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*ЗАСНОВНИК І ВИДАВЕЦЬ:*
КРИВОРІЗЬКИЙ ДЕРЖАВНИЙ ПЕДАГОГІЧНИЙ УНІВЕРСИТЕТ

Рекомендовано до друку рішенням Вченої ради
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Збірник наукових праць «Освітній вимір» містить матеріали, присвячені висвітленню теоретико-практичних проблем педагогіки вищої та загальноосвітньої школи, становлення і розвитку освітньої парадигми, інтеграції психолого-педагогічних чинників в організацію навчально-виховного процесу.

Випуск містить матеріали шостого міжнародного семінару «Хмарні технології в освіті» (Кривий Ріг, Україна, 21 грудня 2018 року). Оригінальна онлайн публікація — у 2433 томі CEUR Workshop Proceedings (CEUR-WS.org, ISSN 1613–0073).

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# Educational digital games: models and implementation

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**Abstract**. Nowadays, social media, ICT, mobile technologies and applications are increasingly used as tools for communication, interaction, building up social skills and unique learning environments. One of the latest trends observed in education is an attempt to streamline the learning process by applying educational digital games. Despite numerous research data, that confirms the positive effects of digital games, their integration into formal educational contexts is still relatively low. The purpose of this article is to analyze, discuss and conclude what is necessary to start using games as an instructional tool in formal education. In order to achieve this aim, a complex of qualitative research methods, including semi-structured expert interviews was applied. As the result, the potential of educational digital games to give a unique and safe learning environment with a wide spectrum of build-in assistive features, be efficient in specific training contexts, help memorize studied material and incorporate different learning styles, as well as to be individually adaptable, was determined. At the same time, the need for complex approach affecting the administration, IT departments, educators, students, parents, a strong skill set and a wide spectrum of different roles and tasks a teacher carries out in a digital game-based learning class were outlined. In conclusion and as a vector for further research, the organization of Education Design Laboratory as an integral part of a contemporary educational institution was proposed.

**Keywords**: educational digital games, game-based learning, advantages and challenges of educational games, Education Design Laboratory model.

## 1 Introduction

Modern media that come in many different formats, including books, magazines, newspapers, television, movies, video games, music, cell phones, various kinds of software and Internet, can be viewed as an important form of pedagogic influence and socialization, as they not only spread information but also form our cultural values and behavioral norms.

In recent years, when contemporary high-tech enterprises require their employees to demonstrate the good level of mathematics, sciences, engineering, be computer literate and solve complex tasks creatively, the training of a new, competitive generation depends, primarily, on innovative technologies and teaching approaches that would enhance students' potential and, at the same time, would be cost effective.

Taking into consideration that the young generation of today is growing up in networked interactive media world where high-speed information acquisition, graphic images, instant rewards and multi-tasking are omnipresent, educational landscape reacts by introducing social media, ICT and mobile technologies to reach new student audience and apply these media as an educational tool on a preschool, elementary, secondary, and higher levels. Most recently, instructional designers have been examining how best use digital games.

Literature review lets us state that on the international level the scope of scholarly works about digital games is wide. For example, the focus of queries of Katie Salen Tekinbas, Eric Zimmerman [27] and Pavel Zemliansky, Diane M. Wilcox [36] falls on game design. Mark Prensky investigates D-generation and argues for partnering pedagogy [23]. Several studies, including papers by Glenda A. Gunter, Robert F. Kenny and Erik Henry Vick [15] discuss the formal design paradigm for serious games. Pieter Wouters, Christof van Nimwegen, Herre van Oostendorp and Erik D. van der Spek [35] presents the analysis of motivational and cognitive effects of video games. The description of frameworks for design and analysis of digital games can be found in the works of Sylvester Arnab, Sara de Freitas, Francesco Bellotti, Theodore Lim, Sandy Louchart, Neil Suttie, Riccardo Berta, Alessandro De Gloria [3] and Christian Sebastian Loh, Yanyan Sheng, Dirk Ifenthaler [21]. Questions related to the game-based curriculum are analyzed in article of Björn Berg Marklund and Anna-Sofia Alklind Taylor [4].

