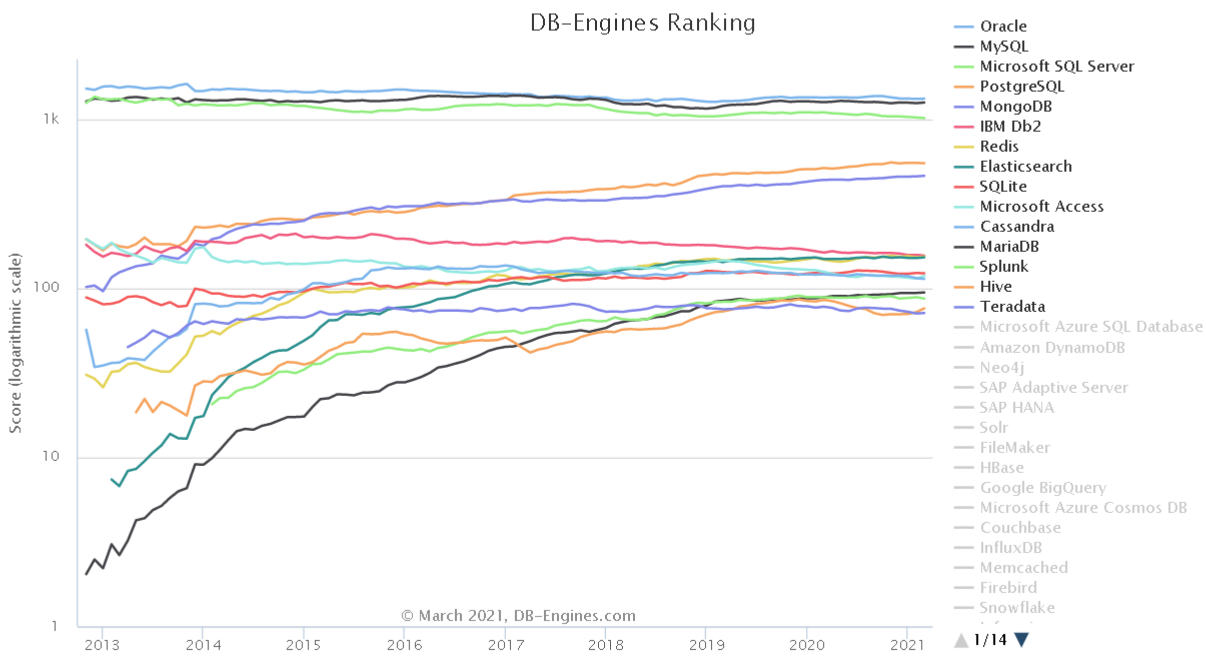

Figure 1. World popularity rating of modern databases according to DB-Engines [12].

For example, the familiar platform for distance learning Moodle [13] can work on the basis of database servers such as MySQL/MariaDB, MongoDB, PostgreSQL, CouchDB, Microsoft SQL Server [14].

These data show that NoSQL databases are important in the IT market, as the modern digital world and modern technologies, for the most part, require the operation of large amounts of unstructured data, support for simultaneous operation of a large number of users, horizontal scaling, application of cloud technologies, ensuring a high level of performance, fault tolerance and reliability [15]. Changes in global trends in IT and databases, in particular, require constant updating of curricula of free economic zones and research institutions to prepare students and graduate students, especially for specialties whose future professionals must master the professional competencies of working with NoSQL databases. In addition, given the current challenges to the higher education system, it is necessary to change approaches to teaching disciplines related to the study of NoSQL databases, in the direction of using a wide range of software tools to improve the quality of teaching in distance learning and blended learning, which is confirmed by the results of the study presented below.

2. Literature survey

The issue of the introduction of modern digital technologies in the educational process of HEIs and research institutions, which increase motivation to study, stimulate students and graduate students to acquire new knowledge and skills, is not new, but now – is quite common and relevant. Various aspects of the application of digital technologies in the training of students and spirants are described in [16–26] and others papers.

Thus, in recent publications [27–33] more and more often the subject of consideration are the problems of effective organization of various learning technologies (e-Learning, mobile learning, blended learning) using online tools, analyze the possibility of transition to specialized platforms for distance learning (Moodle, Google Classroom, iSpring Online, etc.), evaluates the feasibility and effectiveness of their use.

Given the level of penetration of online tools into the learning process are distinguished (by model): traditional, distance, and blended learning [34]. If earlier scientific discussions revolved around the expediency or inexpediency of distance education in the practice of HEIs and research institutions, then, in a global pandemic, blended learning has become a new norm of teaching and learning around the world [35,36]. In particular, the study [37] emphasizes that in comparison with exclusively traditional or exclusively distance learning, blended – shows greater effectiveness because it combines the best features of the previous ones. The use of modern online tools for blended learning allows to support the educational process 24/7, increases the involvement and motivation of students and graduate students, accelerates the development of professional competencies, and forms actual skills for the 21st century [38].

Regarding online technologies, the research of the author's team [39] gives grounds to identify the following key groups of such technologies:

- MOOC platforms (Coursera, edX, Codecademy, Udacity, Khan Academy, HTML Academy, etc.);
- learning management systems – LMS (Moodle, webTutor, iSpring, Canvas, Office 365, etc.);
- online programming judge systems – tools for organizing and supporting various competitions (competitions, quizzes, hackathons, etc.), such as UVa Online Judge, Google Code Jam, E-Olymp, etc.;
- online coding platform – tools for learning and honing knowledge of programming languages (Leetcode, Hackerrank, Freecodecamp, etc.);
- knowledge assessment tools – various platforms for assessment and testing (Classtime, Kahoot, Onlinetestpad, LearningApps, etc.);
- tools of online communication and video conferencing (Zoom, Google Meets, Skype, MS Teems, BigBlueButton, etc.).

As known, the platforms of Massive Open Online Courses (abbreviated as MOOC) are distance learning platforms that contain training courses, which usually include theoretical and practical components of future training, as well as tools for intermediate and/or final control. The issue of improving the efficiency of the educational process in HEIs and research institutions using MOOC platforms, in particular, such as Coursera, edX, FutureLearn, is covered in [24, 40–55].

Features of design, architecture, query language SQL database, and the question of their use in the training of specialists in various specialties are considered in the following publications [16–19, 56–61].

In [56] the problem of using a cloud-oriented environment in the training of databases of future computer science teachers is investigated. The choice of cloud-based tools for training databases is substantiated. A model of using a cloud-oriented environment in database training has been developed. Guidelines are provided to teachers on the use of cloud-based distance learning systems, in particular Canvas in database learning.

The need to introduce into the curriculum of training specialists in various specialties of disciplines that study the principles of working with various databases NoSQL is emphasized in [62]. In this context, it seems interesting to experience the development of its own platform for the implementation of a distance learning system of students based on NoSQL databases (MongoDB, CouchDB) described in [14]. The purpose of this project was to provide engineering students the opportunity to combine practical and theoretical aspects of the study of NoSQL databases. The paper describes the mechanism of setting up the interaction of LMS Moodle and NoSQL databases, as well as the principles of implementation of training modules that allow you to interact with NoSQL DB in the framework of learning tasks on an interactive basis.

Analysis of the practice of distance learning, presented in [63], showed that the work of students on asynchronous platforms such as Moodle, Canvas, Blackboard Collaborate negatively affects the success of the learning process, as most information must be learned independently (without proper interactive interaction with the teacher). This gives grounds to talk about the feasibility of using a mixed form of organization of the educational process, which provides physical participation of the teacher in the learning process, in which lectures are held online, as well as part of practical and laboratory classes – online, where students can ask questions and get an answer right away. In addition, a number of studies [63, 64] emphasize the importance of a sound approach to the teacher's choice of online technologies and their inclusion in their training course. It is important to assess the current level of motivation of students (determine their expectations), to find out the basic technical skills of working with planned online tools to determine the necessary balance between the amount of asynchronous and synchronous work with students.

Based on the above, the purpose of this study is to substantiate the feasibility of using MOOCs as an additional learning tool in disciplines related to NoSQL DB in blended learning and full-time (part-time) higher education in distance learning.

3. Current work

NoSQL is a new generation of databases characterized by models and technologies of operation, different from traditional relational models. They arose as a reaction to the existing problems of traditional SQL databases. The term NoSQL refers to databases whose models are non-relational. Characteristic features of such DB are:

- Lack of SQL query language and mechanism to support transactions with ACID requirements. NoSQL databases support BASE requirements.
- Work in a distributed environment.
- Horizontal scaling.
- Ability to process aggregated, unstructured, non-normalized big data.
- Lack of rigid data storage schemes.

There is currently no clearly defined classification of these DBs. Most scientists agree that all NoSQL databases can be divided into four groups (according to the data organization model): Key/Value, Tabular Column-oriented, Document-oriented, and Graph Databases [65, 66]. Each of these data models is characterized by structural and technological features that should be introduced to students and graduate students. However, unlike relational models, the implementation of the same type of NoSQL database model can have significant technological features and even structural differences depending on the DBMS that supports it. This complicates the work of the teacher with its variability, does not allow to fully consider all aspects of working with NoSQL DB within the relevant course. Therefore, the study of a specific type of NoSQL DB must be supplemented, for example, by the use as an additional learning tool MOOCs platforms.

Indicative, in our opinion, is the experience of using MOOCs in the study of disciplines related to DB NoSQL in Kyiv National Economic University named after Vadym Hetman (or abbreviated – KNEU). In this HEI the discipline "Organization of NoSQL databases" [67] is taught at the first (bachelor's) level of higher education since 2018 and has undergone a number of evolutionary transformations in the context of the transition from traditional learning (2018/19 academic year) to distance (2019/20 academic year), and later blended learning and distance learning (2020/21 academic year), as shown in figure 2. In G.E. Pukhov Institute for Modeling in Energy Engineering of NAS of Ukraine prepares masters and graduate students in the specialty 122 "Computer Science" in the field of knowledge 12 "Information Technology". Therefore, the issue of updating the content and operational components of academic disciplines related to the design and study of databases is also relevant. The experience of KNEU on the use of MOOC in the training of future specialists by the authors of the article will be extended to various institutions, including National Aviation University, Interregional Academy of Personnel Management, National University of Civil Defence of Ukraine and State Institution "The Institute of Environmental Geochemistry of National Academy of Sciences of Ukraine".

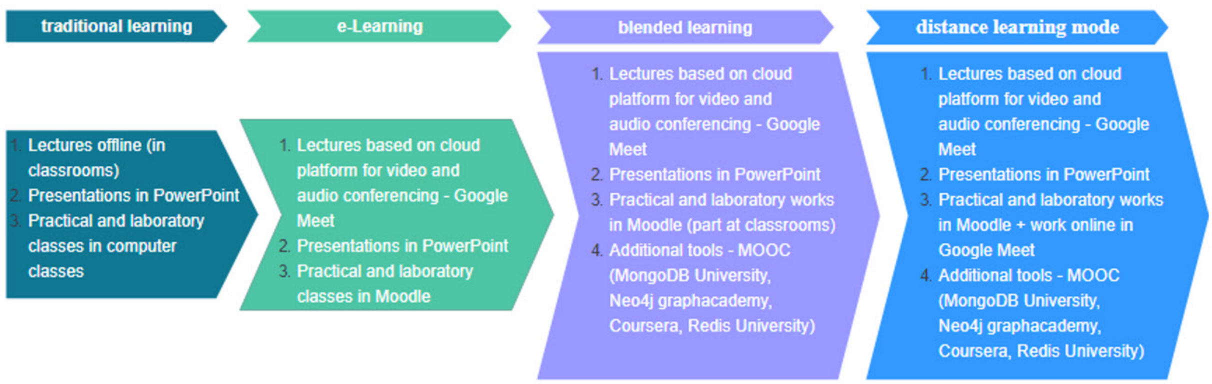

Figure 2. Transformation of the discipline "Organization of NoSQL databases" according to different models of learning organization.

At the stage of organizing the study according to the traditional scheme, the course included the presentation of educational material according to the standard scheme: lectures were conducted in class with a PC and a projector to present presentation materials; practical classes and laboratory work were held in computer classrooms (the teacher offered tasks, provided oral recommendations for implementation and instructions for laboratory or practical work).

The need to move to distance learning has forced teachers of the discipline to reconsider the principles of teaching the material and look for ways to provide work online. Yes, it was decided to use Google Meet as a tool for video communication of teachers, students, and graduate students (KNEU has a corporate license for the G Suite for Education package).

Also, within the requirements for the implementation of the Order of the Rector of KNEU, the transition was made to the use of LMS Moodle as a basic platform for distance learning of full-time and part-time students of higher education.

In the current academic year, the approach to the organization of education was changed again, which was caused by the task of organizing blended learning for full-time and part-time higher education at all levels within the internal regulations of KNEU. The experience gained during the organization of e-Learning showed that the effectiveness of training has decreased. The reasons for this were a significant number of factors, among the main ones are stress from the emergency transition to e-Learning for both teachers and students; partial lack of technical skills in working with Moodle; unpreparedness of students for a high level of workload due to a significant amount of independent work and asynchronous mode of obtaining knowledge (communication with the teacher took place either during lectures or individually by e-mail or other means of communication). These aspects correlate with the results of studies [63, 64], covered in section 2 of this study. Given the experience gained, it was decided to conditionally adhere to the principle of "50/50" during the organization of blended learning, ie approximately 50% of the study time allotted for mastering the discipline should take place in synchronous mode – contact work, the other – in asynchronous. During September-October 2020, the work took place as follows:

- all lectures were held online using cloud video services according to the schedule;
- practical classes and laboratory work in each discipline were conducted according to the following scheme: every two weeks 1 class was held in the classrooms of KNEU (synchronous mode), 1 class – using cloud services of video communication according to the schedule (synchronous mode);
- the rest of the classes were conducted asynchronously through a distance course of the discipline, posted on the Moodle platform.

However, with the transition of Kyiv to the "orange" quarantine zone, blended learning switched to distance learning. What has changed? Contact classes from the audience were moved to a virtual environment, but with the preservation of the aspect of synchronicity of interaction (figure 3).

In addition, there was a question of ensuring the adequacy of students' knowledge during the mastering of the discipline "Organization of NoSQL databases" within the limited time allocated by the curriculum (5 credits), given the fact that the IT market has a significant variety of NoSQL DB, each type and model data in them – have significant technological features, as noted above. Based on previous research, in particular [39], teachers decided on the need for optional (if needed by students) expansion of the course through the use of MOOC platforms. This practice also falls within the framework of the recommendations of the Ministry of Education and Science of Ukraine on the recognition of non-formal learning outcomes.

To select online courses that are potentially relevant to the curriculum of the discipline "Organization of NoSQL databases", an analysis of existing MOOC platforms was conducted using the web resource MOOC-LIST [68], the results of which are presented in table 1, based on the basic circumstances in the course DB NoSQL defined:

- Document-Oriented – MongoDB;
- Graph Databases – Neo4j;
- Key/Value – Redis;
- Tabular Column-oriented – Cassandra.

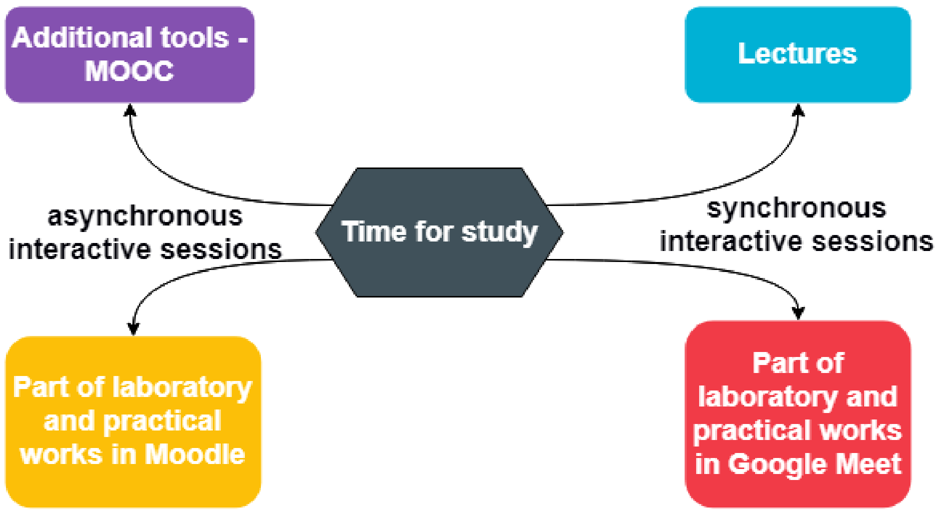

Figure 3. Time distribution between synchronous and asynchronous modes of operation within the distance learning mode.

The presented data show that the presented MOOCs contain courses on various aspects of NoSQL in a fairly wide range. In order to select the most appropriate objectives for the MOOC course, several criteria were established:

- no cost for the course;
- the possibility of obtaining a certificate free of charge for the results of mastering the course (according to the rules, the certificate is the basis for recognition of the results of non-formal learning);
- the MOOC must contain a course related to one or more basic DB NoSQL courses;
- language of instruction – English, because it is the most pragmatic option both in terms of students' understanding of the material and in terms of soft-skills development;
- training period – should not exceed 2 months (ideally – a few weeks).

Thus, the Udemy, LinkedIn Learning Courses, and edX platforms were rejected due to the provision of services and/or certification on a paid basis. But Coursera has opened access to online courses for students and teachers of KNEU under the program Coursera for Campus (Basic plan). Educational MOOCs from NoSQL vendors are essentially open and accessible and are well suited to the task of deepening knowledge and skills of working with NoSQL DB in students within the discipline "Organization of NoSQL databases". For example, MongoDB University offers a wide range of basic courses to study various aspects of MongoDB. Students, depending on the level of their motivation and pedagogical tasks are offered the following: M001: MongoDB Basics, M100: MongoDB for SQL Pros, M201: MongoDB Performance. For completing the current tasks of the online course, the student receives points, similar to the usual educational process in HEI (figure 4).

As a final control, MongoDB University offers to pass the Exam in the form of a test, which contains both theoretical questions and practical tasks to be performed in MongoDB and choose, based on the results, the correct version of the proposed. The overall grade for the course is the average between the scores of the current performance and the results of the Exam (figure 5).

Table 1. Comparative characteristics of individual MOOC platforms containing online courses with NoSQL.

Categories / MOOC	Udemy [69]	edX [70]	Coursera [71]	LinkedIn Learning Courses [72]	Redis University [73]	Nedo4j graphacademy [74]	MongoDB University [75]
Nomenclature DB	MongoDB, Neo4j, Apache Spark, Hadoop, Redis, Cassandra, HBase, IBM Cloudant	DynamoDB, MongoDB, IBM Cloudant	MongoDB, DynamoDB, Apache Spark, Neo4j, Hadoop, Redis, Cassandra	Cassandra, MongoDB, Redis, CouchDB, Riak et	Redis	Neo4j	MongoDB
Available courses NoSql:	12	8	35	160	7	11	13
beginners	8	2	11	29	1	3	4
intermediate	3	3	6	92	5	5	6
advanced users	1	3	12	39	1	3	3
Free of charge	–	almost all	+	1-month free trial	+	+	+
Certificate	included in the price	payment required	for free	included in the price	free certification exams	free certification exams	for free
Period of study	no time limit	4 months	from 2 hrs till 4 months	from 2 months	1 months	from 2 hrs till 2 days	2 months
Language	English, Spanish, Portuguese, Chinese	English, Chinese	English, Spanish, French, Russian, Portuguese, Chinese	English	English	English	English

Based on the overall score, if the student has mastered the course program and passed at least 65% of the course grade, MongoDB University provides a certificate – Proof of completion, which can be printed or shared on social networks such as Facebook or LinkedIn.

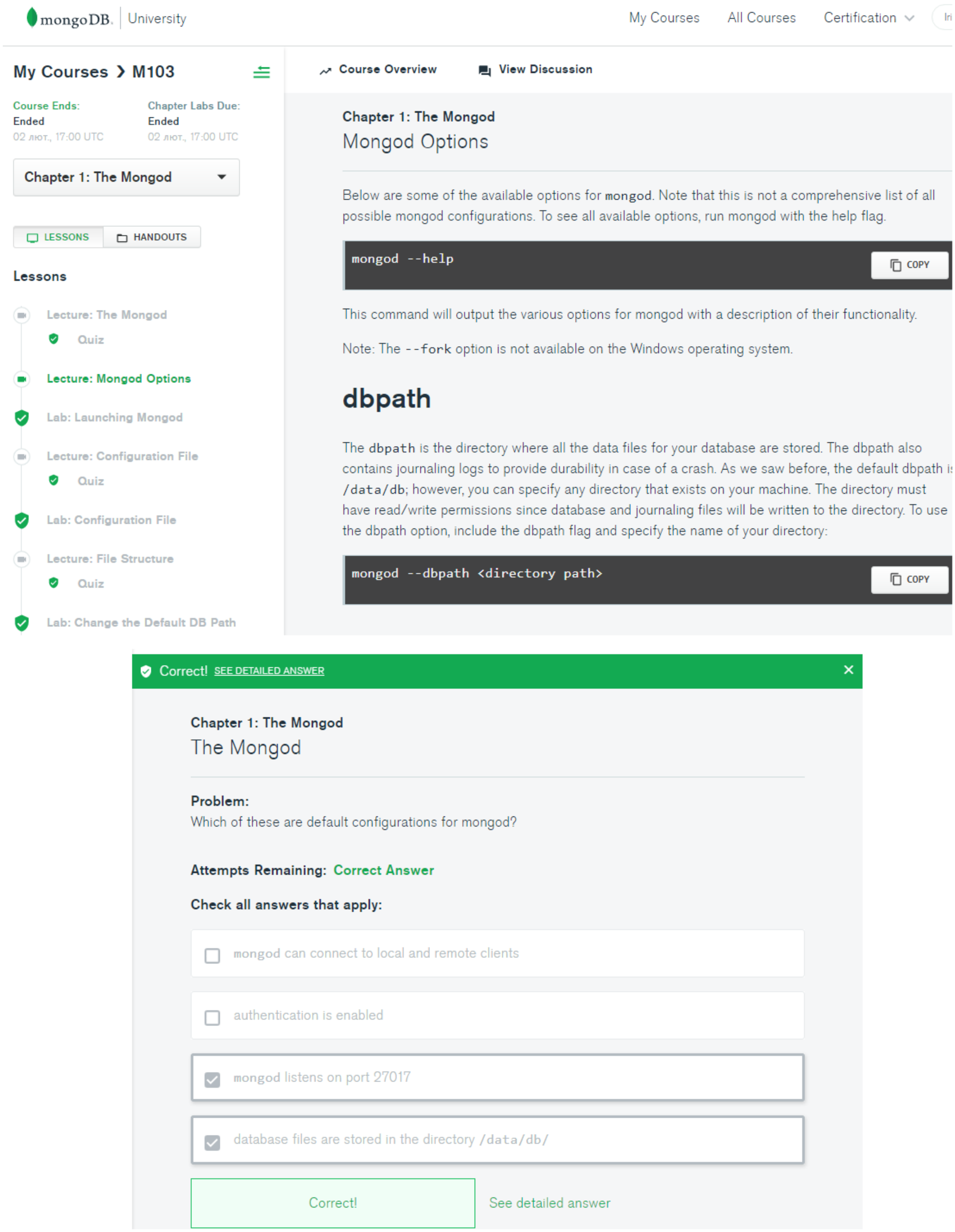

Figure 4. Examples of tasks in online courses at MongoDB University [75].

Figure 5. The results of the course M001: MongoDB Basics [75].

4. Results

To analyze the effectiveness of innovations in the transformation of the discipline "Organization of NoSQL databases", during November-December 2020, an anonymous survey was conducted among students of 3–6 courses (https://forms.gle/bWK9zaubqL4e64eR9). The distribution of respondents is presented in figure 6. The data obtained indicate several important results:

- by the time students studied the discipline "Organization of NoSQL databases", 55.9% of them had already encountered the concept of NoSQL (at work, during training, self-education, etc.);
- 26.5% of students, before studying the discipline "Organization of NoSQL databases" tried to search for online courses and study;
- 76.5% of respondents consider studying this course within the educational and professional program – useful and important, and 44.1% – necessary for a career in IT;
- 52.9% expressed a desire to take an additional (in-depth) course related to DB NoSQL (in particular, to study the processes of administration, integration, etc.);
- 85.3% stated that in this course it is important for them to gain knowledge of a practical nature (query language, syntax, creation, and filling of DB);
- 26.5% of students find it useful to take additional courses at MOOC Coursera, 36.2% – MOOC from vendors, in particular: MongoDB University, Nedo4j graphacademy, Redis University; others noted that they had enough practice material to provide the course (17.6%) and expected to gain more knowledge in the workplace (19.7%);
- 38.2% of students determined that they consider the use of MOOC as an additional learning tool useful for them (figure 7). But here it is worth paying attention to the fact that 44.1% of students note the overload of education, which should definitely be taken into account.

Therefore, the presented results give us reason to believe that the use of MOOCs as an additional learning tool for disciplines related to NoSQL DB in blended learning and distance learning is appropriate, which is also confirmed by the results of the survey. Obviously, the best way to learn the structures of the query language and the principles of operation of a particular NoSQL DB – practical work with them, designing a real DB and query processing. The current limitations of blended and distance learning don't allow for the training of the required skills within the training time exclusively, so it is important to use additional learning tools. At the same time, the problem of overload, which is caused by the increase in study time required to acquire additional knowledge, is also a task that the author's team still needs to deal with.

5. Conclusion

The new reality of the higher education system is blended learning and distance learning, in which part of the time allotted by the curriculum for mastering disciplines should be spent in

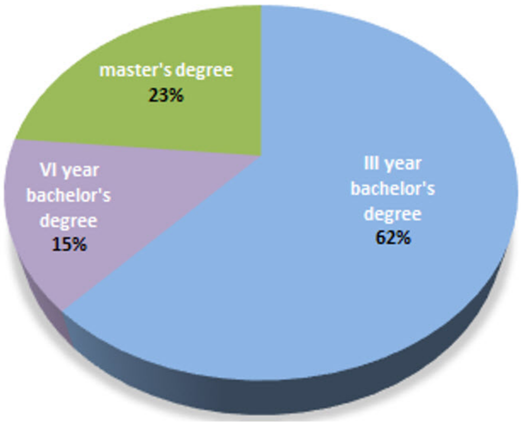

Figure 6. Structure of respondents who took part in the survey (total number – 64 people).

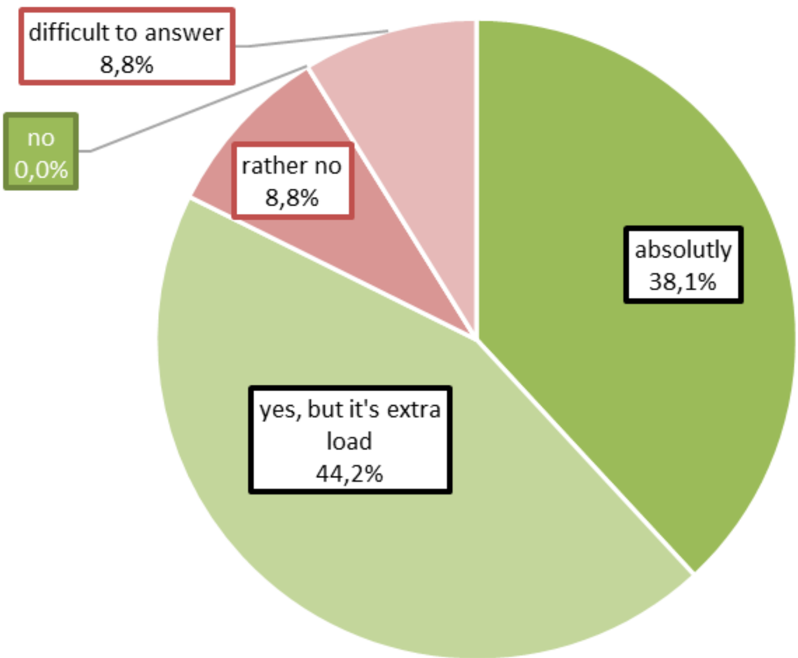

Figure 7. Respondents' level of satisfaction with the use of MOOC as an additional learning tool (total number – 64 people).

synchronous mode (i.e. in interactive interaction "teacher – student" either classroom or virtual), the other – asynchronous. Accordingly, there is a rapid development of software products and online tools e-Learning of various orientations (MOOC, LMS, online programming judge system, online coding platform, etc.). In addition, the organization of the educational process in distance or blended form requires consideration of the specifics of training higher education, taking into account specialties, specifics of educational programs, expected learning outcomes, and, last but not least, the demands of employers. In this context, it is important and relevant for graduates of different levels and specialties to master the skills of working with NoSQL DB and, accordingly, the inclusion in the curriculum of disciplines that shape them.

Analysis of the results of research by various authors has shown that the use of online tools for blended learning is appropriate and justified. In particular, scientists argue that it is appropriate to use, for example, MOOC in training courses for students of various specialties, including engineering and computer specialties. However, the research also emphasizes that important prerequisites for the effective use of MOOC in the practice of HEIs and research institutions should be: 1) maintaining a balance between asynchronous and synchronous regimes of the educational process; 2) the use of MOOC in the educational process must be preceded by a justification for such a choice.

The authors of the publication consider the experience of using MOOC in the study of the discipline "Organization of NoSQL databases", taught in Kyiv National Economic University named after Vadym Hetman. It is shown how the change of teaching models has influenced the transformation of ways of presenting information by teachers to students, the inclusion in the educational process of additional online tools, including a number of MOOCs. Based on the results of a comparative analysis of distance learning platforms containing courses related to DB NoSQL, it was determined that Coursera, MongoDB University, Redis University, and Nedo4j graphacademy will be the most optimal for teaching this course. This experience has been useful in the context of updating the content and operational components of academic disciplines related to the design and study of databases for G.E. Pukhov Institute for Modeling in Energy Engineering of NAS of Ukraine, it is expected to spread to various institutions, including the National Aviation University, Interregional Academy of Personnel Management, National University of Civil Defence of Ukraine and State Institution "The Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine".

A survey of students who studied the discipline "Organization of NoSQL databases" in different years showed a high level of satisfaction with the possibility of acquiring professional competencies, including through the use of MOOC as an additional online learning tool. On the other hand, the survey data showed a high level of concern of students about the increase in the level of study load in the case of decisions on the use of MOOC as an additional online tool for developing skills in working with NoSQL DB. This issue is important, debatable, and therefore requires further study and search for possible solutions.

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Soft Skills in Software Engineering Technicians Education

To cite this article: I P Varava *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012012

Soft Skills in Software Engineering Technicians Education

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Abstract. The research work analyzes the problem of forming software engineering technicians' soft skills, approaches to defining the list, detail and the maturity level of software engineering technicians' soft skills and basic ways of their formation, in particular: development of new academic programs or individual innovative courses, the problem-oriented approach, the AGILE approach, gamification of learning, development of interdisciplinary courses, etc. The obtained data enable developing methodological recommendations to form software engineering technicians' soft skills when studying the humanities and social sciences and experimentally investigating their efficiency.

1. Introduction and analysis of relevant research

Total digitalization and, accordingly, rapid development of the IT industry are becoming defining features of today's being, this causing increased demand for IT professionals. Therefore, the question of determining qualities of future IT specialists is highly relevant. Among these qualities, there are distinguished technical (hard) and non-technical (soft) skills.

As for forming software engineering technicians' soft skills, researchers point out the following:

- Q. Brown, F. Lee, and S. Alejandre, consider that engineering education has evolved from forming students' hard skills only before studying courses encouraging soft ones [1];
- M. Rehman, A. K. Mahmood, and R. Salleh think that "... software development is a human activity (performed by humans)" and, therefore, investigations into soft skills of software engineering technicians need special attention [2];
- G. Matturro thinks that "... soft skills are as important as, or even more important than traditional qualifications and technical skills" [3];
- L. Fernando Capretz believes that "... soft skills enhance job satisfaction, improve efficiency" [4], these competences are necessary at all stages – from problem setting to "... successful completion of a software project" [4];

- D. González-Morales, L. M. Moreno De Antonio and J. L. Roda Garcia consider that students' soft skills should be developed from the first year of their study as they are not sufficiently attended to in early academic courses, though students have a comprehensive amount of theoretical and applied coursework [5];
- V. Thurner, A. Böttcher, A. Kämper think that first-year students have problems with developing the simplest software because of absent soft skills [6].

Based on research analysis, [7] notes "... a lack of understanding of what soft skills are necessary for development of complicated software projects", and for this purpose soft skills adaptation and specification are necessary for software engineering technicians.

Scientists determine the list, details and level of soft skills for IT specialists in various ways, namely by:

- analyzing job advertisements [8], [3] (in [8] based on analysis from over 500 sources, it is determined which soft skills are necessary and which are desirable);
- conducting surveys among software engineering practitioners from software companies [9];
- determining "the skill level expected by the job market" [6];
- developing specific modules to measure certain soft skills, in particular those for assessing team work [10];
- developing new tools that synthesize information about candidates' contributions on various sites (code placement, technical question-and-answer forums) to compare their competences [11].

The problem of forming software engineering technicians' soft skills can be solved in the following ways:

- designing new educational software programmes (the service-learning educational programme called EPICS (Engineering Projects In Community Service) [12];
- introducing specialized courses aimed at forming soft skills [13];
- introducing innovative courses, in particular "... in supervision, project management, quality control and decision-making" [5];
- implementing problem-based learning [14] and the AGILE approach [15];
- gamification of learning [16];
- providing practical training disciplines with examples that contribute to soft skills formation, i.e. integration of soft skills into practical training [4];
- developing multidisciplinary courses [1], e.g. "... a course focused on interweaving software engineering practice, service learning, and development of "soft" professional skills" [17];
- studying the humanities and social sciences.

At the present stage, the task of vocational education in Ukraine is to train competent specialists. This is reflected in "The National Strategy for Education Development for 2012–2021" [18], the Decree of the President of Ukraine "On Goals of Sustainable Development of Ukraine until 2030" [19], which provide for enhancing the role of the humanities and social sciences in higher educational institutions.

At the same time, a number of contradictions arise hindering a full-scale educational process when training competitive software engineering technicians (figure 1).

The **aim** of this work is to highlight methodological recommendations for forming software engineering technicians' soft skills when studying the humanities and social sciences.

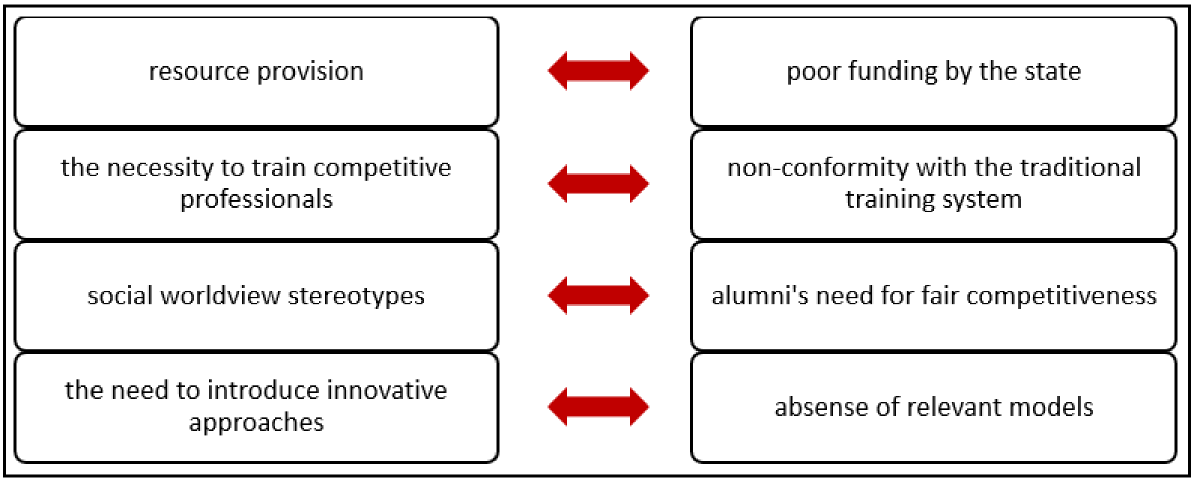

Figure 1. Contradictions in software engineering technicians' training.

2. Methodology

Being guided by analysis of researches into problems of formation of software engineering technicians' soft skills, employers' requirements to candidates for a certain position in an IT company, requirements to IT candidates on the example of Google (the representative office in Ukraine), practice of cooperation of vocational higher education institutions with IT companies, there are distinguished 13 soft skills [20, 21]. Let us consider their formation when studying the humanities and social sciences.

The ability for abstract thinking, analysis and synthesis. For a programmer, algorithmic and structural thinking, the ability to work simultaneously at different levels of abstraction and detail are important. Components of such thinking include reasoning and critical thinking, analytical skills, pursuit of excellence, research skills, reflection and self-knowledge, mega-perception, self-awareness, self-improvement, self-motivation, sensitivity to global social, economic, environmental, ethical and moral issues, entrepreneurship, sense of mission, adaptability, motivation, flexibility, openness and the ability for multi-tasking. This competence is formed when studying primarily the humanities and social sciences, and only then mathematical subjects. History, Philosophy, Political Science, Sociology and Law play an important role in forming this competence.

The ability to communicate in a native language. The level of verbal abilities is crucial for software engineering technicians. An IT specialist's professional and communicative qualities include the ability to organize communication, listen to opinions of others, the ability to discuss acute problems in a positive emotional mood and be an intermediary between conflicting individuals. This competence is closely related to working in a team, the ability to listen, persuade, negotiate, reach consensus and resolve conflicts. No doubt, this competence is formed primarily due to such basic humanities and social sciences as Ukrainian Language and Literature, History, Cultural Studies, Political Science, Sociology and Psychology.

The Ukrainian language is a tool and material for forming a person's personality, his/her intellect, will, feelings and a form of being. Language is a means of communicating between people, transferring one's own experience to others, and sharing it among others. It is a tool for building cross-cultural bridges and contributes much to formation of cultural competences. Language classes provide unlimited opportunities for shaping future software engineering technicians' worldview, their speech and general culture. Language means provide training of competent specialists, upright and educated people who combine a wide scientific worldview, professional competence, the desire for self-improvement, the search for creative self-realization, universal values, and national self-awareness. These are individuals who are good at dealing with current historical, economic, and cultural situations. Taking care of students' literacy and speech culture, language teachers of higher technical educational institutions try to provide language and speech knowledge to develop general erudition and education. A specialist is to be fluent in written and oral forms of the national language, use his/her knowledge in professional activities and interpersonal communication.

The main purpose of studying Literature at pre-higher educational institutions is to get students acquainted with the highest achievements of world literature and culture, universal and national spiritual values, develop students' aesthetic taste, high reading and general culture, and immunity against low-grade phenomena of mass culture. For this reason, literature is an integral part of forming future software engineering technicians' ability to preserve and enhance moral, cultural, scientific values and society achievements based on understanding of history and patterns of the subject area development, its place in the general system of knowledge about nature and society and social advance. Studying History, Philosophy, political Science, Law, Sociology and Cultural Studies is important when forming this competence.

The ability to communicate in a foreign language. This competence is equally important for software engineering technicians, the English language being here of particular importance. All algorithmic programming languages, with a few exceptions, are based on the structures of English, the level of proficiency of which depends on the speed of memorization and interpretation of programming structures. In other words, software engineering technicians' professional activity is English-speaking in its nature.

The main purpose of a foreign language as a subject area is to contribute to future software engineering technicians' mastering communication skills in oral and written forms in accordance with the motives, goals and social norms of speech behavior in typical areas and situations. Learning a foreign language is to form future IT specialists' communicative competence based on communication skills, which involve language knowledge and skills. Communicative competence development depends on sociocultural and sociolinguistic knowledge and skills that ensure the individual's entering another social medium and contribute to his/her socialization in a new society. The general cultural competence allows not only speaking fluently, but also feeling free in a multicultural space.

Analysis of academic programmes in foreign languages enables concluding about a very limited number of academic hours for language training, and this is despite the fact that future software engineering technicians are learning a profession-oriented language that takes more time to master terminology and a category apparatus. Due to the lack of academic hours, there is very little time left to present such language subsystems as scientific style, oral scientific language, lexical and grammatical features of the language of a particular speciality. The system of teaching a profession-oriented language to software engineering technicians should ensure qualitative acquisition of this subject and its effective use in their professional activity, if this system is based on a systematic approach and dialectical combination of invariant and profession-oriented content components of a foreign language course; the principle of professional orientation, its functions, requirements and rules; interaction of the principle of professional orientation with the following principles of learning: humanization, unity of training and upbringing, motivation of learning; a programme-target approach that ensures orientation of goals, content, forms, methods and tools of teaching a foreign language, teachers' and students' activities in the process of training for future professional activity.

The ability to learn and self-study. These competencies imply future software engineering technicians' understanding the importance of updating information and continuous monitoring of skills. The mentioned competence depends on the formed personal motivational readiness for professional self-improvement. It is formed mainly by the system of profession-oriented subjects when studying the humanities and social sciences, in particular and history.

The ability to search, process and analyze information from various sources. This competence is based on the previous one. Research skills formation is realized through the ability to know and apply various software tools while searching for information, determine the most effective methods of collecting and processing information, produce their own algorithms for solving a problem, plan an experiment and process experimental data. Research skills are formed through studying such subjects as history, physics, and mathematics. This important competence is actively formed during teamwork when performing laboratory works and practical tasks in profession-oriented subjects and through students' practical activities in cooperation with stakeholders.

The teamwork skills. A programmer is a team person. This competence is developed through implementing complex group projects which are also a means of training students' teamwork skills, the ability to establish communication with colleagues, listen to other opinions, defend their own point of view, competently represent a project and their colleagues' contribution. The competence is formed through performing project activities and laboratory works, practical tasks in the classroom. History, Ukrainian language and literature and English play an important role in forming this competence.

The ability to act ethically. For software engineering technicians, it is important to form experience that reflects peculiarities of humanitarian-oriented professional activities based on the principles of the absolute value of human life and personality, human safety, ethics and social ecology. Basic humanities and social sciences (Ukrainian Literature, History, Philosophy, Political Science, Sociology, Psychology, Cultural Studies) form this competence.

The social competence expresses the ability to exercise rights and responsibilities of a person as a member of society and his/her need for sustainable development, the rule of law and human freedoms. Software engineering technicians do a variety of things that have ethical, social and political implications.

The course of History is aimed at revealing specific features of social development and socio-economic processes. The concept and structure of the course contributes to formation of a students' holistic vision of the studied era, both generally and in its individual phenomena and processes. It is unequivocal that the course of History is an ideal basis for forming the cultural competence because each topic contains information about a particular culture or a civilization to provide better understanding of the role of dialogue of cultures. As a subject, History expands cultural references and enhances understanding of the human state in the context of developing ideas. History interprets human life conditions. It is based on the theory of political science, economics and sociology, and as an interdisciplinary object, history can also be extremely contextual to the technical and scientific part of engineering programmes.

Thus, humanitarian training is extremely important for software engineering technicians. It forms *the ability to evaluate and take into account economic, political, social, technological and environmental factors* influencing the field of professional activity. Forecasting and evaluating consequences of implementation of programme projects, their impact on environmental safety and society actualize the problem of forming future software engineering technicians' experience of humanitarian expert evaluation of programme projects. This competence is meant to be formed by social and humanitarian disciplines (primarily History, Philosophy, Political Science, Sociology and Cultural Studies) [20].

Such disciplines as Philosophy, Psychology, History, Foreign and Native Languages, Ukrainian and World Literature, Cultural Studies, Law, and Sociology "immerse" students in the world experience of modern existence, interaction, relations and communication of people. It is this "immersion" that enables active development of the consciousness and self-awareness of our future IT specialists.

Development of any activity strategy should be based on integrative, humanitarian-oriented knowledge. Cultural Studies as a science and an academic discipline is the methodological basis of such knowledge. This is an important academic discipline in the system of humanitarian education of students of I-2 accreditation level educational institutions. It provides a holistic, totally new vision of human relations with the world, promotes formation of students' ideas about universal human values and national priorities, simulation of their behaviour in conditions of modern globalization of the information space.

Cultural education of future software engineering technicians is intended to ensure that they comprehend, first of all, cultural thinking, which is formed by human correlation with the social and natural environment within a certain national or historical system of cultural coordinates.

Future software engineering technicians should be ready to conduct professional activity in the multicultural world. Therefore, cultural education of students should be multicultural in its essence, reveal plurality of cultural systems, form experience of cultural activity aimed at determining the socio-functional role of software engineering technicians, and ways of their entry into the social practice, searching for culturally deterministic ways of solving personal and professional problems. Cultural Studies is on the list of mandatory academic disciplines of the State Educational Standard.

Studying economics is a necessary component of basic education. After all, in the system of economic relations, each of us acts as a full participant in economic life of the country and the world, both as a consumer and as a manufacturer of goods or services. Therefore, future software engineering technicians' knowledge of this science will help orient themselves in the world around us, make rational decisions, identify their strengths and weaknesses in the labour market, communicate equally with representatives of other countries and other cultures. Economy unites people of different countries, gives them a sense of confidence in communicating with others, and therefore is important for personality development and formation of the cultural competence.

The main purpose of the discipline "Law" is to shape systemic legal knowledge in future IT specialists, promote formation of their active public position, raise the level of legal culture. Knowledge of their rights and responsibilities contributes to confidence of a person in the current situation. A person's awareness of his/her rights contributes to understanding of his/her place in society, culture and thereby to formation of college students' general cultural competence.

In psychology, the aptitude for "self-determination" – the skill to "... decide for themselves..., and the decision for themselves always means forming themselves" (courtesy translation) [22] is decisive for personal growth, self-improvement of an individual. According to C. R. Rogers, the main driving force of a person's self-improvement is the combination of his/her real and ideal "self" which actualizes the constructive forces of growth and development of the personality, rather than personal complexes, protective mechanisms and non-adaptive behaviors. The combination of "real self" and "ideal self" gives rise to belief in the possibility of self-realization which becomes an internal stimulus of self-improvement of the person.