There are a number of projects that exemplify the gamification process and digital games' application to different contexts, including educational. Among them are Beaconing — Breaking Educational Barriers with Contextualised Pervasive and Gameful Learning (Horizon 2020, EU

Program); Nutriciencia — a research project to increase food and nutritional literacy of high-risk populations (the University of Porto, EEA Grants Program, Ministry of Health, Portugal); Serious Games in Higher Education: Impacts, Experiences and Potential (Research Center CIIE, the University of Porto, Portugal); KidCOG' — Prevention of Online Sexual Grooming of Children' project (the University of Skövde, the Change Attitude Foundation, Sweden).

The research results report a number of successful educational video games' and commercial off the shelf games' uses [14], and confirm that digital games have a potential to increase students' motivation, provide a more authentic learning experience, teach system thinking, facilitate collaborative problem-based learning, and influence social sphere.

Despite these examples, the integration of digital games into formal education is still relatively low. This can be partially explained by the fact that many educators see video games as a leisure time activity with no pedagogic value; many are not familiar with games' interfaces as well as the game based learning concepts and process. Even those teachers who use video games face a wide range of issues to be addressed to, which makes implementing digital games into educational context highly challenging.

In other words, what we observe today is the high popularity of video games and the increase in their production and research importance. At the same time, there is an obvious gap between theoretical claims and practical implementation of digital games into a formal educational context.

Given this, the purpose of this article is to analyze the path of educational digital games from theory to a real-life educational context and to look into what it takes to use games as an instructional tool.

## 2 Research methods

In order to achieve our aim, a complex of qualitative research methods, including synthesis, comparison and generalization of theoretical material was applied, which helped identify the main topics for the analysis. Theoretical analysis was in large part informed by the material related to pedagogical aspects and based on the study of such works as "Digital games in schools: A handbook for teachers" (by Patrick Felicia [10]), "Supporting Teachers in the Process of Adoption of Game Based Learning Pedagogy" (by Valérie Emin-Martinez, Muriel Ney [9]), "Learning with Digital Games: A Practical Guide to Engaging Students in Higher Education" (by Nicola Whitton [33]), "Production of Creative Game-Based Learning Scenarios: A Handbook for Teachers" (ProActive Project [24]), "Best Practices For

Using Games and Simulations In The Classroom: Guidelines for K–12 Educators" (Software & Information Industry Association Education Division [34]), "Poverty is not a Game: A Handbook for Teachers" (by Caroline Kearney [19]). After the theoretical analysis was completed, the most frequently raised topics were identified:

1. game-based learning, its characteristics and distinctive features;
2. advantages of digital games as an instructional tool: cognitive, motivational and social aspects; characteristics of a good game;
3. possible ways of digital games' integration into formal educational context;
4. teacher's role(s) in a digital game-based learning class.

Our analysis is also based on interviews (within interview guide approach) with a selected group of experts from The School of Informatics, University of Skövde. Six people were interviewed, with some people interviewed twice. Each interview lasted from forty to eighty minutes. The detailed notes were taken and/or the recording was done. The group of experts was selected from the lecturers, senior lecturers and the researchers in Serious Games of the School and included the Associate Professor in Educational Game Design and Game-Based Learning and the Researcher in Game Studies; the Lecturer in Media Arts and the Researcher in Virtual Reality; the Lecturer in IT and Game Design and the Researcher in Educational Games; the Senior Lecturer in Informatics and the Researcher in Serious Gaming; the Associate Professor in Media Arts, Aesthetics and Narration, and a Serious Game Designer from ZCOOLY company.

On the later stage, theoretical claims as described in research articles, projects' accounts and web resources were compared and contrasted with the discoveries from the expert interviews, therewith a more all-round view on what digital games can offer, their strengths and weaknesses, as well as what is necessary to start using games as an instructional tool was constructed. Final conclusions were made.

## 3 Results and discussion

We consider it necessary to begin our analysis from defining educational digital games. Educational digital games or EduGames are also known as "video games for learning", "computer games", "applied games", "games for education", "learning games", "electronic educational game resource" (a term recently introduced by the Ukrainian scientific community) [6], "serious games", with the last term as a recent years' mainstream term that describes games for learning, training, healthcare and social change [28]. If video games are considered an activity that includes one or more players, has definite goals, rules, limitations, rewards and outcomes, is artificial with the element of a competition, then serious video games are those that are built on game-based learning principles, include basic elements of video games and are used not only for the entertainment.

In order to clarify the term, we asked the experts the following question, "Is Serious Video Games the best term for the phenomenon and what is your definition of it?"

When comparing two terms — "serious video games" and "educational digital games" (EduGames), all the informants pointed to the broadness of the first term, which, according to their opinion, incorporates educational games, as well as games for health and different types of simulators. In order to designate games used for educational instruction, they prefer "educational games", "game-based learning" or "game-based discussion" terms.

Therefore, further in the article, we choose to use "educational digital games" or "educational games" when speaking about educational context, "serious video games" (SVGs) when analyzing other contests as well, "digital/video games" — to describe a type of a contemporary artifact.

Now we move on to the detailed discussion of the selected themes.

Referring to the first topic, which is game-based learning, we should note that it is considered the context of educational games' application. This, in turn, leads us to a brief description of its main characteristics and distinctive features.

Game-based learning (GBL) — is a type of game-play with defined learning outcomes [29]. The origin of game-based learning (also known as educational gaming) can be traced back as early as the 1980's to the works of Alan Amory [2], Detlev Leutner [20], Thomas W. Malone [22] that described new technology of computers and their unique possibilities for fantasy, sensory effects, individual adaptability and the potential for creating motivation and engagement.

At the beginning of the $21^{st}$ century, the increased interest in the positive impacts and outcomes of games expressed by Clark Aldrich [12], James Paul Gee [11], Mark Prensky [23], led to a dramatic growth of the academic field that argues for the application of the game-based approach in education. Therefore, the argument is no longer whether games should be used, but how they should be used, how they should be designed and how they should be integrated into the curriculum.

In the process of GBL, learners use games as a tool to study a topic or related topics. They work individually or in teams. It is expected that in this process, the use of games will enhance the learning experience through challenge, exploration, interaction, reflection and decision-making, while maintaining a balance between the content, gaming and its application to the real world.

The main features of GBL are that it is interdisciplinary and multimodal (it combines images, sounds, texts, kinesthetic manipulation). It uses such game elements as a rapid pace, a random selection, different roles, presence of rivals and rewards. GBL is supported by the following learning principles: learning by doing or experiential learning; the authenticity of the tasks; motivation; independence and autonomy; team-working and/or competition; playfulness.

It is important to point out that game-based learning is not gamification. If the former is the use of games/digital games with serious goals (i.e. educational objectives) as tools that support learning processes in a significant way, the latter takes game elements (points, badges, leaderboards, competition, achievements) and applies them to a non-game setting with the aim to turn routine tasks into more refreshing, motivating experiences [8].

To understand game-based learning processes in depth, we asked the informants the following questions: 1) how would you describe game-based learning and what learning principles is it backed up with? 2) Is it important to differentiate gamification and game-based learning (GBL)?

As a result, we got the answers that GBL is, first of all, an approach to teaching and learning based on a constructivist pedagogy (one answer). It can be used as an extension to other traditional teaching methods but cannot serve as a substitute for a teacher, because stand-alone games never provide learning (all the interviewees). It is also important to understand that just a few games offer a real picture of the world (principle of authenticity and life skills' development) (one answer). It is the educators' role to transform a game into a meaningful activity via its contextualization, thus making real learning occur (all interviewees).

According to the experts' views, it is very important to differentiate gamification from GBL, as gamification is the use of game elements and their application to non-entertaining activities and contexts with the aim to increase motivation. GBL, to the contrary, is full exploitation of a game with the aim to reach specific learning objectives (all the experts).

To further our discussion of educational digital games, we come to the second topic, which is the advantages of digital games as an instructional tool: cognitive, motivational and social aspects and the characteristics of a good game.

Nowadays, it is the established view that educational digital games create a unique learning environment in which students interact, experiment with their ideas, discover, research, analyze and reflect on the gained experience. Many agree that games affect learning by influencing cognitive processes, motivation, by shaping and advancing social component [9, 10, 14, 19, 24, 33, 34].

*Video games as a change in cognitive processes.*

Up to now, there is a sufficient amount of experimental work that confirms that the material studied in SVGs is stored longer in the memory of students and is more structured [35]. Memorization in the process of video gaming takes place when the tasks are repeated and rewards are given. The analysis and understanding of the studied material are achieved through direct interaction with the game elements, free experimentation and the study of the relationship between different phenomena within the problem tasks. Evaluation skills are developed when students model game objects and processes and change them in order to achieve better results [3]. Among others, not less important cognitive qualities that are formed in video gaming are movements' coordination and spatial sensation.