After analyzing the programmes of the humanities and social sciences, it can be concluded that they all aim to form and develop soft skills of software engineering technicians, help them in orientation in society and adaption to social changes, familiarize with the cultural heritage of humanity and self-affirmation.

The humanities and social sciences fulfill their main purpose – to form software engineering technicians' soft skills. At the same time, along with the above tasks, the humanities and social sciences should be integrated into the general system of vocational training and have close interdisciplinary relations with specialized disciplines. Thus, the concept of the contextual approach fully meets these requirements, awakens interest in the humanities and social sciences, and develops cognitive and professional motivation of future software engineering technicians.

The scheme of soft skills formation in the process of studying the humanities and social sciences is shown in figure 2.

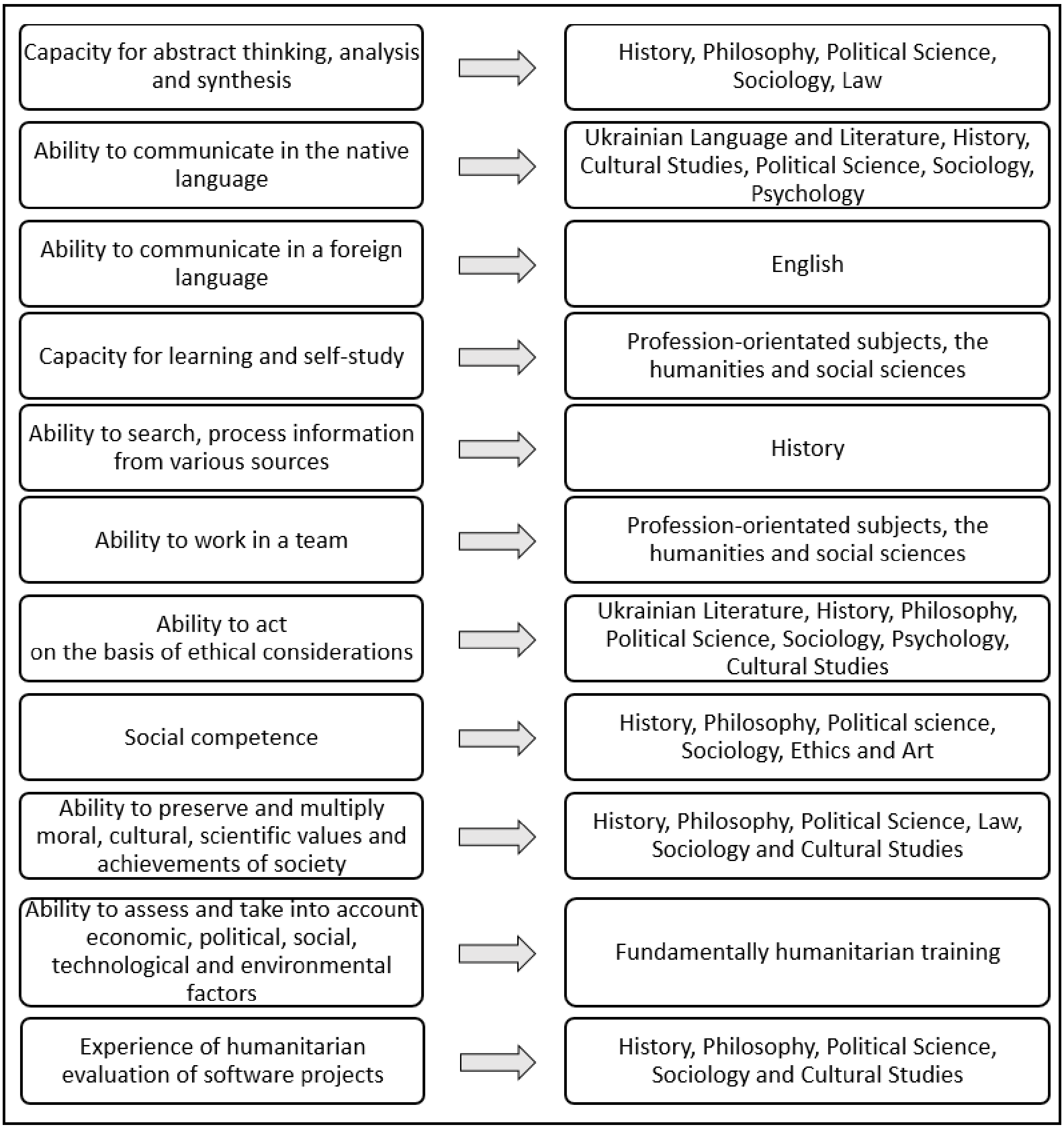

Figure 2. Soft skills formation in the process of studying the humanities and social sciences.

Introduction of innovative teaching methods into the modern educational and pedagogical process is of significant importance nowadays. It is the creation of training programmes, business games or role-playing and brainstorming sessions that are the driving forces provoking future IT specialists' interest in self-improvement and development. This means that now it is extremely important to master new methods of teaching history at institutions of pre-higher education that should be based on active methods and forms of education [23].

A teacher of any academic discipline at colleges should know that the system of requirements and social expectations is the source of self-improvement of the person, while contradictions between the requirements for the person and his/her real behaviour, between his/her existing knowledge and educational standards, etc. are the driving forces of self-improvement. This obviously imposes obligations on teachers to organize classes in such a way so that they can use methods of training selected by them to not only form professional knowledge and skills, but also develop personal abilities in the context of the future profession, including the following skills:

- to independently set main goals of self-education activities;
- to search for and select sources of information – this will ensure success in designing;
- to find and apply specialized software tools using electronic resources to optimize the programme code;
- to independently compare the result in the form of the code of software modules and database objects with the set goals and tasks [24].

The job components of software engineering are defined in corresponding educational programmes developed by individual institutions of vocational pre-higher or higher education. Their analysis enables stating that software engineering technicians should have certain formed general-scientific, instrumental, socio-personal and general-professional competences that will ensure effective execution of their professional functions.

In the 21st century, humanitarian knowledge should be founded on an interdisciplinary complex involving close interrelations of the humanities with practical courses on the basis of combination of specially selected "blocks" of History, Philosophy, Cultural Studies, Sociology, Psychology concerning soft skills formation. First, it combines a significant theoretical layer with the following practical implementation. Secondly, the interdisciplinary approach clearly traces the tendency of creating a "block" of the humanities and natural sciences.

In modern conditions, the traditional understanding of vocational education as acquisition of a certain amount of knowledge based on teaching fixed subjects is clearly insufficient. Education today should focus on ways of thinking and activity, worldviews, stable moral and aesthetic ideals, personality culture rather than educational subjects. Disciplines of the humanitarian cycle of vocational education institutions accumulate the system of universal human values and ideals and can serve as a content of spiritual development, humanization of the person. Strengthening the role of social and humanitarian disciplines in higher technical education should be based on the following principles: orientation of the technical education system to create conditions for spiritual, ethical and cultural self-development of the person; deep fundamental and methodological training of students in the field of humanitarian knowledge, spiritual life of man and society; students' mastery of the methodology of cognition and creativity, practical activity, a person's social behavior and self-development as preconditions for achieving success on the way of life; creation of prerequisites for organic involvement of students in the economic, social and cultural processes of the world civilization development; organic connection of the educational process with extracurricular work, students' leisure and recreation.

The general model of software engineering technicians' soft skills formation is shown in figure 3.

To check the proposed methodological recommendations, an experiment was conducted which involved students of speciality 121 "Software Engineering" (field of knowledge "Information Technologies", specialization "Software Development") at Kyiv Professional College of Information Technology and Economics of the National Aviation University.

Thus, the control group (CG) comprised 46 students (year of graduation – 2018), and the experimental group (EG) – 52 students (year of graduation – 2020). Students were offered a questionnaire:

1. How often were active methods (games, trainings, case methods, discussions, etc.) used in the training process?

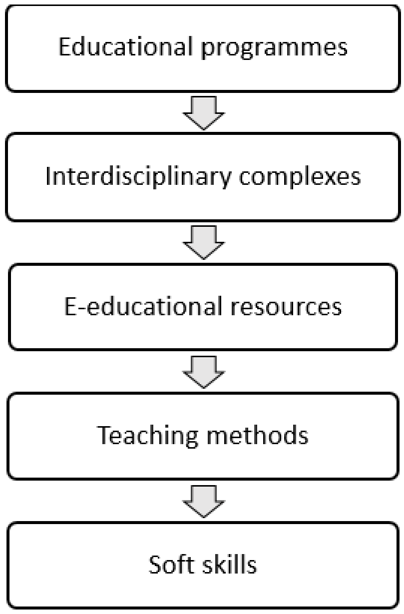

Figure 3. Soft skills development model.

- constantly;
- periodically;
- very rarely;
- almost never.

2. How often were E-educational resources used in the training process?
   - constantly;
   - periodically;
   - very rarely;
   - almost never.
3. Evaluate your level of corresponding soft skills as high, sufficient, medium or low:
   - the capacity for abstract thinking, analysis and synthesis;
   - the ability to communicate in the native language;
   - the ability to communicate in a foreign language;
   - the capacity for learning and self-study;
   - the ability to search, process information from various sources;
   - the ability to work in a team;
   - the ability to act on the basis of ethical considerations;
   - the social competence;
   - the ability to preserve and multiply moral, cultural, scientific values and achievements of society;
   - the ability to assess and take into account economic, political, social, technological and environmental factors;
   - the experience of humanitarian evaluation of software projects;

The percentage results of answers to the first question is shown in figure 4.

The percentage results of answers to the second question is shown in figure 5.

The answers to the third question of the questionnaire clearly showed the positive shift of soft skills levels in all components (figures 6, 7).

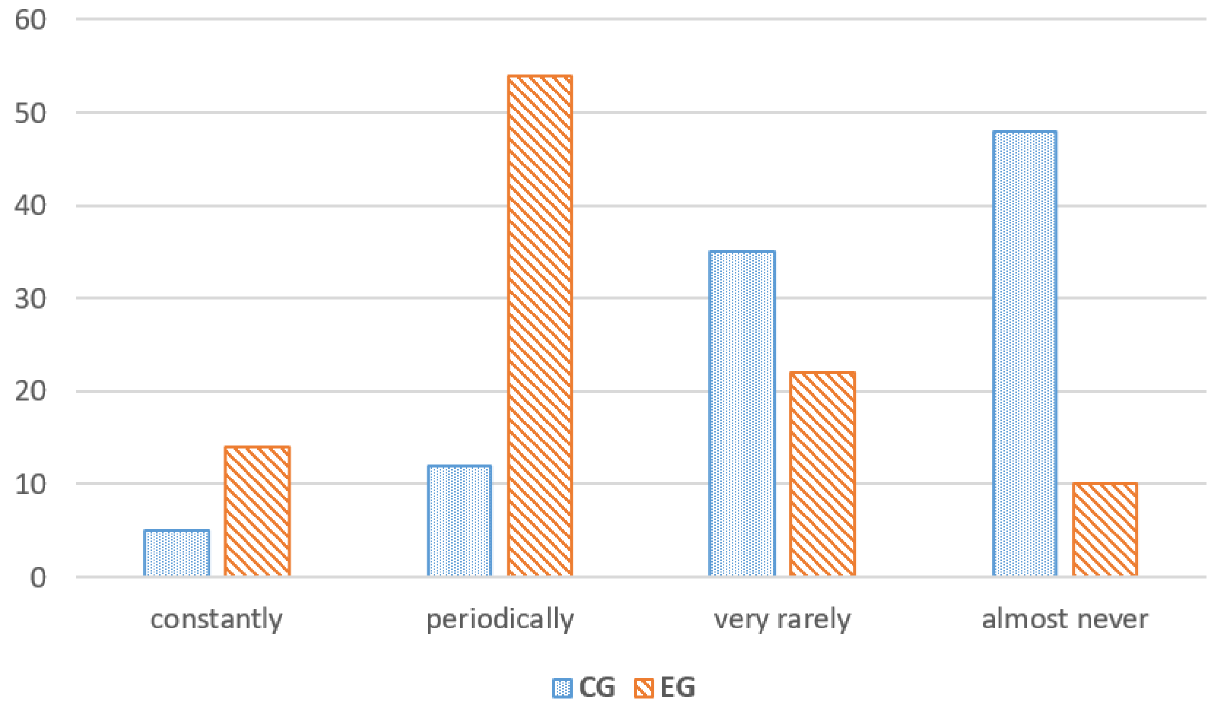

Figure 4. How often were active and interactive methods used in the training process?

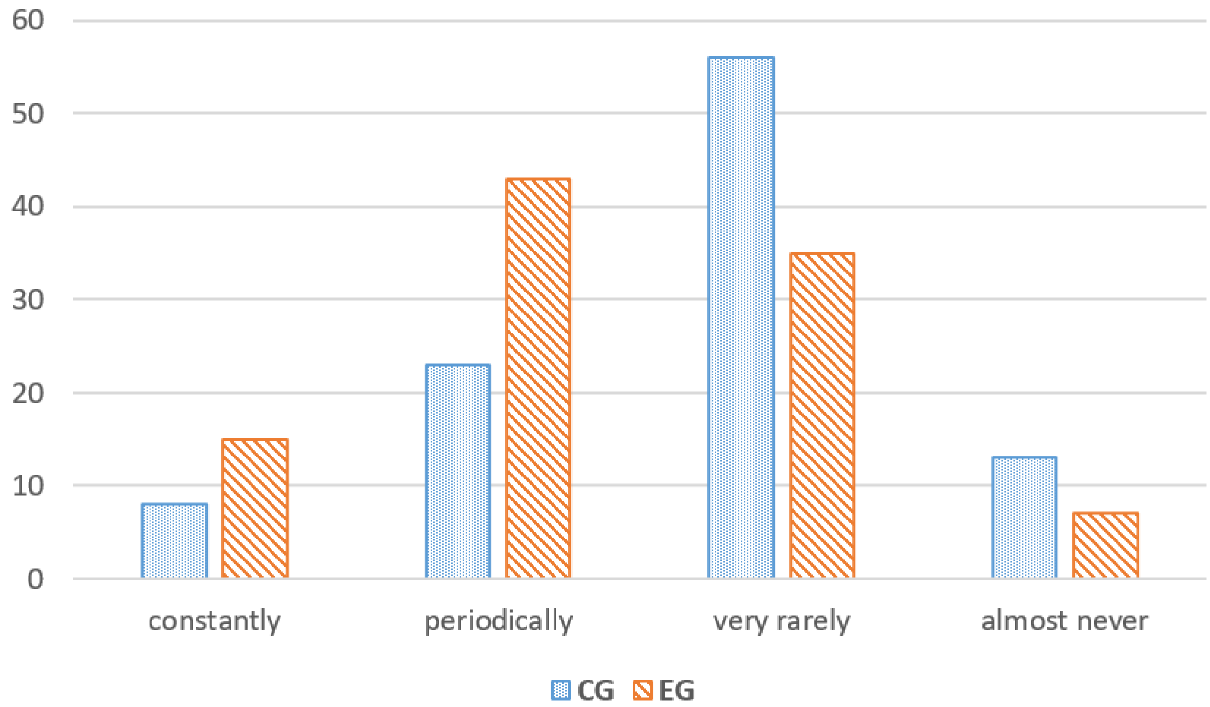

Figure 5. How often were E-educational resources used in the training process?

Since teaching the humanities and social sciences in the experimental group was conducted in blocks (as proposed in the methodological recommendations), teachers (according to the results

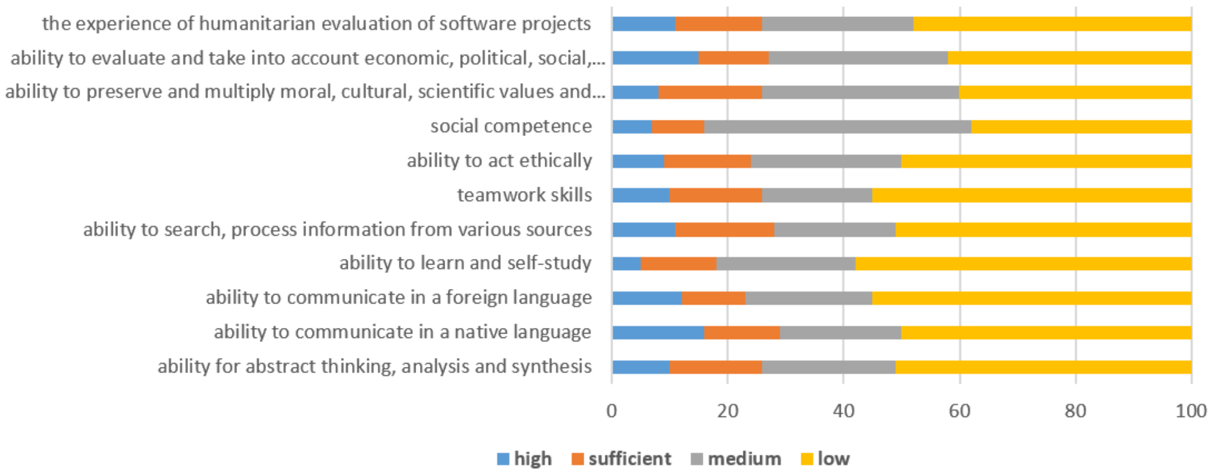

Figure 6. Software engineering technicians soft skills self-assessment (before experiment).

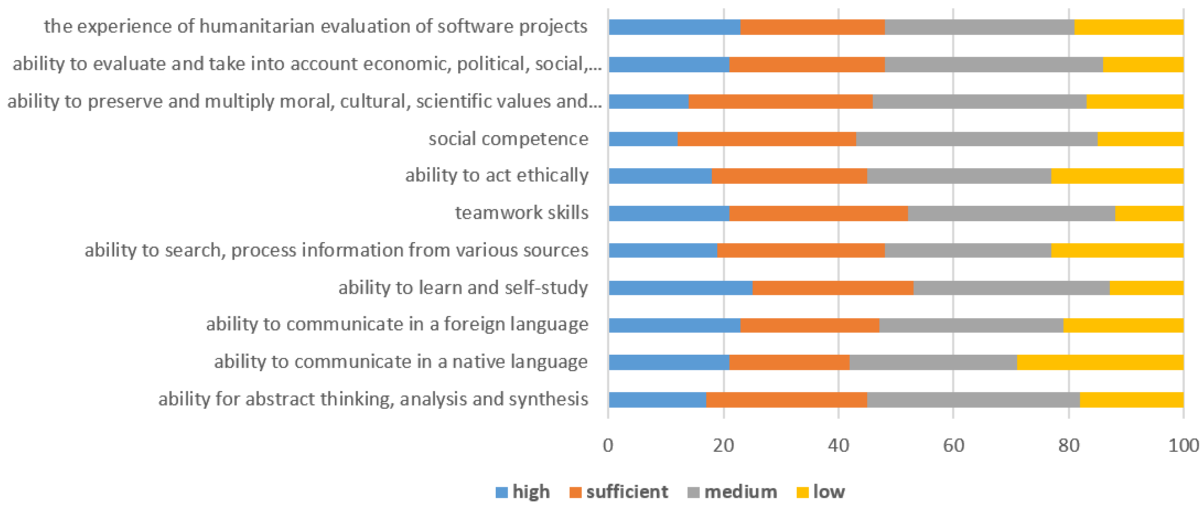

Figure 7. Software engineering technicians soft skills self-assessment (after experiment).

of the questionnaire) more often used E-educational resources and active teaching methods, we can assume that this was an increase in the level of soft skills maturity.

3. Conclusions and prospects for further research

1. Based on the analysis of sources and curricula for training software engineering technicians in institutions of vocational pre-higher education, there has been established a link between soft skills of software engineering technicians and the humanities and social sciences (figure 2) and there has been developed a model of soft skills formation (figure 3).
2. The results of the experimental work (figure 7) have confirmed effectiveness of the proposed guidelines for forming software engineering technicians' soft skills.

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Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Applying CDIO-approach at technical universities

Applying CDIO-approach at technical universities

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Abstract. The article considers the issue of modern engineering training with the use of CDIO-approach (Conceiving, Designing, Implementing, and Operation) aimed to balance the training goals with the practice of teaching at higher technical institutions. Modern pedagogical technologies and innovative teaching methods enable to create such an education medium where the students will obtain profound knowledge, manage the process of designing and exploiting new items and systems, understand the impact of the scientific-technological process on the society. The article also considers various approaches to developing new practice-targeted programs and methods of creating a special education medium. The abilities of students' engineering thinking are a link between university training and professional activity. Future specialists must not only be able to develop and produce engineering systems, but also combine the knowledge of natural and technical sciences to come up with innovative ideas, have a command of professional ethics and understand the principles of business.

1. Introduction

The main peculiarity of modern technical education is training a specialist ready to live and work in the global world, capable of innovations and entrepreneurship, organizing business, developing, and launching new innovative items to the market.

Since the 1980s and especially since the 1990s in the developed countries the employers' requirements for the graduates of technical universities have grown. These requirements concern the practical skills of designing objects, processes, and systems. Syllabi, however, were more theory-focused rather than practice targeted and aimed at developing a scientific basis for solving engineering problems. This resulted in insufficient communicative skills and the ability to work in a team, lack of practical skills to create objects and processes.

CDIO approach is aimed to solve the problem of the gap between theoretical and practical training.

Moreover, modern syllabi have not provided the students with all the necessary knowledge, but with outdated information. This refers to such subjects that are based on outdated technologies and thus distort the interdisciplinary links, which only confuses and demotivates the students, distracts them from the subject core and its importance in the general professional competence. Nevertheless, the students must obtain sufficient scientific knowledge in the sphere of machine building and develop analytical skills.

2. Theoretical background

The creators of the new concept of engineering training note that workshops, team projects, problem-solving, carrying out experiments, and research must become inseparable constituents of engineering education [1]. Nowadays the CDIO approach is supported by over 120 universities from 30 countries of Europe, America, Asia, Australia, and New Zealand.

Change in the professional training demands the development of such the students' skills as designing and producing engineering systems as well as converge information and natural sciences, creating innovations, command of professional ethics, understanding the principles of business development. Unchangeable remains the need to give the students a profound scientific basis, fundamental knowledge of engineering, and develop their analytical skills.

B. M. Crookston et al [2] study the current challenges the modern generation of young engineers face is constantly changing and evolving classrooms and workplaces. Paper [3] shows the association between neurobehavioral traits and intelligence with university-level grades in majoring subjects.

E. P. Dubovikova [4] considers the possibilities of developing general and professional competences of engineering students trained at higher educational establishments. L. C. Félix-Herrán et al [5] explain the ways a teaching-learning concept applies interactive, experiential activities, motivates students, and encourages their creativity to provide solutions to real-world challenges. R. Efendi et al [6] show the effectiveness of a competency-based learning model in computer network courses for developing learning skills and enhancing learning motivation, empowering students to solve given problems, increasing their responsibility and ability to work in teams. The authors also show the difference between students' performance while taught by conventional learning methods and competency-based learning in favor of the latter, which boosts students' cognitive and psychomotor abilities.

Another research [7] showed the ways the pedagogical design of an academic course can develop digital literacy competencies, support students in regulating collaborative technology-enhanced learning, and help them control and improve their collaborative performance. L. H. Kadyjrova and others [8] discuss the use of information and communication technologies in training bachelor-students of design as one of the innovative organizational forms taught at a university, based on modern achievements of the psychological and pedagogical sciences, new generation learning stuff and a wide range of electronic educational resources.

The research aims to analyze the implementation of the CDIO approach in modern professional engineering training. The main feature of this approach is to practice targeted engineering training, while the main aim of modern technical education is training for successful professional activity in the conditions of increasingly complicated production technologies.

3. Materials and methods of research

Nowadays Ukraine is trying to increase the accessibility of competitive high-quality education according to the requirements of innovative sustainable social and economic development [9]. The peculiarity of the CDIO approach lies in the practice-oriented training of engineering students. The main purpose of modern technical education is the training of students for successful professional activity, development of their professional competency in the conditions of the growing complicacy of manufacture.

The above-mentioned complex approach enables to reform professional training of students of technical universities in the context of innovation, leadership, and entrepreneurship, modernize educational programs, teaching methods and the infrastructure of universities, the specialists of the technical sphere are involved into all the stages of the life cycle of objects, processes and systems (designing, planning, production and use) that meet the requirements of the society, use advanced technologies opening new horizons. To solve the set task a modern engineer applying modern technologies and communicative skills can process obtained data to synthesize new information, working in a team.

The researchers of the issue of improving engineering training highlight the principles that would enable its successful realization. The first of these principles is considering engineering training in the context of real engineering practice at production. CDIO approach is aimed to train specialists in the technical sphere able to apply basic technical knowledge in practical activity; manage the process of creation and exploiting engineered systems, objects and systems; understand the importance and impact of the scientific-technical progress on the society [1].

According to the authors of this approach, modern pedagogical technologies and innovative methods of teaching enable to create such an educational medium, in which students will actively apply obtained knowledge, thus understand and perceive abstract theoretical concepts. The outcome of students' training will be the CDIO Standards, presented in the list of graduate's competencies developed with employers' involvement. This list of competencies presents the context of modern engineering education. The curriculum of specialists' training is requested to be complemented with practical tasks on drafting, designing, and creating technical objects that are possible to carry out within workshops. The assessment of the obtained knowledge and skills must be complex and take into account first of all their applicability in unfamiliar situations.

Nowadays, the CDIO approach for developing engineering syllabi is used in over 100 universities worldwide, however, it is not a standard and can be adjusted to any syllabus. The results of students' training at the university are formed together with the future employer based on the rational need in engineers. The assessment is performed in the form of writing and oral exams, presentation, students' reflection over the achieved competencies recorded in portfolios. The CDIO approach is based on the personality-centered principle of assessment of student's achievements, personal and interpersonal qualities.

We must admit that understanding the value of practical skills for modern engineers has considerably decreased, which caused some dissatisfaction with manufacturing companies with the level of training of graduates in the late 1990s. Much attention is paid worldwide to engineers' training with competency-based approach (standards of the Accreditation Board of Engineers' Training (ABET) in the USA, competency standards for engineers UK-SPEC in Great Britain, project EUR-ACE on accrediting engineering syllabi and graduates all over Europe, requirements to the syllabus assessment of the Canadian engineers' accrediting Council).

From manufacturers, an engineer must find potentially successful economic solutions, have an understanding of their profit for the society, and be able to cooperate with other specialists. Modern engineers' education joins 4 interested parties: students, employers, teachers, and public organizations. The outcome of training based on the CDIO approach must reflect the interests of all the parties. The integrated curriculum which comprises subjects based on the interdisciplinary approach plays a decisive role since it promotes the development of skills of creating objects, processes, and systems. Employers can teach students to apply their own devices and systems through modeling real processes, electronic access to the objects at the production.

The desired result of such professional training can be achieved through the increase of practical lessons in the academic load, time redistribution, and implementation of complex teaching activities. CDIO approach means active learning when students are involved in the study process and are more motivated to obtain engineer competencies. The authors of the approach think that at lectures students must be offered the tasks on perceiving the heard information through group discussions, model and analyze real situations at the production. Problem-based training teaches students to formulate, estimate, and solve a problem. Learning theory through practice is based on the theory of cognitive development the authors of which think that the process of perception depends on the stage of human cognitive development [10]. Therefore students cannot learn to apply cognitive structures that they have not developed yet. To study the CDIO approach as the context of modern engineering training, it is better to look back into the stages of the life cycle of engineering solutions [1] (see table 1).

Table 1. The stages of the engineering solution cycle.

Planning	The analysis of the demands of the interested parties, choice of technologies, consideration of valid norms and regulations, concept development, and business planning.
Designing	Detailed project description, drafting and composing algorithms describing the final objects, processes, and systems.
Production	Project transformation into real objects, process or system including all stages of production, testing, and checking.
Application	Effective use of the produced item, process, or system, including maintenance, improvement, change, and dismantling.

In the context of modern engineering activity, students must acquire basic technical knowledge and specific subjects, develop competencies, skills, and personal features required by companies. The students' motivation playing the decisive role is reached through context-based learning when students can apply obtained skills to the earlier developed cognitive structures.

The application of CDIO means the transition to students' integrated teaching aimed to create products, processes, and systems. This is possible only at the subject's integration and practical activity. Naturally, it is complicated to develop practice-aimed syllabi based on new teaching technologies. Open access to materials on designing new programs enables universities to exchange information about the projected training results (CDIO Syllabus) and gradually switch to a new education model. Cooperation of universities enables to allocate the tasks among partners, use the most successful practical experience and education models. The skills of technical thinking are a linking part between university training and real practical activity.

The main document on reforming syllabi for engineering education is CDIO Syllabus, which is sort of a list of employers' requirements for the professional training of technical specialists (engineers). This list comprises a set of competencies, which a future engineer must possess and a list of lacking skills and abilities of graduates [11] (see table 2).

Table 2. The list of important lacking skills and abilities of engineer graduates.

Skills most important for employment	The lacking skills upon graduation
Effective teamwork	Running business
Information analysis	Managerial skills
Effective communication	Project management
Collecting information	Quality management, Effective communicative ability, The knowledge of marketing principles, Professional ethics

Many countries carry out reforms aimed to integrate engineering training and engineering practice with the increase of students' scientific research (Massachusetts Technological Institute in the US, The Royal Institute of Technology in Sweden, The University Jinhua in China).

The list of necessary skills and competencies of graduates (CDIO Syllabus) was first published in 2001 and amended in 2010 and 2011 by the university teachers according to the national peculiarities [1].

CDIO Syllabus became a framework for the development of curricula and is used for the description of specific knowledge the students must obtain within engineering courses. It comprises the following chapters:

1. Subject knowledge and comprehension:
   - basic scientific knowledge,
   - fundamental engineering knowledge,
   - profound engineering knowledge, methods, and means.
2. Personal competencies and professional skills:
   - analytical thinking and ability to solve problems,
   - experimenting, research and obtaining knowledge,
   - systemic thinking,
   - professional competencies and personal qualities.
3. Interpersonal competencies:
   - teamwork,
   - sociability,
   - foreign language communicative competence.
4. Planning, designing, production, and application of systems within the enterprise, society, and environment as an innovative process:
   - external, social and environmental context,
   - business context,
   - planning,
   - designing,
   - production,
   - application.

The presented CDIO Syllabus has a complex nature and in comparison with the national accreditation criteria for engineering syllabi in other countries, enables us to fulfill a broader task, helping to define the ways of improving valid curricula. In the modern world, the role of each graduate of a technical university changes and requires his ability to interact with the representatives of other spheres about life-long learning innovations, entrepreneurship. For instance, a complex concept for steady human development calls for the search of balanced technology that would enable safe utilization of used resources, creating new systems without carbon fuel to preserve the environment. This stresses the importance of the role and responsibility of the graduate of a technical university for the society and the environment. It is necessary to take into account the function of modern engineers in the innovative process since they present new technologies, goods, and services.

The authors of the described approach note the necessity to develop engineers' global outlook and skills to work for an international company, which calls for communication in foreign languages and understanding international standards and norms [1].

The primary tasks of the universities are raising the quality of education, organization of the study process based on a personality-centered approach, creating conditions for students' comprehension activity. At the same time, students must be able to work according to the trends in the modern world economy. The intellectual revolution of the labor forces entailed the rapid advance of intellectual economies, thus overall, harmonious, creative personality development, which meets the employers' requirements. Before switching to CDIO Syllabus all engaged parties (teachers, employers, and students) define the desired level of competencies for future labor activity (production, management, and entrepreneurship).

According to Bloom's taxonomy, training embraces three spheres: cognitive (knowledge and thinking), emotional (personal qualities and values), and psychomotor (movement skills and actions and manipulations). Comparing the level of development of each skill with Bloom's taxonomy, it is possible to differentiate the most significant ones for the graduates: engineering thinking, communication, designing, and personal competencies.

The issues of developing education policy based on competencies, determining the content of curricula, syllabi, textbooks, educational standards for monitoring the quality of education are considered in the guidelines of the educational policy of Ukraine [12].

In our opinion, the next step is determining the ways and means of reforming engineering training. Modern research into practice-based engineering training testifies to the fact that each syllabus for the subject included in the integrated curriculum contains interconnected parts: the objective and tasks; the matrix of the program, its plan with determined methods, and evaluations of the results of CDIO Syllabus. All university training engineers according to CDIO standards ensure that these subjects interlink, converge which is reflected in the matrix of the integrated curriculum. Therefore, there is a method developed to determine the effectiveness, reserves, failures, and advantages of CDIO Syllabus.

There are several approaches to forming a curriculum:

- classical curriculum without taking into account developed skills,
- integrated curriculum with interlinked subjects, skills and students' project work,
- the problem-based curriculum aimed to solve existing problems,
- project-based curriculum to implement practical tasks.

Well designed project work with the aim of its completion serves as an important motivating factor. There are several ways of integrating courses: temporary integration, parallel integration, embedded integration. The integrated course can be taught by one or several teachers who coordinate their actions. This approach is very effective for a project or course paper and basic engineering subjects involve the implementation of some design or project. It is usually done in the conditions very similar to the real practical setting.

The succession of courses is also very important since every course is built on already developed skills. For example, lecturers of the Royal Institute of Technology (Stockholm, Sweden) developed so-called paths of skill development from one course to another, to obtain the final product – developed competencies of creating products, processes, and systems.

The teachers of Singapore technical institute set the integration of personal competencies, professional skills, teamwork as a priority in modern engineering training. The School of machine-building and aeronautics of this institute offered first-year students learning the "Fundamentals of engineering" to design and assemble a race car. While carrying out this task the students produced chassis according to their drawings and modeled the body of the car. After that, the race cars assembled by students were tested to define the failures and strong points. The next step of this integration was the development and production of pilot samples of items for social projects. Before this, the students studied the demand of the market and developed new items employing critical and creative thinking. A compulsory course "Introduction into engineering" implies a lot of practical work and writing projects which are presented at the final conference.

It enables the students to reflect on the outcome of their work, assesses the skills developed as the result of designing and implementing projects, and define ways to improve them. The project-based learning can be presented in laboratory experiments or ICT designed experiments, and the assessment of their results. It enables us to consolidate the obtained knowledge, develop skills and abilities to solve problems, modeling working conditions.

According to some researchers, third-year students should be given tasks to remodel the existing industrial items, to increase productivity, reduce their nominal value, to use the natural resources more rationally and to build environmentally friendly production. Fourth-year students must build the model of a real process. For example, the students of the Massachusetts Institute of Technology had to design two independent 2-kilogram robots able to communicate in space. The project involved 15 students who designed and created prototypes, power plants, navigation, monitoring, and control systems, then tested in the conditions of zero-gravity [1].

4. Results

To achieve an appropriate result, the task for the design-implement activity must be complicated enough, and the role of teacher shifts from lecturing to tutoring and monitoring. Naturally, teachers must be well prepared to teach according to CDIO, therefore training of scientific staff is an important part in this respect. Ukraine's entrance into the European educational and scientific community calls for modernization of the structure of qualifications chart [13].

The realization of the national scientific policy including the system of training university teachers is one of the state's main functions. The next important step is to search for the optimal model of training scientists so that national science and higher education could reach the world level, while preserving national identity, increasing the country's intellectual potential [14].

For the realization of design-implementation activity, it is necessary to create an appropriate setting in the workshops and laboratories with Internet access, library access, computers, and different software. The rooms can be zoned according to the stages of realization of the CDIO model (planning, designing, production, and implementation), where students can communicate with one another and teachers.

To estimate the level of developed competencies of future engineers, their readiness for professional work, we researched at the Zhytomyr Polytechnic State University, comparing the performance results of bachelors and masters. For the research, we used the results of the methods of socio-pedagogical analysis (performance monitoring, expert evaluation, pedagogical observation, questionnaire design of both students and teachers) [4]. Such methods are quite popular since they conform to international standards of teaching and learning results at university and developed competencies of future engineers. First of all, we diagnosed the bachelors' and masters' levels of proficiency in certain competencies according to the 100-point score (see table 3).

Table 3. Bachelors' and Masters' developed competencies (according to 100-point score).

Competencies	Bachelors	Masters
Fundamental knowledge	90	95
Analytical problem substantiation	80	83
Creative thinking	75	90
Experimental research	85	88
Invention	80	95
Team-work	90	90
Communicative skills	90	95
Engineering entrepreneurship	75	85
Planning and project management	85	95

These competencies include the necessary knowledge, skills, and abilities to solve professional tasks, developed personality qualities for effective collaboration and teamwork, the ability to perform production functions.

The results of estimating students' competencies (average rate for students participating in diagnostics) showed, that the majority of future engineers have sufficient fundamental knowledge, can work in a team, possess necessary communicative skills, but are not ready to provide analytical substantiation of any engineering problem, are now enough knowledgeable about experimental research in engineering entrepreneurship. Questionaries' analysis enables to state that the educational process pays little attention to the development of these important professional competencies. Suffice it to note that in recent years the university has been forming a new educational medium aimed at active cooperation with enterprises, implementing new integrated technologies, technical and informational communicative education tools, practice-oriented curricula into the study process.

After the conducted questioning the students we proceeded to their evaluation according to descriptors with the help of experts working at the enterprises hosting students' practical externship. The obtained results enabled us to distinguish three levels of students' professional competency (optimal, functional, basic, and insufficient) in 4 components: motivational, cognitive, operational, and reflexive (see figure 1). When distributed according to these criteria, we have seen the most developed and less developed in the professional competency of students (see figure 1).

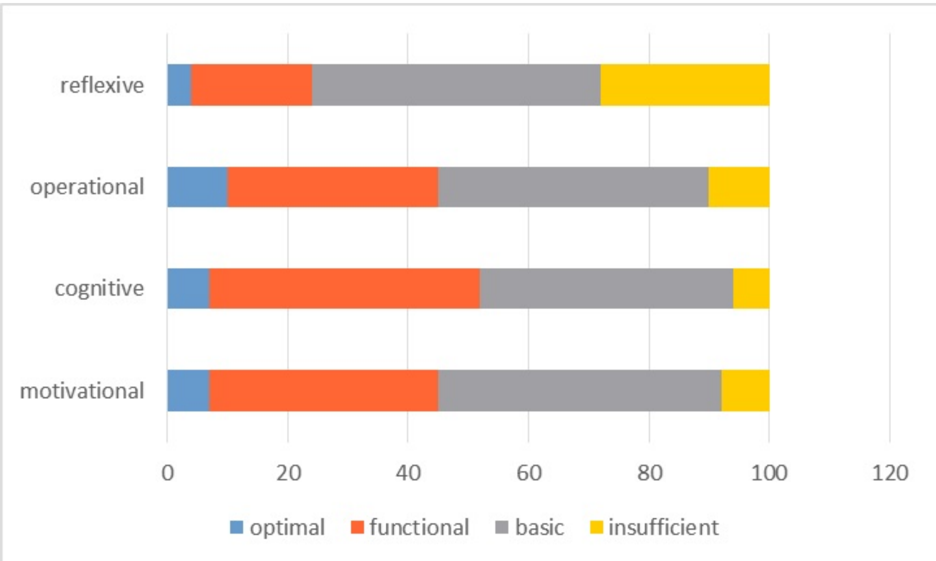

Figure 1. Distribution of students according to the criteria of professional competency.

The diagnostics results of the acquired professional competency of future engineers enabled to conclude:

- most students graduate from the university with the basic level of professional competency in all the above mentioned four criteria,
- as for motivation, 45% of graduate students showed optimal and functional levels, which testifies to their professional interests, engagement, and strife to realize their abilities,
- 52% of students also showed a remarkable level (functional and optimal) in the cognitive criterion of their professional training,
- however, the indices in the operational criterion were the lowest (functional and optimal – 42%), which stresses the need to intensify the practical component of CDIO training,

- the lowest rate was shown in the reflexive criterion (functional and optimal – 24%), since the professional and life levels are the lowest as well, which calls for drawing more attention to students' production internship practice.

The conducted research and the experience of the practical training of the students of Zhytomyr Polytechnic State University testify to the fact that for the transition to the CDIO approach it is necessary to have sufficient staff resources. For the realization of project implementation, there should be an educational setting instead of traditional classrooms, which should be equipped into workshops and laboratories. This approach requires conditions for students' communication, planning, exchanging ideas, carry out experiments. New rooms are equipped with magnet-highlighter boards, Internet access, access to the library resources, computers, and all necessary software. The students are involved in various creative contests, implying research and creative thinking. The obtained knowledge will transform into skills during in-service practice, the concept of which conforms to the "Regulations on practice for students of higher educational establishments of Ukraine". The practice is to develop students' skills and abilities to make independent decisions. The required practical skills are listed in the practice itinerary and their actual achievement is reflected in students' reports. Students' scientific training was performed in the research laboratories based on new technologies, employing development testing, computer-based designing of cutting tools, stereophotogrammetry, studying the ecology of mining, the problems of water resources, etc. this activity involves cooperation with leading industrial companies of the region. A very important feature of students' practical training is their participation in various vacancies fairs, workshops, round tables with the involvement of business culture representatives. It is possible through the collaboration of the departments with the Career Development Centre and the department for international relations. The university houses the only in the region business incubator YEP, among whose goals are the innovative system of promoting and developing youth and academic entrepreneurship. Companies' sponsorship enables students to work over their projects in teams, obtain necessary experience for future professional activity, possible for these companies. It helps students better understand the needs and problems of industrial processes, find the place for internship and further employment.

Furthermore, there is a great problem in the country of graduates' employment. The enterprises where students have their practice not always create necessary conditions for developing students' necessary competencies and the internship/practice is always only formal. This stimulates the university teaching staff to look for ways of improving students' practical training at university, using active methods and technical teaching aids. More and more students get involved in research work into indices and results of real production processes.

5. Conclusion

Changes in modern professional training are determined by the necessity to educate specialists ready to practical work, able to creativity, designing effective systems and items. This calls for the necessity to bring theoretical training and practice together which is possible both in the premises of the university (workshops, laboratories) and industrial enterprises. It is possible within the frames of CDIO Syllabus, which integrates theory and practical work, different subjects, and brings together teachers and students in collaborative activity, from which both parties benefit. Students participating in teamwork are more able to develop their critical and creative thinking, forecast and assess the outcome of their work, communicate their ideas, be flexible in cooperative work, make well-informed decisions based on effective communication. Practical work enhances students' motivation because they can deal with real products and processes, act in real or close to real production setting, can design and implement and discuss the results with teachers and other students. Moreover, embedding such courses as biology, physics, chemistry, and information science into the engineering curriculum and integrating subjects raises the students' awareness about the impact of their products on the society and environment.

Professional technical training at universities of Ukraine based on CDIO Syllabus calls for studying the experience of other European universities such as Royal Institute of Technology (Sweden), The University of Leeds (Britain), Technical University of Turin (Italy) that developed and implemented engineering syllabi to meet the requirements of industrial enterprises and the society.

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Journal of Physics: Conference Series

Technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines

Technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines

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Abstract. The article presents the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines. It was designed the classification of competence-based educational simulators for learning general technical disciplines. There are presented types of educational simulators and outlined professional competencies of general technical disciplines that provide the developed types of simulators. On the basis of passing educational simulators it is formed not only a qualitative indicator of the educational results, but also an indicator of the formation of competencies in the course and curriculum. The method was tested using experimental group and control group (total 1301 students of specialties 'Agricultural Engineering', 'Electrical Power, Electrical Engineering and Electrical Mechanics', 'Professional Education' that studying general technical disciplines) by systematically measuring achievement of professional competencies in the conditions of informational and educational environment by using educational simulators. The results show that higher education applicants in the experimental group achieve better results of acquiring professional competencies.

1. Introduction

In the context of the development of modern equipment and technologies, the question of studying general technical disciplines among future specialists in engineering specialties arises. Technological progress expands the possibilities of using modern educational environments, which requires an appropriate level of training future engineers. The future engineer must be competitive in the global labour market, which means that he must have professional competencies. Therefore, the application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines is relevant.

The use of e-learning strategies in higher education is becoming increasingly popular [1, 2]. Moreover, online higher education is an innovative way to increase the accessibility of university education [3]. Universities with the help of open education can evaluate student without attendance [4–8]. However, the important aspect in the context of learning in the informational and educational environment is feedback between tutor and students [9–14].

The findings show that about 75% of students of engineering specialties agree with the advantages of online learning [15]. The learning in the conditions of informational and educational environment helps to develop an analytical thinking and understanding underlying issues [16]. An increasing number of higher education institutions have deployed learning management systems (LMS) to support learning and teaching processes [17–19]. But implementation learning management system in higher education institutions needs a range of special online tools [20].

Educational innovations such as the flipped classroom, game based learning, gesture based learning, along with pedagogical shifts, such as life-long learning portfolio maintenance, team teaching, and separation of learning and competency assessment are involved in the engineering learning [21–27]. There are opportunities with regard to learning in conditions of informational and educational environment such as: online teaching, supporting mechanisms, quality of education and educational efficiency [28, 29]. The researchers make remote evaluation of engineering competences using progressive competence representation model [30].

In engineering education exists strong evidence for improvement of basic competences: underlying science knowledge, knowledge of fundamental and advanced engineering, engineering reasoning and problem solving, systemic thinking [31]. The emergence of new educational environments, in which digital fabrication techniques are used to turn ideas into digital designs, and these into tangible products through 3D printing offer an opportunity for the development of engineering creativity [32–35]. The engineers have tendencies to face problems with the technical, economic, social and environmental impacts of their solutions [36].

Informational and educational environment provides a common support service for learning outcomes information exchange, referring to a student's knowledge, skills and competence [37]. So, there is a need in development competency management systems and the support of computer technologies to this field [38]. It is important not only to develop a competence model for the future engineer, but also scientifically substantiate it [39]. The data from the interviewing industrial employees, is highlighted as one of the professional skills required of a bachelor-degree-holding engineer working in the engineering industries and it can help to outline professional competencies [40].