*Video games as a change of motivation.*

Beginning from the second half of the 20th-century play became the interest of scientific studies. One of the first fundamental works on the game theory and the play element in culture was the book by a Dutch historian and cultural theorist Johan Huizinga, "Homo Ludens: a study of the play-element in culture" published in 1938. According to his views, the play is not just a pastime. It is the primary category of life and the structural component of culture, as culture is born as a play and never leaves it. The scientist puts emphasis on the indispensable ability of a person to play and speaks about "Homo Ludens" [17].

Alan M. Rubin [25], Jay G. Blumler [18], Thomas E. Ruggiero [26], Bradley S. Greenberg [13], John L. Sherry [30], Michael Gurevitch [18] is another group of researchers who traced connections between video games and motivation. What makes people play video games? The scientists underline seven main motifs: 1) control — over the game character and the game context; 2) challenge — desire to attain a higher level of skill; 3) competition — to win or surpass others; 4) fantasy — to engage in a variety of acts that will be difficult to perform in our everyday lives; 5) interest — to explore the game and gather information about it; 6) distraction — to take minds off usual concerns by doing something completely different; 7) social interaction — to play with each other and against each other [32].

In addition, the ability of video games to offer participants the choice of icons or the names of the players transforms it into a personally significant, increases the pleasure of participation, creates a space for self-realization, leads to the increase in motivation.

*Video games as a participatory culture builder.*

Except building up cognitive skills and the increase in motivation, the game-play lets participants share their knowledge with other players who, very often, have various sociocultural origin. This allows the creation of player communities. The key features, describing such game communities, are: a) open participation for any player; b) common game environment that is shared by novices as well as mature players; c) participants have the right to form and transform the game environment; d) knowledge and expertise are divided between the players; e) there are different ways to achieve the goals of the game, different ways to participate in the game and get a new status. Such communities generate their own practices, social and cultural norms, values and goals, as well as identities of their members [11].

To clarify the above-presented points, we asked the informants the following questions, "What is the advantage of video games as an educational tool?" "Do you agree that video games influence cognitive processes, motivation and social sphere of players?" "What do you think motivates people to play a video game?" "Would you agree that unique game communities are born around a game?" "What is a good educational game for you?"

Related to the first question, the most significant characteristics outlined by the informants were the cost-effectiveness, efficiency and safety of games in military, firefighters and pilots' training (in four answers). Next, video games are good at helping learners remember and grind studied material (in all the answers). Video games stimulate active participation, reflection, and discussion (in five answers). They present complex systems, and let learners experiment, make mistakes without negative consequences (in five answers). They are a visual tool with many build-in features, such as checking the answers, logging, scenario replaying (in two answers).

The second question was, "Do you agree that video games influence cognitive processes, motivation and social sphere of players?"

The informants pointed out that firstly, games per se do not teach or influence anything. They should be contextualized, i.e. tied in with target learning group, curriculum and learning environment (all the experts). Secondly, there are studies that say about players' good results in remembering the content of the game. Games are good at "drilling" the material in many fun activities (four answers). Thirdly, the social aspect of games is important and can be used and elaborated on more than it is done today (three answers).

The next question, "What do you think motivates people to play a video game?" brought the following results — to play is a basic human nature activity (one answer). Among other motifs are the feeling of "empowerment" — that a player is becoming better in the course of gameplay (one answer), a challenge, wish to create, identity-making (four answers).

The important aspect that came up in the interviews was the necessity to differentiate formal and informal contexts where motifs to play are significantly different (in one expert's comments).

There is a unanimous agreement of the informants as to the question, "Would you agree that unique game communities are born around a game?" The examples given included Dota 2, Minecraft, Counter-Strike, EVE, World of Warcraft.

As for "What is a good educational game for you?" question — a good game should be adaptable, short and focused on one main theme (one answer). Its mechanics should follow the learning experience (one answer). Concerning the "fun" component in games, we got two opposite views. The first is that the "fun" part and learning should not be separated. Another one is that "stealthy" approach to learning (when learning is disguised as a fun game-play) never leads to learning outcomes. The "flow" state of a player has to be broken and the educational component should be brought in.

The importance to understand ways of digital games' integration into formal educational context, leads us to the third topic of our discussion.

As an educational instrument, educational digital games require a complex approach in order to be integrated into the teaching/learning process. Recent projects, related to the studies of favorable environments' creation to integrate educational digital games into a particular educational setting, state that the main "stakeholders" in this process are administration, IT departments, educators, students, their parents and the community [34].