The development of the competencies is possible during a laboratory and practical classes [41, 42] that be carried out in the conditions of informational and educational environment. General technical disciplines are designed to perform several main functions: to promote polytechnic education; provide a deeper understanding of special disciplines; to help students better understand the laws of science in their application in engineering and technology; to develop technical thinking [43, 44]. The system of engineering education in the conditions of informational and educational environment requires modernization of theoretical and methodological foundations of training, its structural and organizational restructuring through the introduction of theoretical, interactive and practical tasks, such as educational simulator.

The aim of the article is to develop the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines.

2. Methods

The set of methods used in the research process is represented by:

- theoretical methods – forecasting, formalization, categorical and logical analyses in order to determine the pedagogical characteristics of learning general technical disciplines in the conditions of informational and educational environment, generalization of the results and experience;
- empirical methods – surveys, questionnaires, self-assessment, testing, direct and indirect observation of the learning process, pedagogical experiment;

- statistical methods – quantitative processing of indicators and verification of the reliability of the obtained empirical results using the Pearson's criterion.

In order to statistically verify the equality of use of educational simulators in the informational and educational environment for learning general technical disciplines in control and experimental groups, it was applied Pearson's criterion χ^2.

The following hypotheses are formulated: H_0 – there are no significant difference in the level of application of educational simulators in the informational and educational environment for learning general technical disciplines in control and experimental groups; H_1 – there are significant difference in the level of application of educational simulators in the informational and educational environment for learning general technical disciplines in control and experimental groups.

3. The designing of competence-based educational simulators in the informational and educational environment for learning general technical disciplines

The basis of monitoring the students' results in the informational and educational environments is the assessment, the achievement of points as a result of passing courses. It is proposed to consider the informational and educational environment as system-organized set of hardware, software, organizational and methodological software that is created to meet the needs of users [45] and to focus on its improvement according to the competence-based approach [46]. It is necessary to analyse students' behaviour in online learning activities and detecting specific patterns of interaction in LMS for the purpose of giving recommendations in development educational simulators [47].

Studying in the conditions of informational and educational environment attracts a diverse range of students, but it is important for tutors to anticipate students' individual needs [48]. The system aims to improve the effectiveness of the learning process by providing features for flexible adjusting of the educational tasks [49]. The evaluation of student's results focuses on the learning the participants engaged in the thematic units and the perceived outcomes on the growth of their knowledge [50].

It is recommended that instructors design courses in a way that can promote students' self-regulated learning behaviours in online learning settings and that students in online classes, as in traditional classes, set aside a regular time to concentrate on the course [51]. Adaptive assessment enables to perceive competences of students more efficiently and correctly [52]. The findings indicate that there is significant relationship between the entry test scores and the academic achievement of engineering students [53].

Simulation-based training techniques and tools can be applied in designing structured learning experiences, as well as be used as a measurement tool linked to the competencies and learning objectives [54]. Competence is defined as the level of performance resulting from the skills that can be observed. Digital technologies have an impact on education [55], training and learning by developing modern learning environments and tools that enables obtaining these skills [56]. In this study, we focus on the creation of educational simulators to provide a competence-based approach in the training of future engineers in an informational and educational environment.

Under the term competency-based educational simulator in the informational and educational environment it is implied a set of specialized logical, analytical, visual and practical training tasks on the basis of use of informational tools of the educational environment, the result of which is the acquisition of competencies in specialty. The content of any educational simulator for general technical discipline in the informational and educational environment must be appropriate for the work program for students in the curriculum. The tasks of an educational computer interactive simulator in the conditions of informational and educational environment is not a simple set, but a system of tasks that has the composition, integrity and structure in the direction of training.

It includes tasks, rules for their use and evaluation, and recommendations for interpreting the results.

The designing of competence-based educational simulators starts from the familiarization with the peculiarities of the general technical discipline and the specificity of courses, analysis of the available software tools of the informational and educational environment in order to determine its approximate structure and content.

The next step is selection of some important terms and concepts that must be studied by students and preparation of theoretical material in the form of a presentation with audio content, multimedia interactive lectures, web pages, hypertext etc.

The final stage is linking the educational simulator tasks to the competence repository in the informational and educational environment. It is possible to use educational simulator for checking the modular and final results, performing of practical tasks and consolidation of knowledge from lectures in the informational and educational environment (figure 1).

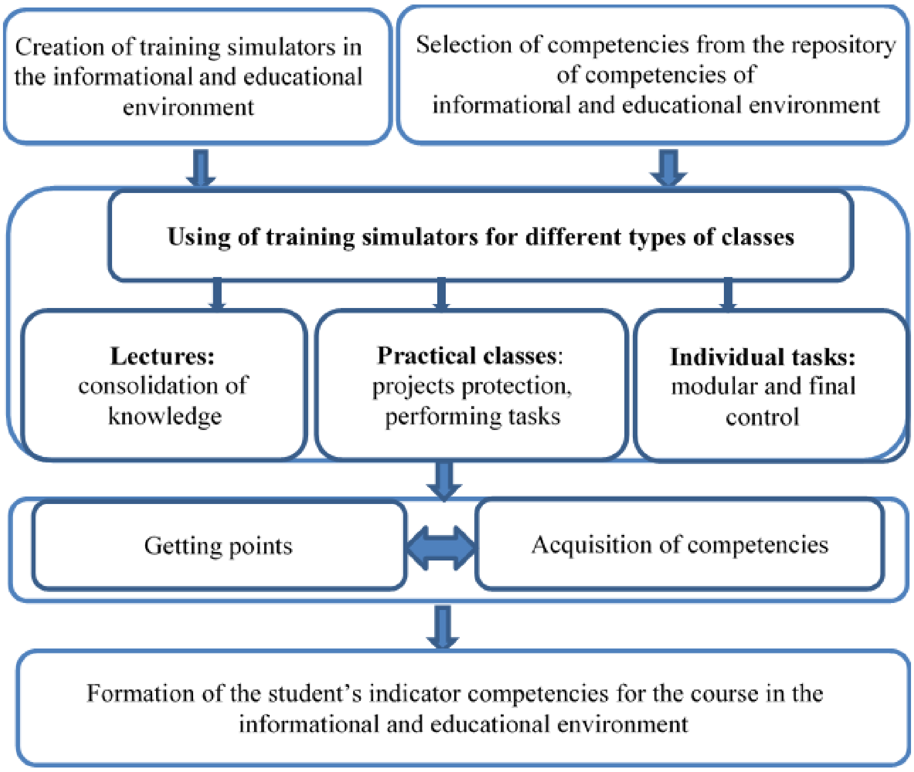

Figure 1. Technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines.

There are three main types of educational simulators for learning general technical disciplines in the conditions of informational and educational environment: educational test simulators, educational graphic simulators, educational gamified simulators.

The educational test simulator is the use of a special training task aimed at the formation of professional competencies based on test tools of the informational and educational environment, which is used to learn the laws, methods, rules, etc. It helps future engineers develop mathematical, analytical and critical thinking skills.

The main task of *the educational test simulator with multiple choice* is to choose the correct variant of the statement, based on the competencies obtained during the study of the course. The basic elements of the tasks for students with the choice of the right answer, include the instructions for the subjects, the content of the tasks, the form, content and number of answers, as well as assessments for correctness of performance, which is the basis for the acquisition of competencies in the general technical disciplines. The answers to the tasks can be in the form of statements, numbers and graphs.

Educational test simulator with the possibility of choosing a match involves the task of establishing compliance. It needs at least two questions or statements and three answers. These can be not only text questions, but also the relevance of text and images, images and images and more. In order to perform the task correctly, it is necessary to set the information to match and connect logical pairs. Such a simulator develops logical thinking, analytical skills and visual perception when using graphic and animated objects.

Educational test simulator with a short text answer contains the answer which can be a word or a few words. With this type of educational test simulators, it is advisable to train the definition of terms, concepts, etc. In the comments it is necessary to leave explanations as to the form of input of the answer. In this type of questions for the educational test simulator it is also possible to enter images, animations to identify phenomena, physical, technical, chemical, biological or technological processes.

Educational test training simulator with choosing the numerical response provides the use and software processing of calculations. Before entering the numerical value, the future engineer must calculate, because the chance of entering the correct answer is eliminated. Such a simulator is able to develop the ability to quickly calculate, clear orientation in the mathematical, technical and theoretical space in the field of engineering.

Educational test training simulator with choosing a right or wrong statement involves identifying the correct and incorrect answer. For objective results, it is necessary to specify the test period and limit the time. During the required period, access to the simulator will automatically open. Students will only see a description of the future task and the requirements for it. Such a simulator can provide a general response to a question – a comment from the tutor, which is shown to the student after the answer. It is also possible to add tags – keywords that are needed in the future to quickly find the right questions, if there are too many.

Educational test training simulator with the ability to choose terms and keywords from the drop-down list is used when studying the methods of performing certain actions, algorithms for solving engineering problems, the sequence of drawing up the scheme. It is advisable to design such educational simulators from tasks that would meet all levels of complexity.

Simulation and manipulation play vital roles in teaching procedural knowledge in engineering education [57–60]. *The educational graphic simulator* is the use of a special training task aimed at the formation of professional competencies based on the informational and educational environment, based on the training of visual perception and work with engineering drawings, diagrams and other graphic objects. This simulator is an appendix to the theoretical study of teaching material, practical and laboratory work, and provides an opportunity to expand the understanding of individual processes and engineering systems in the complex.

Educational simulator for dragging a graphic image into a text area provides for analysis and differentiation of educational information. The task is offered a description of graphic objects, processes, complex systems, elements of engineering machines. Higher education applicant should review the proposed graphic images and objects and assemble the description and the corresponding graphic image. Such simulators are capable of training memory, visual perception, and developing analytical skills. Educational simulator focused on working with graphic markers is concentrated on the acquisition of skills of visual perception of engineering objects. Graphic marker is a tool that allows to graphically supplement the submitted image in an educational environment. Moreover, it can be a straight line, a curve, geometric images of figures and engineering objects, both in the plane and in space. Simulators that work with graphic markers are able to train the higher education applicant in the work with the elements of graphic design.

Educational simulator for dragging text to a graphic image is based on a plane or a spatial image. The visual images are selected accordingly and contain appropriate areas for explanation in an educational setting. Text explanations provide an opportunity to activate the relevant knowledge of the depicted elements of the proposed graphic image.

Educational simulator for dragging image to image focuses on the logical visualization of plane or spatial figures and the integration of their elements in the conditions of the informational and educational environment. It is advisable to study elements of deformation, diffusion and conversion of liquid materials to other aggregate states; complex components of engineering machines and processes in these machines and it is possible to drag the elements to the appropriate area of the drawing with the task of studying the components of the machine or mechanism, the design of certain details in the drawing, etc. Thus, this type of simulators enables the training of visual memory, familiarization with the practical aspects of engineering without the use of specialized equipment, develops practical skills.

Gamification can provide engaging learning experiences for students, the studies reveal four reasons for learners' enjoyment of gamification: it can foster enthusiasm; provide feedback on performance; fulfil learners' needs for recognition; promote goal setting [61–66]. *The educational gamified simulator* is the use of a special training task aimed at the formation of professional competencies in the informational and educational environment based on a task, the performance of which develops professional engineering competencies and includes acquaintance with the details and devices that are the basis of engineering, the principles of teaching the operation of complex technology; installation skills, assembly systems and repair of machinery.

Educational gamified simulators by puzzle type is used for the logical formation of engineering objects. Such objects include the results of modern technological progress.

Educational gamified simulators by crossword type presents a technique, the essence of which is to solve words according to the above definitions. Crossword simulator allows to train the skills of terminology, training the study of professional concepts. The use of a simulator-crossword contributes to the development of the ability to navigate independently and quickly in the educational material and develop creative skills.

Educational gamified quiz simulator is a cognitive task in an informational and educational environment, which consists of questions and answers from different directions of the engineering field, combined by some common topic. It develops the ingenuity and activity of students, expands their outlook, promotes mental education, development of cognitive interests and creative abilities, helps to identify modern competencies in the engineering industry.

Each task in the *educational interactive simulator* can have different complexity, duration and time to solve. The essence of such a simulator is to simulate the control of any process in the field of engineering, apparatus or vehicle. In an informational and educational environment, the simulator can give the impression of reality, reflecting some of the real phenomena and properties in the virtual environment.

Educational animated simulator is presented on the basis of GIF animation of engineering processes. GIF elements create an animation of a process, and one of the steps can be left out. From the proposed images, it is necessary to choose one and thus restore the whole process. Animated simulators can illustrate such processes of simulation of physical interaction of solids, simulations of motion of systems of particles, liquids and gases, simulation of dynamic motion and spatial animation of geometric figures. The use of animated training simulators is very useful in classes that require additional equipment. It allows to perform chemical tests without reagents, physical experiments that require special equipment and understand the principle of their action.

The types of educational simulators in the informational and educational environment for learning general technical disciplines provide acquisition of the competencies.

Educational test simulators provides the

- knowledge of the basic properties of materials and technological requirements for materials,
- ability to determine the static and dynamic loads on the working bodies and transmissions,
- ability to calculate the structures for strength, rigidity and durability,
- ability to theoretically calculate machines and mechanisms,
- ability to perform technical documentation for the product,
- ability to calculate the required capacity of machines,
- ability to make equations of motion of machines and mechanisms.

Educational graphic simulators provides the ability to

- perform drawings of non-standard parts,
- perform assembly drawings of machines on the basis of standard units,
- design connections and mechanisms of machines and equipment,
- design and research systems of maintenance of machines and equipment,
- determine the compliance of modes of operation of machines with structural features
- coordinate the parameters and modes of operation of machines.

Educational gamified simulators provides the ability to

- analyse the designs of machines and equipment and evaluate their technical level,
- predict the technical condition of machines, equipment and systems,
- to organize maintenance, diagnosis and storage of machines and equipment,
- technologically adjust complex machinery to perform technological processes,
- defect machine parts,
- choose the technical means for basic and auxiliary operations.

4. Results

It is presented the calculation of the empirical value of χ^2 based on the results of the use of educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups before the experiment.

Table 1. Calculation of the empirical value of χ^2 based on the results of the use of educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups before the experiment.

Level	EG,%	EG, n_i	CG, %	CG, n_{i1}	$(n_1 - n_{i1})^2$	$\frac{(n_1-n_{i1})^2}{n_{i1}}$
High (A)	4.95	5	5.73	6	1	0.2
Sufficient (BC)	62.37	63	58.65	61	6	0.06
Initial(CD)	32.68	33	35.57	37	16	0.48
Total	100	101	100	104		0.74

The empirical value of χ^2 is the result of the sum of the values of the levels in the last column. Therefore, the empirical value of $\chi^2 = 0.74$. The degree of freedom ν is calculated by the formula $\nu = k - 1$, where k is the number of levels. Therefore, $\nu = 2$. For this degree of freedom is defined a critical value $\chi^2_{critical}$ for the levels of statistical significance $\rho \leq 0.05$ (5.991) and $\rho \leq 0.01$ (9.210). Levels of statistical significance allow to delineate the zones of significance

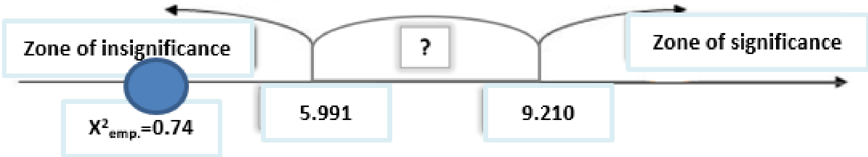

Figure 2. Empirical value in the zone of insignificance before the experiment.

and insignificance for the obtained values [67]. The axis of insignificance is presented on the figure 2.

$\chi^2_{emp} \leq \chi^2_{critical}$, which means that the deviations between the distributions are insignificant. So it is accepted hypothesis H_0 – there are no significant difference in the level of application of educational competence-based simulators in the training of future engineers in the experimental and control groups. Also it is checked the statistical verification of the equality of the use of competence-based educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups using the Pearson's criterion χ^2 at the end of the experiment (table 2).

Table 2. Calculation of the empirical value of χ^2 based on the results of the use of educational simulators in the informational and educational environment for learning general technical disciplines in experimental and control groups after the experiment.

Level	EG,%	EG, n_i	CG, %	CG, n_{i1}	$(n_1 - n_{i1})^2$	$\frac{(n_1 - ni1)^2}{n_{i1}}$
High (A)	11.88	12	5.76	6	36	3
Sufficient (BC)	81.18	82	69.24	72	100	1.21
Initial(CD)	6.94	7	25.00	26	361	51.57
Total	100	101	100	104		55.79

The empirical value of $\chi^2 = 55.99$. The value for the degree of freedom $\nu = 2$ is calculated. For this degree of freedom is defined a critical value $\chi^2_{critical}$ for the levels of statistical significance $\rho \leq 0.05$ and $\rho \leq 0.01$. Levels of statistical significance allow to delineate the zones of significance and insignificance for the obtained values. The axis of significance is presented on the figure 3.

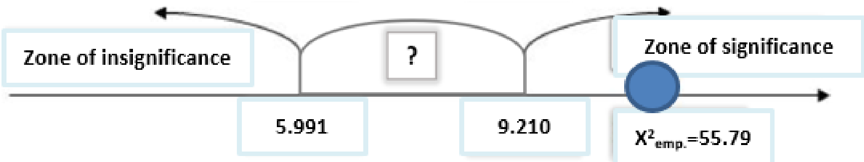

Figure 3. Empirical value in the zone of significance after the experiment.

$\chi^2 emp \geq \chi^2 crit$, which means the presence of significant deviations between distributions. So it is accepted hypothesis H_1 – there are significant difference in the level of application of educational competence-based simulators in the training of future engineers in the experimental and control groups.

5. Conclusion

It was developed the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines. It was outlined types of educational simulators, that increase the ability to provide educational services, emphasize the diversity of educational materials in the field of general technical disciplines and are able to provide quality training of students based on modern needs and relevant competencies. Educational test simulators are based on engineering test tasks that help to master the rules, techniques, laws, theorems and other content in the field of engineering. Educational graphic simulators are based on the training of visual perception and work with engineering drawings, diagrams, and other graphic objects. Educational gamified simulators consist of the task, fulfilling which develops professional engineering competencies. For designing the tasks of educational simulators in the professional training it is advisable to attach to each task the competencies that are represented in the competence repository in the conditions of informational and educational environment. Thus, the main purpose of the experiment is to check the quality of knowledge of students in the experimental and control groups at the beginning and at the end of the experiment. The reliability of the obtained results was verified using the Pearson's criterion. At the end of the experiment, it can be claimed that the using of competence-based educational simulators in the informational and educational environment for learning general technical disciplines is effective. The implementation of the outlined technology provides an opportunity to combine the educational process in the audience with the training in the informational and educational environment, forming analytical abilities and competencies for professional activity, increases the students' level of professional motivation and self-stimulation.

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Journal of Physics: Conference Series

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Technological model of training of Masters in Electrical Engineering to electrical installation and commissioning

Technological model of training of Masters in Electrical Engineering to electrical installation and commissioning

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Abstract. The article presents the technological model of training of Masters in Electrical Engineering to electrical installation and commissioning. In the structure of the model of training future electrical engineers, three basic blocks are identified: motivational-target, content-procedural and resultant. The following components act as structural elements of the motivational-target block of the model: social order, technological progress and normative base, purpose, tasks. The content-procedural block of the model includes components of the Master's readiness to electrical installation and commissioning (motivational, orientation, operational), as well as methods and tools of training. The resultant block contains a system of criteria for the formation of the Master's readiness to electrical installation and commissioning, control procedure, levels of formation, self-assessment, result, as well as elements of self-correction and correction of content and methods of education. It is noted that the practical implementation of the proposed model involves a special organization of the learning process, application of appropriate methods and learning tools that would ensure the formation of components of readiness for this activity. The obtained results of the experimental study provide an opportunity to assert that the model of training of Masters in Electrical Engineering to electrical installation and commissioning is effective.

1. Introduction

Due to socio-economic transformations in the country, there is a need for engineers who have a new type of thinking, able to successfully, creatively and quickly solve professional problem. The profession of an electrical engineer in the context of technological progress is developing rapidly due to the intensive development of machinery and technology, as well as the scale of their application and safety. The training of highly qualified specialists of the relevant profile and level, who are ready for constant professional growth, self-education and self-realization, comes to the fore. A modern university must train not just an educated specialist, but a specialist who is able to understand and navigate in the system 'nature – man – technology'. However, the existing system of training an engineer in the electrical industry does not fully meet the needs of society in the development of a competitive, competent specialist. Outdated style prevails in teaching, and innovative processes and methods are only gaining momentum. Insufficient attention is paid to the development of independence, creativity, personality of the engineer. There is a need to renovate the existing systems of training engineers in the electrical industry and their improvement. Therefore, the development of a model for training future specialists in electrical engineering to electrical installation and commissioning in the context of modern needs is quite relevant. The novelty of the author's work is that was developed a set of means of selection and implementation of a step-by-step educational process of training Masters in Electrical Engineering on the basis of tasks using appropriate methods to obtain the result of integrated readiness for electrical installation and commissioning.

An analysis of the literature leads to the conclusion that the curriculum in electrical engineering begins with a comprehensive review of engineering mathematics and maintenance [1]. Students then receive more focused training in electrical and mechanical principles and applications such as circuits, microprocessors and motors. Rapid strides made in technological advancements call for a paradigm shift in engineering education [2]. In modern conditions, there is a need to ensure the operation of the system and take prompt measures to eliminate violations that arise in the process, to improve the knowledge of engineers and, consequently, their training methods [3] and technical tools for numerous engineering purposes [4]. In the context of technology-enhanced learning three support types are distinguished: technical tools, technical tools with predefined guidance, and technical tools with human interaction guidance [5]. The study points out the possible gaps between Software Industry and Education [6]. It is presented a statistical analysis of the views of Electrical Engineering students, regarding the knowledge formation process in a Project-Based Learning application, as a complement to classical teaching methods [7]. The American-Japanese Joint Working Group on Engineering Education (M. S. Dresselhaus, E. Baum, G. Bugliarello, S. C. Florman) determines that the key tasks of training a modern engineer should take into account the competence approach and practical experience [8]. G. Gorshkova investigated application of mathematical modelling in the training of future metallurgical engineers [9]. A. Manikandan and M. Muthumeenakshi emphasize the role of engineering education in supporting India's economic development [10]. S. Zappe, T. Litzinger and S. Hunter point out the need to improve seminars, practical classes and engineering courses [11]. From the standpoint of the European Review, C. Baillie and P. Walker [12], M. Lande [13], Z. E. Liu and D. J. Schnwetter [14], S. Morin, J.-M. Robert and L. Gabora [15] outline the directions of modern creative approach to the training of engineers in Europe. D. Schaffhauser outlines the key skills of the engineers of the future [16]. Z. Bakum and L. Tsvirkun emphasize the need to intensify the cognitive activity of future engineers during graphic training [17].

Engineering education is experiencing a paradigm shift from teacher-centric to student-centric teaching and learning process, content based education to outcome based education, knowledge seeking to knowledge sharing classrooms, teachers to facilitators, traditional engineering disciplines to interdisciplinary courses, lecture based learning to technology driven learning [18]. The mechanism of collaborative education receives the most attention, while the talent ability pays more attention to the cultivation of soft skills [19]; it the transformation of traditional disciplines, and there is little construction of corresponding disciplines for certain key industries [20]. The Renewable Energy program at Holon Institute of Technology gives the students technical and practical aspects of energy use (technology and methodology of the study) and energy efficiency [21]. New ideas for engineering design and engineering education is presented by M. Zilbovicius and J.R.C. Piqueira [22]. Features of the development of training simulators for the training of future engineers are covered in the works of N. Dotsenko [23] and I. Batsurovska [24]. Skills development and training for engineers investigated by H. Tank [25]. The issue of forming competencies in engineering specialists was studied in [26–32]. Engineering student's motivation towards an engineering career was investigated by R. Kjelsberg and M. Kahrs [33]. ICT is important part in electric engineering education [34]. O. Sushchenko, I. Trunina, D. Basyuk and M. Pokolodna presented coaching as education technology on electrical engineering education [35]. The findings are experienced from practical work and student evaluations in the field of electrical engineering described T. Fuhrmann [36]. But the issue of the model of training future specialists in electrical engineering to electrical installation and commissioning has not been sufficiently studied.

The aim of the article is development and experimental verification of the technological model of training of Masters in Electrical Engineering to electrical installation and commissioning.

2. Methods

At the first stage of the study, we used the survey method, the method of evaluation of educational activities, taking into account the quantitative and qualitative indicators of the results of professional training of Masters in Electrical Engineering to electrical installation and commissioning. The experiment involved 267 higher education applicants in electrical engineering. The division into control and experimental groups was statistically checked for homogeneity using Fisher's criterion. It is determined that the formed groups are homogeneous. In the control group, the number of higher education applicants in electrical engineering is 135, in the experimental – 132 persons. After the division into control and experimental groups, it was implemented the author's model of training future electrical engineers to electrical installation and commissioning. At the end of the experimental work, the input and output quantitative indicators of the quality of training were checked using Student's t-criterion. T-statistics is usually based on the general principle: in the numerator – a random variable with zero mathematical expectation (when performing the null hypothesis), and in the denominator – a selective standard deviation of this random variable, obtained as the square root of the unbiased estimate of variance.

3. The technological model of training of Masters in Electrical Engineering to electrical installation and commissioning

Modelling becomes the optimal method of studying specifically organized objects, and the model is a means of cognition based on analogy. The model serves as a generalized reflection of the process, is the result of an abstract generalization of practical experience [37]. Technology is a system of functioning of all components of the pedagogical process, built on a scientific basis, which ensures the achievement of the intended results [38, 39]. The technological model in education is a set of ways, means of selection of the control process from a set of possible implementations in order to generalize the sequences and achieve the result. Under the technological model of training Masters in Electrical Engineering for electrical installation and commissioning it is meant a set of methods, means of selection and implementation of step-by-step control process based on tasks using appropriate methods to obtain the result of integral readiness for electrical installation and commissioning.

Formation of readiness for activity of future specialists is based on their readiness for work [40]. The readiness of Masters in Electrical Engineering to electrical installation and commissioning is a professional quality, which includes a set of professional knowledge, skills and attitudes that determine the effectiveness of actions within the competence of the technician and lead to professional safety tasks. In order to increase the readiness of Masters in Electrical Engineering to electrical installation and commissioning, it was developed a technological model of their training. The method of modelling allows to meaningfully reveal the essence of the model and present it graphically.

In the structure of the model (figure 1) of training future specialists in electrical engineering to electrical installation and commissioning, three basic blocks are identified: motivational-target, content-procedural and resultant. The following components act as structural elements of the motivational-target block of the model: social order, technological progress and normative base, purpose, tasks. The content-procedural block of the model includes components of the Master's readiness to electrical installation and commissioning (motivational, orientation, operational), as well as methods and tools of training. The resultant block contains a system of criteria for the formation of the Master's readiness to electrical installation and commissioning, control procedure, levels of formation, self-assessment, result, as well as elements of self-correction and correction of content and methods of education.

The proposed model can be considered as a structure that has a function given by the social order and personal needs of Masters in Electrical Engineering to electrical installation and commissioning. Management of such a system involves diagnostic tasks. Then it is possible to correlate the purposes and results and to draw a conclusion about efficiency of functioning depending the declared purposes and the received results.

The first structural element of the technological model is the goal, determined as the formation readiness of future electrical engineers to electrical installation and commissioning, which will lead to the successful solution of professional problems to ensure safety in the workplace. This goal is due to the social order in modern conditions, technological progress and regulatory framework.

In the educational process of the university as tasks of formation of readiness of masters in electrical engineering the formation of motivational, orientation, operational component of readiness for electrical installation and commissioning is considered. Formation of future specialists in electrical engineering of integral readiness to electrical installation and commissioning is carried out step by step, on the basis of the set tasks.

The first stage is aimed at forming motivation to electrical installation and commissioning through the formation of interests, inclinations, in the development of social and professional values, value orientations in the learning process. At this stage, the future specialist acts as a subject of value self-determination in the professional activities of the specialist. As a result, higher education applicants must have a focus on the chosen profession, it is formed a conscious motivation to electrical installation and commissioning and self-realization in the socio-economic conditions of future professional activity, as well as a positive attitude to important aspects of future professional activity.

The second stage in the formation of Masters' readiness to electrical installation and commissioning is aimed at mastering the system of functional knowledge, conscious skills, abilities and actions in the process of training. The result of the second stage is the formation of the orientation component of the integral readiness of future specialists in electrical engineering to electrical installation and commissioning.

The third stage solves the problem of improving the professional activities of the future specialist in electrical engineering, the readiness of the Masters to varying the tasks of electrical installation and commissioning; achieving a high level of operational component of readiness for professional activity through testing as a subject of this activity in the learning process. The result of the third stage is the formation of the operational component of the integral readiness of future specialists in electrical engineering to electrical installation and commissioning. The practical implementation of the model of formation readiness of future specialists in electrical engineering to electrical installation and commissioning involves a special organization of the learning process, the use of appropriate methods and learning tools that would ensure the formation of components of readiness for this activity.

There are considered the didactic methods and means of formation of readiness of Masters in Electrical Engineering for electrical installation and commissioning. Methods that attributed to the *motivational component*:

- solving problem situations and creative tasks related to the installation of wiring, grounding, repair of electricity in apartments, offices and industrial accommodations,
- discussions on electrical installation and commissioning,
- business and role-playing games in the process of work on electrical sites.

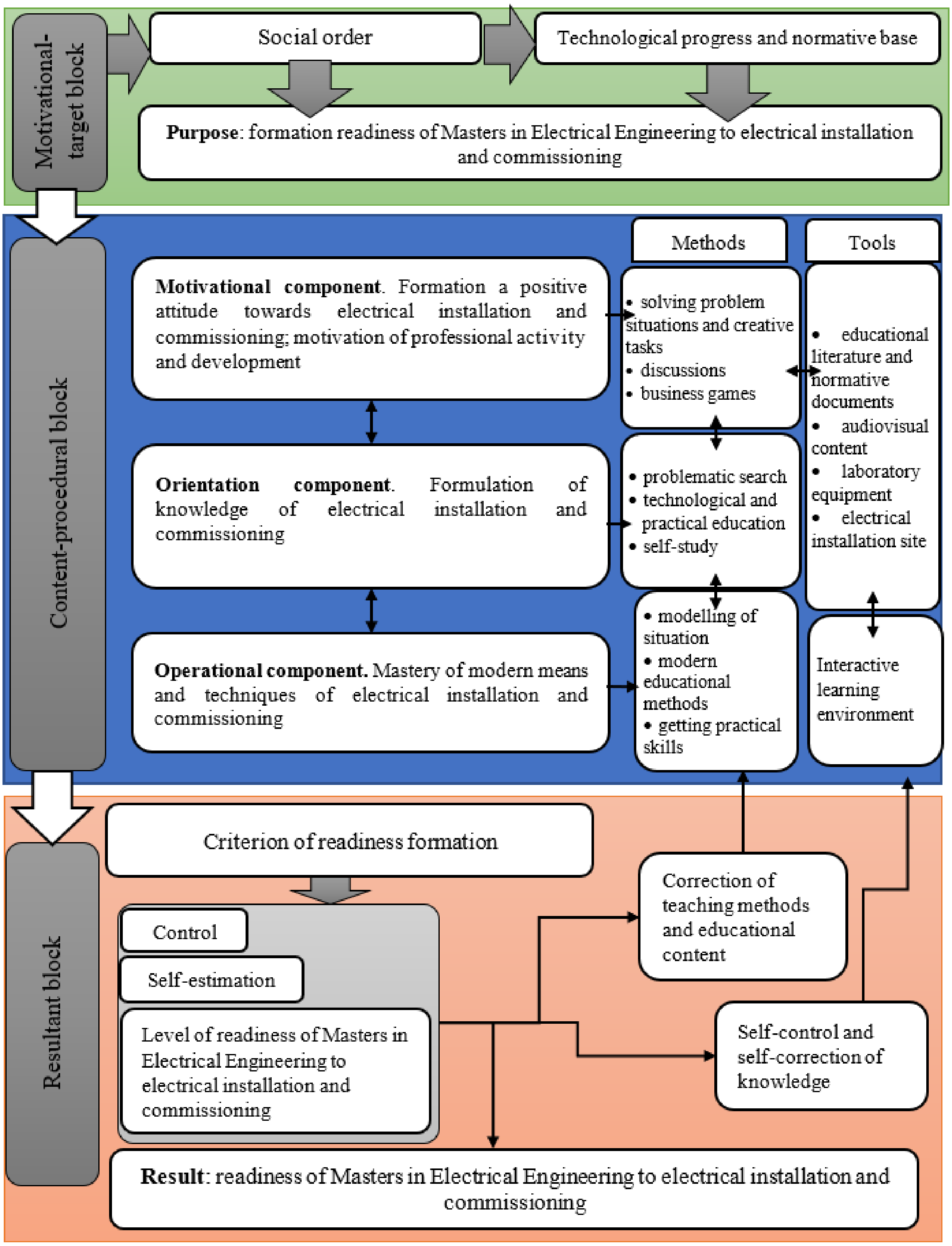

Figure 1. The technological model of training of Masters in Electrical Engineering to electrical installation and commissioning

The methods involve work in laboratories and on experimental electrical sites. Methods that attributed to the *orientation component*:

- problem-searching method (provides for the creation of problem situations of electrical installation and commissioning, active reflection and on this basis their independent promotion in the acquisition of new knowledge),
- technological method (provides an orderly set and sequence of methods and processes that ensure the implementation of the project of the didactic process and the achievement of the diagnosed result of electrical installation and commissioning),
- method of practical training (determines the conduct of joint tests and electrical installation and commissioning),
- method of self-learning (provides opportunities for self-improvement).

Methods that can be attributed to the *operational component*:

- modelling of situations of the process of installation of cable power lines,
- active methods of teaching elements of automation of technological processes,
- acquisition of practical skills.

The means of forming the readiness of Masters in Electrical Engineering for electrical installation and commissioning include the following:

- educational literature and normative documents (lay the basis for the study of key theoretical provisions, laws and regulations and relations in power companies),
- audiovisual content (helping to expand the perception of debugging processes),
- laboratory equipment (is the basis of work with electrical appliances and electrical systems based on training models and simulators),
- electrical installation site (lays the foundation for the operation of commissioning systems for street lighting of residential areas).

Interactive learning environment is one of the key aspects of training Masters in Electrical Engineering based on interactive, visual and audio content.

Criteria and indicators. A key element of the model is a system of criteria and indicators of the level of formation of the components of readiness of future professionals to electrical installation and commissioning. Among the criteria for the formation of Master's readiness to electrical installation and commissioning, there are included:

- awareness of the importance and necessity of the electrical installation and commissioning,
- possession of a system of special knowledge necessary for the activities of the electrical installation and commissioning,
- possession of methods and techniques of necessary actions of the electrical installation and commissioning,
- performance, ability to apply the acquired knowledge and skills in terms of production activities.

Determining the formation of the components of readiness of future electrical engineers to electrical installation and commissioning has three levels: modelling, adaptive and reproductive. The level of formation of the components of readiness is determined by the results of the control procedure. If the control procedure reveals a discrepancy between the level of readiness of the student to some criterion of readiness of the future specialist, the system provides a set of corrective actions: self-correction of higher education applicants by developing an interactive learning environment, or correction by tutors of content and methods of education. If all the components of future specialists in electrical engineering are formed in accordance with the criteria, it can be concluded that their integral readiness to electrical installation and commissioning has been formed.

4. Results

The results of the study of the level of formation of the components of readiness of future specialists to electrical installation and commissioning in the experimental (EG) and control groups (CG) is presented in the table below. The reliability of the data obtained at the beginning and after the experiment was verified using Student's statistical T-criterion [41] (table 1).

Table 1. The results of the study of the level of formation of the components of readiness of Masters in Electrical Engineering to electrical installation and commissioning.

Level	Before the experiment				After the experiment			
	EG	EG, %	CG	CG, %	EG	EG, %	CG	CG, %
Reproductive	2	1.52	4	2.69	24	18.18	14	10.37
Adaptive	44	33.33	47	34.81	92	69.70	68	50.37
Modelling	86	65.15	84	62.22	16	12.12	53	39.26
Total	132	100	135	100	132	100	135	100

At the beginning of the experiment, the deviation from the mean value does not exceed a difference of 5 units. The calculated squares of deviations provide an opportunity to determine $t_{emp.}$=1.27. The critical values are the following: $t_{crit.}$=2.78 ($\rho \leq 0.05$); $t_{crit.}$=4.6 ($\rho \leq 0.01$).

So, $t_{emp.}$ is more than $t_{crit.}$ The empirical value of t is in the zone of significance, and therefore the indicators at the end of the experiment according to the modelling, adaptive and reproductive levels differ significantly.

At the beginning of the experiment $t_{emp.}$=18.27. and falls into the zone of significance. So, $t_{emp.}$ is more than $t_{crit.}$ The empirical value of t is in the zone of significance, and therefore the indicators at the end of the experiment according to the modelling, adaptive and reproductive levels differ significantly.

At the beginning of the experiment, quantitative indicators at high, sufficient and initial levels do not differ in quantitative ratio. Figure 2 shows the results obtained as a percentage according to the levels.

The figure in the form of histograms shows the increase in quality indicators at the adaptive and reproductive level after the introduction of the model of formation readiness of Masters in Electrical Engineering to electrical installation and commissioning. At the end of the experiment in the experimental groups at the reproductive level there is an increase of more than 15%, at the adaptive level – more than 30%. At the modelling level, there is a reduction of more than 50%. The existing increase in indicators provides an opportunity to argue about the effectiveness of the proposed methods.

Figure 3 presents a graphical comparison of data relative to the three levels in the experimental and control groups before and after the experiment.

Figure 3 shows the dynamics of each level. Indicators increase significantly in the experimental groups at the end of the experiment at the adaptive and reproductive levels.

5. Conclusion

Therefore, a technological model has been developed to prepare Masters in Electrical Engineering to electrical installation and commissioning. There are three basic blocks in the structure of the model: motivational-target,content-procedural and resultant. The following components act as structural elements of the motivational-target block of the model: social order, technological progress and normative base, purpose, tasks. The content-procedural block of the model includes components of the Master's readiness to electrical installation and commissioning (motivational, orientation, operational), as well as methods and tools of training. The resultant block contains

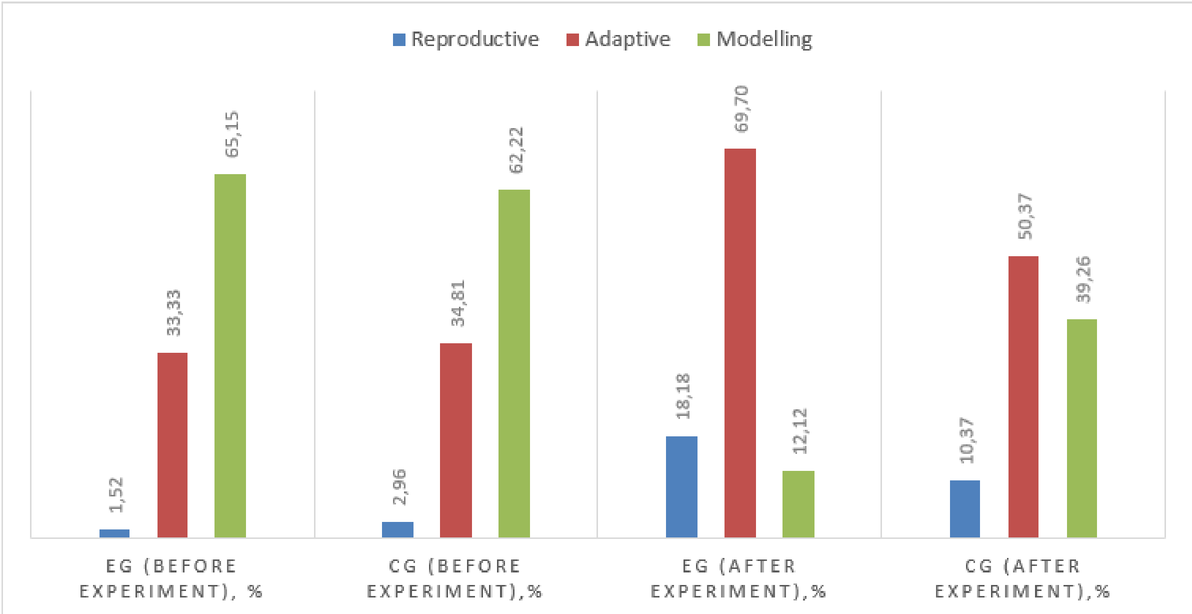

Figure 2. The study of the level of formation readiness of Masters in Electrical Engineering to electrical installation and commissioning.

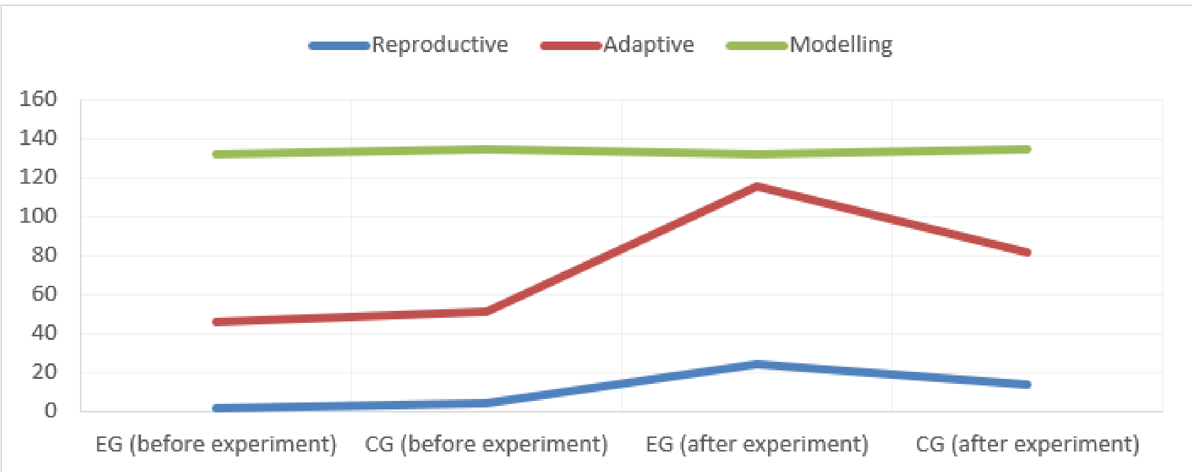

Figure 3. Dynamics of indicators according to the level of formation readiness of Masters in Electrical Engineering to electrical installation and commissioning.

a system of criteria for the formation of the Master's readiness to electrical installation and commissioning, control procedure, levels of formation, self-assessment, result, as well as elements of self-correction and correction of content and methods of education. The proposed model can be considered as a structure that has a function given by the social order and personal needs of Masters in Electrical Engineering to electrical installation and commissioning. The efficiency of the model was experimentally tested. The obtained results of the experimental study provide an opportunity to state that the model of training future specialists in electrical engineering to electrical installation and commissioning is effective.

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Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Teaching robotics to future teachers as part of education activities

Teaching robotics to future teachers as part of education activities

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Abstract. One of the most effective ways to implement STEM education in full secondary education is through research activities. It is implemented by performing certain projects. Professional activity of teachers of natural and mathematical disciplines in STEM education is aimed at the students' mental, cognitive, and personal qualities formation and development. Their level determines the possibility of further mastering by students of a promising specialty STEM industry. It also involves the formation of the ability and willingness to solve complex problems, which is possible with the appropriate level of critical thinking, creativity, cognitive flexibility, teamwork, as well as the ability to implement research activities. In article determines the nature of the relationship between disciplines and the degree of integration. The place of project activity on robotics in school training is considered, describes the competencies that are formed as a result of such project activities. the possibility of teaching robotics to future teachers within the framework of existing curricula is also considered. The concept of STEM education has a broad interpretation: from a simple list of "exact" or "engineering" disciplines to inventive activity. In Ukraine, this area has become synonymous with scientific and research work: research and experiments. From this point of view, robotics is an effective means of developing STEM education. But this is a new tool and schools have a low level of interest in its study. Therefore, our article focuses on finding opportunities to implement the basics of robotics in education. The article formulated course requirements in accordance with the educational needs of the future teachers of science, mathematics and the level of technology development. The paper presents an example of project implementation in robotics, describes the stages of its implementation and achieved educational results.

1. Introduction

In the course of research activities, students have the opportunity to independently search for information on the project's topic, to analyze and systematize it, using a variety of information technologies. This allows them to see and solve a specific problem situation, which is essentially a research activity. Such activities also make it possible to fully work out a certain technological algorithm, which begins with the emergence of an innovative idea and ends with the commercial product creation – a startup, which must learn to present to potential investors.

Educational robotics is an innovative tool that ensures the effective implementation of STEM education [1–7]. The combination of basics of robotics, the natural sciences and mathematics study, design and research activities significantly expands the scope of educational projects that can be performed by students at school. For example, the issues of environmental projects may include environmental protection, disaster relief, conservation of flora and fauna, creating favorable conditions for humanity in extraterrestrial conditions, eco-energy, and etc. Also quite interesting are projects related to technologies for development of artificial intelligence, big data processing, nanotechnology and bioengineering, the Internet of Things, etc. Soon, it is projected to move from "desktop" robotics to the cloud, on the principle of IoT (Internet of Things) [8].

All this should contribute to the formation of students' holistic picture of the world, awareness of the practical value of knowledge in mathematics, physics, engineering, and other STEM education subjects, as well as the formation of soft skills necessary for the information society [9, 10]. But the activity of a teacher in STEM education is not limited to school activities, but also includes extracurricular activities in the form of excursions, quests, competitions, festivals, hackathons, workshops, etc. In distance learning, it is not always possible to fully implement such projects [11–13]. Therefore, the question of future teachers training in research work in distance learning is important.