To persuade all stakeholders to support game-based learning requires much more time and energy than to develop traditional educational and methodologic materials, as the course of establishing and carrying out game-based learning is accompanied by a lot of preliminary work, such as surveying educational organization and preparing it for implementing educational games. Preliminary analysis of the organization may comprise questions, connected with organizational culture, teachers' attitude, parents' attitude, students' experiences with game-playing, teachers' computer and technology literacy, teachers' gaming literacy, availability of devices (PCs, tablets, etc.), information storage and access, classroom size, number of students, schedule and curriculum, management and support, etc.

It is highly important to develop teachers' understanding of educational games as an innovative tool. This can be done through the initiatives that facilitate a few teachers in developing their competencies with educational games, rather than having a universal training for the entire staff. Top-down initiatives, where new techniques and tools are "pushed onto" teachers, ran the risk of being expensive and alienate teachers by limiting their involvement in decision-making [5, p. 112].

Another important factor in applying video games is the knowledge of possible integration scenarios into the educational context. We maintain that the most comprehensive analysis was made by Nicola Whitton, Professor of Education at the University of Manchester, Faculty of Pedagogy, who suggested six possible models.

Model one — application of one game per session, which involves using a game in one lesson to achieve a specific goal. Model two — one game per several session that can be used as a direct replacement for two or more lessons. Model three — use of a separate element of a game as an additional task, which involves the application of some game element as an auxiliary tool. In this case, a game does not replace a lesson. Model four — integration of a complete game into the curriculum when a digital game is used as an alternative means of presenting the material, which, in turn, leads to the reorganization of teaching, learning and evaluation process, i.e. to the redevelopment of the course. Model five — use of online games as a part of blended learning or online course. In this case, students do not necessarily meet each other, because the game runs online — synchronously, or asynchronously. Model six — implementation of a game as a "mixed reality" type [31] — the use of the elements of online environment and personal interaction, often involving mobile technologies, such as mobile phones or other portable devices [33, pp. 85–88].

The questions we asked the informants to support this discussion were: 1) should educators take a game and try to tie it in with the curriculum or should they follow the curriculum trying to pick up the right game? 2) Are there two different approaches to implement Educational Games and Commercial Games (COTS) into educational context? 3) What are possible scenarios to integrate video games into a classroom? 4) Do you think it is a viable idea to teach teachers to design their own games for their specific purposes?

The interview data related to the first question tell that this choice may depend on the level of schooling. For example, if it is an elementary school —

it is easier to find a ready-made game and to use it in class, building up a lesson with specific learning outcomes around it. At the same time, this approach may not work in higher education, where teachers have to follow the curriculum to let students master a particular subject. Games take many hours to play, which may not comply with the time frame of the course (one informant).

There is, though, another opinion, stating that teachers know the curriculum and have enough traditional material to achieve its goals. However, sometimes there may be parts of it that are not quite successfully presented by a traditional material. In such cases, teachers may opt for finding a game that would explain or help master this part. It is the example when a teacher follows the curriculum and chooses a game that may enhance a particular element (three answers).

As for the second question, many answers underlined that entertainment games are time-consuming, unlike educational games that are usually small, replayable and are directed at a specific learning objective (all the interviewees). When COTS are used, most probably a teacher has to design his/her lesson plan around it. With EduGames that are not easily re-interpreted, a teacher has to adapt the working process to the game (one answer). Another difference between COTS and EduGames is the time one learns how to play them. With EduGames it is shorter, which makes the process of a game's integration into educational context faster. At the same time, with both COTS and EduGames there are the same issues of finding the right game, understanding how it can be used for a specific subject, issues of licensing and technical support (three answers).

As for the third question about possible scenarios to integrate educational digital games into a classroom, there is no one universal way to do it. The right way is the one that works best for the educator (all the answers).

Because of the time issue, many educators may prefer to use a mini-game as a complementary means to enhance learning. To the contrary, as the time that takes to find, contextualize and start playing a game is relatively long, it may be sensible to use the same game for a longer period. Whatever choice is, a game should be an integral part of a bigger educational process.

As for the idea to teach teachers to design their own games for their specific purposes (question four), all informants agreed that it is a good one. To start from analog games and move on to digital tools with the aim to help teachers understand how games work. It is also reasonable to provide teachers with courses in programming to get such experience. For example, simple programming languages, like SCRATCH or online courses on game design. At the same time, it is rather challenging to teach an educator to think like a game designer.

Now, we come to the discussion of the last topic on the teacher's role(s) in a digital game-based learning class.

Here we have to say that knowledge acquisition is possible in many different ways, which depends on learners' characteristics, material to be studied, the situation where learning takes place. The same is true about teaching styles that differ depending on a particular educational context.

For the present discussion, we use five metaphors of learning and the accompanying teaching styles as described in ProActive: Fostering Teachers' Creativity through Game-Based Learning project. These are learning through knowledge transfer, learning though imitation, learning though experimentation, learning through participation and learning through discovery [24].

The way of knowledge transfer is the information pass from one person who possesses it (a teacher) to another one who acts as a receiver (a student). Learning is targeted at memorization of facts and concepts' acquisition and is rooted in repetition and replication. In this context, the teacher acts as an expert who conveys information. The way of imitation is when learners model behaviors or make a copy of the proposed model. Learning is targeted at improving practical skills. Here, the teacher acts as a coach. The way of experimentation takes place when teachers provide a task and let learners experience it. Here, the teacher acts as a facilitator. The way of participation is targeted at social aspects of learning. To encourage learners to be a part of the community, teachers stimulate interaction between peers, organize discussions, view-exchange and collaboration. Teacher's role is also of a facilitator. The way of discovery is aimed at establishing new relations between objects and concepts. Here the teacher acts as a facilitator who organizes guiding activities for the learners to discover and construct new meaning.

Thus, within the five metaphors, the teacher may come as a knowledge expert, a coach, a facilitator, an evaluator.

In the context of digital game-based learning, an instructor carries out all the roles listed above, guiding learners into their specific task and experimentations within the game, reflection, consolidation, and reinforcement of the gained experience (Figure 1).

Research carried out on game-based learning confirms that when conducting game-based classroom activities, teachers take on a wide range of roles in order to successfully and significantly integrate the educational game into their classrooms. During a typical game-based exercise, teachers act as game administrators, lecturers, game tutors, subject matter anchors and authority figures that keep students in an educational mode of play. This, in turn, requires a diverse skill set, including technology expertise, gaming literacy, subject matter knowledge, and a strong pedagogical foundation [5, p. 206].

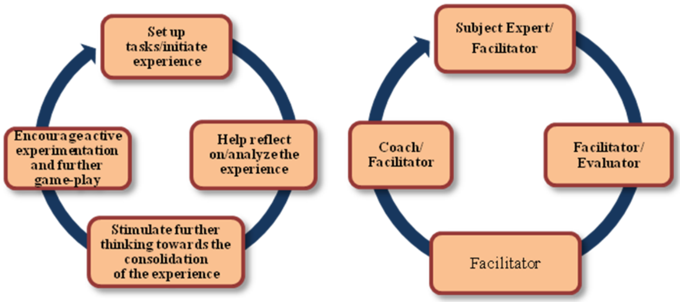


**Fig. 1.** Example of educators' tasks and roles in experiential learning cycle

Another important principle outlined in many research works states that for a game to have positive educational value, briefing before the game and reflection after the game (known as a debriefing or after-action review AAR) are a must. Debriefing — is a meeting that takes place in order to get information about a particular piece of work that has been finished, for example about what was done successfully and what was not [7]. Debriefing after the game facilitates reflection and serves to check whether participants learned what was intended to learn. It also allows the participants to reflect upon the training experience and make connections between game events and real-world events [16].

Therefore, a digital game-based lesson passes three distinct stages: 1) before the game-play stage (organized as a briefing); 2) during the game-play stage (the game-play itself); 3) after the game-play stage (in a form of a debriefing or after-action review).

The model of "a coaching cycle" (Figure 2) developed by Anna-Sofia Alklind Taylor serves as a good illustration of a digital game-based session [1, p. 193].

Consequently, in preparing and conducting a digital game-based lesson, a teacher follows the path from making up a lesson plan targeted at a specific learning group and a syllabus (scenario authoring), setting up the gameplay (briefing), guiding learners in the game-play process (gameplay) and finalizing the experience afterwards (debriefing).

To reinforce the discussion, we asked the experts these questions: 1) how are the roles between a teacher and a student distributed when digital games are used in educational context? What roles does a teacher carry out? 2) What are possible ways to transfer knowledge from a game-play to real-life situations?