2. Related works

Research works of recent years [14–25] are particularly informative, they determine the essence of the project activity process, the corresponding technology, and the conditions for its use in the educational process.

The scientific works analysis convincingly testifies that project activity is an effective form of the pedagogical activity, one of the most productive technologies of the person's formation. It is based on an interdisciplinary approach to the learning process and the direct application of students' acquired knowledge during practical activities.

The curriculum determine the nature of the relationship between the disciplines and the degree of integration. There are the following types of inclusive courses [26]:

1. *Discipline-based integration* – focusing on each discipline provides students with specialized skills and concepts in the field. The specialized training provides teachers and students with an in-depth knowledge of the sector. However, this study may lead to fragmentation of information that does not reflect the comprehensiveness of scientific research. There is no knowledge of the connection between the different subjects. This type is possible for theoretical courses, as a basis for further study of scientific concepts and formation of ideas on the orientations of scientific research in certain areas.
2. *Study of parallel courses/modules* – in this case, the content of each discipline does not change. Only the study order changes. In this way, an effect is obtained when students can establish the connections between individual phenomena by themselves or with the help of a teacher. The only disadvantage is that students do not see cooperation among teachers. Moreover, this work requires sufficient time for planning.
3. *Additional courses or disciplines* – comparison of different disciplines focused on a problem, without a direct attempt of integration.
4. *Integrated courses/modules* – are short-term project activities. Some activities are based on an interaction between different subjects. Efforts are being made to address issues of social importance.
5. *Integrated days* – long-term projects, mainly on topics and issues arising from personal experience.
6. *Full-time program* – fully integrated programs in which the daily learning of students is linked to their lives. An example is a summer scientific camp.

Project activity contributes to the formation of the modern student personality; it can be considered an educational process independent structural unit.

Project technology is a special type of cognitive activity, which consists in contrasting the known and the unknown, and aims to activate the process of learning and understanding new things. It stimulates cognitive activity, promotes creativity and the formation of certain personality traits.

In [27] the authors classify educational robotic resources. They distinguish between the terms "educational robotics (ER)" and "robotics in education (RiE)". Using the results of the study [28], they define robotics in education as a category that includes "the learning environment, the impact on students' school curriculum, the integration of the robotic tool in the activity and the way evaluation is carried out".

The importance of the educational environment is also emphasized [29]. In the concept of Smart Pedagogy, they distinguish between three conditions that must be taken into account for successful training: human developmental regularities, the taxonomy of the educational process, technological progress, a shift from an activity-based approach to a results-based approach.

Thus, the characteristic features of natural sciences and mathematics teacher's professional activity in terms of STEM education are:

- the usage of active and widespread use of students' research activities through the implementation of various projects, the most important of which are projects related to educational robotics;
- the professional activity of natural and mathematical disciplines teacher in STEM education is not limited to teaching natural and mathematical disciplines at school, but also covers significant extracurricular work (excursions, quests, competitions, festivals, hackathons, workshops, etc.);
- in extracurricular work, an important role is played by the Minor Academy of Sciences, which provides regular research training in many areas, including STEM disciplines;
- the role of information and STEM technologies, which are ubiquitous in teaching natural and mathematical disciplines, performing projects, as well as in extracurricular activities, is extremely important.

The training of future teachers in the context of STEM education has its characteristics. One of the problems is the inability to fully exploit interdisciplinary research until the teacher acquires an in-depth knowledge of the different disciplines in which integration takes place [30, 31]. Adequate attention should therefore be paid to basic subjects in future teachers' programs. In 2010, an attempt was made to compare teacher-training programs in the European project SITEP [32]. The purpose of this study was to obtain information on the content of curricula for future teachers, as well as to establish skills and competencies that are important for the training of professionals. Following this study, many proposals were put forward to improve the practice of teacher training in different stages of learning according to different parameters:

- Knowledge of the subject is the main criterion for evaluating the educational activities of future teachers and future teachers with experience in teaching.
- Self-evaluation and independent professional development are sufficient for an experienced teacher, but it will be more appropriate to manage self-evaluation for future teachers.
- Self-learning experience often turns into a transfer to professional activities. Thus, the use of different practices and approaches during education will have a positive effect on both teachers' teaching and professional activities.
- Cooperation with colleagues (future colleagues) will be an incentive for professional growth.
- The involvement of teachers with experience in teaching in the development and implementation of the evaluation system will enable the development of professional standards that will influence the quality of the training for future teachers.

Based on the value attitude of future teachers of natural sciences and mathematics to technology, we will follow such guidelines: awareness of the place and role of technology in human life; efficient use of equipment (literate, rational, timely, effective; safe use (both for themselves and others); environmental consequences of use.

3. Results and discussion

Project-based learning reinforces students' desire to learn because it is:

- person-oriented;
- uses a whole arsenal of didactic approaches: business training, independent classes, collaborative learning, interactive learning exercises;
- implies a high motivational level, which means an increase in interest and inclusion in joint activity in the course of its implementation;
- supports pedagogical tasks at all levels – knowledge, understanding, application, analysis, synthesis;
- promotes the formation of your own experience when performing specific tasks.

Project activity is one of the most active methods, its main advantage is that children's activities take place in a micro-social environment, where they acquire practical skills and can test their theoretical achievements in practice.

At the same time, the project activity of schoolchildren differs significantly from educational and research activities. If the educational and research activity is individual and is aimed at obtaining new knowledge, then the goal of design is to go beyond a separate study, implement the acquired knowledge and skills in practice and form certain competencies.

The project method involves a detailed and comprehensive study of the topic and the development of a specific final practical result, and not just certain information analysis.

Robotics is also a unique technology that involves exploring interdisciplinary connections in various subjects based on active learning, integration with science, technology, engineering, mathematics, and other subjects. It is this direction that opens up huge opportunities for students to study technologies of the 21st century, forms communication skills, spatial imagination, teaches interaction, the ability to make decisions independently, reveals the creative intellectual potential of students, and develops design thinking and creative imagination.

Teachers who use robotics in their practice can achieve a number of goals:

- joint work on ideas;
- analyze results and search for new paths;
- systematic observation;
- development of logical thinking;
- formation of the ability to establish cause-and-effect relationships.

Nowadays, robotics constructors for children are becoming increasingly popular. Most designers assume that several models can be assembled from one set at once. Kids also have the opportunity for creativity and can create their own original models.

The fundamental novelty of using robotics in the educational process lies in the change of fundamental approaches: the introduction of new information technologies into the learning process that encourages students to solve various logical and design problems. The study of each topic involves the implementation of projects implemented with the help of innovative technologies.

However, it should be noted that today teachers have very little material to prepare for robotics classes. Therefore, the development of materials for practical use by teachers in the preparation and implementation of STEM projects is very important.

- The elementary school – materials should focus on primary STEM courses, as well as STEM fields and professions. This first step offers training based on standards, structured queries, and actual tasks that integrate the four STEM topics. The aim is to involve students in the desire to continue their studies, not because they have to. The focus is also on the combination of STEM learning opportunities within and outside the school.
- Junior high school – at this stage the courses must be more complex. The awareness of students in STEM areas and professions, as well as the academic needs in these areas. At this level, students are beginning to study careers related to STEM.
- Senior school – a curriculum focused on the use of materials in a complex and rigorous manner. Courses and areas are now available in STEM areas and professions, as well as in preparation for employment. Greater attention is paid to the combination of STEM opportunities within and outside the school.

The main regulatory document in the activity of a computer science teacher is the curriculum of the course "Informatics", which regulates the specifics of using project activities in the classroom: individual and group educational projects are focused on independent activities of students – individual, pair or group. In the process of implementing educational projects, both the educational goal (expansion and deepening of the theoretical knowledge base of students, giving the results practical significance, their suitability for solving everyday life problems, differentiation of learning according to requests, inclinations and abilities of students) and research are achieved.

According to this document, the solution of competence tasks, the implementation of individual and group educational projects is allocated in 7th grade – 8 hours, in 8th grade – 9 hours, in 9th grade – 15 hours. In addition, the teacher can use spare time, from 3 to 4 hours in grades 5-9.

The curriculum of the course "Informatics" for 8th and 9th grades of secondary schools with in-depth study of informatics determines that for individual and group educational projects in 8th grade provides 8 hours, in 9th grade – 12 hours with the possibility of using spare time in the amount of 4 and 5 hours in accordance.

The curriculum of elective-compulsory subject "Informatics" for students of 10-11 grades of secondary schools (standard level and profile level) provides even greater opportunities for the use of project activities, because to implement the activity component of the curriculum provides for various tasks, including individual and collective projects. The teacher can plan the time for their implementation independently within the hours provided for the development of the basic module or elective modules.

In order to realize curricula, we have formulated course requirements in accordance with the educational needs of the future teachers of science and mathematics:

- the content of the course should be appropriate to the level of technological development and should encourage students to adopt new approaches in practice,
- the content of the course reflects and builds understanding of current developments and trends in science and technology,
- the objectives should be of practical significance and the result should be the completed product,
- the task should be creative and address the problem in an integrated manner,
- each task is performed in the following stages:
  - formulation of the research task,
  - research planning,
  - hypothesis formation,

- role allocation,
- implementation of the action plan,
- study of theoretical material,
- performing works,
- testing and analyzing results,
- testing hypothesis,

- course elements (problems, surveys, etc.) should help students see the availability of innovations and feel successful in STEM disciplines,
- the clarity of the criteria and requirements for the preparation of the project, its evaluation and the availability of all teaching materials designed to increase the motivation for training,
- every project completed must pass a public demonstration (protection, competition); the demonstration should be based on evaluation criteria,
- students should have the opportunity to influence course development, to express their wishes for further design work, the level of difficulty in learning about projects to organize teamwork; active use of formative assessment techniques.

The level of interaction and contribution of each discipline in different projects will vary. There will also be different types of activities at each stage of the stem robotics project implementation.

Cross-cutting lines include environmental security and sustainable development, civic responsibility, health and security, entrepreneurship, and financial literacy. They show the main social and personally meaningful ideas, which are constantly revealed in the process of teaching and educating students. They are common to all subjects, they are a means of integrating the educational content, correlated with the key competencies, whose mastery provides the formation of values and visions of the student's world, which determine their behavior in life situations.

In the course of design and research, a holistic vision of the problem forms as a complex scientific task that requires the integration of knowledge from various fields (e.g. physics, mathematics, geography, algorithmization, programming) and has a socially significant component. For design and research activities to succeed, coordinated work is required for the entire team.

The future teacher training program consists of:

- general disciplines of social and humanitarian orientation, which contribute to the development of the general culture and the socialization of the personality of the future teacher;
- the main disciplines providing disciplinary training (theoretical, practical);
- the disciplines of the psychological and pedagogical cycle which prepare future teachers for educational work.

Besides, practical training in the form of training and production practices (pedagogical) and research work in the form of written and final qualified research courses are mandatory.

Some of these disciplines can be classified as those that contribute to the development of skills in one of the fields: science, technology, engineering, mathematics. A quantitative evaluation was carried out of the number of profile discipline credits in the list of curricula programs was carried out taking into account their membership in one of the areas.

In the disciplines of the scientific direction, they have been considered as: bases of scientific research, methods of optimization and research of operations, the theory of information and coding, etc. The cycle of these disciplines allows future teachers to carry out research and evaluate the importance of using mathematical methods and basic science knowledge. Mathematical disciplines of specialty "014. Secondary Education (Mathematics)", such as calculus, algebra and geometry, discrete mathematics and others, are designed to provide an understanding of the fundamentals of building algorithms and mathematical methods of information processing to solve applied and scientific problems. For the specialty "014. Secondary Education (Mathematics)" these disciplines are specialized and, as a result, most of the credits. In curricula, in which mathematics is not specialized, the disciplines of this block have small differences and almost the same number of credits allocated to the study.

Relationships between areas are almost indistinguishable, except for engineering and technology components. They differ according to the scientific traditions of educational institutions and scientific schools. Technological and engineering disciplines are profile disciplines for the specialty "014. Secondary Education (Informatics)". They include disciplines such as algorithm theory and data architecture, programming and databases, and so on [33]. The disciplines of technology management are also included in those that allow you to navigate in the modern world of technology and learn future teaching techniques to work with digital tools. For example, information technology, operating systems, web programming, mobile device programming, databases, etc. It should be noted that in all curricula there were working disciplines on information technologies, distance learning technologies, algorithmization, and programming. Engineering disciplines include computer architecture, the basics of the physical organization of computer systems, and computer networks. The curricula under consideration outline the modernization of curricula from the point of view of the development of technologies. For example, teachers of mathematics and physics introduce modeling and 3D printing, robotics, and the Internet of Things in the list of disciplines. Computer education programs introduce disciplines such as data analysis and machine learning, modeling and programming robots, cloud computing, and digital marketing. As a result, each of curricula contains between 12 and 15 percent of the discipline credits in which an integrated STEM course can be taught. The presence of disciplines corresponding to modern trends in the digital development of society suggests that the list and content of disciplines are being modernized in higher education institutions. Such a renewal is possible only if there is a professional community that supports innovation and meets the requirements of modern society for educational activities. This community projects STEM culture through its activities, forming through the education and education STEM culture of future teachers.

Here is an example of a long-term project for the construction of a self-driving vehicle, which was implemented by the students to participate in robot-refuge competitions. The model creation process has gone through the following steps.

1. Study of the rules of competence and determination of the technical characteristics of the vehicle. This phase of project activity is organizational. To implement it, it is necessary to:
   - Define the theme and objective of the project: in this case, the theme is the creation of autonomous transport, and the aim is to participate in the competitions and to achieve maximum results. Technical task formulated briefly: to create an autonomous robotic vehicle (TC), capable of moving autonomously along the line (without leaving its path) and to be part of the urban traffic model, following the rules of the road (traffic).
   - Problem formulation – you must carefully study the rules of the competition and pay attention to the particularities of their conduct that should be taken into account. The creation of such a project consists of two interdependent processes: the construction of a physical model – the vehicle is subject to technical requirements and the programming of the model – describes the rules of conduct in certain situations. It is also necessary to take account of the needs of the environment. For example, traffic lights, road signs, and a pedestrian model must be used to construct an urban traffic model.
2. Review of modern autonomous vehicle control systems and study of control autonomy levels. This is the planning phase of the activities and the determination of the means for

the implementation of the projects. At this stage, existing automotive systems are taken into account and a decision is made on the technology that will be used to implement the autonomous control, review, and analysis of existing semi-autonomous automotive systems and their functions of the main manufacturers (Audi Traffic Jam Pilot, BMW Traffic Jam Assistant, Cadillac Super). Cruise and others), technologies for detecting objects and interferences (surveillance chambers, radars, handles, etc.), different levels of automation are also considered. The Society of Automotive Engineers (SAE) has defined the term "driving mode", meaning "a type of scenario with characteristic requirements for dynamic driving". The familiarity with this material makes it possible to form the concept of standard for the development of hardware and software products. The familiarity with standards and their comparison offers an opportunity to professionally evaluate their results and form a technological literacy and gives the concept of society's technology and the degree of change that occurs with the development of technology.

3. Development and creation of a model. Vehicle design and model testing. This step in the implementation of the project is the main one in the development of an autonomous model. As part of the model of autonomous, unmanned vehicles for on-line traffic, it is necessary, first of all, to become familiar with the processes of development, creation, configuration, and operation of robotic systems, which are prototypes of systems that will be implemented under real conditions to reduce car accidents. At this stage, the development of the technical base for the creation of the model, the selection of components, the definition of patterns will help to achieve the maximum of results. The material architecture of the model is developed, the basic concepts of the circuits are studied, the principles of micro-controller programming are studied and projects are created with its application. The main problem in the implementation of such a project is the problem of speed regulation: on the one hand, speed must be maximum for the rapid passage of the route; on the other hand, the excessive speed does not allow the vehicle to follow traffic rules or to follow the line. This part of the project has become experimental and has required proof of different hypotheses. When creating the model there was a problem with the regulation of the vehicle and determining the current speed. Based on the studied material, it was decided to record the fact of rotation by the sensor. Several hypotheses have been taken into account to solve this problem and experiments have been carried out with which this operation can be performed. Each hypothesis has been tested and analysis of these results has been carried out. The calculation of velocity in each hypothesis is based on the data obtained by the sensor. When testing the model for each of these options, its disadvantages and advantages have been identified.
4. Programming of car's autonomous movement following traffic regulations. At this stage, autonomous vehicle movement algorithms are considered as discrete control systems and proportional control. It investigates the apparatus of automation theory for the realization of the logic of vehicle management that should respect traffic rules are studied.

The development and running of this project require substantial training from students and teachers. The content of the educational material involved in the project's implementation corresponds to the fundamental concepts of such disciplines/scientific sections such as classical and electronic mechanics, automatic theory, programming, mathematical modeling in the curriculum of future teachers of natural sciences and mathematics. The process of preparing and implementing a STEM project contributes to the formation of a scientific approach to problem-solving, technological literacy, the skills in the use of modern digital technologies, the integration of scientific concepts, and the understanding of interdisciplinary connections in future teachers.

4. Conclusions

Research analysis showed that STEM education forms certain competencies that determine the ability to innovate, as well as contributing to the participation of future teachers in research and understanding/motivation to follow/study new technologies.

The future teacher of natural sciences and mathematics must be able to train key competencies among students, according to the current level of technological achievements, and to involve them in innovative activities. For robotics to become an integral part of the educational process, it is necessary to train future teachers in a sustainable interest in its application in the future and to show its benefits as a tool for universal learning. The development and running of this project require substantial training from students and teachers. The content of teaching material involved in the implementation of the project corresponds to the fundamental concepts of such disciplines/scientific sections as classical mechanics and electronics, automatic theory, programming, mathematical modeling in the curriculum of future teachers of natural sciences and mathematics. The process of preparing and implementing a STEM project contributes to the formation of a scientific approach to problem-solving, technological literacy, the skills in the use of modern digital technologies, the integration of scientific concepts, and the understanding of interdisciplinary links.

Analysis of the curricula for future teachers in natural and mathematical disciplines has shown. They are focused on the training of thematic skills in knowledge and application levels. Valuable components are present but to a lesser extent. They are more often concerned with the integration of information technologies into the education process and, in a smaller number of cases. They are concerned with STEM education technologies.

The results of the study have led us to conclude that there are disciplines in curricula contribute to the development of competencies in each of the fields: scientific, technical, technological, or mathematical. There are sufficient disciplines in the curricula. So, it is desirable to carry out integrated classes that contribute to the construction of a holistic vision of fundamental laws in the study of science and the formation of the image of the world's natural sciences. The presence of disciplines such as 3D moderation, robotics, the Internet of Things provides construction of the educational process according to integration and innovation criteria. They offer a mastery of technological and innovative skills.

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Journal of Physics: Conference Series

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A Comprehensive Program of activities to develop sustainable core skills in novice scientists

To cite this article: K V Vlasenko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012017

A Comprehensive Program of activities to develop sustainable core skills in novice scientists

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Abstract. This paper is aimed at studying scientific communication as an integral part of a scientists activity. The authors of this article analysed the development of informational technologies, which gave rise to a new paradigm of scientific communication Research 2.0. In the present study the analysis of research papers, describing models of scientific communication is done. The findings allow to define the structure and content of a comprehensive program of activities, connected to scientific communication in compliance with the Scientific Communication Life Cycle Model. In order to implement the program, aimed at developing core skills through scientific communication of scientists, a target audience, comprising postgraduate students and young researchers in Mathematics and Teaching Methods was engaged. A five-stage program of activities, which was developed, prompted scientific activity of young researchers and gave them an opportunity to learn about means of presenting research results, elements of management, mechanisms for applying the findings. A constructive description of each module of the program is done, actions and a strategy are described, communication between participants and tutors through the platform Higher School Mathematics Teacher is arranged in this research. In order to assess the efficiency of implementing the program, Researcher Development Framework (RDF) is used. The study also presents the results of the activity of young researchers, who were engaged in the program. Following the change in the phase of the development of researchers characteristic features and in compliance with RDF, a conclusion is made about a positive impact of the program on the development of career skills of young scientists, their interaction skills, awareness of professional behavior procedure.

1. Introduction

Career development of young scientists is an attribute of sustainable development of the society. Preparing young researchers for independent scientific activity, the development of intellectual and psychological qualities of a scientist, correlation between the process of thinking and creativity, phenomena of scientific discovery and genious were always of high interest for psychologists, educators, science historians. Numerous researches were done into specific attributes of a scientist, considering them from different theoretical perspectives. Attempts to identify personal qualities, which are central to the professional activity of a scientist, were made late 19th century in papers by Terman [1], Hollingworth [2], Guilford [3] and others. In the 20th century classical research by Roe [4] stated, that scientific communication (a complex of processes and mechanisms of transmitting scientific ideas inside a scientific community) is an integral part of a scientists activity. Fast-paced development of modern science and the level of scientific achievements prompted scientists to search for new means of scientific communication.

The first aspect meant integrating skills of scientific communication into a basic set, which is identified by educators, employers and scientists (Brownell et al. [5], Gray et al. [6], McInnis et al. [7], West [8], Vlasenko et al. [9]) as critical for any scientist. Hence, courses in communication are introduced into curricula for postgraduate students in many countries, among which are the following: Great Britain (Quality Assurance Agency [10]), the USA (American Association for the Advancement of Science [11], [12]), Canada (Ontario Council on Graduate Studies [13]) and Australia (Australian Qualifications Framework [14]). In turn, in educational literature there are numerous papers by Levine [15], Mulnix [16], Gillen [17], Kozeracki et al. [18], Jones et al. [19], Cameron et al. [20], which state, that such components of scientific communication as reading scientific papers by other scientists and promoting own scientific concepts can help budding researchers to develop core skills of a scientist and boost their confidence in scientific thinking. So, inspired by this idea, the authors in the present paper did an overall review of the history of communication in science. A paper by Vickery [21] presents detailed means and attributes of oral and written communication in pre-digital era and shows a picture of prerequisites for modern methods of scientific communication. Special attention is given to the development of scientific communication in the 20th century, resulting from industrial research, occurrence of Big Data, computer networks and Internet communication. Early in the 21st century, in his papers Hurd [22, 23] offers a new paradigm of communication in science and shows that digital media offer new roles and functional opportunities to the participants. Thus, the development of information technologies changed the mode of scientific communication. The conventional system based on printing, which relied on a referred scientific journal as a key mechanism for presenting scientific findings, underwent transformation and turned into a system, dependent on digital means of transmitting information. As Hurd [23] stated, scientometrics bases replaced conventional libraries and publications turned to electronic formats; communication in science evolves to the process, which counts more on on-line resources. This transition from printed to digital format changed the roles of all the participants of the scientific communication system. The challenges, prompted by these changes stay topical nowadays.

2. Literature review

In educational literature, dedicated to academic education, scientific communication is considered from a point of view of positive impact on the process of developing a personality of a would-be scientist. In papers by Levine [15], Mulnix [16], a correlation between the skills level of processing scientific literature and efficient scientific activity is stated. Research by Gillen [17] proves that though a majority of postgraduate students are able to understand and absorb informative aspects of scientific articles, they often face difficulties interpreting the findings and analyzing them critically. As young researchers lack in strategies, necessary for building up credible criticism, then developing the skills of scientific communication becomes critical for engaging them into active scientific process. Research papers by Kozeracki et al. [18], Vlasenko et al. [24] highlight, that designing courses, aimed at the critical analysis of articles in scientific journals and presentation of own research increases scientific literacy and self-confidence.

Researching the problem of developing a skill in scientific communication, Cameron et al. [20] came to a conclusion, that behavior and attitude to scientific writing, speaking and presenting findings are prior to the intention to pursue academic research career through scientific identity. As the main factor of this process is its fulfillment in all the academic stages from a postgraduate student to a scientific advisor, it is indicative of a potential for engaging means of scientific communication for enhancing career perseverance. Research papers by Smyrnova-Trybulska et al. [25], Kuzminska et al. [26], look into this issue and allow to state that introducing the learning environment in scientific communication into educational process ensures developing and improving in young researchers such a skill as undertaking scientific communication; contributes to developing digital competencies and building up an image of a scientist, thus integrating into a single scientific community. The researchers [27–38] confirmed that digital competencies concerning scientific competencies allow researchers to search for scientific and professional information more efficiently, to work with open systems of scientific research support, to analyse data and visualize them with the help of up-to-date informational computer technologies (ICT), to create and manage personal educational environment, a portfolio, etc.

Studying the problems, connected to developing professional skills in a young scientist, experts emphasized the necessity to build models of scientific communication. One of the earliest models of scientific communication is the UNISIST model [39] (the United Nations Information System in Science and Technology), offered by the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the aim to improve scientific and technical communications. Taking into account ever-growing impact of the Internet technologies on communication between scientists, Søndergaard, et al. [40] presented an extended and revised UNISIST model. One more model by Garvey and Griffith [41] means to describe the communication process in science, but it lacks informational technologies support. In studies by Hurd [22, 23] this model is revised in order to consider the impact of ICT, such as electronic publications, self-publications and electronic libraries.

Kling et al. [42] offer a model of scientific collaboration STIN (Socio-Technical Interaction Network), which allows to understand better the character of professional relationships inside scientific communities. In a paper by Swisher [43] they offer a linear step-by-step model which defines the stages that a new concept goes through in the system of scientific communication. In a cycle of research by Björk [44–48] a model of SCLC (Scientific Communication Life Cycle) is presented. It describes the process of communication from the beginning of a research up to using the findings for the benefit of the society. This model covers both, formal and informal communication, but the main focus is on the life cycle of publications as well as readers activity aimed at getting access to those publications. A systematized review of the characteristics of these and other models of scientific communication can be found in a study by Lugović et al. [49]. The scientists put focus on the development of technological innovations of Web 2.0 that resulted in occurrence of a new paradigm of scientific communication Research 2.0.

The analysis of papers by Luzon [50], Ullmann et al. [51], Procter et al. [52], Koltay et al [53] shows, that the term "Scientific communication Research 2.0" determines new approaches in creating scientific knowledge, based on the notions of unity and collaboration. The scientists describe how generating and managing collective knowledge brings about new structures and systems of scientific communication. Kuzminska et al. [26] consider that scientific blogs, social networking sites for the collaboration of scientists ResearchGate and Academia.edu, applications for managing and sharing publications (Mendeley, Qiqqa, EndNote), services Open Peer Review, international and national bibliometric systems (in Ukraine – Open Ukrainian Citation Index, "Bibliometrics of Ukrainian science") and other make part of such structures. Though the main channel for publishing the research findings is still an article in a journal with a peer review, Research 2.0 provides wide opportunities for the improvement of research processes and can lead to changing the principles of research activity in future.

The present study is dedicated to developing a comprehensive program of activities, concerning scientific communication in compliance with the SCLC Model and the principles of Research 2.0.

One of the objectives is to confirm that the introduction of the developed program into the process of advanced training of young scientists contributes to improving their skills in scientific communication and confirms their role as a catalyst for developing core skills of young researchers.

3. Method

3.1. Participants

Throughout 2019–2020 a comprehensive program of activities, aimed at developing a scientist score skills through the means of digital scientific communication, was introduced into the educational process of advanced training of young scientists at Ukrainian universities. 67 postgraduate students and young researchers under 40 participated in the experiment (figure 1).

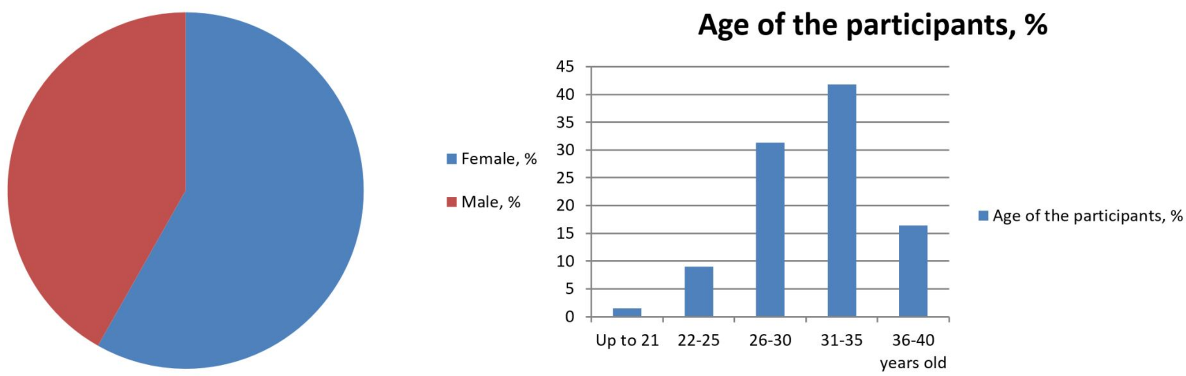

Figure 1. Gender and age sampling frame, % of the total number of participants.

According to targeted selection, the sampling frame must comprise researchers working in the same area of knowledge. It was done, taking into account the specifics of the scientific communication system for different mathematic disciplines. The experiment was done at scientific schools, where the researchers work in the domain of Mathematics and Teaching Methods. The quality composition of the program participants in accordance with specialization and professional attributes is presented in figures 2–3.

Development of a comprehensive program of activities in scientific communication in compliance with SCLC Model. In the first stage of the program development with the help of the deductive content analysis of the research papers (Søndergaard et al. [40], Kling et al. [42], Swisher [43], Björk [47, 48], dedicated to the models of scientific communication, the authors of this study defined the structure of the program and the key aspects of the content, designed to provide its compliance with the paradigm of Research 2.0. Compared to other models, the SCLC Model Björk [47, 48] is more comprehensive, detailed and contains more constituents that reflect activity, findings, elements of governance, mechanisms, etc. when developing the program of activities, connected to scientific communication, the SCLC Model serves as a roadmap for positioning all the components of the system of scientific collaboration as a global interconnected informational system. The developed comprehensive program consists of five stages of different duration from 0.5 to 2 credits ECTS, each of them contains 2–5 modules (table 1).

In the second stage, when doing analysis concerning the nature of Research 2.0, Koltay et al. [53], Sheombar [54] gave a constructive description of activities and projects, as well as actions

Table 1. The structure of the comprehensive program of activities, concerning scientific communication in compliance with the SCLC Model.

Stage	Activities concerning scientific communication	Content of the activity
Creating the information environment	An on-line course in scientific communication	Watching video lectures, chatting
	Practical assignments	Doing practical assignments on searching information, quoting, preparing presentations, designing a manuscript, etc.
	Presentation of University programs, events by the Ministry for Education and Science and businesses, aimed at supporting young scientists	Electronic mailing of video materials and samples of documents; meetings with management, representatives of the Ministry for Education and Science representatives of business, program alumni
Doing the research	Searching for ideas, defining a topic for research	Getting acquainted with social networking web-sites for scientists; creating profiles and micro-networks.
	Searching the information resources	Searching publications in databases, archives, bookmarks, getting (saving) the publications, paid and free subscriptions
	Reading publications	Reading summaries, full texts
	Doing the research itself	Communication with an advisor, communication in collaborations
	Integrating the results into the context of a general problem	Work with references, quoting
Presenting the findings	Non-formal communication	Seminars, conferences, mailing colleagues, microblogs, subscriptions to the projects in social networking web-sites
	Publication in a reviewed edition	Preparing a manuscript, searching publishing houses. Designing the manuscript, communication with an editor and a reviewer
	Promoting sharing and search	Promotion in blogs, social networks for scientists, open libraries, University resources
	Tracking the publication	Indexing, bookmarks, tags
	Secondary publications	Monographs, publishing in mass media
Applying the findings	Promoting the improvement of the standard of living (application in industry, IT, healthcare)	Getting acquainted with the process of standartisation, filing an author certificate/a patent
	Education	Passing on knowledge through workshops, educational videos, one-to-one counselling
	Feedback for science	Forecasting benefits for the future of science
Contests for scientists, grant programs	Contests for young scientists by Universities and the Ministry for Education and Science	Filing documents
	Contests organized by businesses	Preparing presentations, participation in startup-schools

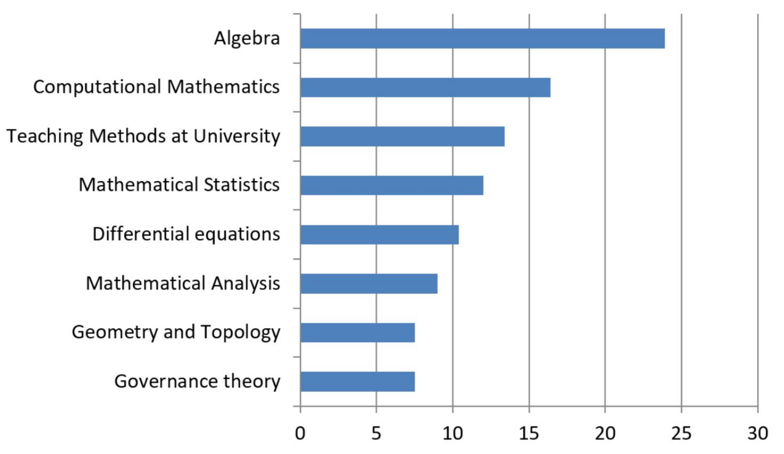

Figure 2. Specialisation of the participants of the experiment, % of the total number.

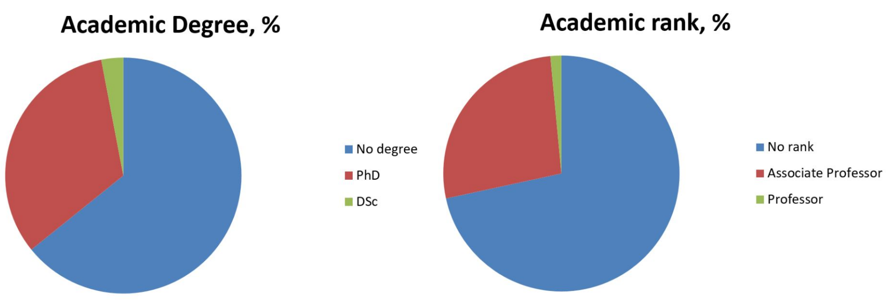

Figure 3. Qualitative composition of the participants of the experiment in accordance with professional attributes, % of the total number.

and strategies which contribute to developing scientific research skills in young scientists and which are based on the principles of openness, collaboration, conversation and connectedness.

Communication between the program participants and tutors took place on the platform Higher School Mathematics Teacher [55–57]. Forum, on-line chatting and electronic mailing were chosen as the means of communication. Through their personal accounts the participants got access to the description of events, activities and strategies for each of the stages of the program, listed below.

3.2. Developing topics for the informational environment
In the early stage of their activity as scientists, most young specialists have no proper information database on scientific communication, which is explained by the fact that scientific communication is a specific activity, which postgraduate students did not face before. Even some years later, the knowledge of the scientific communication tenets is fragmentary. The main goal of this stage is developing in young researchers a systematic knowledge concerning scientific communication, its key components, new trends and technologies, basics of efficient work with information, research data management. Watching video-lectures allows the participants to understand how scientific communication happens nowadays, how open access, open science and

licenses, research data management impact the life cycle of a research. Participation in seminars, trainings means applying best updated practices and search techniques in order to work with scientific sources, to use universal and specialized information resources, new web-applications for various types of research, etc.

The authors of the present study believe, that in the informational environment, dedicated to the problem of scientific communication, it makes sound sense to highlight the following topics:

1. General overview of key components and strategies of scientific communication, usage of new web-applications in all the stages of the research life cycle, especially when searching for information and spreading the findings. Social networks for scientists ResearchGate, Mendeley, Academia.edu.
2. Scientific information: main types of sources. Specialized search systems such as Google Scholar, ScienceDirect, DOAJ and databases (Web of Science, Scopus, ZbMATH, MathSciNet), strategies for efficient search on the Internet.
3. Tools for monitoring new publications on the research problems. Subscriptions (Mendeley Groups, ResearchGate). Scientist's profiles (Scopus Author ID, ResearherID, ORCID iD).
4. A scientific article in a reviewed journal as the main element of scientific communication. Academic publishing houses (Springer, Elsevier, Pleiades Publishing).
5. Studying various aspects of scientific papers and publication strategies. OJS/PKP journal systems.
6. Management of bibliographic references (applications Mendeley Web Importer, EndNote, BibTex, Zotero).
7. Key notions of scientometrics. Scientometric indices Web of Science, Scopus, Google Scholar, Open Ukrainian Citation Index et al.
8. Copyright. Creative Commons license.
9. Archiving the research data. Repositories DOAJ and ArXiv.

When creating the informational environment, educational materials published on the platforms Prometheus [58], EdEra [59, 60], YouTube channel [61–63] and own materials by the authors of this study were used [64]. As an illustrative basis for scientometric and bibliometric techniques, a cycle of research by Rovenska et al [65–68] were used.

As the main indicator of the efficiency of scientific work is receiving accolades and financial rewards, the authors of this paper believe it pertinent to share relevant links to grant programs and awards with the program participants, announced by university management, businesses and professional unions. Receiving an accolade by a young researcher can serve as one of the criteria of developed skills in scientific communication and core skills in general.

3.3. Doing research

The firs module, which is to define the topic, initiates the research. Review of ideas is the main function of this module. Social media offer useful communication channel for finding new ideas and communicating with the world. Participants register and create own accounts in the main social networks for scientists, such as ResearchGate, Academia.edu and Mendeley. According to a research by Nentwich and König [69] on academic use of social networks, the function "Profile" comes top among eight most popular functions of social media for scientific purposes. The profiles created can be filled with publications that the participants already have. In this module the participants also create micro-networks with the representatives of a certain scientific school. When the topic is defined, social networking sites for scientists become an additional tool for searching partners for collaboration.

Since the research process is based on the competencies, related to searching, assessing and applying information, the second module is dedicated to developing skills in searching information resources. The development of Web 2.0 brought about easy and accessible means of receiving information. Still, access to information does not necessarily mean expanding knowledge. Research 2.0 resources allow to make changes in the methods of assessing information sources on their topic. The participants are offered to focus on the assessment of the accessible information, based on bibliometric indicators. The module gives an opportunity to master the specifics of work with both, interdisciplinary (Scopus, Web of Science, Google Scholar), and specialised (ZbMATH, MathSciNet) scientometric databases.

It is necessary to draw the participants' attention to the opportunities which subscriptions (both, free and paid) give as well as risks arising out of it. Not only using social media for private purposes, but also for academic ones requires preventive measures from spam and harassment from unscrupulous communities. Participants can also face challenges when receiving publications, for instance, if the publication is not accessible any more, or the publication was not digitalized. When such situations happen, it prompts finding alternative ways of receiving the publication, such as buying a hard copy, search in archives or among colleagues.

The third module is dedicated to the development of practical skills in reading publications. The participants work on the constructive methods for reviewing the content of a publication with the help of key words, summaries, reading full texts, creating bookmarks, comments and annotations in Mendeley, applications for tracking quotes EndNote, BibTex.

When doing own research, the need for expanding own scientific horizon through communication with single-minded scientists increases, and most of the young scientists enhance live communication etiquette. However, the challenges of the time require mastering on-line modes of communication with colleagues. According to a recent research by the Ministry for Education and Science of Ukraine [70] the most common reasons that hamper the development of scientific communication among young scientists are: psychological unpreparedness for new types, modes of scientific communications and underdeveloped network of personal connections and communication channels. For remote communication the participants are recommended (but not limited by) such means of communication as Zoom, e-mail, Viber, Facebook Messenger, Telegram, Skype, WhatsApp. As the survey shows [70], these channels are the most widely used in professional communication among young scientists.

The final module of this stage is dedicated to improving the practical skills in working with reference-messengers, such as Mendeley Web (functions Web Importer and Citation Plugin), EndNote (adding information about sources from Web of Science, from on-line libraries, websites of publishing houses, and own notes), Zotero and others.

3.4. Presentation of findings

This stage comprises five modules, which are – informal communication, presentation of findings through publishing, sharing promotion, tracking and secondary publications. The main difference from communication within the first module is that an author has a complete control over those who become the receivers of the information about the findings. On top of conventional presentations at conferences, seminars, the participants also learn about informal communication channels which are accessible tools of Research 2.0, such as blogs, subscriptions for ResearchGate projects, tags and opportunities for joint work in Mendeley Groups. Using the resources of Research 2.0 increases the efficiency of scientific communication, as researchers receive a feedback (on-line comments) much earlier and can fix the errors, complete the article and send it for publication.

In the module, dedicated to presenting the findings through publication in a reviewed journal, the participants can learn about the proper formats of articles for academic publishing houses Springer, Elsevier, Pleiades Publishing (mastering AMS-LaTex is an obligatory prerequisite) and acquire the practices for communication with the editor and reviewers through open journal systems OJS/PKP. An important nuance of the module is that some participants experience communication with predaceous publishing houses and for the first time face academic plagiarism. Taking it into account, maintaining academic reputation becomes profoundly valuable.

Modules, dedicated to sharing, promoting search and tracking publications, encompass the whole spectrum of practical skills in using bibliometric means – from identifying the indices universal decimal classification (UDC) and Mathematics Subject Classification (MSC) to using descriptors (DOI, ISSN). The basics of information search and scientometrics, which the participants learnt during lectures and seminars in the first stage, are now acquired through personal experience in using scientometric databases (Scopus, Web of Science, Google Scolar), archives (arXiv), etc. The participants are recommended not only to create formal profiles Scopus Author ID, ResearcherID and ORCID, but also de-facto analysis of absolute and normalized indicators, namely h-index and impact-factor of the publication.

The final module of this stage concerns secondary publications of scientific findings. As a rule, writing a monograph or a popular science article is not common among young researchers. This module significantly falls behind the previous ones and is optional. Secondary publications make sense in terms of sustainable impact on the development of science, when they give other scientists or external experts an opportunity to learn more about the findings in solving a certain problem. Among the communication norms, which are also mastered in this stage are copyright for scientists, open access and research ethics.

3.5. Application of findings
This stage highlights practical skills in transferring scientific knowledge in several directions in parallel – improving the quality of life through its application in industry, IT, healthcare; integration of the knowledge into education and learning; feedback in science. The participants are recommended to select a direction of application, depending on the kind of scientific research. Thus, in order to commercialize scientific knowledge, the participants are advised to register a patent or an author certificate. Application in education and learning means running classes and workshops for students in their first years of studying, one-to-one counselling, creating educational videos, etc.

The specifics of scientific communication in Mathematics is to use the findings broadly in order to amass theoretical knowledge. The research findings, as well as the methods of receiving them can be used for further studying various issues of Mathematics, including Applied Mathematics, prognostication, hypothesizing and other. Secondary publications, for instance sections of monographs or a popular science article allow the participants to acquire the skills in communication with the audience outside their own scientific school.

3.6. Contests for scientists and participation in grant programs
According to Björk [47], the global system of scientific communications performs two functions – the first is to pass on scientific knowledge, the second is to contribute to decision-making in supporting research from the side of University leadership, business, non-governmental organisations. This stage must be introduces into the program, as lack of understanding concerning the mechanisms of grant participation is a strong communication barrier in the general system of science and innovations support. Participation in contests is not obligatory, but is recommended to all the program participants. This stage allows to develop skills in preparing contest papers, presentations, startup projects.

3.7. Method of assessing the findings during the experiment
The assessment of the program implementation was done with the help of Researcher Development Framework (RDF) (Vitae [71]), offered by a world leader in supporting professional

development of researchers, the Research and Advisory Centre "Vitae", Cambridge, UK. RDF is made of the empiric data, collected through surveying experts in order to identify characteristic features of researchers, defined in RDF as descriptors. Descriptors are structured into four domains and twelve subdomains that cover knowledge, intellectual abilities, methods and professional standards of doing a research, as well as personal qualities, knowledge and ability to ensure efficient collaboration with others, and a wider impact of research (figure 4). Each of sixty three descriptors contains three to five phases, that are separate development stages or the efficiency level within the descriptor [71].

Figure 4. The Researcher Development Framework by Vitae [71].

3.8. Findings
The comprehensive program of the activities, which is aimed at developing core skills of a scientist with the help of scientific communication means, was introduced into the educational process of advanced training of young scientists in 9 scientific schools of and Teaching Methods of Donbas State Engineering Academy, Kryvyi Rih State Pedagogical University, Sumy State Pedagogical University, Berdyansk State Pedagogical University.

The assessment of the results of the program implementation was done through surveying 25 stakeholders, namely heads of scientific schools, leading scientists, who are directly concerned with scientific collaboration with the program participants, University management and business representatives. Every participant of the program was assessed by at least 2 stakeholders through an on-line surveying. The goal of the survey was to identify the skills level in the participant attributes that encompass professional qualities, methods and standards of doing research, personal communication skills that prompt the progress in scientific activity and academic career.

The data concerning changes in the descriptor development or the level of efficiency within the descriptor in the program participants can be found in table 2 (Domain A: Knowledge and intellectual abilities; Domain B: Personal effectiveness) and table 3 (Domain C: Research governance and organisation; Domain D: Engagement, influence and impact).

Positive results of implementing the program (marked as "+") are confirmed by deepening of the development phase or the level of efficiency within 15 descriptors in 30–50% of the participants, 16 descriptors in 50–75% of the participants and 21 descriptors in more than 75% of the participants of the program. The program has the most significant impact on the development of career skills, necessary for responsibility and control over professional development (B3); awareness of the standards, requirements and procedures of professional behavior, necessary to manage research efficiently (C1, C3); skills, necessary for interaction, management and influence on academic, social, cultural and economic context (D1, D2).

Forming such skills as financial management of research, understanding of academic and commercial systems of financial support becomes an additional factor for the impact that the program has, which is proved by the data concerning the program participants' involvement in contests and grant programs for young researchers (figure 5).

Hence, it can be stated, that the structure of the program encompasses knowledge, behavior and attributes, which are defined by the sector of tertiary education as critical for a researcher. The content, identified by the research environment is also validated by expert stakeholders – employers and sponsors.

4. Discussion
In connection with the present research it makes sound sense to mention the papers, dedicated to defining skills of researchers that characterize them as scientists in a volatile informational environment. Davies et al. [72] define a set of central skills of an efficient researcher that are linked to the adaptive nature of thinking. These authors consider that scientists do cognitive activity filtering information according to its importance, using various tools and methods for it. Such an activity is defined by a certain type of thinking, which allows to use these tools and methods in the working processes, aimed at achieving the desired outcome. As Koltay et al. [53] mention, researchers have to acquire skills, linked to innovative thinking and problem-solving. They also believe that the research process nowadays is defined by comprehending and justifying data, as the ability to find deeper meanings is more important than formal reading. Moreover, due to globalization and increased international cooperation a practical skill of working in social networks as well as cross-cultural communication skills are becoming more and more vital.

Comprehension, justifying, adaptive thinking, problem-solving and innovative activity depend on the information and define the circle of skills, necessary for a modern scientist. Contemporary resources of Research 2.0 have an impact on all the stages of the life cycle of a research, which

Table 2. Changing the development phase of a descriptor or the level of efficiency inside a descriptor in the program participants.

Descriptor/Subdomain	in 30-50% of the participants	in 50-75% of the participants	in more than 75% of the participants
A1 Knowledge base			
Subject knowledge	+		
Research methods – theoretical knowledge	+		
Research methods – practical application		+	
Information seeking			+
Information literacy and management			+
Languages			
Academic literacy and numeracy	+		
A2 Cognitive abilities			
Analysing			
Synthesising	+		
Critical thinking			
Evaluating		+	
Problem solving	+		
A3 Creativity			
Inquiring mind		+	
Intellectual insight			
Innovation		+	
Argument construction	+		
Intellectual risk			+
B1 Personal qualities			
Enthusiasm		+	
Perseverance	+		
Integrity		+	
Self-confidence			+
Self-reflection			
Responsibility	+		
B2 Self management			
Preparation and prioritisation	+		
Commitment to research			
Time management		+	
Responsiveness to change			+
Work-life balance			
B3 Professional and career developmen			
Career management			+
Continuing professional development			+
Responsiveness to opportunities			+
Networking			+
Reputation and esteem		+	

Table 3. Changing the development phase of a descriptor or the level of efficiency inside a descriptor in the program participants.

Descriptor/Subdomain	in 30-50% of the participants	in 50-75% of the participants	in more than 75% of the participants
C1 Professional conduct			
Health and safety			
Ethics, principles and sustainability		+	
Legal requirements			+
IPR and copyright			+
Respect and confidentiality			
Attribution and co-authorship			+
Appropriate practice		+	
C2 Research management			
Research strategy	+		
Project planning and delivery		+	
Risk management			
C3 Finance, funding and resources			
Income and funding generation			+
Financial management		+	
Infrastructure and resources			+
D1 Working with others			
Collegiality			+
Team working			+
People management		+	
Supervision			
Mentoring	+		
Influence and leadership		+	
Collaboration			+
Equality and diversity		+	
D2 Communication and dissemination			
Communication methods			+
Communication media			+
Publication			+
D3 Engagement and impact			
Teaching	+		
Public engagement		+	
Enterprise		+	
Policy			
Society and culture	+		
Global citizenship	+		

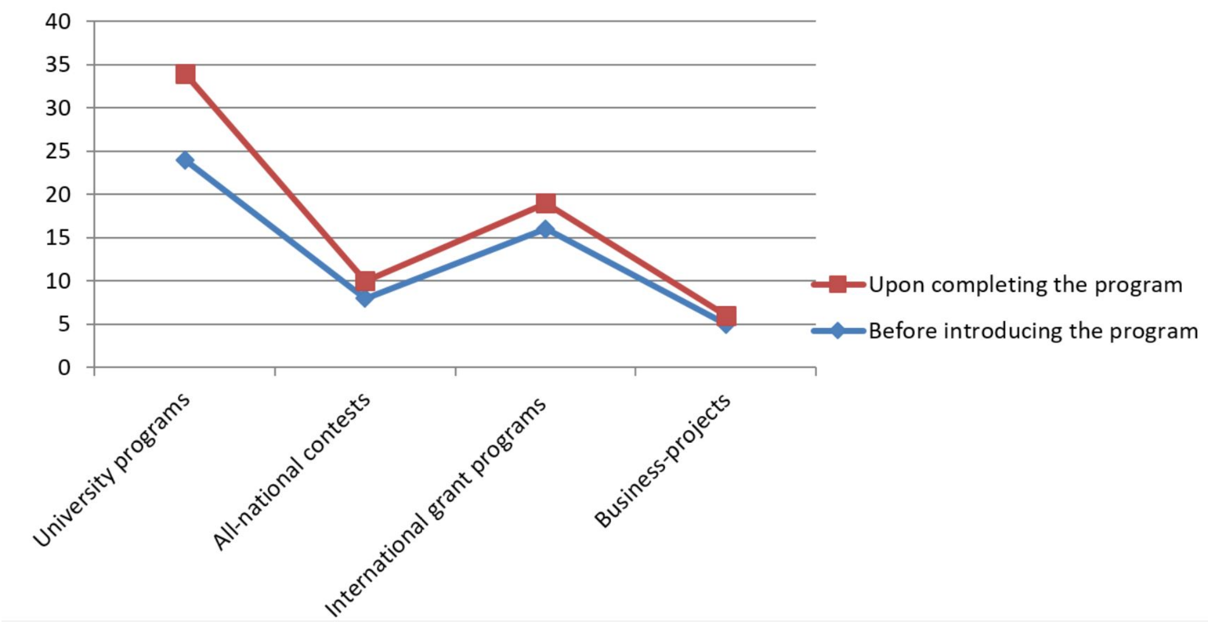

Figure 5. The number of co-participation in contests for young researchers among the program participants.

are connected to information, starting with identifying an idea to spreading the results. Thus, Research 2.0 gives a wide spectrum of opportunities for personal growth of scientists, who nevertheless are reluctant to use these opportunities and excuse themselves by lack of time or experience. According to conclusions by the Social media and research workflow (CIBER [73]), Nicholas and Rowlands [74], Sheombar [54], Vlasenko et al. [75] only a few researchers make the most of all the tools that social media provide.

The authors of this paper believe that creating in young researchers a quality experience of using Research 2.0 resources in professional communication could become a solution to this problem. As Mogull [76] states, novice scientists often follow bad communication practices, reiterating typical mistakes. The most typical problems are: lack of ideas because the content is inadequate when the information is processed (inability to read summaries, incorrect application of search techniques); lack of clearly defined conclusions because of inability to integrate the findings into the structure of the general problem; poor choice of the edition for publications; ignoring the process of managing the publication, etc. By the present research the authors join such experts as Mogull [76], Albert [77], Szklo [78], Vlasenko et al. [79] who consider, that clear and transparent communication practices can make a difference to scientific thinking and improve the quality of scientific advancement. Thus, the suggested program of activities is based on acquiring by novice scientists some personal experience in research work through the usage of the means of digital communication.

The constituents of the program are aimed at improving core skills of young scientists through their scientific communication. Each stage of their activity (from developing topics for the informational environment to presenting the research findings) is ensured by a program of activities, divided into several modules. Every module focuses on developing certain skills. The program means, that postgraduate students and novice researchers, who advance their qualifications, will master the basics of efficient work with information, research data management, and will get an insight into scientific communication, its components, new trends and technologies of scientific communication; they will learn how to use contemporary practices and search techniques when working with information resources. The attendees also master constructive means of reviewing the publications content, acquire the skills of creating bookmarks, comments and summaries as well as communicating with editors and reviewers through open journal systems. Communication between the program participants and tutors takes place on the forum and via an on-line chat on the platform Higher School Mathematics Teacher [55].

The assessment of the results of the program implementation was done with the help of Researcher Development Framework (RDF) [71], as the latter was created based on the empiric data, collected to identify characteristic features of researchers and for that purpose methods and professional standards of doing research were applied. This assessment showed that combining means of digital scientific communication on a certain system and ensuring personal experience in using those means contributes to the development of career skills, necessary for responsibility and control over professional development; awareness of the standards, requirements and procedures of professional behavior, necessary for the efficient research management; development of the skills, central to interaction, management and influence on academic, social, cultural and economic context, for instance, skills in financial management of research, understanding of academic and commercial system of the financial support of science.

5. Conclusions

Fast-paced development of informational environment, opportunities for researchers to communicate with their colleagues and the whole scientific world via the Internet ensured new opportunities in strengthening the global system of scientific communication. This fact made it possible for novice researchers to improve their core skills through promoting scientific knowledge, ensuring mechanisms of participation in contests, interaction, collaboration, personal development and justified the timeliness of developing the program of activities in scientific communication among young scientists, based on the principles of Research 2.0.

Analysing the research into the models of scientific communication and considering the experience of mature scientists, working in Mathematics and Teaching Methods, allowed the authors of the present paper to define the structure of a comprehensive program of activities, aimed at developing skills in scientific communication and core skills of novice researchers, as well as to devise educational and methodological materials for its implementation in compliance with the SCLC Model, which ensures acquiring personal user experience through the practice of using the means of digital scientific communication.

The abovementioned program of activities was structured in accordance with certain stages of a novice researcher's activity and involves scientific communication through the means of digital learning environment. Among such activities were: on-line courses in scientific communication, presentations of programs for supporting young researchers, workshops, educational videos, one-to-one counselling. These activities prompted young researchers to seek informational sources and integrate the results into the context of the general problem; learning about social networking sites for researchers; creating profiles and micro-networks; informal communication through seminars, conferences, mailing with colleagues, publications in reviewed editions. When doing those activities, the participants were aimed at creating systematic comprehension of scientific communication; skills in communication with colleagues and presenting the research findings in a remote mode; skills in practical usage of bibliometric means; skills in using up-to-date practices and search techniques when working with informational sources; practical skills in transmitting scientific knowledge; skills in preparing startup projects.

Stakeholders, namely managers of scientific schools in Mathematics and Teaching Methods, leading scientists, who are directly concerned with scientific collaboration with the program participants, University management and business representatives assessed the results of implementing the program with the help of Researcher Development Framework. Through an on-line survey they defined the participants' level of a researcher characteristic feature in such domains, as: A – Knowledge and intellectual abilities; B – Personal effectiveness; C – Research governance and organisation; D – Engagement, influence and impact. Positive changes in the stages of the descriptor development or changes in the level of its efficiency prove the efficiency of implementing the program and its influence on the development of young researchers' skills in scientific communication. It was also confirmed, that the latter became a significant catalyst for the development of career skills of novice scientists, their awareness of standards, requirements and procedures of professional behaviour, developing skills, necessary for interaction. The analysis of the information on the participants involvement in contests and grant programs for young scientists proved the skills level of in financial management of research and understanding of the system of financial support.

The authors of this paper see the perspective for further research, which is developing on-line support of such a discipline as Methodology and Arranging Scientific Research in overall preparation of Philosophy Doctors.

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Integrating business simulations software into learning environment of technical university

To cite this article: D S Antoniuk *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012018

Integrating business simulations software into learning environment of technical university

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Abstract. The development of active learning approaches and the need in raising economic competency of the people within all the age groups brings business simulations software to the front of the appropriate tooling lists. The aim of the study considers the ways and approaches to introduce and effectively integrate business simulations software into learning environments of technical university. The object of the study is the learning environment of Technical University. The subject of the study is using business simulations software in the learning environments of technical university. The result of the study: several approaches of integrating business simulations software into a learning environment of technical university were analyzed and discussed. The paper is dedicated to generalizing practical experience of the authors in technical and logical implementation in the pedagogical practice, usage of business simulations software as students and users with theoretical research of broader set of approaches used to integrate business simulations software into educational software-based and organizational environments. Conclusions and future plans based on the results of the experiments were made. Main conclusions and recommendations: the range of approaches between deep integration with the learning management tools used in the learning environments and independent usage of business simulations software is possible to implement. Choice of approach depends on the goals, ICT-related maturity of the learning infrastructure and the percentage of active learning cases in the syllabus of the class. Future experimentation is needed to collect extensive data on integration possibilities, efficiency and effectiveness of the level of integration of business simulations software into learning environment of technical university.

1. Introduction

The concept of active learning has been widely discussed since its substantial introduction and description in the last decade of 20th century. Research results conclude a significant positive influence of the active learning approaches to the educational results [1,2]. Cooperation, collaboration and group activities embedded into active learning practices provide the most significant outcome [3]. Among modern ICTs in the field of economics, scientists are distinguishing business simulations. Using business simulations to enrich classes on the economy, finance, classical and behavioral is an example of active learning, need to be used in modern learning environments.

Business simulations software, providing significant possibilities to implement active learning approaches in studying economy to the classrooms of schools, higher education establishments and corporate learning environments. There is a need in developing approaches and ways to introduce and integrate business simulations software into educational environments of technical university. Business simulations software are being used by educational institutions of all levels and corporate training establishments as a valuable part of the classes and training in economics and finance. They might be used as the mean for formation of economic competence of the students. Finance literacy in high school is being developed more efficiently and with better involvement of the students [4].

While using business simulations software in the educational process has some coverage by researches and discussions, integrating simulations into a learning environment technical university is less discussed. Logical integration of business simulations into curriculum have been discussed by academics and practitioners. Approaches of implementing of business simulations usage into the educational process of higher education establishments were offered and discussed using MobLab and Economics Games software complexes. Descriptive example of integrating business simulations not only into a classroom, but also into scientific research, based on the collected during simulations data is described in the "General Economic Principles of Bargaining and Trade: Evidence From 2,000 Classroom Experiments" paper with the team of authors [5]. Educational institutions have technological setup, consisted of systems of ICT environment virtualization, authorization systems, Learning Management Systems (LMS), Learning Record Systems (LRS), Student information management systems, etc.

Business simulations themselves are the valuable tools to let students immerse in the experience otherwise impossible, expensive or dangerous to have. This is passive usage of the active learning tool. Technical universities with Computer Science, Information Technologies, Mathematical Modelling and alike specialties available may benefit from integration of business simulations software development into their educational activities.

That is why in this study, business simulators will be understood as the software of business simulations, and the modern educational environment – the educational environment of the Technical University.

Recently, scientists around the world are paying more and more attention to the educational environment [6–10]. In particular, Nataliia Soroko considered methodology for Teachers' Digital Competence Developing through the Use of the STEAM-oriented Learning Environment [11], Sanchia Janita Prameswari and Cucuk Budiyanto investigated the development of the effective learning environment by creating effective teaching in the classroom [12]. Aysen Ozerem and Buket Akkoyunlu also considered learning environments designed according to learning styles and their effects on mathematics achievement [13]. Eziyi Ibem, Oluwole Alagbe, Abraham Owoseni in their joint work considered students' perception of the learning environment [14]. Rudite Andersone investigated the learning environment in today's school in the context of content reform of curriculum [15].

Modern ICT setup of the educational institutions is mostly cloud-based [16–29]. Principles of the cloud-based ICT environment creation were discussed, the models of the general structure and the private academic cloud of the modern university were presented in the publication of Olena H. Glazunova. The architecture of information-educational environment of the modern university was substantiated and the number of solutions was presented for implementation of the modern ICT infrastructure in the higher education establishment in the publication of Olena H. Glazunova and Oleksandr V. Yakobchuk [30, 31]. A cloud-oriented green computing architecture for E-Learning applications was proposed and described in the paper of K. Palanivel and S. Kuppuswami [32]. Marinela Mircea and Anca Ioana Andreescu in their study analyzed the possibilities, conditions and enablers of the migration universities ICT resources to the efficient cloud-based infrastructure [33].

The options of integrating business simulations into technological ICT setup of modern learning environments are being analyzed in this study.

It is already discussed that learning happens when effective educational strategies are being combined with technological tools, effectively and sometimes also efficiently enriching learning experiences. Triple E Framework substantiates and describes one of the approaches to choose and validate the appropriate combination of the traditionally proven teaching techniques with technology usage. Three main principles of the Framework are: engage with others in social interactions, enhance and extend class learning to the real world application cases [34]. Principle of enhancement require leveling up "order of thinking" needed to perform learning activities [35].

The purpose of the work is to analyze, classify and generalize the approaches to the integration of the business simulation into the technical education environment and educational activities.

2. Results

2.1. Business simulations as specific type of educational tools

Educational environment as the term and the phenomenon is being rapidly evolving these days. The educational environment might be defined as the set of material objects and their connections that form a system for educational activities of learning subjects [36]. Another definition might be found in the works of Valeriy Yu. Bykov. Scientist highlights the educational environment as an artificially created system with the structure and components, enabling reaching educational goals [37]. Modern learning environment requires a synergetic complex of modern pedagogy with modern ICT and learning tools. Educational (learning) tool is being defined as the didactic system element that forms a learning environment and is being used in an educational activity. Business simulations are one of the examples of the learning tools used in the modern learning environment to introduce active learning approach and some degree of practical and visualized activity to the class.

The present state of the business simulations development and implementation characterizes by the absence of a dominant leader or unity of approaches to the organizations of the business simulation complexes. Business simulations might be simple standalone applications, open web or (and) mobile applications, online games, collections of separate simulations and complexes, hosted by vendors or integrated into the ICT environments of publishers or educational establishments.

Business simulations are being used as educational tools within different educational establishments. Business schools, universities and colleges use business simulations to add active learning and practical trainings to the MBA programs as well as to Masters and Bachelors curriculum. Executive programs from the traditional educational establishments and from corporate educational centers embed business simulations into their educational process. Business simulations are able to model simple economic concept, functional or operational area of the company, financial situation or process. Both classical and behavioral economy and finance concepts may be modelled and simulated. Visualization of the economic concepts or quantitative functional areas gives a better understanding and some level of hands-on experience to the students, using business simulations in their courses. Qualitative variables and interactions with the students might also be implemented into the logic of business simulations. An important area of using and value creation for business simulations in scientific research. Data generated during educational usage of business simulations might be used to study economic or behavioral concepts. Educational and scientific usage of business simulations might be combined within properly organized disclosed experiments conducted during the classes. The problem-based workshop is another educational form where business simulation usage as a learning tool is advised. Business simulations are being productively employed by the corporations to augment teaching the ways to use their products to the customers. One of the proven productive approaches is to use business simulations to teach customers to use ERPs [38].

Authors used business simulations in their educational activities for more than 16 years. Personal experience ranges from business simulations design for academic purpose as well as for corporate marketing purpose, using them to teach classes for Master students, employing business-simulations to introduce game theory to the high-school students, giving problem-based workshops in the corporate educational activities and playing simulations being a student of Global Executive MBA program. There were simple "one step" simulations, complex single-payer corporate operational simulations and competitive simulation, played by the remote diverse team in 5 different countries. Business simulations cover a wide range of topics and knowledge areas as well as a broad set of purposes and are being used for one as well as for hundreds of students simultaneously. Some business simulations are implemented in online games and let students interact with an extensive set of counterparts and diverse economic entities [39].

Business simulations follow general patterns of usage and integration of the other types of educational content. They have a lot of characteristics like other types of content and multimedia used in educational activities. We may observe a high level of similarity in the ways to create, host and use between business simulations and tests. Being close to each other in the use case scenarios, business simulations have several specific differences:

- they don't have standardize formats of presentation and interactions with the system (like the type of questions in the tests),
- might have complex logic of interaction with the user (some algorithmic/conditional logic might be present in adaptive tests, but it usually will be more consequent),
- might incorporate interaction with other users, working with the same simulation,
- are following developments in mathematics, economics, game theory, etc. The concept of different nature from other areas of science is being implemented in business simulations.

This specific defines the ways business simulations might be integrated to the modern learning environments of the educational establishments of all types. Neither type of integration we acknowledge as the right one. The set of approaches for each specific educational systems and situation will be discussed. The dominating types of integration are visualized on figure 1 and described in table 1. Mentioning "educational institution" we mean: university, college, school, training center, corporate training facilities. Mentioning "external provider" we mean either company or a private person – developer of the business simulation or publisher, providing a wide range of business simulators and (or) educational materials of other types.

2.2. Integration of business simulations

This work will be dedicated to the server- (web-) based simulations. Majority of the modern business simulations and complexes of the simulations are built using this approach. The user interface in case of web-based simulations and complexes of simulations might be implemented as: web-page (web-site); native application for one or several mobile platforms; adaptive web-page, allowing appropriate representation on the screens of the mobile devices; combination of several or all above-mentioned options.

Following currently accepted by default trend in the software development organization, business simulation developers usually start from the creation of single simulation as MVP (minimum viable product), test it with the target audience (teachers and students), correct the product and expand the offering, adding other simulations of enhancing the present one. It results that initially, business simulation is a simple server web-based application, that might be installed on the servers of educational establishment or on the server of simulation producer. We call it "standalone" setup. The business simulation might be used as real SaaS [40] offering, where instances of simulation environment for each game/class are being created automatically.

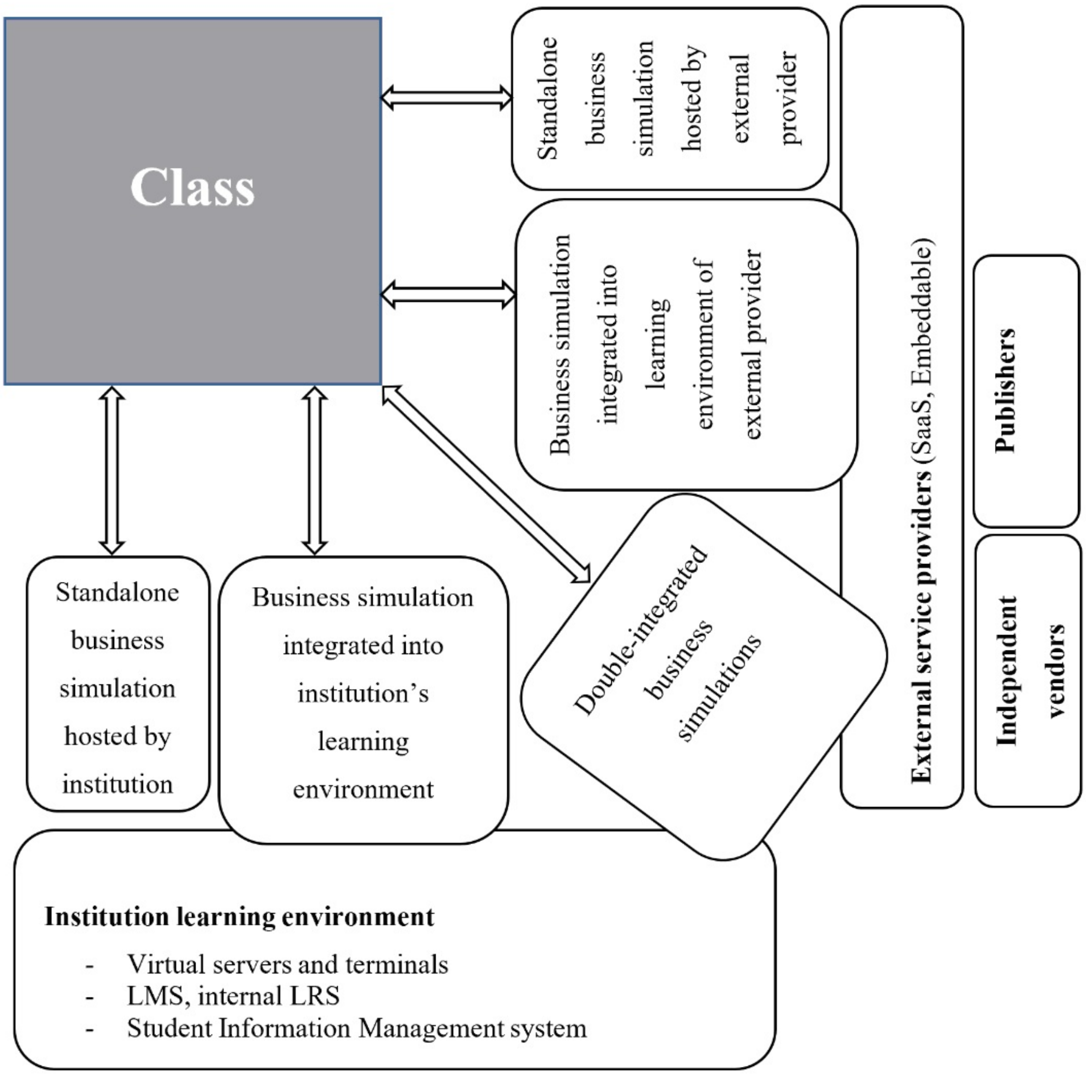

Figure 1. Business simulation integration approaches.

A simpler option for the producer that just starts to test hypotheses, might be used as "semi-SaaS" where simulation environments are being manually created for each game/class.

The same approach to hosting of business simulations is usually being used when it is being created by some educator (teacher/professor/lecturer), sometimes in collaboration with the students for particular class or topic.

After business simulation proved its usefulness and (or) profitability, the set of simulations is being developed using the same platform. Simulations are being used by the wider audience on the infrastructure of a producer or educational establishment that defines the need in the simulations and user (both: educators and student) management functionality. It requires integration either into the technical learning environment of educational institution or external provider. The same complex of business simulations might have the functionality to be integrated into the technical learning environment of either party.

The other approach might be used by the established education materials creating companies and publishers, who may order to create separate simulation as an addendum or enhancement to the available book, course or material set. This is the case when business simulation usually

Table 1. Business simulation technical integration approaches. Description.

Integration approach	Description	Educational setup
Standalone business simulation hosted by institution	Software, representing business simulation is hosted on the server of the educational establishment and is a separate program. Might have a different type of user interface (web, mobile, native application etc.)	Educational establishments, corporate learning centers
Standalone business simulation hosted by external provider	Software, representing business simulation is hosted on the server of the external provider and is a separate program. Might have a different type of user interface (web, mobile, native application etc.)	Educational establishments, corporate learning centers, private trainers.
Business simulation integrated into institution's learning environment	Software, representing business simulation is hosted on the server of the educational establishment and has integration with the other software systems of educational institutions.	Educational establishments, corporate learning centers.
Business simulation integrated into learning environment of external provider	Software, representing business simulation is hosted on the server of the external learning provider. May have matching or integration with the learning content and materials of other types.	Educational establishments, corporate learning centers, private trainers, private learners.
Double-integrated business simulation	Software, representing business simulation is hosted on the server of external learning provider, in the same time integrated with the other software systems of educational institutions. May have matching or integration with the learning content and materials of other types on the resources of the external learning provider.	Educational establishments, corporate learning centers.

appears in the category of "Business simulation integrated into the learning environment of external provider" from the time of creation.

The next level of integration is "Double-integrated business simulation". We call business simulations "double-integrated" when simulations management and user management are integrated with the technical learning environments of the external provider and learning institution simultaneously. In this case complex of business simulations or single business simulation is hosted on the physical infrastructure of the external provider (might be server, private, public or hybrid cloud), is integrated into its authentication, authorization, the other systems, and, in the same time, is integrated to some systems of the technical educational environment of an educational establishment.

This type of integration enables producer or external provider to enhance and update the software continuously and provide the educational establishment with qualitative service within a reasonable time and with lower cost. Maintaining software on its own infrastructure is easier and more efficient for the external provider. The educational establishment has the next benefits from this level of integration: continuous updates and bug-fixes of business-simulations; absence of the need to install and maintain the software in its technical educational infrastructure; integration with its authentication, authorization, Learning Management Systems, Student Information Systems etc.

So-called "White-label" solutions are the logical type of presenting different types of products to the customers. In the case of business simulations, it means that a company develops a complex of business simulations and let educational establishments to label it with its brand to their students. "White-label" business simulation might be used by the educational establishments in most part of above-mentioned integration approaches, except "Business simulation integrated into the learning environment of external provider". This type of integration is being used to benefit from integration with the systems and content of an external provider, so branding of the external provider will be part of the beneficial offering for the students and educator.

Technical integration of the business simulations into the educational environment of modern educational establishments need to be defined by:

- the goals of the institution and its educators;
- the familiarity of the educators with using business simulations in the educational process in general and either particular business simulation or complex to be integrated fits the educational goals of the institution, educators and the students;
- financial and technical abilities of the educational establishment;
- type of the audience to use the business simulation for (permanent students, students of short-term courses, distance learners, technical savviness).

The type of integration might be also defined by the policy of producer of business simulation or publisher.

2.3. An educational approach to use business simulations

Another point of attention to use business simulations is an efficient and effective logical integration of the business simulation into the educational process.

Approaches to logically integrate business simulations into the educational process are presented in the table 2.

An important question to address from the author's personal experience and analyzes sources is the preparation process for using business simulation in the class. Different logical and technological integration approaches might require the preliminary setup of the business simulation by the teacher or lecturer. An additional hurdle is the registration of the students in the simulation. These points need to be carefully addressed within the preparatory phase of business simulation usage to make it efficient and effective within the educational process.

3. Conclusion

As a result of the study, the approaches to integrating business simulations software into learning environment of technical university were presented. The work describes technological setups of learning environment technical university, using business simulations software complexes in the classrooms and for scientific research. Business simulations software might be used as standalone applications on the side of the institution or in the infrastructure of solution vendor, they may be integrated either into the technological environment of educational establishment or vendor, the highest level of integration is double-integration into both infrastructures of institution and vendor. Logical integration of the business simulations into the educational process was shortly named and described. Significance of the preparatory phase before using business simulations was mentioned. Simplification of the business simulation usage for short easy-to-use simulations and double-integrated solutions need to be further studied, idealized and developed.

Table 2. Business simulation logical integration approaches.

Logical integration approach	Description
Short inclusion	Business simulation is the short inclusion into the educational process to visualize particular economic concept or theory
A meaningful integral part of the class or workshop	Business simulation is being presented and played introduce active learning approach to the class and to visualize and let students deeper understand the economic or financial topic or a set of concepts.
Simulation-based class or workshop	The business simulation might be used as the basement or "scaffold" for either particular problem- or topic-based workshop or even complete class.
Group or individual in-class or home assignment	Business simulation is being used to organize in-class or home assignment for an individual or a group.
Scientific tool	Business simulation is being used to collect needed data from the class or workshop participants. The purpose of using business simulation to collect data might be disclosed to the class or not. It might influence experiment results. Sometime bias of disclosure might be predicted and intentionally expected.

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Implementation of web resources using cloud technologies to demonstrate and organize students' research work

To cite this article: I V Hevko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012019

Implementation of web resources using cloud technologies to demonstrate and organize students' research work

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Abstract. The possibility of increasing the efficiency of research work of students by introducing specialized web applications for group work and presentation of research results is substantiated. The main directions of using web resources in research work are determined. Possibilities of cloud services for the organization of cooperation of teachers and students on scientific projects are opened. The expediency of creating specialized websites and mobile applications to present research results is emphasized. Requirements for the content of web resources used for the presentation and organization of research activities of students, which should provide the ability to manage research projects, communication between all participants in the learning process, as well as providing the necessary scientific and methodological materials are determined. An interactive prototype of a specialized site and a corresponding mobile application has been created, which contains files and services necessary for coverage of research areas and activities of collective scientific work at the department. An experimental study of the effectiveness of using a specialized web service has been carried out. The final survey of the students involved in the experiment indicates a significant increase in the number of students interested in scientific work. This confirms the expediency of using the proposed resources for the development of research work.

1. Introduction

The intensive introduction of high technologies and high-tech industries requires the use of new approaches to the organization of training and the introduction of advanced educational technologies based on the achievements of scientific and technological progress [1–5]. In this regard, the requirements for a modern specialist who are capable of innovative activities and solving non-standard professional tasks based on the development of research competencies are increasing.

The innovative potential of the modern specialist is characterized, first of all, by creative ability to generate the new ideas caused by the professional attitude to achievement of priority tasks; the ability to model their ideas in practice; also the perception of new ideas, trends based on the breadth and flexibility of thinking [6].

The introduction of new information technologies in the educational and cognitive activities of students would expand the forms of self-education, intensify the research work of students and contribute to the development of innovative potential among future specialists. These requirements require the transformation of the educational system, namely the transition to a new psychological and pedagogical technology – the creation of an open, intellectually rich educational information environment [7].

Research by S. Amelina [8], V. Bondarenko [9], S. Bondarevskyi [10], V. Bykov [11], M. Kyslova [12], O. Lavrentieva [13], S. Malchenko [14], I. Mintii [15], Y. Modlo [16], N. Morze [17], V. Osadchyi [18], T. Selivanova [19], S. Semerikov [20], K. Slovak [21], V. Soloviev [22], M. Striuk [23], V. Tkachuk [24], S. Tolmachev [25], T. Vakaliuk [26] and others is devoted to the disclosure of new trends in the organization of scientific and communication activities using web resources and the use of mobile information and communication technologies in education. The work of P. Nechupurenko [27], N. Morze [17], A. Gritchenko [28], O. Potapchuk [29], S. Semerikov [20], Y. Shramko [30], I. Sinelnik [31], V. Soloviev [32] and others is devoted to the disclosure of aspects of the use of information technologies that contribute to the activation of scientific and cognitive activity. The analysis of the researches indicates that, despite the theoretical and practical achievements of scientists in the field of information technology, the issues of their application for the organization of research work are relevant and require more careful study. In particular, V. Lamanauskas and D. Augien noted the need to develop scientific cooperation between teachers and students, as a result of which students would have the opportunity to actively participate in scientific research, receive effective support, gain experience and see the results of activities [33]. Therefore, a detailed study of the possibilities of using web technologies for organizing student research work, taking into account the specifics of applied problems, is relevant.

In addition, in the information and educational sphere, it should be noted a fairly low level of information about the conduct of research work in student societies. Information about students' research work presented on the websites of educational institutions is usually limited to announcements of the results of students' participation in competitions, a list of research clubs and a list of master's theses, as well as announcements of planned conferences. Under such conditions, these web resources do not contribute to the activation of students' scientific development. To change this situation, it is important to create specialized web resources (websites and mobile applications) that not only provide information on the list of planned seminars or conferences and the results of participation, but also coordinate student research clubs and provide detailed information on current research.

The analysis of modern research on this issue indicates the relevance of further development and implementation of new methods of using cloud services in higher education, including research [34–48].

The purpose of this study is to reveal the specifics of creating and using specialized web applications using cloud technologies to organize research work of students.

2. Presentation of the main material of the study

2.1. The directions of using of web resources in scientific work of students

Modern scientific research in the context of the application of information technology is taking new forms. This is facilitated primarily by the technology of automatic data collection and processing, statistical data analysis systems, Internet search technology and remote information processing, data storage, presentation of results [28].

The use of the latest information technologies in science leads to the emergence of new methods and directions of research, the development of tools and methods for formalizing research.

Particularly relevant for research is the use of network technologies at the stage of accumulation of knowledge and facts. Thus, for the analysis of literature sources, searching in electronic catalogues of libraries, ordering literature sources through the internal network of libraries and through online stores is becoming increasingly effective. Also important is the ability to automatically translate the text using online resources, storage and accumulation of information, communication with leading experts [49].

An important area of application of network technologies in science is the organization of the work of virtual research laboratories. This allows, in particular, to attract scientists from different parts of the world to conduct research directly in their laboratories with the subsequent exchange of information through a computer network [50, 51].

It should be noted that modern communication technologies provide unique opportunities for the mass publication of information. However, with the loss of control over publications, the level of information becomes too uneven, in fact, noise, among interesting scientific ideas.

Thus, today there is a problem of awareness among the general public of network users, future professionals about the activities of research laboratories and student research clubs. Most of the research units do not have their own official websites where information about their work would be available. A small number of laboratories are represented online by pages on the websites of higher education institutions and research institutes in the structure of which they are included, but the information on such pages is insufficient and does not allow to get a complete picture of the research, activities and scientific interests of the laboratory. Therefore, there is a need to create your own network resource for the presentation of scientific research.

So, the creation of a web resource for the coverage of research works is relevant and will not only reflect the scientific activities of students for the general public, but also concentrate and systematize useful and reliable information about this applied area on one network resource.

In the process of analysing the available web services for organizing research work, it was found that existing solutions, usually, do not provide the required level of detail of scientific content and are also expensive to maintain. Therefore, we consider it necessary to focus on the benefits of SaaS services for organizing student research work.

2.2. Using cloud SaaS services for organizing research activities of students

It is possible to increase the efficiency of students' scientific work and motivate them for research by introducing Web based systems for organizing joint work on research and maintaining appropriate documentation.

The formation of a cloud educational and scientific environment in higher educational and research institutions is an important condition for the training of ICT specialists capable of further active, scientifically grounded application of cloud technologies in their professional activities [33, 52, 53].

The use of web resources based on cloud services allows to unite both teachers and students into a single university network for collaborative work on projects, organizing web conferences, using e-mail and expanding functionality [11, 54]. The development of cloud technologies makes it possible to introduce an innovative program into the educational process to optimize it, simplifying the joint work of students and teachers, significantly expanding the types of cooperation, developing cooperation skills, rationally using time and learning opportunities [55].

The most common cloud services are: SaaS – software as a service, PaaS – platforms as a service, IaaS – infrastructure as a service, DaaS – virtual workplace as a service [56].

Google's SaaS cloud services are focused on broad and open access, maintain a common mode of operation that ensures communication, collaboration between educational process subjects and significantly enhances the factor of motivation and mutual intellectual activity. For educational institutions, Google offers a free version of the Google Apps Education Edition. SaaS services have a number of benefits for educational institutions to use in a learning environment. Indeed, at any time, any student can access their resources and make changes [57, 58].

The use of cloud SaaS services in the organization of scientific research has several advantages (see figure 1).

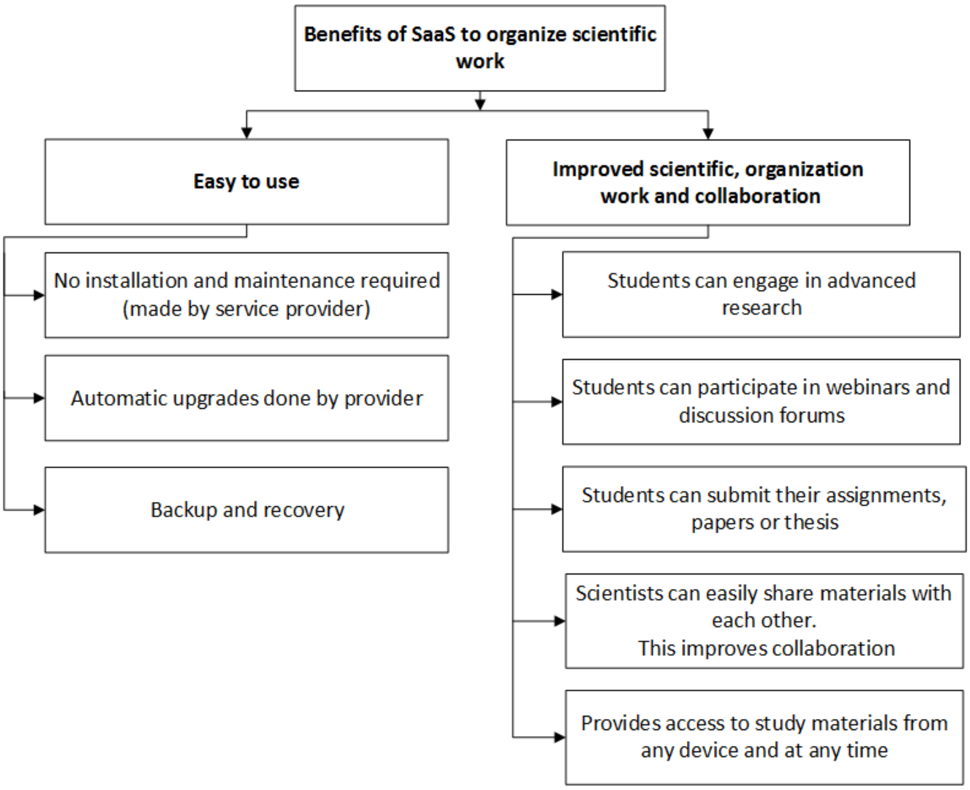

Figure 1. The benefits of SaaS to organize scientific work of students.

It should also highlight the shortcomings of SaaS cloud services: information security problems, vulnerability of personal data; additional training is required to implement this type of system; you need constant access to the Internet Insufficient network bandwidth will lead to incorrect operation of services.

Despite these shortcomings, cloud services today are a full-fledged tool with which you can organize the joint work of teachers and students on research projects, without being tied to the place and time of research. This, in turn, facilitates individual and collective research by students. In addition, the use of SaaS services will not only increase the efficiency of research work and the convenience of teachers and students, but also reduce economic costs.

2.3. Requirements for the structure and design of the web resource

A web resource for the coverage and organization of students' research work in scientific clubs and laboratories should provide:

- the ability to manage a scientific project process (electronic journal, calendar),
- communication between all participants in the educational process (discussion, chat, online consultations, webinars),
- joint activities of students to create joint projects,
- provision of scientific and teaching materials (electronic library, presentations, video files, cloud data storage).

In figure 2 shows diagrams of use cases, which represent the interaction of the user with the system, and also reveals the main capabilities of the web resource, in accordance with certain requirements.

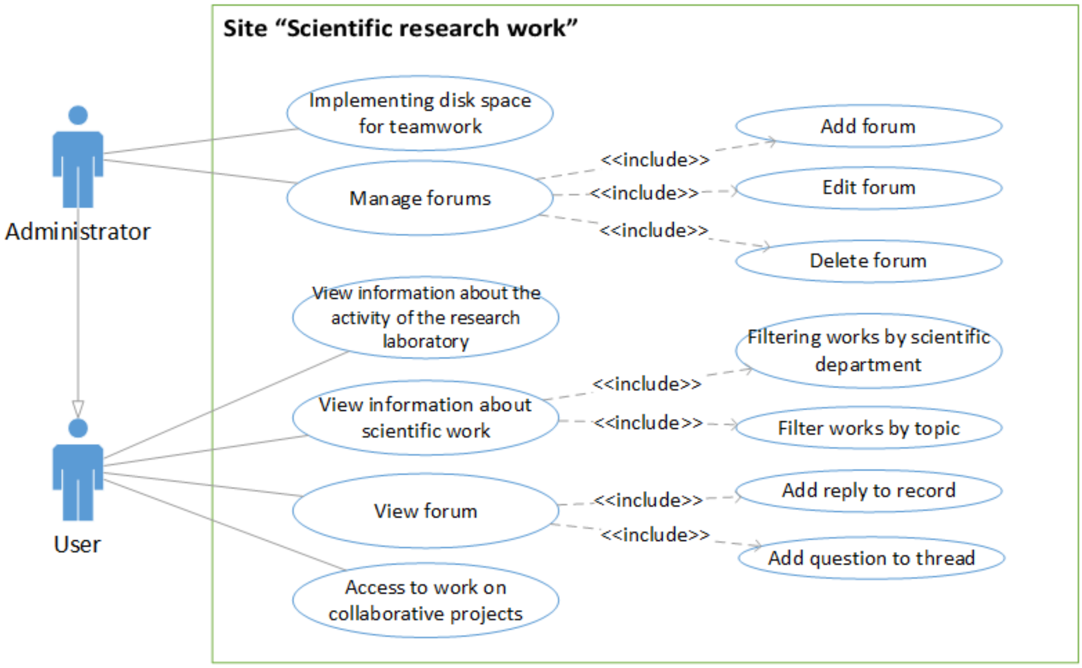

Figure 2. Use case diagram.

Development of site pages is carried out in accordance with the laws of ergonomics: the location of information on the page, ease of navigation, stylistic design, loading speed [59–61].

In the process of designing a web resource to ensure maximum efficiency of work and communication, it is necessary to take into account the ergonomic requirements, the description of which is given in figure 3 [62, 63].

In addition, to ensure communication between students and teachers, it is effective to implement a forum that discusses pressing research topics or provides links to relevant information that reveals the problem in a particular area of application. For the exchange of experience and its accumulation on a web resource, it is necessary to provide for the possibility of archiving, which will save information about the research problems and promising ways to solve them, discussion issues or presentations of scientific research.

2.4. Functional characteristics of the developed web resource

Functions performed by a research site arising from its content. First of all, it contains information about the directions of scientific activity, theoretical and experimental research, presented in a form accessible to both a scientist and a non-specialized reader.

Thus, the purpose of the site is to disseminate scientific achievements and organize research work of students, which will improve the efficiency of research and promote the growth of scientific interest among students.

In addition, the information on the web pages contains information of a scientific and applied nature in the form of general laws and concepts, knowledge of which is necessary to understand the essence of the research.

This web resource is primarily aimed at people who want to apply the results of scientific research in their professional activities, as well as specialists working in related fields of science.