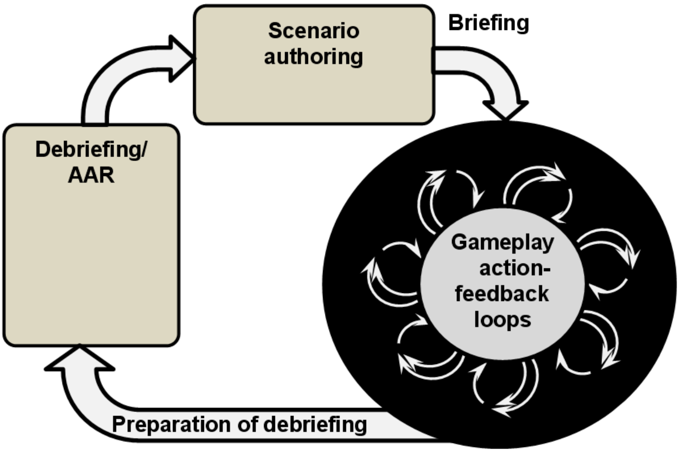


**Fig. 2.** Game-based session coaching cycle (used with permission)

Answering the first question, all our informants confirmed that a teacher carries out different roles, including a facilitator, a knowledge expert, a de-briefer, etc. At the same time, and what is very important, in digital game-based learning the teacher also acts as tech support, a moderator who explains how the game works, as an IT administrator. These extra functions often distract teachers from their immediate tasks (four answers).

Situations may occur when students who often play games outside school help teachers during the game-play and become facilitators of the learning process, and this changes lesson's dynamics (one comment).

The teacher also may act as an active player involved in the game along with students. Assuming this role, a teacher can give feedback from "inside" the game by responding to students' actions (Figure 2). In this case, the game flow and the students' engagement are not broken (one comment).

The teacher may act as a game developer, which requires good experience with games (four answers).

Concerning the second question, it is a hard task to transfer knowledge gained in the game-play to real-life situations (all the experts). One way to do it is to pause the game and to highlight a specific learning point.

Conversations and discussions around the game build up the knowledge and help make connections with the real world. One way to get students into conversations is to sit two of them at a computer. Another way to transfer knowledge from a game-play to real-life situations is to carry out a debriefing. Here, it is important to explain the difference between the game and the real life, reflect on practices inside the game and outside it. Reflection is the way to transfer the knowledge and the experience into real life contexts. As in a game it is hard to simulate all possible real-life scenarios, it is the teacher's role to help students make these connections and that is one more reason why games cannot replace teachers.

## 4 Conclusions and prospects for further research

Having conducted theoretical analysis and expert interviews and having compared and contrasted the obtained data, we may come to the following conclusions:

- although "Serious Video Games" is considered the recent years' mainstream term to describe games used not for entertainment, the experts' practical opinion states that "Educational Games" is a better term for the phenomenon;
- game-based learning (GBL) is one possible approach to teaching/learning that is supported by a constructivist experiential pedagogy. It uses educational games as a tool of instruction. GBL is an extension to other traditional methods but not a substitute for them or a teacher. In the process of GBL the game is fully used to reach specific learning objectives and the teacher is the key actor to make learning happen;
- educational digital games (EduGames) are complex systems that provide a unique and safe learning environment for experimentation. In reality, there are only a few games that provide authentic material and real-world tasks. To get the most of learning out of games a teacher should help students make connections between the knowledge and experience from the game with real-life scenarios;
- content studied in game-play is stored longer and is better structured in learners' memory. There are different motifs why people play but it is important to remember that motivation to play in formal and informal contexts differ. Games stimulate active participation and create communities around them;