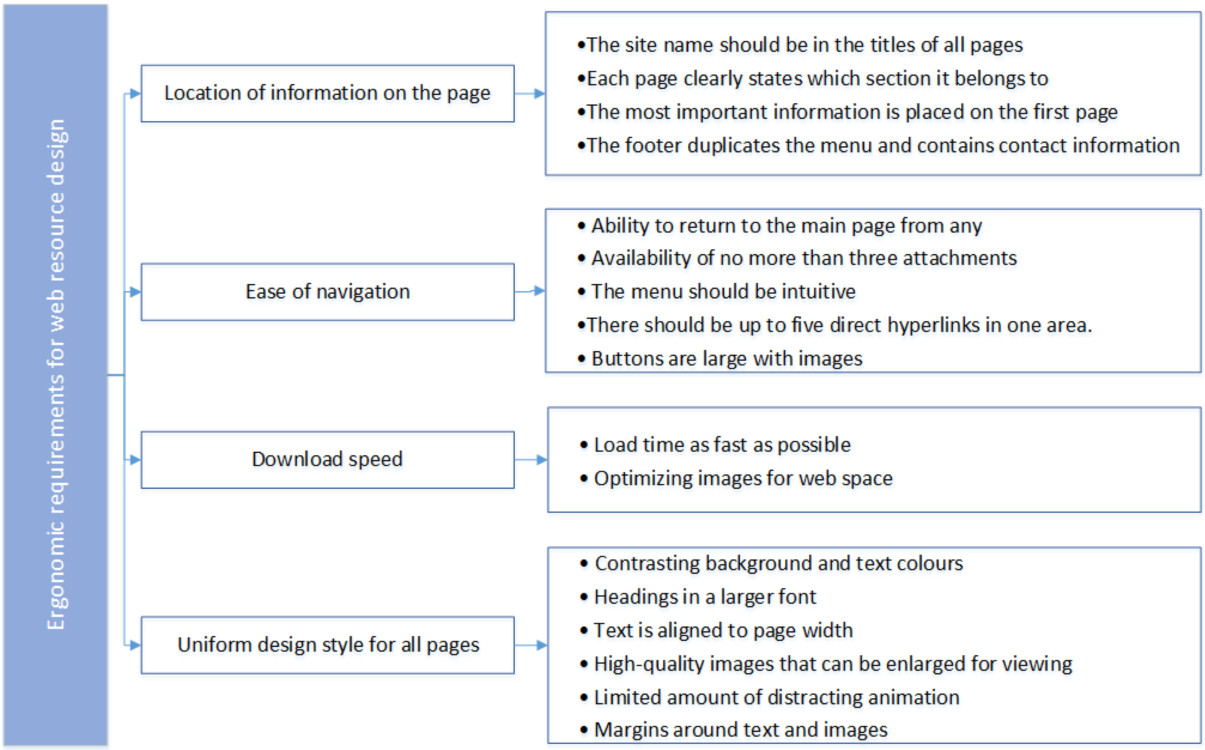

Figure 3. Ergonomic requirements for web resource design

Therefore, such a site performs a number of important functions. The main function is informational, which consists in presenting information on the site about the main areas of scientific work, background information on research problems, interesting news in this area. The communicative function is also important, which allows the use of network technologies to communicate between students and specialists in a general field of scientific interests.

Such a popular science web resource is designed to perform a number of scientific, organizational and educational functions to generalize the results of theoretical or experimental research, stimulate further scientific developments from these problems, consolidate the results of scientific knowledge and stimulate the creative professional activity of young scientists. This helps to create conditions for the exchange of experience and ideas between young scientists representing various scientific schools, to attract students to scientific activities, to acquaint them with the results of the latest research and the latest trends in the applied field.

Thus, the structure of the site is designed in accordance with the tasks that it must solve, and their specifics. As a basis, the hierarchical type of site structure was chosen, which is the most convenient for the user and involves the division of pages into categories and subcategories. In addition, the content of the sections, the structure and formatting of the pages are determined in accordance with the above ergonomic requirements.

Therefore, in order to effectively inform students and researchers about the results of scientific research, the developed online resource contains the following sections:

(i) Section with general information about the activities of the research laboratory or club, its employees, history of development, etc.

(ii) A news section that contains articles about events related to the field of scientific interests. These are, for example, information on conducting scientific seminars and conferences, articles on innovative research solutions.

(iii) The section in which the directions of scientific research are revealed. It reflects information about the scientific work that is carried out on the basis of this scientific unit and the subject of scientific research with a brief description of their content.

(iv) Section with information about student research papers: planned and completed term papers and master's theses. It is also advisable to disclose information about students' participation in scientific seminars, conferences, competitions and olympiads.

(v) Section containing scientific articles of students and laboratory staff, materials of seminars and conferences with their participation.

(vi) Section with presentation materials (photographs of installations, videos, a short description of projects) related to scientific projects that are currently being developed.

(vii) The section for the discussion of scientific problems, which contains a forum, provides an opportunity for online communication between scientists and students, as well as simply interested people on the proposed topics. Topics on the forum are added by registered users or by the site administrator after passing the moderation procedure.

To organize joint work on existing projects, the site also provides a section that gives access to documents for registered users. In addition, a calendar with scheduled events has been added to this section. For example, holding a Zoom or Meet conference to discuss pressing issues.

It should be noted that the learning process involves the use of mobile Internet devices, thereby encouraging each student to work independently, creates a favourable situation for communication and conditions for the development of the creative abilities of the individual, increases the motivation and cognitive activity of students [64, 65]. Thus, for a more convenient access to the site, a mobile application was created on its basis (figure 4). The AppsGeyser platform was used to quickly and efficiently create a mobile application. This platform allows you to turn a developed website into a mobile application for free. Conversion occurs according to the following sequence of steps: template selection, design settings and main sections, publishing the application.

The developed web resource allows to use the information about research work of students as much as possible. The network resource provides interconnection and the possibility of online communication between scientific departments, specialists and research students.

The ability to view your own search results on the site and interactively add to the scientific developments of the department and its laboratories gives the student confidence in the importance of knowledge gained during scientific work or a seminar. The result of this is an increase in the level of interest in scientific research in this area, a wider involvement of future specialists in the development of science.

The importance of using such technologies in research activities is confirmed by the requirements for the formation of the competencies of future specialists, provided for by the standard of higher education in specialty 015 "Professional education". The document notes that in accordance with general and professional competencies, a graduate must have "the skills to use information and communication technologies, the ability to study and master modern knowledge, as well as the ability to use the basic principles and methods of fundamental and applied sciences in professional activities" [66].

In order to analyse the effectiveness of using the developed website and mobile application for the formation of the above professional competencies, an experimental study was carried out. This made it possible to verify the feasibility of using the proposed resources for the development of students' scientific thinking, which is necessary for future scientists to make independent decisions in the process of preparing, writing and defending scientific projects, articles and reports.

The study was carried out on the basis of a research group, which functions at the innovation centre for 3D design and production technologies. It should be noted that before the introduction

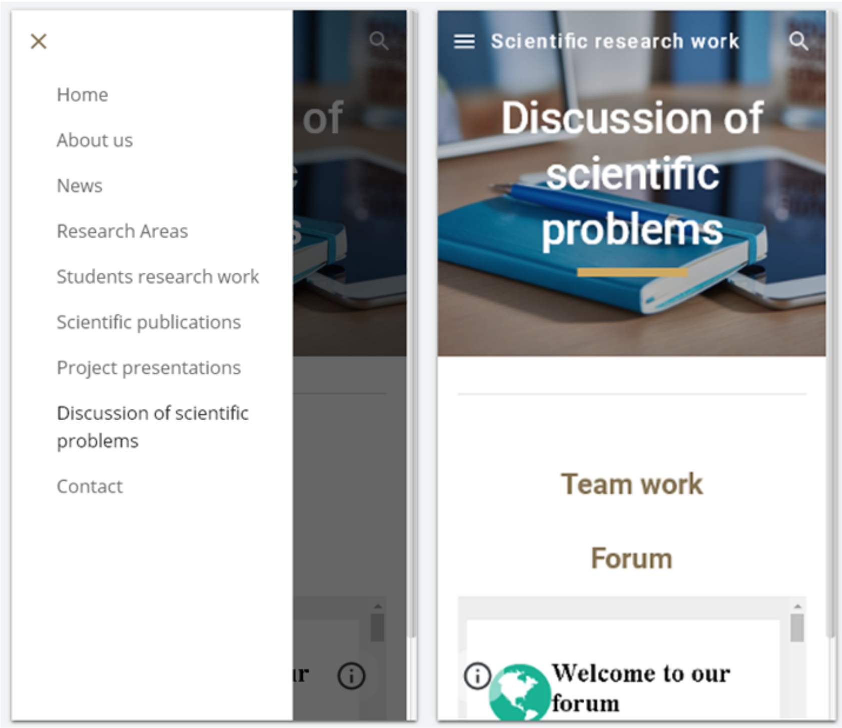

Figure 4. Pages of a mobile application for organizing research work of students

of the proposed resource, there were 14 students in the group. With the introduction of a web resource that popularized research work, the number of students who became interested in research work in the group increased to 27. This indicates a growing interest in research work using specialized web resources.

Today, attracting students to expert groups is an integral part of the quality assurance process in higher education. Therefore, we will consider the results of the survey of students as an expert assessment.

In addition, a survey was conducted among students of the faculty, in which 124 students took part, where they had the opportunity to answer a multiple choice question. Among the questions posed were the following:

- What do you think: is it advisable to use specialized web resources for organizing research work?
- Do you consider this form of organization of student research activities convenient?
- Have you used the proposed mobile application?
- Have you identified any inconveniences the organization of your scientific activity in this format? If so, which ones?
- Indicate (if any) proposals for the structure and content of the developed resource.

A significant number of surveyed students (92%) consider this form of organization of their scientific activities convenient, especially in the conditions of distance learning (figure 5). It also promotes the popularization of research activities (noted by 84% of students) and motivates people to participate in research activities (68%). However, it should be noted that a small number of students showed no interest in the developed resource (12%).

During the survey, students also noted certain features that would improve the work with the web resource. In particular, the respondents' suggestions regarding the foresight of the English-

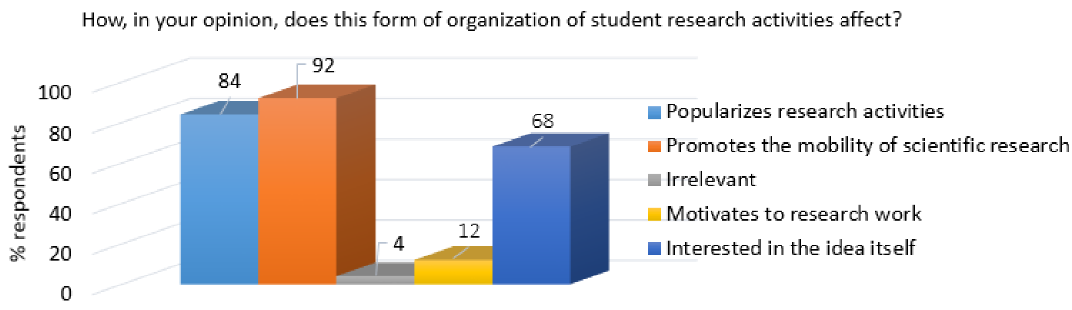

Figure 5. Results of a survey on the feasibility of introducing web resources.

language version of the resource were appropriate, which will contribute to its popularization in the Internet.

After analysing the results of the survey, we conclude that the use of a website and a mobile application to coordinate and present research activities is an effective way to develop students' scientific thinking. It also contributes to the development of professional and research competencies required by future scientists for their scientific activities.

So, using web technologies to organize the research work of students, we get the main advantages:

- ability to obtain relevant scientific information according to the research topic,
- the possibility of operational cooperation of research subjects on-line,
- development of students' cognitive activity and their research competencies.

However, we consider it expedient to highlight the disadvantages of using web technologies for organizing students' research work [29]. This is, first of all, the need for proper hardware and constant monitoring of the resource, its content.

In addition, the negative aspect is the reduction in the time of direct communication with research participants. The use of online conferences only partially compensates for this disadvantage.

Taking into account all the positive and negative aspects of using web technologies for organizing the research work of students of higher educational institutions, it can be argued that the use of such modern technologies contributes to the qualitative formation of professional and research competencies of future specialists.

3. Conclusions

Thus, the use of the capabilities of modern web technologies ensures the effective research work of students, not limited to the time and spatial framework of the organization of educational interaction and cooperation. The use of specialized web resources allows you to systematize and organize information about research conducted in a specific scientific field and to enhance the cognitive activity of students.

The capabilities of Google services allow you to create a full-fledged web resource that will provide online communication between research departments and specialists in the process of working on projects. This will not only increase the efficiency of research, but also reduce economic costs. The development of a web resource based on the free Google Sites platform information about the research work of students, as well as access to files and services used to organize collaboration on projects. Adapting the resource to mobile devices using, for example, the AppGeyser service provides more convenient and faster access to all information on the web resource.

An experimental study of the feasibility of using the created prototype of a web resource has been carried out. The study was carried out on the basis of a student research group, which functions at the innovation center for 3D design and production technologies. The final survey of students involved in the experiment indicates an increase in the number of students interested in scientific work. After the introduction of the proposed service for organizing research work, the number of students interested in research work almost doubled. Thus, as a result of the study, it was found that the use of such means contributes to the improvement of the presentation and coordination of research works and is an effective means of developing student research activities.

The developed resource is currently designed for the organization of research work, without taking into account specialization. Prospects for further research lie in the diversification of the resource, in particular, expansion with the help of external services of specialized content (for example, input / output of mathematical formulas, connection of graphic online editors, etc.). In addition, further research will be aimed at studying the technologies of using other Internet services, including social networks, which contribute to increasing student motivation for research and the effective organization of students' research activities in the process of their professional training in higher educational institutions.

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Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Communicative patterns for IT professionals as means of mastering communication skills

To cite this article: S V Symonenko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012020

Communicative patterns for IT professionals as means of mastering communication skills

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Abstract. The paper deals with the aspects of English communicative pattern implementation into IT professional training. It is emphasized that the communicative pattern usage enhances prompt and fluent profession-related real-life communication and it is the essential part of education of IT specialists. Peculiarities of communication in the IT environment are highlighted. Considering typical situations and issues of communication the guidebook which contains recommendations and communicative patterns for IT undergraduates both for oral and written communication has been developed. In order to evaluate the purposefulness of the guidebook implementation in IT specialist training, two surveys (among lecturers and among undergraduates) of six universities have been conducted. The guidebook has proved to be suitable for practical classes, independent learning and laboratory works in humanities and profession-related disciplines. The survey conducted among English teachers has proved the increased interest, higher motivation and willingness to participate in communicative tasks crucial for specific employment.

1. Introduction

Ukrainian IT professionals successfully compete with specialists from other countries in the European and world labour markets. Software development, for instance, is a quite complicated process, so software products are rarely created by individual specialists, software engineers have to work in groups and teams [1–4]. In their professional activities IT professionals must ensure communication with customers, colleagues, project managers, board and team members in their own team, directly and remotely, so communication in a native language or foreign languages is an essential part of the productive work of software engineers.

The situations when IT professionals work in an international team, which is formed for a specific project, are quite common. The main grounds for selection of specialists for such a project are not the geographical location of all participants, but correspondence of high qualifications, logic, analytical, mathematics and problem-solving skills, professional knowledge and soft skills of a particular specialist to the project.

2. Peculiarities of communication in the IT environment

Numerous studies on distinguishing features of the current generation of students and young professionals have been presented in many international and national studies: Net Generation

Survey [5], The Net Generation: A Strategic Investigation [6], Grown Up Digital [7], Nielsen NetView Audience Measurement Survey [8], and Technological preparedness among entering freshmen [9]. Summarizing the results of these studies, R. Berk had identified twenty common characteristics of this generation of students and young professionals [10]:

- technological savvy – the modern generation is quickly mastering new technologies or digital devices; they expect that information will always be at hand;
- dependence on search engines – students begin to search for information using search engines, re-evaluate their skills in finding and evaluating information;
- interest in multimedia – young people are accustomed to entertainment, speed, aggressive sound and visual accompaniment of any information, prefer interactive media to passive television;
- "creators" of Internet content – even schoolchildren and humanities students develop websites, publish blogs with photos and original creative works, upload their own videos to YouTube every day;
- receptivity to inductive teaching methods means that students prefer practice over oral or written instructions;
- multitasking in everything – young people are able to perform several tasks simultaneously;
- "visual" communication involves the total visualization of information and the use of images, animated images, stickers and other features of messengers and social networks to reflect feelings or their own attitude to a particular event;
- emotional openness – students easily express their feelings, they are open to meeting new people, share personal information and publish their stories online on blogs, wikis, social networks, magazines and other social media;
- teamwork and cooperation – representatives of this generation work better in a team compared to representatives of previous generations;
- electronic record keeping – young people work quickly with the keyboard, type notes, messages, essays and term papers on computers, laptops or other digital devices.

Information technology as the least communicative field is rightly considered to be one of the most resource-intensive and complicated professions. IT specialists work not only with the newest technologies, but predominantly they are to interact with numerous people in the company and outside the company (colleagues, managers, customers) to create a successful product. The human factor along with the technical factor often becomes the reason of the low-quality software product [11]. Among other factors according to O. Titova and N. Sosnytska [12] intelligence, creativity, motivation, will, productivity and reflection are basics of engineering profession which is equally implied to information technology.

Since most of communication in the IT environment occurs with the use of information and communication technologies, it is obvious that specialists in such an environment communicate directly ("human – human") or indirectly ("human – digital device – human"). Indirect communication is commonly more preferable for the IT environment as a specialist has to understand the task and implement it accurately. As we stated in our previous research, almost 90% of communication in the IT environment is indirect, that is, the asynchronous symbolic communication system as opposed to the verbal one is dominant [13].

In case of indirect communication an IT specialist receives a conventional message which corresponds to the corporate ethics and regulations. The response is based on the phrase patterns, which help to describe tasks and errors, get the formalized answer, fix the problem or follow the guideline in the message. In the event of direct communication emotions can prevent quick problem-solving.

According to the mode of responses communication within an IT environment can be synchronous (face-to-face communication, meetings, instant messaging, chatting) and asynchronous (e-mail messages, newsgroups, task and time control systems, chats, correspondence etc.).

Communication types and techniques can be classified according to their formality. Pikkarainen et al. describe formal and informal communication types. Formal communication techniques include group, steering group and milestone meetings, status meetings, formal meetings, formal documentation, and a source code. Informal communication techniques comprise face-to-face discussions in co-located or distributed teams, informal discussions by use of various communication channels, including ad hoc communication [14]. W. Reinhardt emphasizes that "informal communication activities seems to make the difference between just working and great experience projects" [15].

Particular attention should be paid to the types of communication in terms of its content:

- cognitive communication which is aimed at obtaining necessary information for self-development. This type of interaction is relevant for specialists in software engineering, computer science and computer engineering as these professions involve self-education throughout life due to the rapid change of technology;
- material communication is aimed at obtaining material benefits, in particular, for the work performed and the conclusion of mutually beneficial agreements. This type of communication should be well developed for a successful career in the IT field, which is manifested in high wages, migration of specialists between IT companies, concluding agreements with customers taking into account risks;
- motivational communication refers to motivational actions, when the need for something (recognition, assistance, etc.) forms the need for an IT specialist to be in contact with other people (friends, colleagues, customers, like-minded people);
- activity communication relates to the field of personality and has a specific purpose: to expand the boundaries of the essence of a specialist, the disclosure of their individual potential for professional growth, transition to another, higher position or role in projects.

The analysis of professional activities of software engineers according to the Jung's theory of personality taking into account professional deformation and natural ability to certain profession allows us to state that the positive traits of software engineers are perseverance, persistence, resilience, as well as the ability to concentrate more deeply and feel the task, which are inherent in introverts. Thus, most software engineers are introverts and they communicate with introverts in their professional activities, and therefore they must understand the peculiarities of this type of personality in their interaction and communication.

For introverts, it is best to work on long-term projects in which they can be fully immersed, there is a need to prepare the workplace and be able to isolate themselves from the outside world (headphones, partitions, multiple monitors, even if they are not urgently needed). This type of personality works better on a pre-prepared plan (they know the time and topics of meetings in advance, have a plan of tasks for the day), distribute tasks and have some time reserve. It is especially important for introverts to choose a convenient communication system for them, namely messengers, electronic mail, stickers with notes instead of personal meetings.

However, in order to succeed in the IT profession in a modern corporation, certain traits of extroverts are needed, as the corporate culture of a modern IT company includes open offices, regular meetings, or mob-programming practice [16]. Therefore, introvert specialists need to be taught to gradually expand the circle of communication, gain credibility, offering help to colleagues and asking for help to establish contacts.

Thus, to train a highly qualified specialist in software engineering, computer science and computer engineering at higher educational institutions it is crucially important to identify typical situations and forms of communication of software engineers, to form templates and patterns for communication in each situation and to create conditions to practice these patterns.

M. Bartyzel [17], studying communication among software engineers, has noted that conversational patterns are techniques for managing conversation, asking questions, finding needs and explaining expectations, which are called, organized and described algorithmically for their direct use by specialists. It should be noted that it is important for an IT specialist not only to master a certain set of phrases that will help solve certain problems quickly and professionally, but also have certain psychology knowledge.

In our opinion, knowledge of psychology is needed primarily for communication processes. It is necessary for learning and a successful professional activity to master affective strategies aimed at reducing anxiety and stress, forming positive attitudes, overcoming fatigue, controlling the time of the task, etc.

At the same time, it is necessary not only to provide theoretical knowledge, but also to apply it in practical classes in the form of trainings, business games and using other methods, as these strategies directly affect the quality of communication and, consequently, professional problem-solving.

To communicate effectively the following significant aspects should be taken into account:

- motivation – internal motivation to communicate as a universal and professional value and motivation to develop teamwork skills, values for cooperation and solving professional problems through the organization of effective communication,
- cognition – knowledge of psychology of communication, teamwork, patterns of professional phrases,
- communication activity – the ability to use patterns to solve professional problems, the ability to organize communication both in personal communication and mediated by ICT,
- performance and evaluation – focus on communication in order to obtain a specific professional result, assess problems with communication and determine a new communication strategy.

3. Communicative patterns as means of training communication skills

Communication within an IT environment as S. Kumar states is to be strategically planned (planning, preparing, starting a discussion), but interlocutors are to think tactically, improvise and make choices about their communication to get the excellent result [18].

To analyse the efficiency of application of communicative patterns as means of training communication skills the following questions have been arisen: 1) improvement of communication skills and professional vocabulary due to usage of special teaching aids (a course book and supplementary materials); 2) impact of the motivation increase on the student knowledge level; 3) adequacy of student self-assessment as to their discipline advance. To answer the research questions the following methods have been applied: surveys and questionnaires, focus groups (teachers and students), expert evaluation.

Taking into account distinguishing features of the current generation of students and young professionals, the peculiarities and types of communication within an IT environment, the aspects of successful communication, considering typical situations and issues of communication we have developed the guidebook which contains recommendations and communicative patterns for IT experts both for oral and written communication. Communicative patterns can be defined as logically complete balanced phrases to control the conversation, the use of a sequence of which leads to the desired result without losing and distorting the content of messages.

The guidebook consists of 12 units on topics, situations, problems and tasks that arise during professional activities in the process of software development. Each unit contains guidelines and patterns for the most typical workplace situations: writing letters within and outside an

IT company, writing cover letters, curriculum vitae and resume writing, job interview, job hunting, teleconferencing, making presentations, meetings, discussing a profession, teamwork, and customer service. The communicative patterns are presented in two languages: English and Ukrainian.

The guidebook is not just a phrasebook with the list of ready-to use conversation phrases; it includes certain useful recommendations on managing particular psychological, organizational and interpersonal issues which can emerge in professional activities of IT professionals.

For instance, in the "Customer service" section certain useful advice on handling complaints is given with some focus on psychology of customers, dealing with problems and finding efficient solutions. Communicative patterns are grouped into subgroups (acknowledging the customer's emotions, collecting information about the problem, apologizing to the customer, offering a solution etc.), and several options are given to make a choice to make communication more efficient and successful.

The guidebook can be used at practical classes at higher educational institutions during group discussions, round tables, role plays, brainstorming, the case method and others. The book can be also useful at workplaces during trainings aimed at team building, trust building and team communication; development of skills to negotiate, resolve conflict situations; development of communication management (regulation of basic communication strategies; regulation of relations with the customer; management of anti-crisis communications; creation of a favourable socio-psychological climate; change management).

In order to evaluate the purposefulness of the guidebook implementation in IT specialist training, two surveys (among lecturers and among undergraduates of six universities) have been conducted.

The objective of the lecturers' survey has been to estimate the suitability of the guidebook for enhancing specific English skills of the students majoring in software engineering, computer science and computer engineering.

Depending on the prospective tasks, IT undergraduates should be informed by their instructors about the priority of the typical communication activities and encouraged to practice them more intensely. So, for instance, software engineers mostly correspond with their superiors and inferiors in writing, work independently or in pairs. The computer science graduate sphere of their social activity is much wider and includes numerous professional tasks like collaborating, providing services to non-experts, sometimes even teaching. For this reason, four main communication aspects have been concentrated on while teaching the mentioned above undergraduate categories and these aspects have been tested separately.

The guidebook provides all the necessary links to authentic websites with English interfaces in the reference section, where practicing both synchronous and asynchronous communication is possible. The tasks for enhancing written formal and informal communication have been introduced as essays, blogs, forums, business letters which should be compiled of the patterns introduced in the guidebook (at the first stage – with provided bullet points, but with no strict time limitation and no assessment; at the control stage – as a writing task in an exam card).

Oral communication includes, first of all, training quick information reception and comprehension. Secondly, the objective has been to prepare the students to spontaneously react verbally. Multiple role plays, producing and dramatizing dialogues and polylogues have been reproduced by students using the provided patterns in current training.

The more complex task has been to react to partner's lines in handouts in order to lead the conversation to its logical final according to a provided script in Ukrainian. The example of the dramatizing task is when one student gets a card where details on order placement are given (e.g. development of a website of the sportswear online shop in the short period of time and meeting uncommon customer needs). The first student has got a set of selected communicative patterns on the script, but their partner has to select and order the patterns from the vocabulary box matching the given lines of their counterpart. The rapport of the negotiation process depends on the second student's choice if they prefer communicating in more polite manner or using less official style.

The most challenging but the most appreciated due to its profession-related nature task included improvisation of all the communicators – an urgent real-life situation which needs to be attended immediately. In contrast to the previously described script partner tasks in the improvisation tasks the student communication is not supported by pattern prompts. They are given cards with a puzzling task (e.g. defective computer equipment causes negotiation disruption and an IT expert has to take efficient measures to please the superiors). The student has to get to know the details of the equipment failure, precisely explain the possible causes, give instructions on how to deal with the problem and provide recommendations on prevention of the mentioned situation reoccurrence).

All the other students present in the classroom are welcome to react verbally and to speak their lines as disturbed co-employees in order to complicate the initial task or to support the leading speaker. Such tasks increase motivation to learn the obviously useful patterns, show relationships within the team and teach collaboration under various real-life conditions. Teachers usually appreciate the possibility to set an example of crucial necessity of fluent speaking skills and quick verbal reaction in polylogues for not sufficiently motivated students.

All the mentioned above activities are aimed at student preparation for participating in a business game involving all the students of the group and their English teacher. The script supposes a computer classroom as a location, requires the Wi-Fi access and a whiteboard. The participants should be reminded in advance how to use the screen demonstration function of a certain web-conferencing tool.

The locations of the three act play are the CEO office, the technical support department and the distant participant's office. The actors personify the characters according to students' communicative skills, the advanced speakers have to react spontaneously and have more voluminous parts. The following roles are to be allocated: the owner of the IT company, the CEO, a technician, a CEO's secretary, a web-developer, a system analyst, a manager, an HR-manager, a trade-union representative. The particular emphasis should be put on the choice of a player acting as a video conference counterpart who has allegedly pronunciation issues (stressing a wrong word in a sentence, strong accent, mispronunciation of certain sounds). This student should be able to react differently (e.g. expressing anger, embarrassment, guilt) and provoke partners' usage of adequate communicative patterns.

The mentioned above characters are to interact in the sequence of polylogues synchronously and asynchronously. The theme of the business game is the annual general meeting of the company. Most of the actors have to prepare a short report on results for the meeting, while the owner and the CEO have to sketch an agenda for the next year. During the staged meeting prospective outcomes of the year are discussed, bonuses and reprimands are given. The mentioned above conversations drafts encourage a great variety of using patterns for praising, disapproving, criticizing, apologizing etc. The preplanned scenarios scrutinized by the game participants in advance and augmented by their vision of their character personality are supported by improvisation when all the players underlie the equal conditions and depend on each other's verbal proficiency.

The role game foresees written correspondence alongside with oral communication: prepared and current personal students' notes, various lists, memos, and final minutes taken by the CEO's secretary (admittedly acted by the English teacher who circulates between groups and coordinates the game process if necessary). The suggested game duration is up to 60 minutes, and the rest of the class time is devoted to evaluating, discussing the final script and forming the list of ideas for the next possible business games.

The final module assessment of the student ability to communicate their intention included (in spite of the variety of practised communicative tasks) using freely the learned patterns according to the provided script, but students who feel confident at the end of the mentioned above English course could volunteer to improvise in a staged conversation with their teacher reflecting the professional environment atmosphere.

In order to analyse the English lecturers' perspective on the communicative skills significance for graduates' efficient functioning in the professional environment the survey has been conducted among English teachers of Dmytro Motornyi Tavria State Agrotechnological University, Bogdan Khmelnitsky Melitopol State Pedagogical University, Classic Private University, Zaporizhzhia National University, Lviv Polytechnic National University, Luhansk Taras Shevchenko National University. The English teachers training software engineering, computer science, informatics, computer engineering and information systems and technologies students have been asked to estimate interdependence of involving students in English communicative activities both within classes and in independent learning and their readiness to get engaged voluntary as participants gradually gain more communicative experience. The more tasks student do (every English class in the winter term at Dmytro Motornyi Tavria State Agrotechnological University includes at least 3 communicative activities, the total amount equals 75 tasks in accordance with the term syllabus), the more confident they feel in communicating with each other and their colleagues.

35 of 40 respondents (87%) have noted the positive effect of communicative task application in the English course for IT students. Placing the emphasis on the specific communication aspect with students majoring in more or less introverted professions ensures the increased interest, higher motivation and willingness to participate in communicative tasks crucial for a specific professional position.

Nevertheless, the difference in indices of the mentioned above majors should be noted: prospective computer engineering specialists are less inclined to get motivated by the interaction process since their professional requirements are the least communication-intensive and undergraduates are least predisposed to train customer-oriented communicative strategies for working mostly in "human – digital device" systems. Correspondingly, the computer engineering students least advance both in acquiring English communication skills and boosting English vocabulary. That is why students majoring in computer engineering have been asked to contribute to the English class content and their list of preferable communicative activities is going to be considered and logically implemented into the syllabus for the next study year.

The progress in the communication activities of software engineering, computer science and computer engineering students according to their test results is presented in table 1.

Table 1. The progress in the undergraduates' communication activities.

	Software engineering	Computer science	Computer engineering	Average
Formal written communication progress	83%	78%	81%	81%
Formal oral communication progress	82%	86%	78%	82%
Informal written communication progress	87%	81%	84%	84%
Informal oral communication progress	85%	91%	82%	86%

Separately, the student vocabulary knowledge progress after scrutinizing the guidebook in the English for specific purposes course has been monitored. The average indices are presented in table 2.

Table 2. Vocabulary knowledge progress (average of 6 universities).

	Receptive knowledge	Controlled productive knowledge	Free productive knowledge
Module test results	78%	74%	67%

While checking receptive vocabulary knowledge students have been given short texts for understanding the meaning of the highlighted English patterns from the context and giving their precise translation. Controlled productive knowledge is tested in close tests and the positive grade means that a student is able to choose one pattern of four that fits the required meaning. Free vocabulary productive knowledge supposes speaking out freely and producing the right grammar and syntax forms in order to express the required meaning.

The second question of the survey has been the guidebook suitability for different learning activity types. Practical classes have been ranked first by 89% of the responders, due to the synchronous and dynamic nature of communication tasks involving the patterns. 82% of the surveyed lecturers have ranked the project activities in independent learning second (when one compiler or team partners deliver their self-study creative product). Laboratory works have been ranked third by 78% of respondents due to the reproductive activity nature when a provided algorithm is followed.

The third question of the survey among the universities' teaching staff has contained the request to suggest related disciplines where the guidebook (possibly, with the emphasis on the Ukrainian language component) could be implemented. The suggestions included English for specific purposes, business English, English for scientific purposes, profession-related Ukrainian, management disciplines (e.g. the section of patterns for dealing with complaints), psychology and business Ukrainian (e.g. for studying intercultural aspects in professional environment).

The students learning from the guidebook have been asked to participate in the survey, too. The results of the self-evaluation of software engineering, computer science, computer engineering students are presented in table 3.

Table 3. The results of student self-evaluation of the English skill progress.

	Software engineering	Computer science	Computer engineering	Average
Vocabulary knowledge boosting	85%	89%	84%	86%
Spontaneous verbal reaction in profession-related situations	79%	82%	85%	82%
Acquiring new information	97%	96%	98%	97%

86% of all the respondents of the Google-form questionnaire have pointed out their English vocabulary knowledge improvement after completing the communicative pattern guidebook, 82% of respondents indicated increased readiness to spontaneously verbally react in profession-related situations, 97% of respondents pointed out acquiring a great amount of new information about verbal behaviour of potential English speaking counterparts. The student self-assessment results are completely in accordance with the module test grades which confirm the adequacy of the students' vision of the progress in English and awareness of the communication skills necessity in their professional life.

4. Conclusions

Facing the challenges of integrity into the multicultural professional environment current undergraduates in Ukraine are aware of the necessity to intensely improve their foreign language communication skills. This trend is more than urgent for prospective IT specialists who must overcome their psychological and language usage obstacles to communicate their professional intentions. They have to communicate with customers, colleagues, project managers, board and team members in their own team, directly and remotely.

Considering the template nature of professional tasks delivering communicative patterns is the most productive and effortless way of ensuring their verbal and symbolic activities. These patterns are logically complete balanced phrases to control the conversation, the use of a sequence of which leads to the desired result without losing and distorting the content of messages.

The analysis of distinguishing features of the current generation of students and young professionals, the peculiarities and types of communication within an IT environment, the aspects of successful communication has been conducted and considering typical situations and issues of communication the guidebook which contains recommendations and communicative patterns for IT undergraduates both for oral and written communication has been developed. The guidebook has been implemented into IT specialist training at six Ukrainian universities. Successive surveys have demonstrated the significant progress in the communication activities of software engineering, computer science and computer engineering students. The guidebook has proved to be suitable for practical classes, independent learning and laboratory works in humanities, in profession-related disciplines and, most of all, in English, business English and English for specific purposes.

The survey conducted among the English teachers has proved that focusing on the specific communication aspect with students majoring in introverted professions results in the increased interest, higher motivation and willingness to participate in communicative tasks crucial a for specific position. The described in the paper issue of motivating introverted students who prefer and aim at the "human – digital device" professional environment and avoid training people-oriented communicative strategies is a significant concern and an imperative for teachers to consider. Nevertheless, the average indices of all IT students and the current results of computer engineering students confirm the successful implementation of communicative objectives.

The results of the student questionnaire have substantiated the positive effect of training communicative strategies within the English course. More than 80% of all the student respondents have pointed out their English vocabulary knowledge improvement, increased readiness to spontaneously verbally react in profession-related situation and acquiring a great amount of new information about verbal behaviour of potential English speaking counterparts.

Communicative pattern usage for English skill mastering enhances prompt and fluent profession-related real-life communication and thus is the essential part of the productive work of IT experts.

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Digital transformation in society: key aspects for model development

To cite this article: N V Morze and O V Strutynska 2021 *J. Phys.: Conf. Ser.* **1946** 012021

Digital transformation in society: key aspects for model development

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Abstract. The paper is devoted to the analysis of the digital transformation processes that are currently taking place in the economy, production, education and society as a whole. The main reason digital transformation is impact of the digital technologies. Modern digital technologies, services and systems are extremely important for social development. One of the key issues for the implementation of digital transformation is changes in the way of thinking and requirements for the competencies of workers in the industry. First of all, it is connected with people's understanding of digital transformation processes and with their ability to use digital technologies effectively. For specifying Ukrainian educators' awareness level about digital transformation processes, there were conducted survey. Research results have shown that there is a need to increase their awareness level about digital transformation processes. Based on the analysis of the considered researches the authors have developed a generalized model of digital transformation for enterprises, businesses and educational institutions.

1. Introduction

The basis of modern society is digital technology: artificial intelligence, robotics, IoT, blockchain and 3D technologies, etc. [1–14].

An example of how digital technologies have become a part of our everyday life is the infographic (figure 1). It is developed according to the Internet portals Statista, Visual Capitalist, Business Insider, Gamespot, Techcrunch, Omnocode Agency, Doordash, Business of Apps, New York Times, Music Business Worldwide, INC., Hootsuite, Dustin Stout, Reddit, Uber, Amazon, Wox that demonstrate what happened within one minute of human activity with the use of digital technologies in 2020 [15].

The report of the consulting company Accenture (for 2017) identifies five new digital technologies that can transform global economic development [16]: Internet of Things (IoT), Artificial Intelligence (AI), Blockchain, Big Data, Robotic Process Automation (RPA).

The use of digital technologies is transforming business models, resulting in new products and services; the format of works is changing (outsourcing, online platforms, improved automation, robotics, etc.). Real-time work with digital data fundamentally changes the ways of management, production, sale and use of products [17].

Thus, modern digital technologies, services and systems are extremely important for social development. Their introduction into the activities of enterprises and organizations, engineering and technology, production and non-production processes allows to expand the range of goods and services, improve their quality and compliance with consumer demand, increase productivity

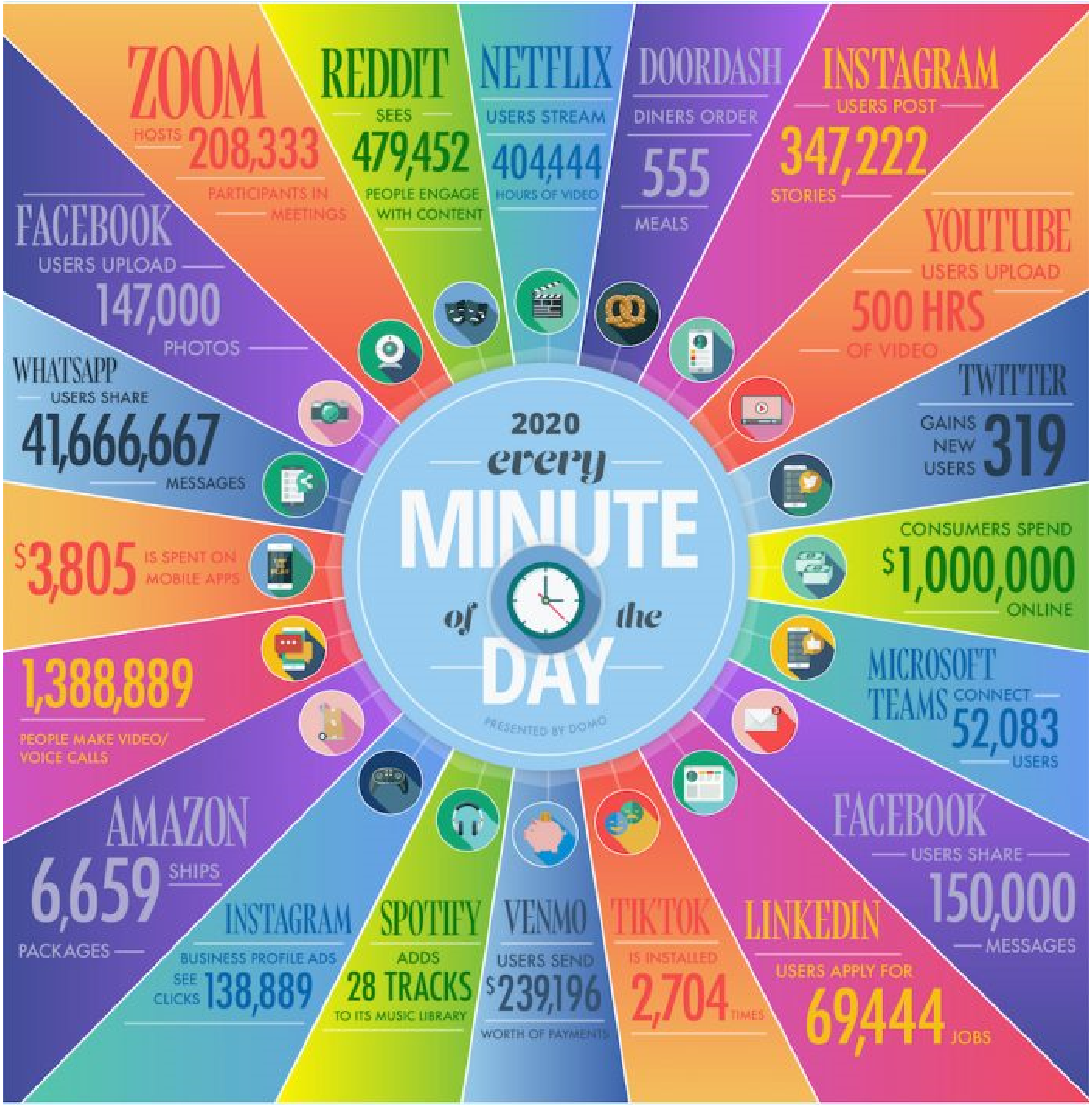

Figure 1. The results of human daily activities with the use of digital technologies within one minute in 2020. Source: data from https://www.domo.com/learn/data-never-sleeps-8.

and form new value-added chains. This will ensure growth and creation of jobs in all economy sectors (from the smallest traditional enterprises to the latest high-tech industries).

However, the education system is failing behind the general state of digital transformation in society. In our opinion, the main problem is the lack of understanding by the participants of the educational process of the institutions (higher, secondary and vocational) what is the difference between the use of digital technologies and innovations provided by the transformational changes that digital technologies bring to the educational process, and comprehension of concepts, structure, required and sufficient conditions and processes of digital transformation in general and in education in particular.

Paper goals. That is why, the purpose of this paper is to define Ukrainian educators' awareness level about digital transformation processes; to analyze and develop model of digital transformation that can have a place in enterprises, businesses and educational institutions.

2. Research methods

The authors have used the following research methods and tools for the investigation (2020).

Quantitative methods: 1) study and analysis of scientific monograph; 2) study and analysis of research papers; 3) study and analysis of documents about digital transformation; 4) analysis approaches for development digital transformation model; 5) (online) meeting, (video) conference, seminar, workshop, etc.

Qualitative methods: survey and interview of the Ukrainian educators to determine their awareness about digital transformation.

3. Theoretical background

The rapid development of digital technologies and, as a consequence, the digitalization of many sectors of society have led to the introducing such terms as *"digitization"*, *"digitalization"*, *"digital transformation"*, which, in its turn, led later to the *digital transformation concept* [18–21].

Digital transformation is the use of digital technologies [22] to fundamentally increase the productivity and value of enterprises [23]. Now this is the focus of managers and employees of actively competing industries around the world. It is understood as a profound transformation of:

(i) production and organizational operations,
(ii) processes,
(iii) responsibilities of employees, and
(iv) models of their activities.

Digital transformation is due to the use of rapidly developing digital technologies and their accelerated impact on society. Such transformation takes into account the changes that have already happened, happening and will happen in the future [24]. The processes of digital transformation are affecting many areas of human activity. They are felt in all areas where there is mechanization and automation of data processing.

During the process of digital transformation, enterprises should:

- turn customers into partners,
- elicit the creative potential of staff,
- make all business processes flexible, scalable and natural,
- review or, if necessary, develop a new business model;

Not every innovation related to the introduction or modernization of information systems can be attributed to the digital transformation of the enterprise. In order to be "digital transformated", the implementation of an information system should [25]:

- lead to a fundamental (a qualitative step forward) increase in efficiency upon key performance indicators of work organization (improvement by many times),
- use modern digital technologies that are economical, scalable and flexible, adapted to rapid change (cloud computing , big data, artificial intelligence, virtual reality, etc.),
- be cross-cutting, i.e., affect several areas of transformation (customers and products, employees and processes, etc.),
- transform the enterprise into a learning organization $\rightarrow$ knowledge,

- be accumulated, analyzed and applied by using digital technologies with the participation of staff and/or external experts.

The stages of **digital transformation** include:

1. Digitization.
2. Digitalization.
3. Digital transformation.

Digitization, digitizing is a technical process of converting analog data streams into digital format (in bits). The same interpretation of this concept is also followed by scientists from various fields (J. Beniger [26], S. Brennen [27], J. Bumann [28], V.D. Chekina [17], P.N. Edwards [29], T. Feldman [30], O.M. Harkushenko [17], D. Kreiss [27], S.I. Kniaziev [17], D.V. Lypnytskyi [17], M. Manoff [31], J.M. Owen [32], R. Pepperell [33], M.K. Peter [28], D. Robinson [34], D. Savi [35], J. Van Dijk [36], S. Verhulst [37], V.P. Vyshnevskyi [17] and others).

Owing to digitization, data becomes easily available for use on various platforms, devices, and interfaces.

The Ukrainian (V.D. Chekina [17], O.V. Dannikov [38], O.M. Harkushenko [17], S.I. Kniaziev [17], D.V. Lypnytskyi [17], K.O. Sichkarenko [38], G.O. Tkachuk [39], V.P. Vyshnevskyi [17]) as well foreign researchers (B. Bimber [40], S. Brennen [27], U. Bruegger [41], J. Bumann [28], M. Castells [42], A.J. Flanagin [40], K. Knorr Cetina [41], D. Kreiss [27], M.K. Peter [28], D. Savi [35], C. Stohl [40], J. Van Dijk [36], S. Verhulst [37]) pay their attention to the issue of defining the concept of "digitalization". Based on the analysis, synthesis of experience and research, we understand **digitalization** as a process of transformation and/or improvement of enterprise activities, business models, business functions, communications, use of online platforms, training and retraining of staff to work in new conditions, etc. based on the widespread use of digital technologies and digitized data.

The issue of defining the concept of *"digital transformation"* is currently quite relevant in foreign and domestic scientific literature. Research papers [17, 27, 28, 32, 35, 42–47] propose different approaches to the definition of this concept. In our opinion, the approaches do not significantly contradict each other. However, these definitions are not complete enough, in our opinion.

Based on the analysis and synthesis of the concept interpretations, we define **digital transformation** as fundamental changes in the organizational structure of companies, production, ecosystem, industry as a whole by optimal integration of traditional processes and digital technologies with their gradual implementation at all levels.

The last stage is final in the concept of digital transformation. Owing to its introduction, the modern digital business models and processes are restructuring the economy. Society is also developing and changing when people integrate digital technologies into their life and daily habits [48].

Summarizing the abovementioned considerations, we present the stages of digital transformation (figure 2).

The researches of Cognizant Center for the Future of Work (USA) [50] showed that the rapid development of digital technologies has already affected traditional business processes, IT infrastructure and social life (figure 3).

At the beginning of 2020, production and social life are generally affected by such technologies (figure 4) [50].

Combined digital technologies (shown in figure 3 and figure 4) are increasing their impact on business and social life.

Figure 5 shows the areas in which fundamental changes are expected due to the digital transformation.

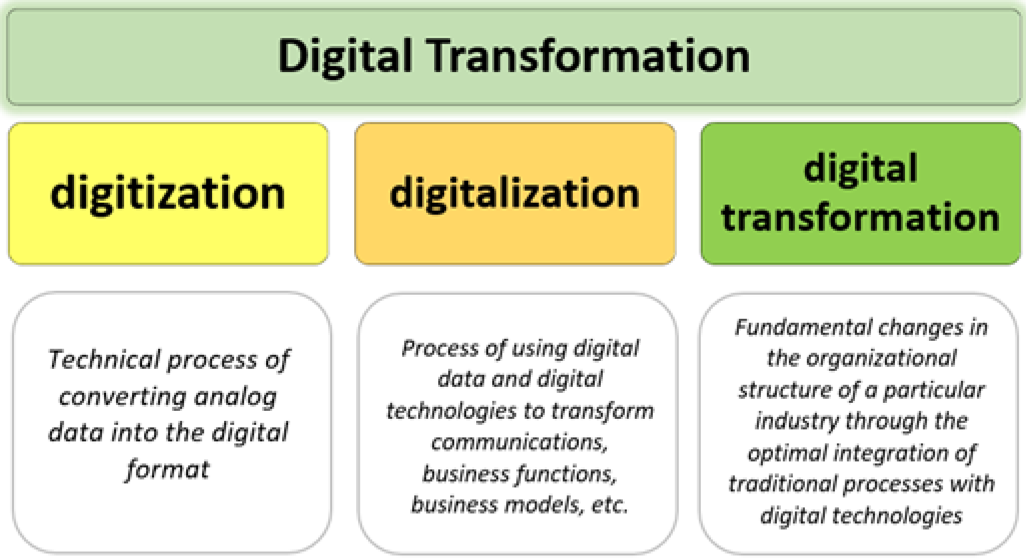

Figure 2. Stages of digital transformation (based on [48, 49]).

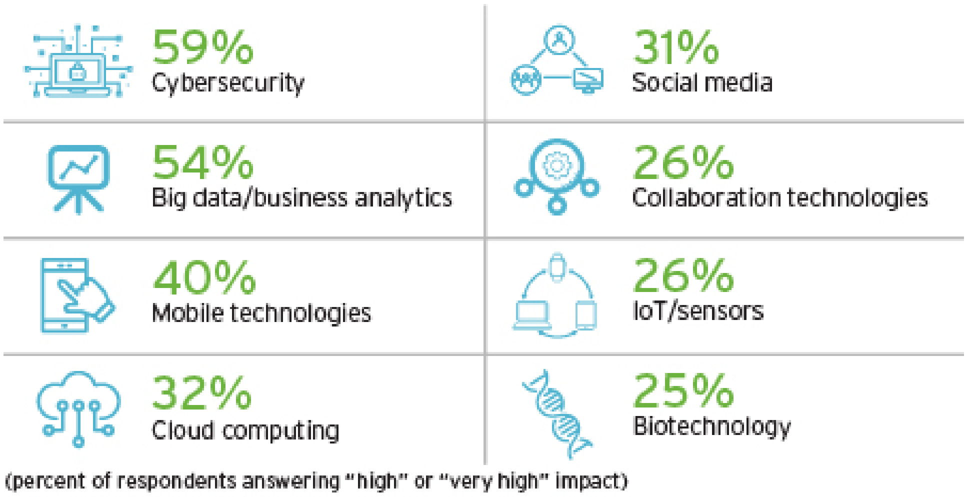

Figure 3. Stages of digital transformation. Source: retrieved from https://www.cognizant.com/content/dam/CognizantDotcomimages/monthofhyperdigital transformationfigure2.jpg, (accessed on 19.12.2020)

4. Development of digital transformation model

Digital transformation (DT) is the result of digitisation and digitalisation of economies and societies. DT is an ongoing process. The introduction of digital technologies creates both new opportunities and new challenges.

Consider the challenges posed by a process, digital transformation, which is a complex phenomenon of different development. These challenges are related to the following issues:

- which areas are most affected by the digital transformation,
- how the digital transformation affects the labor market, training of future professionals, and social life in general,
- what are the ways to implement digital transformation for different industries,

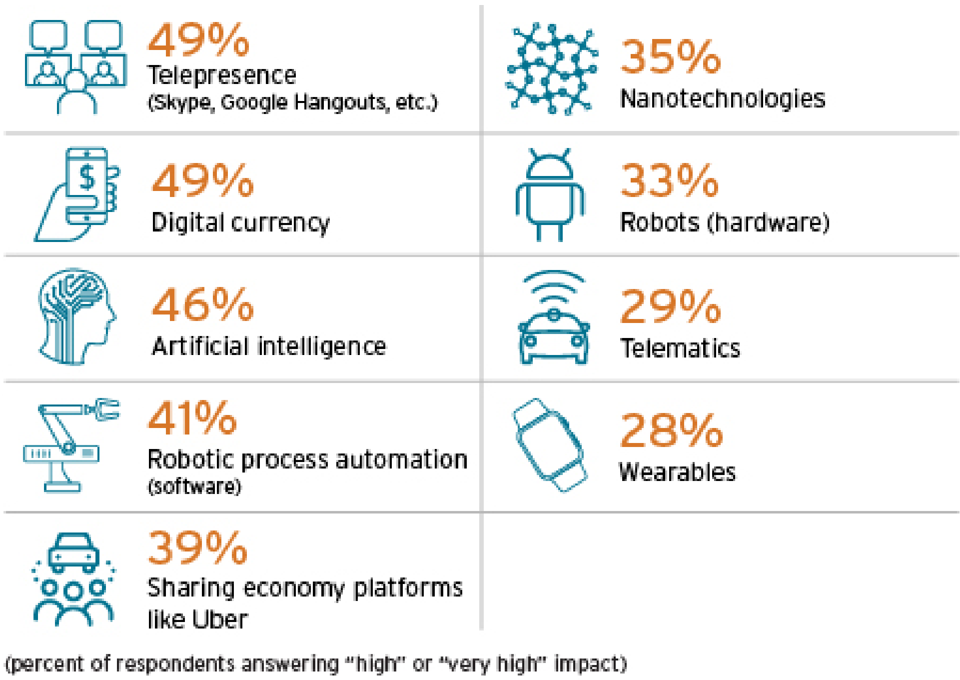

Figure 4. The impact of technology that is the basis for the digital transformation of the economy, production, and social life [50]

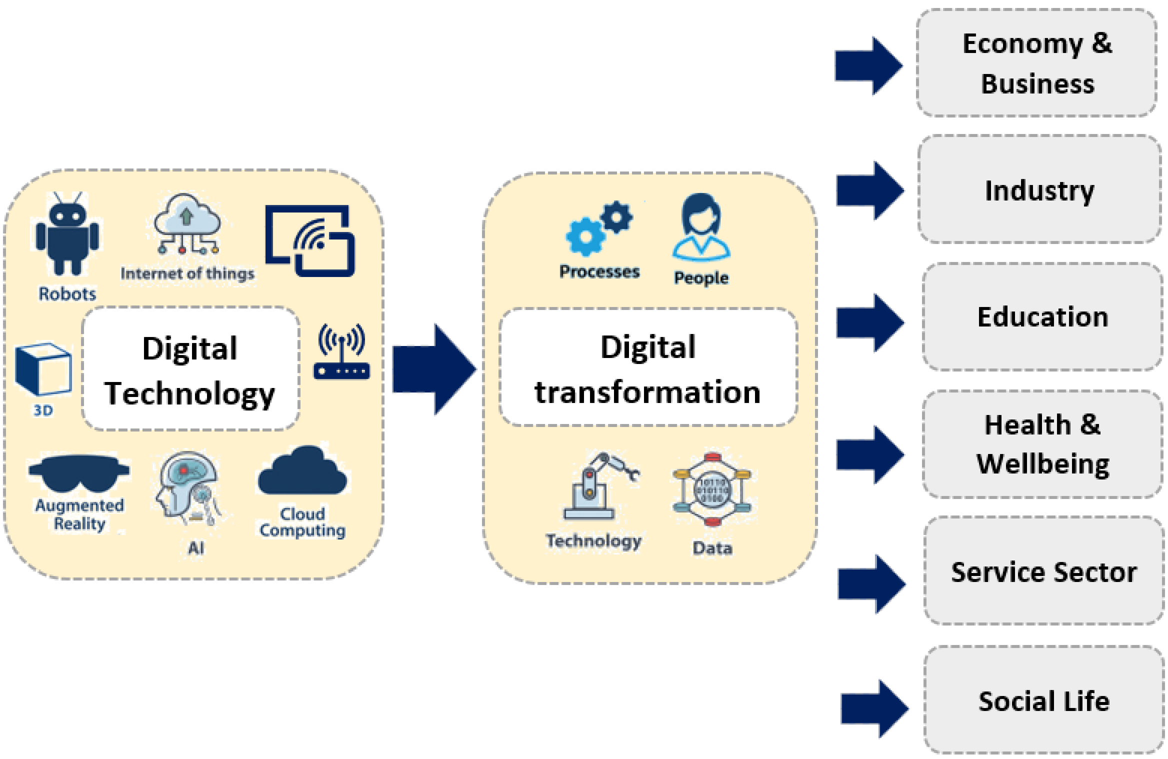

Figure 5. Areas in which fundamental changes take place due to the digital transformation.

- what steps need to be taken for the digital transformation of companies, production, ecosystem, and a particular industry as a whole,
- what changes in educational systems need to be made to adapt people and accelerate their inclusion into the processes of digital transformation.

One of the key issues for the implementation of digital transformation is changes in the way of thinking and requirements for the competencies of workers in the industry. First of all, it is connected with people's understanding of digital transformation processes and with their ability to use digital technologies effectively.

For specifying Ukrainian educators' awareness level about digital transformation processes, authors have conducted survey. The online survey was elaborated (in Ukrainian) using Google Forms. 78 Ukrainian educators have taken part in the present research (during December 2020). We guaranteed participants that only anonymized data would be shared.

The survey contained information about digital transformation processes in society and education.

The data on the Ukrainian educators' awareness level about digital transformation processes are presented in figures 6–9 below.

Q.: *How do you understand the digital transformation?*

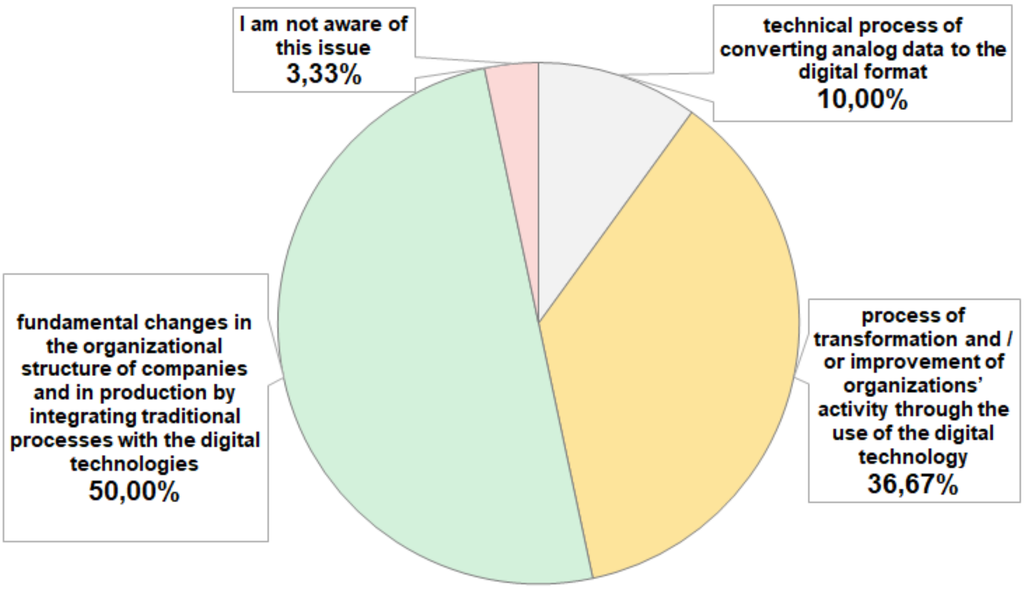

Figure 6. Survey responses on understanding the digital transformation.

As we can see from figure 6, the largest group of respondents (50%) understands the digital transformation correctly. At the same time, about 37% of educators have defined the digital transformation as process of transformation and / or improvement of organizations' activity through the use of the digital technology (digitalization). 10% of respondents have defined it as digitization. This means that there is a need to increase their awareness level about digital transformation processes.

Q.: *Is the digital transformation a priority identified at the national level in Ukraine?*

Figure 7 are shown that despite the fact that the majority of respondents are aware of this issue (almost 61%), a large percentage of respondents (39%) do not know whether the digital transformation a priority identified at the Ukrainian national level or not. This means that there is a need to disseminate these issues at national level, for example to introduce these questions as a part of training and retraining of specialists. especially for educators.

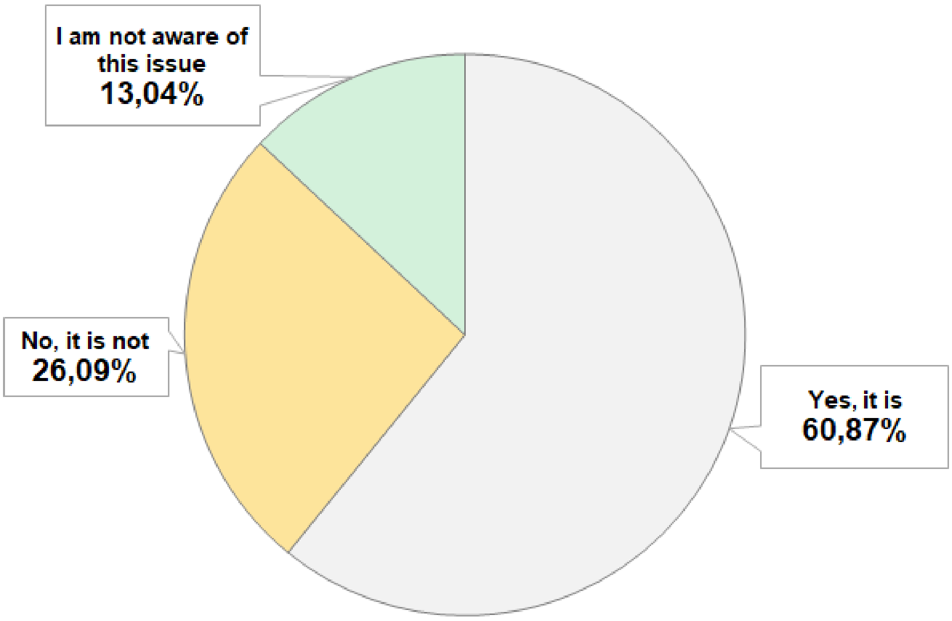

Figure 7. Survey responses on awareness of the respondents about is the digital transformation a priority identified at the national level in Ukraine.

***Q.**: What are the prerequisites for the digital transformation of society?*

Survey responses on prerequisites for the digital transformation of society are shown in figure 8 (multiple answers are possible, that is why the total responses can be more than 100%):

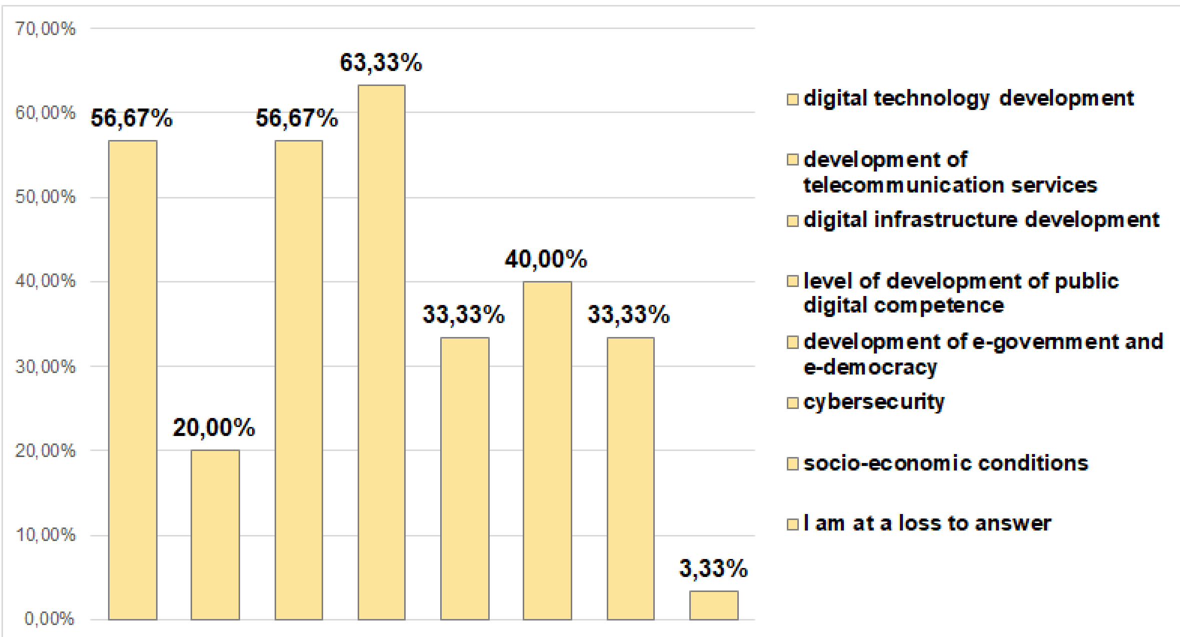

Figure 8. Survey responses on prerequisites for the digital transformation of society.

As we can see from figure 8, the most popular answers are ***"digital technology development"*** (57%), ***"digital infrastructure development"*** (57%) and ***"level of***

development of public digital competence" (63%). That means that respondents have defined of the main needs for digital transformation correctly. But citizens also should will know about other needs for digital transformation such as cybersecurity, telecommunication services and e-government and e-democracy development etc.

Q.: *What are the most important steps to carry out digital transformation?*

The most popular answers are ***"development of the digital transformation strategy"***, ***"ensuring cybersecurity"*** and ***"development of a new level of employees' thinking"***. Second in importance are the following issues: ***"digitalization of processes"***, ***"retraining and advanced training of employees"*** and ***"introduction of digital tools in the activities of a particular sector"***. That means that citizens have general idea about the steps of the digital transformation processes.

Q.: *Which of the following causes the digital transformation of education?*

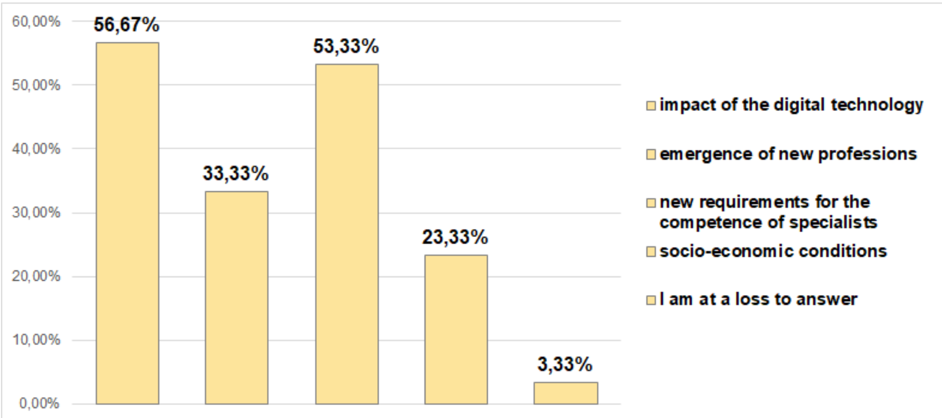

Figure 9. Survey responses on the causes the digital transformation of education.

As we can see from figure 9, the largest group of respondents defines of the digital technology impact (57%) and new requirements for the competence of specialists (53%) as the main causes the digital transformation of education. At the same time, about 33% of educators suggest that emergence of new professions also impact on the digital transformation of education.

According to the conducted research we can make conclusion about necessary to increase awareness level of the Ukrainian citizens about digital transformation processes in whole. One of the ways for solve this problem is to development digital transformation model and implementation it to companies, production, ecosystem, industry, education etc.

Now, the topical issue of numerous studies of researchers, economists, public and state specialists, etc. is developing of the digital transformation, through which it will be possible to determine the digital transformation strategies and ways to implement them. Such issues for the digital transformation of various areas are actively explored by the following researchers as J. Bumann [51], M.K. Peter [51] (general research), M.W. Wildan [52], A.I. Umri [52], H.U. Hashim [52], A.R.A. Dahlan [52] (economy, business), J.M. Pawlowski [28], A. Rof [53], A. Bikfalvi [53], P. Marqus [53], T. Muluk [54], T. Nanaeva [55], D. Nguyen [56] (education), I. Mergel [57], N. Edelmann [57], N. Haug [57] (public administration) and others.

Based on the analysis of the considered researches [28, 51–54, 56–58] the authors of this paper proposed a general model of digital transformation (figure 10).

The main components of this model are:

1. The reasons that lead to the need in digital transformation of the area/industry (the impact of digital technologies, new services, new requirements to life in a digital society, etc.).

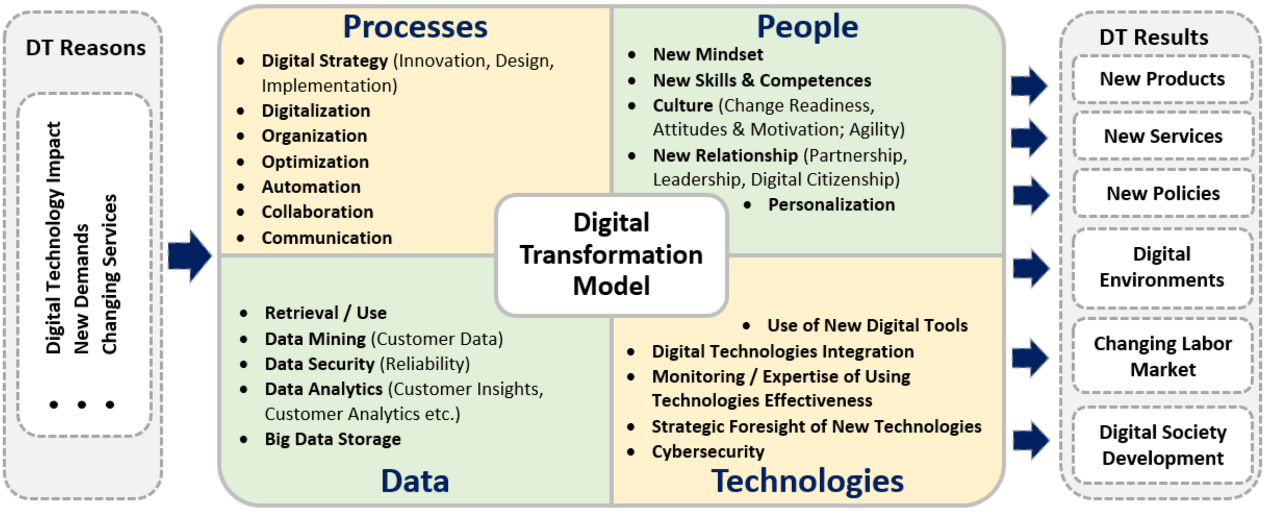

Figure 10. Digital transformation model.

2. The use of digital technologies to change business processes in the industry to increase its efficiency.
3. Preparation of workers, employers, the population as a whole for life in new socio-economic conditions (change of culture, way of thinking, abilities, skills, and mutual relations) and development of their digital competences.
4. Effective use of existing data, including the use of modern tools for their analysis with elements of Artificial Intelligence and Big Data.
5. The main results of digital transformation include new products, services, policies, markets, environment and development of the digital society as a whole.

The proposed model takes into account the goals, digital technologies impact, changing services and new demands. The brief description is below.

Block **“Processes”**:

- Digital Strategy (innovation, design, implementation).
- Digitalization.
- Organization.
- Optimization (paperless trend).
- Automation.
- Virtual collaboration and virtual communication.

Block **“People”**:

- New Mindset (computational thinking, design mindset, emotional intelligence, social intelligence).
- New Skills & Competences (digital skills & competences, soft skills, media literacy, transdisciplinary competences).
- Culture (innovation culture, change readiness, attitudes & motivation for education; lifelong learning, non-formal learning, informal learning; agility).
- New Relationship (partnership, leadership, Digital citizenship).
- Personalization.

Block **“Technologies”**:

- Use of New Digital Tools.
- Digital Technology Integration.
- Monitoring / Expertise of Using Technologies Effectiveness.
- Strategic Foresight of New Technology.
- Cybersecurity.

Block **“Data”**:

- Retrieval / Use.
- Data Mining (customer data).
- Data Security (reliability).
- Data Analytics (customer insight, customer analytics etc.)
- Big Data Storage.

5. Conclusions

Thus, the results of the digital transformation are new products, services, policies, markets, environment and development of the digital society as a whole. The process of the digital transformation is unavoidable of all spheres of human life. Firstly, for this, we should transform the education.

The main steps for the successful implementation of the digital transformation in education are following:

- creating a modern digital educational environment to provide equal access to quality educational services and resources anywhere, anytime and in order to improve the quality of education,
- digitalization of all components of the educational process,
- effective use of modern digital technologies and data through the development of digital skills and competencies of all education stakeholders,
- formation of new competencies of the educational process participants, i.e., competencies which are necessary for a successful life in the digital society,
- defining requirements for digital competencies of heads of educational institutions and educational policy makers,
- developing special innovative courses for heads of educational institutions, which provided them with an understanding of the concept of digital transformation of education and ways to ensure its,
- introduction of SELFIE in all educational institutions.

In the future, the authors will plan to design the recommendation for building of the digital transformation model of education.

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Journal of Physics: Conference Series

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Specific features of the use of augmented reality technologies in the process of the development of cognitive component of future professionals' mental capacity

To cite this article: V V Osadchyi *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012022

Specific features of the use of augmented reality technologies in the process of the development of cognitive component of future professionals' mental capacity

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Abstract. Ways of development and modernization of modern higher education are largely determined by the scientific and technological progress. The article is devoted to the current issue of the augmented reality technology use in professional education. The paper analyzes foreign and domestic experience of the use of augmented reality technologies as a means educational, research and project activities implementation. The author also describes the benefits of the augmented reality technologies use for the curricula design. Taking into account the reorganization of the educational process due to pandemic isolation, caused by COVID-19, the issue of the identification of AR technologies impact on the development of cognitive component of future specialists' mental capacity is becoming extremely relevant especially in the conditions of adaptive and blended learning. The paper, in a structured way, describes the experience of introducing the augmented reality elements in the process of developing cognitive component of future professionals' mental capacity. The ascertaining and formative stages of the empirical research were carried out during 2020 on the basis of Bogdan Khmelnytsky Melitopol State Pedagogical University. Relevant interdisciplinary research is a logical construct of cooperation between leading scientists of the Department of Psychology and the Department of Informatics and Cybernetics of Bogdan Khmelnytsky Melitopol State Pedagogical University. The structure of the study includes the main scientific developments in the context of the research work, performed at the expense of the General Fund of the state budget: "Adaptive system for individualization and personalization of professional training of future specialists in blended learning". Based on certain psychological and pedagogical determinants of the AR technologies use for the development of cognitive component of the future specialists' mental capacity, we have proposed the implementation of interactive technologies at three levels: competence-oriented, structural-cognitive, emotional-reflexive, on the example of doing the course "Introduction to Specialty (Psychology)" in the conditions of distance learning. According to the results of an interdisciplinary research, it was found out that students gained skills which are necessary for their adaptation to a new intellectual and educational environment. Due to positive qualitative and quantitative changes in the cognitive structure of personality there was an increase in the first-year students' mental capacity in its main components (the level of attention stability and selectivity, short-term memory span and analytical thinking, level of development of special qualities necessary for mental capacity, formation of mental capacity culture).

1. Introduction

The processes of socialization, education and professional activity in the conditions of society transformation are accompanied by an unprecedentedly rapidly changing information infrastructure in everyday and business life. The current phenomenon of modern society is a continuing formation of new knowledge and competencies. Human existence in various communicative areas requires permanent mastery of new ways of communication and interaction at all levels. Technological innovations affect almost all areas of human activity; they are especially important and relevant in the field of education. The Digital Agenda of Ukraine 2020 states: "Rapid and profound consequences of the transition to "digitalization" will be possible only when "digital" transformation becomes the basis of Ukrainian society, business and government institutions, when it becomes a commonplace and everyday phenomenon, becomes our DNA, our key agenda on the path to prosperity, will be the basis of Ukraine's well-being" [1]. Digital literacy (or digital competence [2–5]) is recognized by the EU as one of the key competences necessary for a full-quality life and human activity, so in the Law "On Higher Education" [6] it is stated that the formation of information and communication competence is a compulsory one.

Modern higher education, as an important part of the future professionals' resourceful personal and professional development, is focused on the formation of a specialist of a new format – capable of professional self-realization in the conditions of revolutionary digitalization and technological breakthrough. Higher education cannot exist without the introduction of new technological modifications. Among the most noticeable trends in modern learning technologies, augmented reality occupies a leading position. The use of modern technologies in the organization of educational activities and implementation of competency-based approach allow not only to study current computer technology, but also to organize the learning process in such a way that the study of innovative technologies is accompanied by their integration into personal information, communication and competence environment. Accordingly, the issue of integrated implementation of augmented reality technologies while using a competency student-centered approach is quite relevant [7–22]. Formation of cognitive component of mental capacity is a key element in the context of the development of future specialists' professionally important qualities and competencies.

The aim of the study is to analyze the features of the integrative use of augmented reality technologies in the development of the cognitive component of the mental performance of a future professional in the context of adaptive learning.

2. Literature review

Mixed reality technologies have become highly popular in higher education in recent years. Projects of modeling the elements of augmented reality are actively implemented in the educational process in foreign and domestic higher educational institutions. Analyzing the current study, done by C.-H. Chen, regarding the introduction of augmented reality technologies in the educational process in higher education we came to the conclusion that a teaching method, based on AR games through the integration of AR technology and digital games, is quite interesting and innovative one. It promotes students' learning and facilitates the research of metacognitive and motivational factors of multimedia learning. Based on the implemented approach, the author has designed a contextual mobile learning system with tips for the personality's cognitive structure development. The results of the research allow us to state that digital games play an important role in promoting affective and motivational states in multimedia learning and in the development of future professionals' cognitive abilities [23]. A multifactor study, done by R. Sitharan, N.T. Kian, N. Mai, H.T. Yeen-Ju, M. Syahmi Abd Aziz and K.S. Bin Dollmat demonstrates the possibilities of implementing a competency-based approach in line with the integration of different learning technologies, namely virtual reality, augmented reality and holograms. Using the process of MOOC development as a case study, the authors made an attempt to reveal some factors and barriers to creating a cohesive and holistic learning experience of using these technologies [24].

The presentation of ARETE (Interactive Educational System for Augmented Reality) allows us to have a new look at the technological progress in the development of interactive tools for the content of augmented reality (AR). The authors demonstrate modern capabilities of the ARETE system, which corresponds to human-oriented practices of interaction design and has considerable impact on the interactive, multi-user and multilingual technologies. In the research structure, researchers demonstrate positive impact of ARETE system implementation and the educational value of AR for mastering English language, developing STEM skills (science, technology, engineering and mathematics), which provides a positive behavior support in educational institutions (PBIS) [25].

Research works of the Ukrainian scientists demonstrate the priority of implementing augmented reality technologies in the design of project activities in higher education. It is considered to be a determinant of creative self-development, self-realization of project executors, as it develops cognitive activity and various future professionals' life competencies. Researchers emphasize that the augmented reality program for the implementation of educational projects helps to: enhance students' interest in educational material; develop new competencies; increase motivation for the autonomous educational and cognitive activity; intensify educational activities and mental capacity; form a positive motivation for personal and professional growth; create conditions for the development of future specialists' professionally important personal qualities [26].

Considering personality's cognitive structure and individual features of thinking processes as an important condition for constructive implementation of the concept of adaptive learning, the scientists in their empirical research works substantiate the prospects and priorities of using VR and AR technologies as a special information environment, which is used according to the identified dominating thinking type of students. The authors emphasize the prospects of using the proposed model in the educational process of educational institutions. They demonstrate the benefits of these technologies in terms of implementation and support of new teaching and learning strategies, as well as for the improvement of the future professionals' learning outcomes on the example of such courses as "Algorithms and Data Structures", "Computer Graphics and 3D Modeling", "Scheme of Engineering", "Computer Architecture" [27].

Modernization and digitalization of the higher education system in the context of pandemic limitations does not go beyond the attention of domestic researchers. Thus, mobile Internet devices (MID) – multimedia mobile devices that provide wireless access to information and communication Internet services for collection, organization, storage, processing, transmission, presentation of all types of messages and data become a part of the distance education optimization by means of the use of leading learning tools (on the example of Bachelors of Electromechanics). The authors describe the main possibilities of using MID in the sphere of education in order to ensure equal access to education, enhance personalized learning, provide instant feedback and evaluation of learning outcomes, stimulate mobile learning, productive use of time spent in the classrooms, promote a creation of mobile learning communities, support of localized learning, and continuing professional development. They restrict a gap between formal and non-formal learning, minimize disruption of education in conflict and disaster areas, help students with disabilities, improve the quality of communication and institution management, and maximize economic efficiency [28].

Taking into account a wide range of possibilities of augmented reality technologies use in the process of developing cognitive structure of personality, increasing cognitive motivation, researchers demonstrate the possibility of introducing elements of augmented reality into the structure of kinesthetic learning or "Learning by Doing". The researchers presented a study of this concept by demonstrating an initial prototype system, which was developed and implemented on the basis of adaptive learning methodology in the AR application, with the prospect of the future use of intelligent agents [29].

Thus, summarizing theoretical, methodological and empirical research done by leading experts in the field of design and implementation of augmented reality technologies in the educational space of higher educational establishments, we can say that the perspective research area is the integrative use of augmented reality technologies in the structure of competence-based, practice-oriented and adaptive concept of education reorganization [30]. At the same time, the identification of AR technologies impact on the personal construct and professionally important qualities of future specialists is relevant and poorly studied issue so far. Under the conditions of the adaptive and blended learning, the issue of AR technologies impact on the development of cognitive component of future specialists' mental capacity is a relevant research area.

3. Research background

The problem of increasing students' mental capacity in the conditions of blended learning, and identification of their cognitive structure specific features in solving intellectual problems in the process of training is extremely important. Working capacity, as a state of the system "man-machine", was analyzed in studies dealing with the rationing of optimal time parameters of students' activity, which can maintain a high productivity level in certain microperiods. To solve this problem, scientists used indicators of physical and mental health, preparedness, level of development of professionally important personal traits, conditions of activity. The level of the highest capacity (its optimal level) is determined by the following features: employment period reduction (transition from rest to a high level of capacity); the highest indicators of system functions (reaction rate, signal processing, etc.); the most economical bioenergy costs; long-term preservation of working capacity (increase of endurance); adequacy of body's reactions to external actions; the easiest adaptation, regulation of functions and automation of skills [31]. Changes in capacity can be caused by various factors: fatigue caused by prolonged work in the information space; emotional and physical state; external environmental conditions [32]. Along with this, the researchers pay more attention not only to the personal features but also to the emotions, impact of emotional stress on the assimilation of information. They are organically linked to thinking and, thinking, as a mental process, is a combination of intellectual and emotional activities. Analyzing theoretical achievements of scientists, based on the analysis and generalization of the scientific outcomes, we have identified 4 main criteria for mental capacity:

(i) development of cognitive processes (the level of students' cognitive processes functioning, ability to perceive and select information in accordance with the purpose of mental activity, ability to highlight main issues, analyze, compare, provide rational for their thoughts and actions, memorize necessary material),

(ii) emotional and motivational activity while performing intellectual actions (desire for knowledge, initiative in performing intellectual tasks while maintaining emotional stability, activity and productivity),

(iii) subjectivity, objectivity, regulation in the implementation of mental actions (person's ability to initiate, carry out mental activity independently and persistently, evaluate it independently and critically, and take responsibility for one's own actions),

(iv) intellectual activity effectiveness (completeness of mental actions, focus on the intellectual activity performance).

Based on all mentioned above, we can say that we view students' mental capacity as their integrative ability to perform purposeful intellectual activity, provided by the development of cognitive processes. Summarizing and systematizing the above mentioned scientific achievements, we have identified the specific features of the development of cognitive component of students' mental capacity (figure 1).

Psychological and pedagogical conditions of the use of augmented reality technologies in the process of development of cognitive component of future professionals' mental capacity

Optimization of students' mental capacity	**The use of augmented reality technologies in the educational process**
• culture of mental work; • rational organization of mental activity; • hierarchical entry into intellectual activity; • uniformity and rhythm in the performance of mental operations and exercises; • systematic and planned approach to the solution of intellectual problems; • conscious (honest) attitude to the intellectual activity.	• innovative and intellectual techniques of pedagogical activity; • novelty effect in the organization of students' thinking; • means of maintaining semantic connections while teaching complex logical schemes (use of algorithms, heuristics); • availability of teacher's requirements for students in the process of using innovative technologies.

Figure 1. Psychological and pedagogical determinants of AR technologies implementation in the process of teaching disciplines on the Moodle platform.

Taking into account the psychological and pedagogical conditions of AR technologies introduction in the educational process in higher educational establishments, in order to form a cognitive component of future professionals' mental capacity, we have analyzed the possibilities of implementing elements of AR technologies at three levels: competence-oriented, structural-cognitive, emotional-reflexive.

At the competence-oriented level, the experimental group students (n=30) were offered to search for an independent solution of problem-based tasks using AR technologies:

1. Design of a professional profile with the creation of a structural model of a modern psychologist. To fulfill this task, students were asked to use the following AR applications:
    - Pose Maker Pro - 3D art poser app – an application for creating characters, it is used as a guide for drawing physical image of people, for designing illustrations or framing individual visual objects.
    - D3D Sculptor - 3D modeling – a tool for creating digital sculptures and objects, it combines 3D modeling, texturing and drawing. D3D offers tools for creating a 3D model or other manipulation with a digital object as if it is made of real substance.

    With the help of appropriate applications, students were able to independently create an image of a modern psychologist, reflecting even the nonverbal behavioral components – posture, facial expressions, and gestures. Based on the created image, students described psychologist's personal, professionally important qualities in a particular field of psychology, analyzed the peculiarities and conditions of work, and demonstrated the algorithm for performing the assignment.
2. Construction of the design model of modern psychologist's office:

- Myty AR – an application which allows you to create a 3-D model, project or collage of any room, office, workspace.
- Floor plan – Home improvements in AR – Wodomo 3D – using this program students can see in augmented reality (AR) the result of virtual changes made to their workspace. Interaction with augmented reality begins with the creation of a 3D plan of the project model. The user sends a request to the application where the characteristic points are located, simply by pointing them at the camera screen. There is no need for the tape measure, the application automatically measures all dimensions, and reproduces the exact plan of the room project in 3D. Due to augmented reality, the user can gain an exciting experience of what the final product can be.
- Home AR Designer – an application for interior design in augmented reality. Convenient 3D models of furniture, space with the possibility of adjustment. By controlling high-quality 3D models, users themselves create their dream workspace in augmented reality. In the application there aren't any markers or objects floating in the air! Augmented reality from Project Tango is the absolute accuracy of surface recognition.

Using appropriate AR technologies, future psychologists have the opportunity not only to demonstrate creativity in designing their future workplace, but also with the help of 3D spacious structures they can visualize the relevant licensing standards for the establishment of modern psychological services.

3. Construction of personal and professional growth trajectory:
   - Remente: Self Help, Mental Health and Improvement – a universal application that acts as a life-coach, and allows you to plan, monitor and regulate personal plans, actions and emotional states. This application includes:
     (a) goal setting guidance to help students to achieve life and professional goals on the path to their self-improvement,
     (b) day planner, which contains a list of tasks for the day, as well as long-term goals and objectives for self-development and professional growth,
     (c) life assessment tool that provides an overview of life priorities for an active lifestyle development,
     (d) reflective journal, which explains what affects mood, motivation, emotions and well-being,
     (e) gallery of professionally designed goal plans that the students can use for their personal and professional growth. Personal growth and professional development can be achieved only by creating good life goals and positive intrinsic motivation.
   - Pockets Goal – an easy-to-use application that allows students to make a complete plan of achieving educational and professional goals through a well-thought-out task. In the application, students can create a new goal, set necessary deadline to achieve it, then a countdown system starts functioning and it clearly shows the time left for the plan implementation. In any vital life and professionally important categories, the users can safely set both short-term and long-term goals, and with the help of Pockets goal students can achieve the desired outcomes in the required time.

The use of appropriate mobile applications with AR component in the process of solving new intellectual tasks or project activities at different stages of learning the discipline "Introduction to Specialty (Psychology)" allows students to immerse themselves in a new information space that stimulates independence, creativity, readiness to solve non-standard practice-oriented tasks. All these applications are focused on the visualization process stimulation and immersion in the future professional activities.

At the structural-cognitive level, students were offered AR simulators, aimed at the cognitive processes activation, development of attention stability, analytical thinking and logic. They expand short-term memory span and increase endurance and mental capacity:

- CubeAR: 3D and AR Maze is a maze game with 3D and AR game modes with new interesting mechanics. The application has 10 different cubes, each of them has its own unique texture and the complexity of passing the maze. In the game you need to roll the ball on all sides, going from point A to point B. Each next level is more difficult than the previous one. It stimulates interest to pass the maze. CubeAR is an educational puzzle game; it develops logical thinking, memory, fine motor skills, stimulates the speed and stability of attention.
- AR Sandbox is a block-based augmented reality game. The application has all necessary tools to create everything that can be visualized or imagined. The user will be able to see their creations as if in the real world. This game stimulates the development of creativity, creative thinking, attention span and planning skills.
- NeuroNation is one of the best applications of the year according to the official version of the Google Play Store. The users can effectively improve brain functions through interactive research by the German research project NeuroNation. Appropriate interactive application promotes the development of memory, intelligence, and logical thinking, it increases concentration. The advantages of this application are: 27 interesting interactive activities and personalized courses; detailed report on personal and cognitive strengths and weaknesses; personalized interactive trainings based on the latest scientific discoveries; comparative analysis with a certain age group, normalization and interpretation of individual successes.

At the emotional-reflexive level, students were offered to perform tasks using interactive technologies for self-analysis, self-reflection and assessment of the current emotional state, levels of personal and professional development. The appropriate level provides an opportunity to summarize the impact of AR technologies on the development of cognitive component of future specialists' mental capacity:

- Reflectly is a personal journal and diary that works on the basis of artificial intelligence and allows you to cope with negative thoughts, analyze personal and professionally important events, and strengthen a positive attitude to activities and learning. It also helps to stabilize emotional states and mood and cope with destructive feelings. This application is based on the principles of positive psychology, self-actualization and cognitive behavioral therapy.

Comprehensive three-level implementation of interactive AR technologies in educational activities stimulates the development of positive motivation and cognitive activity, increases interest in learning and project-based tasks, promotes emotional satisfaction with visualization and created products on the way to professional self-realization, readiness to perform tasks in modern technological progress. The proposed model of AR technologies use in the process of future specialists' professional training promotes the development of mental capacity and endurance.

4. Experimental results of research

Taking into account the peculiarities of educational process reorganization, caused by the transition to distance learning in the conditions of pandemic isolation, the empirical study was conducted in two stages. The first ascertaining stage was carried out in the first half of 2020 – from March to May, 2020. The first-year students, who were studying distantly, but without the introduction of augmented reality technologies, participated in the ascertaining stage of the research. The second, formative stage, was implemented in the second half of 2020 – from October to December, 2020. As a part of the formative research, first-year students were offered to perform tasks of the same discipline, but with the introduction of augmented reality elements, in order to develop the cognitive structure of mental capacity of future professionals. According to the results of the ascertaining research of the cognitive component of mental capacity, the indicators of the development of students' cognitive processes have been identified. The obtained results are presented in table 1.

Table 1. Quantitative indicators (%) of levels of development of a cognitive component of the first-year students' mental capacity ($n = 58$).

Levels of cognitive processes development	Selectivity of attention	Stability of attention	Analytical thinking	Short-term memory span
High	29,47	9,12	17,90	11,93
Medium	43,85	52,63	61,05	69,12
Low	26,68	38,25	21,05	18,95

As we can see from table 1, taking into account the indicators of the level of attention selectivity, 43.85% of students demonstrated a medium level of the development of attention selectivity. It indicates their ability to select relevant information and ignore insignificant and incidental issues, to distinguish objects by essential and non-essential features. These students also demonstrated the ability for the partial generalization and schematization, and it somewhat reduces the level of their intellectual and cognitive activity. 29.47% of respondents are dominated by a high level of attention selectivity. They are able to distinguish objects by essential features, to generalize and schematize them, as well as to find some images in the background. These are those first-year students who completed the task quite well and demonstrated sufficient indicators to perform intellectual activities which require the use of this feature of attention.

But there were also students who showed a low level of attention selectivity (26.68%). They are not always able to choose necessary items from the proposed material, they distinguish items only by the insignificant features, and therefore they have some problems performing intellectual tasks. This result may be related to a state of strong emotional experience, external obstacles that lead to the disappointment of a respondent.

After processing the data of "Dot Cancellation Test (Bourdon Test)" technique we obtained results on the level of development of the first-year students' attention stability. The majority of students (52.63%) demonstrated a medium level of the attention stability. These students are able to focus their attention on a particular subject, without being distracted and becoming less focused. But this situation takes place only in the case the students are motivated enough and if the features of these subjects are attractive for students and stimulate their curiosity. Personal activity is also important. This allows us to state that according to this indicator they have a sufficient potential to successfully master the high quality knowledge and productivity.

According to the results of the corresponding method, it was found that 38.25% of first-year students demonstrated a low level of attention stability. They tend to be distracted by other bright objects; they can change their purposeful activity and experience certain problems when performing long, monotonous and complex mental activity.

In the process of diagnosis it was found that 9.12% of respondents are characterized by a high level of attention stability. It indicates their ability to maintain a high degree of concentration of attention for a long period of time. These students are aware of the importance and significance of mental tasks even working in the unfavorable conditions. It is the main prerequisite for the intellectual productivity and mental activity of students.

The research results, obtained by "Research of analytical thinking" technique, successfully demonstrate that the majority of first-year students (61.05%) are diagnosed a medium or satisfactory level of analytical thinking. This indicates that they are able to make logical conclusions in case of attractiveness and significance of intellectual activity, which allows them to successfully carry out various activities, including mental ones.

According to the results of quantitative analysis of empirical data, it is established that 21.05% of respondents demonstrated a high level of this indicator, which is manifested in the effective solution of mental problems based on logical conclusions. They also have an ability to plan their activities, find specific solutions to problems, they have a desire to search. While solving mental tasks these first-year students are able to split information into separate components, carry out a comprehensive analysis of both of these components and initial information, select several options for their solution, carry out an analysis and objective evaluation of each option. They solve complex problems more efficiently and faster than others, make logical conclusions even in the absence of information, and view the problem from different perspectives, so they are able to find the best solution.

Unfortunately, in the course of research low results on the specified characteristic of thinking have been also revealed. In particular, 16.14% of the respondents showed a low and 1.76% – a very low level of analytical thinking. They experience significant difficulties in drawing logical conclusions while solving intellectual problems, they are unable to theorize, find causal relationships between phenomena, they don't have skills to make reliable assumptions about the most likely scenarios, to effectively restore necessary information by logical reasoning, which affects the process of mental activity and its effectiveness.

"Research of short-term memory span" technique was aimed at the identification of students' short-term memory span. It showed the following results (table 1). The majority of first-year students (69.12%) demonstrated a medium level of short-term memory span, showing the ability to memorize and reproduce only relevant, interesting, necessary information and expressive features of some subjects. Therefore, taking into account that modern educational process is associated with a large mental load, they have some potential opportunities for successful mental activity. 11.93% of respondents have a high level of this type of memory. They are able to memorize a large amount of intellectual information, quickly retain and reproduce it, which ensures high productivity of mental activity. Despite this, 18.95% of students showed low results on this indicator. Respondents experience difficulties perceiving information, memorizing and reproducing the material, they are motivated to memorize only a small amount of information, and need systematic memory training.

Assessing the effectiveness of creating psychological and pedagogical conditions for developing mental capacity, based on the integrated implementation of AR technologies in the educational process, it should be noted that we have noticed some positive changes after the research work has been conducted (table 2).

Thus, table 2 demonstrates the outcomes of the research work, and it shows a positive dynamics of changes in the conditions associated with the effectiveness of the learning distantly and implementation of AR technologies (experimental group students mention that with the use of interactive technologies their classes have become more informative and meaningful, they have changed their perception of a teacher and the requirements). In particular, students emphasize that they have become more conscious of their intellectual activity (due to the motivation for learning), they acquired skills of rational organization and planning of their mental activity, and most importantly – mastered basic techniques and methods which help them perceive, process and internalize learning material.

The organization of appropriate research work, based on the above mentioned changes

Table 2. Psychological and pedagogical conditions of the development of mental capacity of first-year students of experimental ($n = 30$) and control ($n = 28$) groups as a result of the introduction of AR technologies in the educational process.

No	A list of conditions	Assessment in Experimental group (before)	Assessment in Experimental group (after)	Assessment in Control group (before)	Assessment in Control group (after)
1	The novelty effect in the organization of students' thinking	3	4.5	3	3
	Means of maintaining semantic connections when teaching complex logical schemes	4	4	4	3.5
	Innovative-intellectual pedagogical activity	4	4	4	4
	Availability of teachers' requirements	3	4	3	3.5
	Friendly and highly intelligent relations between students and teachers	4.5	4.5	4	4
	General atmosphere in the university	5	5	5	5
2	Culture of intellectual activity	2	4	2	2.5
	Hierarchical entry into intellectual activity	4.5	4.5	4.5	4.5
	Uniformity and rhythm in the performance of mental operations and activities	4	4	4	4
	Systematic and planned approach to solving intellectual problems	3.5	4	3	3
	Rational organization of mental activity	3.5	4	3.5	3.5
	Conscious attitude to intellectual activity	3	4	3	3.5

in psychological and pedagogical conditions, had a positive impact on the indicators of all components of experimental group students' mental capacity. In particular, we identified significant changes in the indicators of stability and selectivity of attention. According to the results of the experimental work, there was an increase by 20.01% and 23.34% in the number of the experimental group students with a high level of stability and selectivity of attention (from 13.33% to 33.34%, and from 26.66% to 50.00%) and with a medium level (from 53.33% to 60.00% and from 40.00% to 43.33%) respectively. There is a decrease by 26.68% (from 33.34% to 6.66% in both cases) in the number of students with a low level of these indicators. Students developed the ability to identify certain objects, summarize and schematize them. They demonstrated the ability to find definite images in the background, gained skills that allow them to successfully master knowledge in the university, perform intellectual tasks and productively organize their mental activity. Thanks to research work conducted, students became more able to maintain a high intensity of attention for a long period of time, to realize the importance and significance of mental tasks, even in unfavorable conditions, which is the main prerequisite for intellectual productivity, learning and mental activity of students. Instead, changes in these indicators in the control group are less significant and noticeable.

Implemented components of AR technologies have contributed to the development of students' short-term memory span. In particular, the number of experimental group students with a high level of short-term memory increased significantly (by 23.34%) (from 13.33% to 36.67%) and the percentage of first-year students with a low level of short-term memory decreased (by 13.34%) (3.33% instead of 16.67%). So, the implemented measures allowed students to perceive and reproduce the material more easily, they became more able to memorize a large number of elements, without using the techniques of semantic organization of the material, which provides prompt retention and conversion of data to long-term memory and high level of productivity of mental activity. Consequently, students have gained more opportunities to carry out a successful learning process. The results of the control group on this indicator have insignificant dynamics.

The implemented measures contributed to the development of students' analytical thinking. In the experimental group there is a positive dynamics of change, which is manifested in an increase (by 20.00%) in the percentage of students (from 16.67% to 36.67%) who have high levels of development of the specified parameter, a number of those, having a medium level, has increased by 3.33% (from 50.00% to 53.33%).

In addition, due to the change of approach to solving practice-oriented and project tasks, we identified students with a very high (3.33%) level of analytical thinking. The percentage of respondents with a low level of this parameter is only 6.67% (instead of 30, 00%). Thus, first-year students acquired skills that contributed to the development of analytical thinking, their ability to operate with data, theorize, and find cause-and-effect relationships between phenomena. While performing their mental activity, they began to use different methods of splitting the information into separate components, comprehensively analyzing them, identifying several options for the best solution, analyzing and objectively evaluating each separate option. They began to solve complex problems more effectively, learned to draw logical conclusions even feeling a lack of information. It allows students to successfully master various activities, including learning ones. Instead, in the control group, the results remained almost unchanged.

As it can be seen from table 3, students of the experimental group demonstrated a significant increase of the quantitative indicator of a high level of cognitive component of mental capacity. This indicates the mobilization of students' mental processes, formation of skills necessary for the successful performance of intellectual tasks. These students also showed an increase in the development of critical thinking, perseverance and independence in assessing their capabilities in the process of mental activity fulfillment. They showed productive performance of intellectual tasks, they are fluent in the amount of educational material, capable of generalizing and systematizing it, and it allows them to successfully study in a higher educational establishment. In order to identify the correlations between the levels of development of cognitive component of future professionals' mental capacity we used Spearman's rank correlation coefficient, which was calculated by the formula:

Table 3. Quantitative indicators (%) of the levels of development of mental capacity of experimental group students ($n = 30$) and control group students ($n = 28$) before and after the formative experiment.

Level of mental capacity	Cognitive component in Experimental group (before)	Cognitive component in Experimental group (after)	Cognitive component in Control group (before)	Cognitive component in Control group (after)
High	16.67 (5)	36.67 (11)	14.29 (4)	17.86 (5)
Medium	50.00 (15)	56.67 (17)	53.57 (15)	57.14 (16)
Low	33.33 (10)	6.66 (2)	32.14 (9)	25.00 (7)

$$r_s = 1 - \frac{6 \cdot \sum(d^2)}{N \cdot (N^2 - 1)}$$

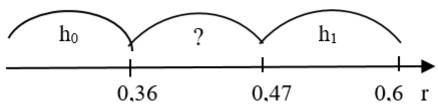
where d – difference between the ranks of two variables for each respondent; N – a number of respondents. So, let's calculate the empirical value r_s:

$$r_s = 1 - \frac{6 \cdot 1760}{30 \cdot (30^2 - 1)} = 1 - \frac{10560}{26970} = 0.6$$

We determine the critical values of the coefficient rank correlation coefficient for the number of subjects $n = 30$.

$$\begin{cases} r_{cr} = 0.36 & \alpha \leq 0.05 \\ r_{cr} = 0.47 & \alpha \leq 0.01 \end{cases} \quad (1)$$

$$r_s > r_{cr}\alpha \leq 0.01$$



Thus, hypothesis H_0 is rejected, hypothesis H_1 is accepted. In other words, it can be argued that the indicators of the cognitive structure and the levels of mental performance are positively related to each other – the higher the level of development of the cognitive component, the higher the indicators of the general coefficient of mental performance. According to the mathematical calculations, the reliability of the obtained empirical data and conclusions is established, and it is determined that the corresponding quantitative and qualitative changes presented by the results of the formative research are not accidental.

5. Conclusions and prospects for further research

Our research allows us to emphasize a high degree of relevance and demand for the use of new technologies in the field of higher education, as well as to state that AR technologies are being actively implemented in the educational component of higher educational institutions. Due to the unprecedented speed of development and implementation of information and communication technologies in all spheres of human activity, domestic universities are actively using the latest learning formats. It doesn't only improve the quality of education but also increases future professionals' competitiveness in the global labor market. The process of introducing new learning formats is not only in demand but also interdependent. On the one hand, students are interested in any technological innovations in education, and in the framework of scientific work, educational and project activities they actively use various applications with AR technologies. On the other hand, teachers are well aware of the latest developments in AR technologies, use online systems in their work and are ready for further implementation of relevant information and communication technologies in the educational process of higher educational establishments. According to the results of an interdisciplinary study on the use of augmented reality elements in the process of organizing learning activities on the distance learning platform Moodle, it was found out that students gained skills necessary for their adaptation to a new intellectual and educational environment, they became more optimistic, using basic adaptive mechanisms. Due to these changes there was an increase in the level of development of main components of first-year students' mental capacity (the level of stability and selectivity of attention, short-term memory span, development of analytical thinking, level of development of special qualities required for mental activity, formation of students' mental work culture and skills of their mental activity organization), which allows them to successfully carry out intellectual activities in higher educational establishments. Thus, the obtained data make it possible to state the feasibility and high efficiency of the introduction of AR technologies in the process of developing future professionals' mental capacity. It can be stated that AR technologies, being actively modernized day by day, have a huge potential for the future prospects of higher professional education.

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Journal of Physics: Conference Series

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Using interactive semantic networks as an augmented reality element in autonomous learning

To cite this article: R O Tarasenko *et al* 2021 *J. Phys.: Conf. Ser.* **1946** 012023

Using interactive semantic networks as an augmented reality element in autonomous learning

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Abstract. This paper focuses on the using augmented reality elements in the educational process, in particular in autonomous learning. The possibility of using interactive semantic networks in learning foreign languages is considered. The technology of selection and structuring of specialised terminology on the basis of interactive semantic networks for their further use in the study of foreign languages and mastering automated translation systems has been developed and proposed. The criteria for creating and supplementing terminological databases with appropriate structuring of the domain terminology selected on the basis of interactive semantic networks have been defined, namely universality, structurability, convertibility, extensibility. The possibility of further use of terminology bases for foreign language learning using mobile applications, mastering Computer Aided Translation (CAT) systems, mastering Computer Aided Interpretation (CAI) are outlined. Based on the practical use of the developed technology in the process of autonomous training of translators, positive results have been concretised and areas for further activities in their technological training have been identified.

1. Introduction

In a changing world at the beginning of the 21st century, education is also changing rapidly. Learning is now seen as a lifelong process that is essential for adapting to new environments, and therefore for ensuring personal economic and social success. Such learning implies that people have to ‘learn to learn’. Consequently, providing students with the knowledge and skills to enable them to manage their own educational process effectively becomes one of the aims of higher education. During the evolution of the education system, the issue of autonomy has become one of the main themes of language education research, and in the context of recent global developments (the coronavirus pandemic, COVID-19, restrictive quarantine measures and lockdowns, the transition to distance learning [1–9]) it has become particularly relevant.

At the same time, the new format of the educational process puts forward new requirements regarding the ways of realising learning objectives, methods of learning communication and teacher-student interaction, means of ensuring the effectiveness of learning subjects and achieving the programme learning outcomes envisaged in the standards and curricula for training specialists, including translators. Both in terms of learning activities and in terms of the future work of translators, technological training is becoming increasingly important. The present is forcing, on the one hand, a strengthening of the technological aspects of university translator training and, on the other hand, a rethinking of the organisational forms of training, the search for appropriate means, the combination of students' independent mastering of individual study materials with the technologicalization of the educational process. Using elements of augmented and virtual reality can meet such complex objective requirements of the current situation.

2. Theoretical background

An analysis of the psycho-pedagogical literature has shown that there has recently been increased interest in certain aspects of autonomous learning by researchers in different fields of science. Philip Benson, noting the recent increased attention to learning autonomy and self-organised learning, including in foreign language learning, emphasised the importance of different levels of student autonomy in distance learning [10]. Sara Cotterall identified five principles on which a stand-alone language course should be based and attributed them to learners' goals; language learning process; theory – task, design; learners' strategies; reflection on learning [11]. Stella Hurd, Tita Beaven and Ane Ortega emphasise one of the main problems of autonomy in distance learning, which in their view is the difficulty of selecting learning material for students to learn independently. This decision is complicated by two factors. On the one hand, in order to be successful in the programme, students must develop a number of strategies and skills that will allow them to work individually. At the same time, the syllabus of an academic course has a definite structure in which the scope, pace and content of the syllabus are determined by the teacher. Exploring the notion of autonomy in distance language learning, scholars have identified some of the skills that distance learners need to achieve successful outcomes [12]. Similar views are held by Linda Murphy, who emphasizes that the success of autonomy in distance learning depends largely on the teaching materials, and demonstrates the role of the teacher in the process of autonomy in the language distance-learning programme of The Open University in the UK [13].

While considering the organisation of autonomous language learning, scholars have also explored the possibilities of using information technologies in this process. In highlighting the changes in educational philosophy reflected in the theory of language learning, Richard Pemberton, Edward S.L. Li, Winnie W.F. Or and Herbert D. Pierson noted the need to adapt to the rapid changes in the areas of technology, communications, and the labour market and to realise that the ability to learn is now more important than knowledge. In his view, it is advisable to take full advantage of the opportunities for expanding educational services that come with the development of technologies [14]. In this context, it should be noted that foreign scholars and practitioners are increasingly hoping for the integration of augmented reality elements into the training of university programmes in philology and translation. Indiana University, in particular, has initiated one such project, which involves the multidimensional deployment of elements of AR technology that can meet precisely the specific needs of these programmes in the form of individual modules: "We plan on compiling the following learning modules 1) listening comprehension; 2) pronunciation practice; 3) animated 2D and 3D vocabulary introduction; 4) vocabulary quizzes; 5) roleplay dialogues where students interact with an avatar and 6) videos with cultural content, geography, and history. In contrast to other digital technologies available at IU, such as embedded videos in Canvas, we will be able to bring real objects into language classrooms, such as cultural artifacts, culinary samples, maps and other objects, and connect them virtually to an augmented world" [13, 15].

According to Terry Lamb and Hayo Reinders, in order to provide students with easy access to learning materials during offline foreign language learning, it is advisable to create an appropriate e-learning environment. The main aim is to support students in their self-directed learning by structuring self-study by providing a recommended sequence of steps, providing students with information on learning strategies and conducting electronic monitoring of student work, with advice if necessary [16, 17].

Researchers whose academic work is related to foreign language teaching point out that special attention should be paid to the development of students' responsibility; otherwise, the learning process will not be successful [17]. Ivan Moore even points out that student autonomy begins with students taking responsibility for both the process and the results of their learning: "In doing this: They can identify their learning goals (what they need to learn), their learning processes (how they will learn it), how they will evaluate and use their learning; they have well-founded conceptions of learning, they have a range of learning approaches and skills, they can organize their learning, they have good information processing skills, they are well motivated to learn" [18].

David Little considers it likely that in the next few years much of the research on student autonomy will focus on the impact of autonomous learning, particularly when learning a foreign language, on everyone involved – students, teachers and educational systems in general. According to the researcher, the role of the teacher is to create and support a learning environment in which students can be autonomous. The development of their learning skills cannot be completely separated from the learning content, since learning how to learn a foreign language differs from learning other courses in some important respects [19].

At the same time, as the above list of issues examined by scholars from various countries shows, autonomous learning, in particular the learning of foreign languages, is associated by many with the using information technologies and the search for new approaches, not the least of which are nowadays augmented, virtual and mixed reality [20, 21]. Ozlem Yagcioglu, focusing his research on new approaches to student autonomy in language learning [22], relies on UNESCO's declared role of information and communication technologies in learning: "Information and communication technology (ICT) can complement, enrich and transform education for the better" [23]. Some academics, while extremely appreciative of the potential of augmented and virtual reality in learning, have expressed concerns about whether the education system is ready for the fundamental changes in the educational process that arise from these technologies, or even their elements. Carlos J. Ochoa Fernandez sees augmented and virtual reality as a new challenge for education [24].

Given the importance of the factors for organising offline foreign language learning identified in the reviewed studies (students' motivation, choice and access to learning material, skills and strategies for offline learning, use of information technology, AR-technology), we consider it advisable to introduce the use of augmented reality elements in this process, which can provide the above aspects. In previous studies to determine the possibilities of using AR technology in the process of learning a foreign language, a number of advantages of using elements of this technology have been identified: the involvement of different channels of information perception, the integrity of the representation of the studied object, faster and better memorization of new vocabulary, etc. [25]. The study of a certain section of a foreign language's vocabulary – domain-specific terminology – is relevant both for specialists studying a foreign language and for translators who plan to translate the field. Therefore, continuing our research, we will focus on autonomous learning activities using AR technology in terminology work, which is the initial phase for several possible directions of further development of the educational process – language learning, scientific and technical translation, mastering automated translation systems [26].

The purpose of this paper is to consider the possibility of using interactive semantic networks as elements of augmented reality in the process of autonomous learning to improve the technological training of translators in the aspect of creating domain-specific terminology bases for their further use in foreign language learning and mastering automated translation systems.

3. Result and discussion

Translation education at the current stage necessarily involves technological training of translators, which aims to develop competencies in the use of modern tools and techniques of translation, based on the use of information technologies. An important part of this training is for translators to acquire skills in working with electronic terminology resources, such as searching, structuring, storing, using terminology in computer-assisted translation (CAT) systems, computer-assisted interpreting (CAI) systems, interactive foreign language learning systems and the like. The search for effective technological training for translators is becoming increasingly urgent, but is complicated by the emergence of new tools and the rapid growth of their number. At the same time, there is a trend towards the increasing use of cloud services and online resources. All this makes it necessary to constantly update the content of the educational programme components. One of the ways of solving this problem could be the implementation of augmented reality elements into the educational process [27–29]. The application of augmented reality (AR) technology will allow students to find and obtain the necessary information more quickly, which can be presented in symbolic, audio, graphic or animated form [30, 31]. The use of such technology will be particularly effective in off-line learning, as its peculiarity is the absence of constant direct contact with the teacher and, consequently, the possible complications of acquiring certain knowledge [32–37]. This necessitates a search for augmented reality technologies that were primarily aimed at building professional skills [38–41], particularly in the case of autonomous learning for translators in their technological training.

3.1. Technology for selecting and structuring domain-specific terminology based on interactive semantic networks

One of the options for using augmented reality elements in the technological training of translators can be developed by us the technology of selecting and structuring domain-specific terminology based on interactive semantic networks for their further use in the study of foreign languages and mastering automated translation systems. A schema of this technology based on interactive semantic networks is shown in figure 1. This technology is designed to be used in the learning process by undergraduate students who have already acquired the skills of working with CAT and CAI [42]. In developing it, we used existing interactive semantic networks, which are new online services and have only become available for use in the last few years. In particular, one such service has been developed in the framework of the EU Terminology as a Service (TaaS) project. The goal of the TaaS project was to provide operational access to up-to-date terms based on the exchange of multilingual terminology data and to create effective mechanisms for the reuse of terminology resources.

According to the developed technology (figure 1), the initial step is to use interactive semantic networks for the selection and structuring of domain terminology, which consists in the possibility of defining a semantic field within a certain domain to identify terminological entities for integration in the terminological database of the respective domain. In this case, to initialise the algorithm for the student's construction of his/her individual semantic network, he/she only needs to decide on any source term that relates to the domain with which he/she plans to work on the basis of the created terminological base. This term is entered into the relevant elements of the interface and a hierarchical structure of the semantic field with multi-level relationships between its elements is formed around it by means of the search engine of the interactive semantic network. In this way, the student is at the outset provided with a defined set of directions, each of which opens up a separate terminology pathway. At the same time, the system provides easy and clear visual identification of the elements in their hierarchical order and the different types of links between them. Figure 2 shows the initial phase of building a personalised interactive semantic network based on the original term 'vegetable growing'.

Further action should be taken by the student to develop the semantic network in one or

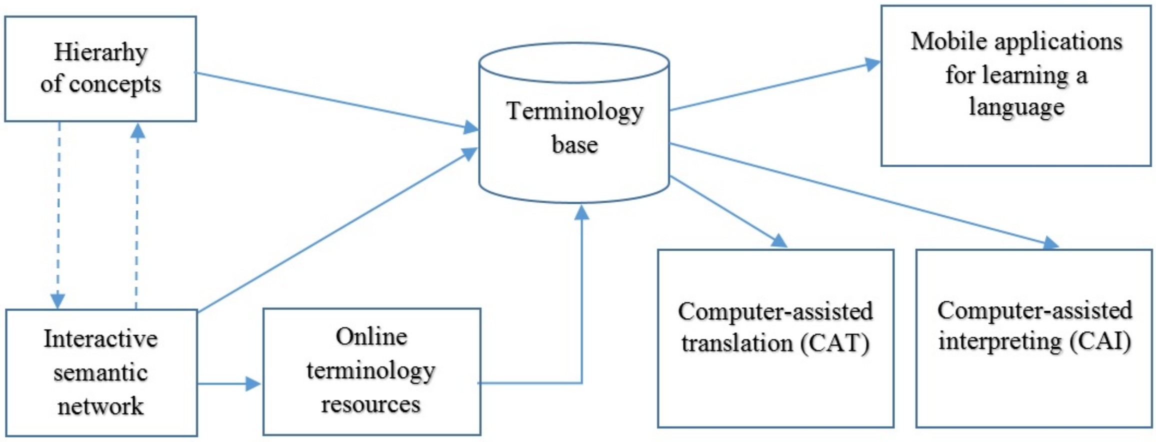

Figure 1. The scheme of technology for selecting and structuring domain-specific terminology based on interactive semantic networks for further use in foreign language learning and mastering computer assisted translation systems.

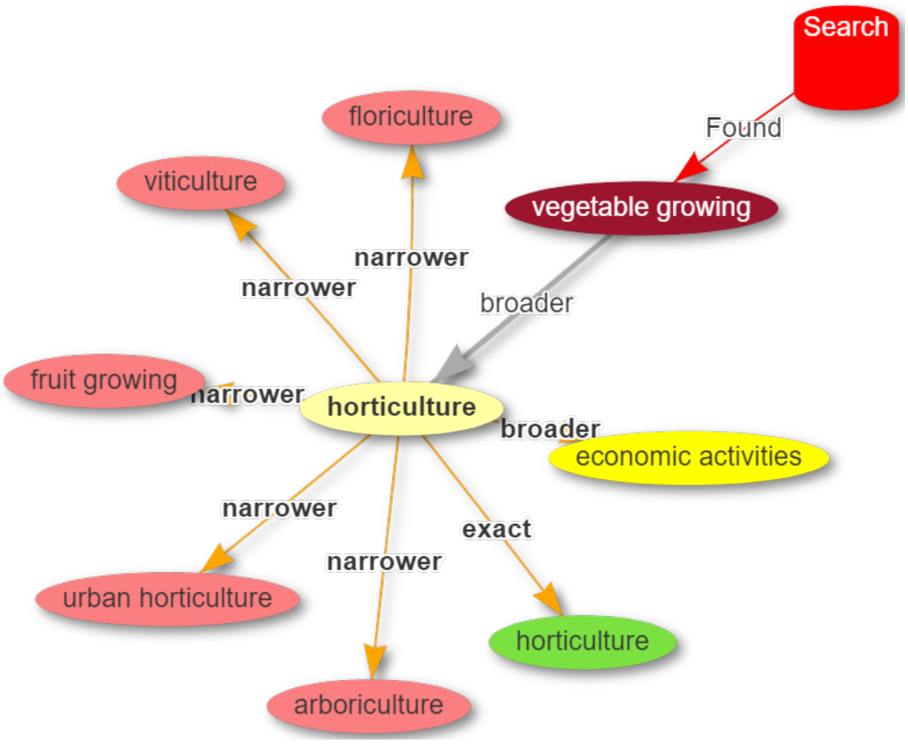

Figure 2. Initial phase of creating a personalised interactive semantic network based on the source term "vegetable growing".

more directions that are appropriate for his or her individual task. The types of links between the elements of the network, which indicate the hierarchical relationship between them, can help the student to decide on the appropriate direction. In particular, the system can automatically establish four types of such links: exact, broader, narrower, related. The exact type of link means that it is an exact match or synonymy. In terms of moving along the development of a network with such a link, the system can provide additional opportunities to obtain search results in the form of related terms. Using the network development direction of the broader link, the student will be able to further search for terms at a higher hierarchical level of concepts and move to related domains, which will contribute to his/her understanding of the integrity of a particular domain. A 'narrower' link will allow the student to build a network in the narrower direction of the field and access a list of terms that under other circumstances he/she might have obtained after a lengthy search in the relevant reference books. This is an important aspect of using such online networks, given that the translator is usually not an expert in a particular domain and therefore cannot have a detailed understanding of the terminological vocabulary of that domain. Given the development of the network to cover a wider terminological spectrum, it is advisable to move along the related type links. The results of the development of the individual interactive semantic network in different directions depending on the type of linkage are shown in figure 3.

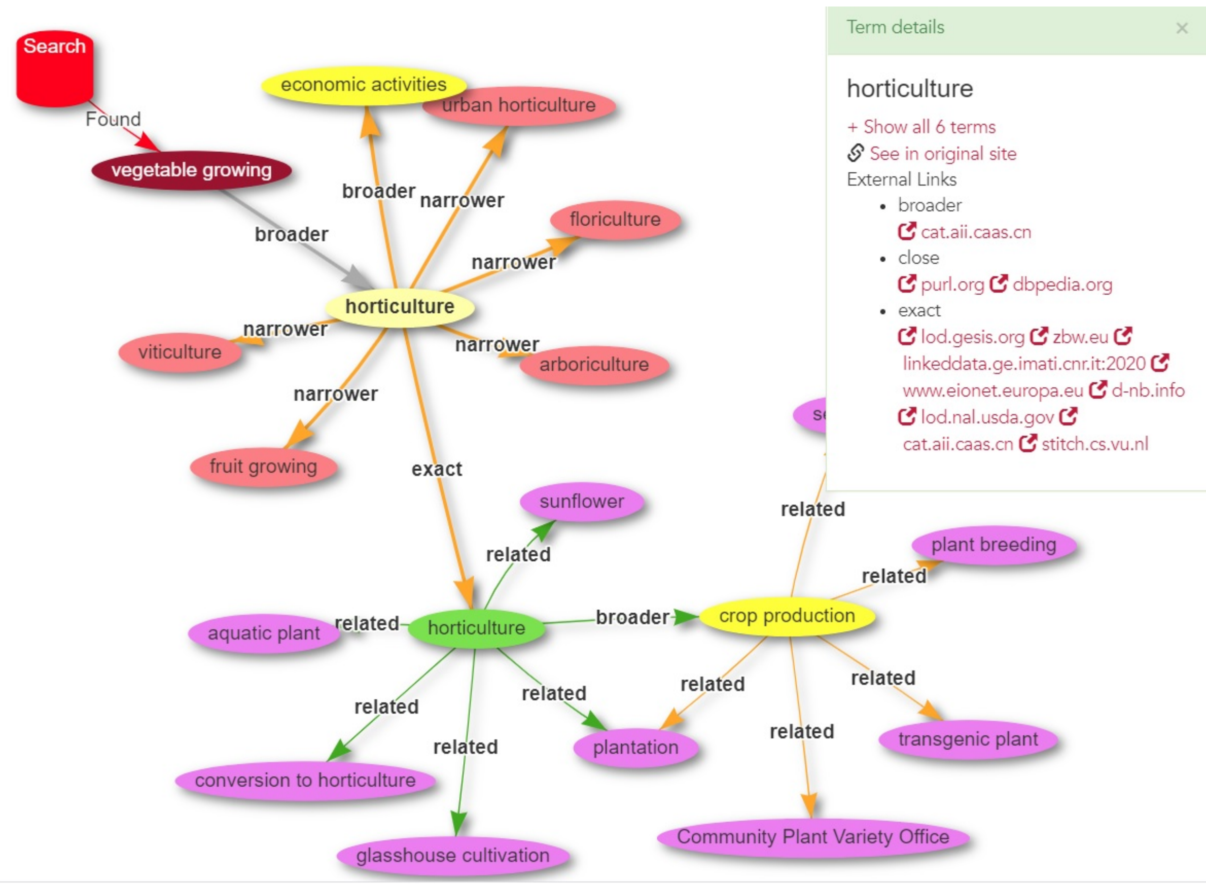

Figure 3. A individual interactive semantic network, developed along different lines depending on the type of relationship.

At this stage in the implementation of the technology for selecting and structuring sector-specific terminology based on interactive semantic networks, students can already begin to extract selected terms from the constructed network and place them into the terminology database. In doing so, the students must be made familiar with the criteria we have defined for creating and completing terminology bases in which it is appropriate to structure domain-specific terminology derived from interactive semantic networks. In defining the criteria, we were guided primarily by the possibility of further use of terminology bases for such purposes as: learning foreign languages using mobile applications, mastering Computer Aided Translation (CAT) systems, mastering Computer Aided Interpretation (CAI) systems, which corresponds to the logic of the developed technology. To such criteria, we have classified:

- universality (ability to meet the need for terminological support for different processes directly or with minimal modification),
- structurability (possibility of placing terms), synonyms, matches and other additional information to the term in compliance with generally accepted principles,
- convertibility (the ability to convert to other formats for the needs of other systems without changing the structure and content),
- extensibility (the possibility of changing the structure of the database to accommodate additional information in the entry at any stage of its completion, without loss of data).

After being introduced to these criteria, the students had to decide on their own about the software to create the terminology database, the format of the database and its initial structure. The autonomy given to the students to make such decisions was due to their experience with CAT and CAI and therefore with the terminology bases used in such systems.

However, using the specialised functions of the interactive semantic networks, the students were able to obtain extended information about the terms defined for entry into the terminology base, if necessary. This toolkit is based on the interactive use of online resources that can be accessed via external links and which concentrate a considerable amount of terminology indicating its affiliation to a domain, its interpretation, definitions of terms, their matching, etc. (see figure 3). The online resources used include powerful bases such as: Interactive Terminology for Europe (IATE), General Multilingual Environmental Thesaurus (GEMET), National Agricultural Library's Agricultural Thesaurus and Glossary, LusTRE (multilingual Thesaurus Framework), TAUS (The language data Network) etc.

Using the resources of such databases makes it possible to extend the content of terminology bases beyond the simple structure, containing only terms and their matches, to the use of extended information. In particular, the extension of each terminology entry with additional information such as domain, definition, synonyms, etc. (figure 4) contribute to increasing their informative value. They can be useful when such databases are used with automated translation systems. In this case, the terminology databases should be structured with appropriate fields for structuring such information.

In the list of links to external online resources generated by the interactive semantic network, there can also be resources containing additional information in the form of multimedia documents, electronic documents, videos, books, images (figure 5). The value of such resources in autonomous learning lies not only in the selection of terminology for terminology bases, but more in the opportunity to understand in detail the nature of the term, the context of its use, and to form an idea of defining the object. With this technology of using semantic networks, students are able to learn more about the objects of a particular domain through a terminological apparatus without being overloaded with redundant information.

It is important to note that a developed interactive semantic network can be automatically converted into another format for displaying its elements, namely by hierarchical structure (figure 6). This format of presenting the network allows students to enhance their ability to explore the constructed network in terms of the interrelationship of its elements, in particular in the aspect of distinguishing more general concepts from highly specialised vocabulary.

According to the scheme of technology for selecting and structuring sector-specific terminology (figure 1), working in the Hierarchy of concepts representation of the interactive semantic network, students can also extract terms from it and add them to the terminology base, but without the possibility of obtaining additional information from the online resources.

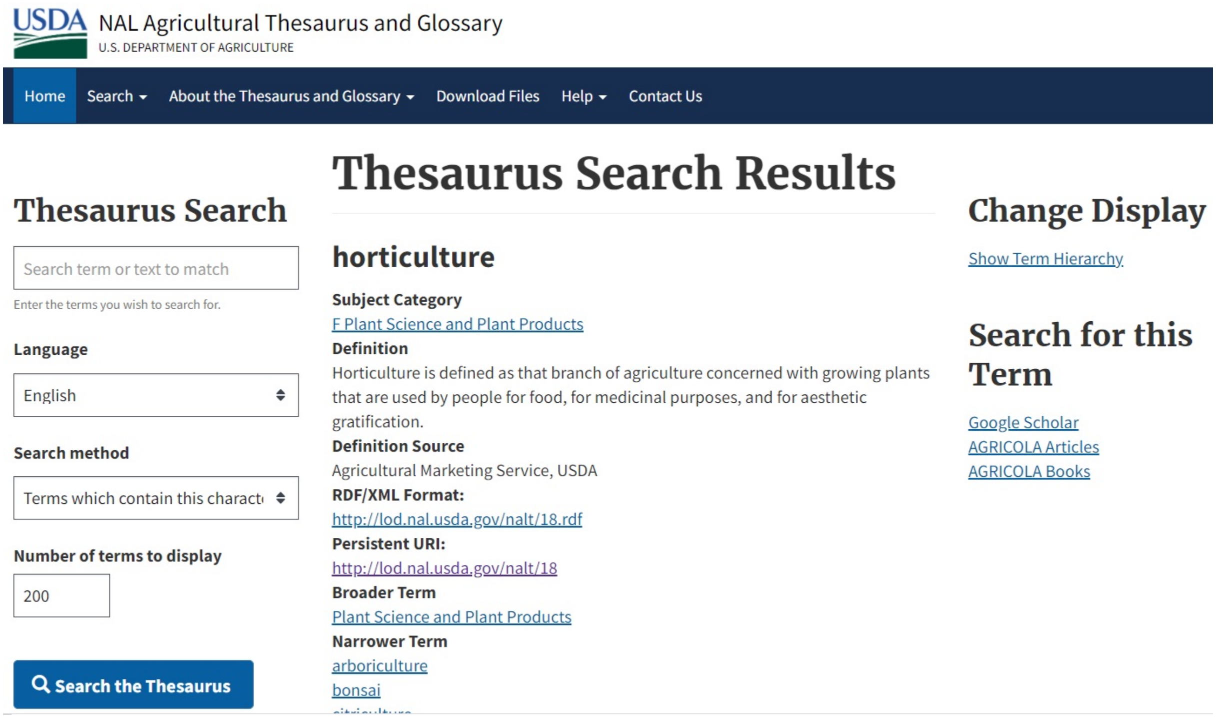

Figure 4. Structure of the presenting additional information on the term “horticulture” in the online resource “National Agricultural Library’s Agricultural Thesaurus and Glossary”.

3.2. Experimental testing of the use of interactive semantic networks in translator training
In order to identify the possibilities and ways of using interactive semantic networks in the process of technological training of translators, we conducted a survey of students who were asked to experience them while they were in distance learning, which created a situation of autonomous learning. 38 students took part in this type of experiential learning, learning how to create terminology bases with a view to their future use in foreign language learning using mobile applications and mastering the use of computer-assisted translation systems. The questionnaire used for the survey contained 11 questions and provided two alternative answers to each question – “Yes” or “No”. The content of the questionnaire, as well as summarised quantitative data on the responses, are shown in table 1.

The responses to the first question show a positive effect on the learning of domain-specific terminology bases precisely in the aspect of term identification and selection technology in the lack of an in-depth understanding of the domain. This was made possible precisely using interactive semantic networks, as indicated by 78.9% of the students. A convincing proof of the effectiveness of interactive semantic networks was the responses to the second question of the questionnaire, as 84.2% of the students owe it to them to be able to identify related concepts and terms related to a certain source term. In other words, only 15.8% of the students could identify the lexical field of certain terms based on their own prior knowledge in a certain field.

The high number of affirmative responses to the third question (81.6%) is most likely due to the easier perception of information presented in visual form, which is generally an effective support for autonomous learning. In particular, the functionality of the interactive network to visually reproduce the terms of a particular area and the relationships between them contributed to an understanding of its integrity, even at an early stage of familiarity with it.

In addition, the use of an interactive semantic network to highlight terms of a particular domain allowed the students to detail the elements of the terminological system in the right

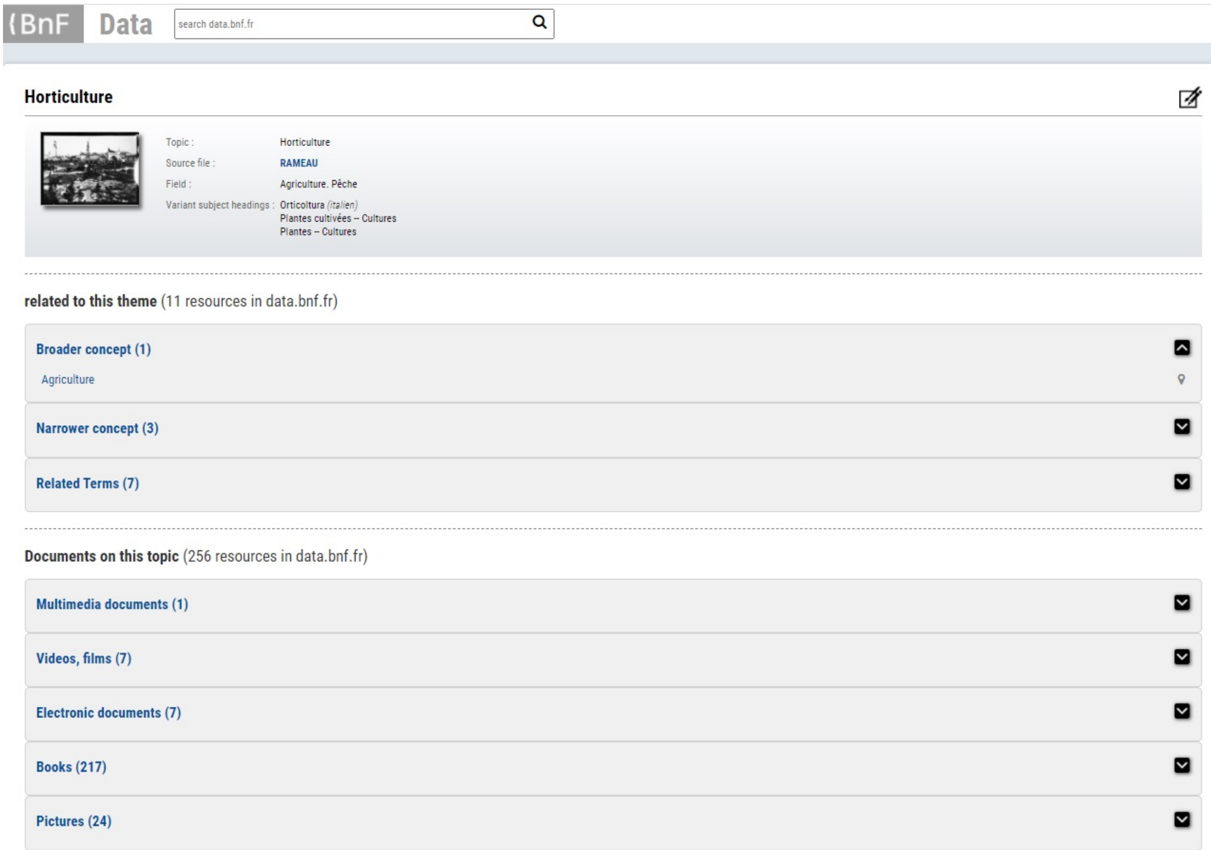

Figure 5. Structure of presentation of additional information about the term "horticulture" in online resources in the form of multimedia and electronic documents, videos, books, images.

direction quite effectively, as reported by 73.7%. This kind of activity is directly related to the filling of terminology bases and would have required significantly more time if done by other means.

The availability of an automated function in the interactive semantic network to generate relationships between terms across the four hierarchical levels proved to be an effective tool for 76.3% of the students, who indicated that it allowed them to identify the right set of terminology data to add to the terminology database aimed at solving a specific problem.

The responses to the questions on the software that the students used to create the terminology bases can be explained by the influence of two factors, namely the availability for use of a particular software product and the level of proficiency in it. The fact that 68.4% of students chose MS Excel to create and complete their terminology databases, confirms the fact that the programme is commonly available and the experience of using it is acquired not only in the study of specialised courses, but also in previous phases of mastering information technologies. However, it is important that 21.1% of the students created terminology bases using specialised modules designed to generate such bases when working with CAT systems. This indicates that a fairly large proportion of students have not only mastered these modules to a level which has enabled them to carry out such operations at a higher technological level, but are also aware of possible ways of obtaining and using them. It is important to note that although only 10.5% of students reported using the functionality of CAI systems to create and complete a terminology base, but due to the relatively low prevalence of such systems, this indicates that students valued certain aspects of these systems and gave them preference over

Figure 6. Presentation of the created interactive semantic network with a hierarchical structure.

others.

Judging by the responses to the question about finding and using additional information about terms, more than a third of the students used the available potential of interactive semantic networks for this purpose. This is an indication that some of the students were not only forming terminological bases, but also trying to understand the essence of the industry in more depth. Analysing the high number of "No" responses (86.8%) regarding the need to modify the structure of the database in order to expand it, it can be stated that the students had sufficient experience in designing the structure of the terminology bases during the creation phase. This allowed them to predict the necessary fields for concentrating the information available in the semantic network about the term entered in such a way that, in the vast majority of cases, they met the requirements.

Overall, the results of the survey indicate the potential of interactive semantic networks in the process of technological training of translators, in particular for forming terminological bases for their further use in learning foreign languages and mastering automated translation systems.

4. Conclusions

In the process of technological training of translators, it has been found that it is advisable to implement elements of augmented reality in order to increase its efficiency. One of these elements can be interactive semantic networks, the technology of using which for the selection and structuring of industry terminology we have developed and tested in the conditions of

Table 1. Results of a student questionnaire on the using interactive semantic networks.

Question	Response rate	
	Yes	No
Did the use of interactive semantic networks help you acquire the skills to create domain-specific terminology bases?	78.9	21.1
Has the use of interactive semantic networks contributed to the identification of related concepts and terms associated with a particular source term?	84.2	15.8
Has the visualised representation of the interactive semantic network contributed to an understanding of the integrity of a particular field in which you are not an expert?	81.6	18.4
Has the use of an interactive semantic network enabled you to understand better the range of components of a particular field in order to detail terminology in the right direction?	73.7	26.3
Does the presence of established relationships between the different hierarchical levels in the interactive semantic network help to outline a terminology dataset for input into the terminology database according to a certain logic?	76.3	23.7
Have you used MS Excel to create and complete your terminology database?	68.4	31.6
Have you used specialised CAT system modules to create and complete your terminology base?	21.1	78.9
Have you used the functionality of CAI systems to create and complete your terminology base?	10.5	89.5
Did you fill your terminology database with additional information about the terms entered?	34.2	65.8
Have you used the specialised functions of interactive semantic networks to find more information about terms?	39.5	60.5
Have you needed to change the structure of your base in order to expand it?	13.2	86.8

autonomous learning. This technology allows:

- create a personalised, interactive semantic network to form a domain-specific terminology base,
- to develop a personalised, interactive semantic network along various lines, depending on the need for detailing and structuring domain-specific terminology,
- to select domain-specific terminology on the basis of its detailing, taking into account the types of hierarchical relationships of the interactive semantic network,
- to get more information about terms through the interactive use of external online resources, the links to which are automatically generated by the created semantic networks,
- to investigate the generated semantic networks in the aspect of distinguishing more general concepts from highly specialised vocabulary.

To structure the domain terminology selected on the basis of interactive semantic networks we defined the criteria of creation and filling terminological bases, with possibility of their further use for foreign language learning with mobile applications, mastering computer aided translation (CAT) systems, mastering computer aided interpretation (CAI). These criteria are universality, structurability, convertibility, extensibility.

The experimental use of the developed technology in the process of autonomous training of translators has shown a positive influence on their technological training, in particular in the aspect of the ability to define and select terms when there is no deep understanding of the domain, to detail elements of the terminological system in the right direction, to create terminological bases on the basis of selection and detailing of terms using interactive semantic networks.

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