- there are two different views on "fun" component of games. The first is that fun and learning should not be separated. The second is that to achieve a desired learning outcome, the "flow" state of a play should be regularly broken and a reflection and discussion brought in;
- to integrate video games into educational context requires a complex approach. It includes cooperation between administration, IT department, educators, learners, community. In this process, it is highly recommended to survey and to prepare the target organization to work with EduGames, as well as to help teachers understand EduGames as an innovative tool. It is better to start from a small group of teachers, rather than to facilitate the whole staff;
- if a teacher chooses a game to use in the class, he/she should build up the entire lesson and lesson materials around it by tying it in with the curriculum. To the contrary, a teacher may follow the curriculum and try to find a game to enhance a particular part of it. Whether COTS or EduGames are used, the issues of finding the right game, understanding how it works for a specific purpose, licensing and technical issues are the same. There is no one universal scenario of how to integrate EduGames into an educational context. Some may opt for a mini-game or a bigger game for a longer period of time. It's important that the chosen game fits right into a general educational process;
- in the context of digital game-based learning, a teacher carries out the roles of a facilitator, a knowledge expert, a coach, an evaluator. The teacher also acts as tech support, IT administrator, a moderator, a de-briefer, which may distract from exercising immediate teaching tasks. The teacher may act as an active player and provide feedback from "inside" a game. In addition, a teacher may be a game developer. These roles require good experience with games;
- the positive educational effect is achieved if briefings and debriefings become a part of a game-based learning process. Properly organized debriefing is the way to transfer knowledge and experience from a game to a real-life context. As games cannot simulate all possible real-life scenarios, a teacher, as a de-briefer, cannot be replaced by games.

The implications of the study presented in this paper are that what educational digital games may give as an instructional tool is a unique and safe learning environment with a wide spectrum of build-in assistive features. They are very cost-effective and efficient in specific training contexts. Digital games are good at helping learners memorize studied material, appeal to different learning styles (visual, audio, kinesthetic) and individually adaptable. As a novel educational instrument, they increase motivation, stimulate players' interaction, active participation, discussion, and reflection.

At the same time, the path of digital games to formal educational context requires complex approach that may affect administration, IT departments, educators, students, parents, community and is accompanied by many preliminary arrangements, starting from the analysis of the target organization to the choice of the most appropriate scenario of a game's application. The key figure in the process of transforming a game into a meaningful activity is an educator. This demands a strong skillset of gaming literacy, technical skills, knowledge of the taught subject, pedagogy, psychology, etc., as in the process of digital game-based learning a teacher exercises different roles of a subject expert, a facilitator, a coach, an evaluator, a game moderator, a tech support, a de-briefer, a co-player, a co-designer. Teachers build up lesson plans, conduct the lesson and debriefing, follow the quickly changing market of digital games, play games to be able to choose the right one for the class.

If we place the results of this brief study into a broader context, we may state that digital games as a contemporary cultural artifact are here to stay with no turning point, as well as other modern digital tools, gadgets and applications. They may not revolutionize education but it is highly possible that a new generation of teachers will come that are used to playing video games and who will be ready to put their knowledge of a game-play into learning in the attempt to get to the present and future generation of learners.

Therewith, the importance of information dimension in the development of the 21st- century skills as well as the digitalization of education will stay as important elements. This will lead to the re-evaluation of the teaching process in terms of how to teach with modern digital tools, including digital games.

We conclude this article with the idea (and the prospect for further research) of building up Education Design Laboratory as an integrative part of a contemporary educational institution. This laboratory may stream its work into Contemporary Multimedia in Education Unit, Educational Game Design Unit, Teacher Training in Multimedia and EduGames Unit, Gamification Unit, etc. This, as we see it now, may help teachers gain and/or upgrade their competences and get support in implementing cutting-edge instructional tools, assist the administration in building up a contemporary technologically rich research model of an educational institution and students — to develop the 21st-century skills.

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## Навчальні цифрові ігри: моделі та реалізація

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**Анотація**. У даний час соціальні медіа, ІКТ, мобільні технології та додатки все більше використовують у якості інструментів для комунікації, взаємодії, побудови соціальних умінь та унікальних навчальних середовищ. Один з останніх трендів, що прослідковується у навчанні — спроба спрямувати навчальний процес за допомогою використання навчальних цифрових ігор. Однак незважаючи на численні дані досліджень, що доводять позитивний ефект цифрових ігор, їх інтеграція у контексті формальної освіти залишається достатньо низькою. Мета цієї статті — проаналізувати, розібрати та зробити висновок стосовно того, що є необхідним для початку використання ігор як навчального засобу у формальній освіті. Для досягнення цієї мети було застосовано комплекс якісних методів дослідження, включно з напівструктурованим опитуванням експертів. У результаті було визначено потенціал навчальних цифрових ігор, що полягає у наданні унікального та безпечного середовища навчання з широким спектром вбудованих допоміжних рис, ефективних у специфічних контекстах підготовки, які допомагають запам'ятовувати матеріал що вивчається та включати різноманітні стилі навчання, разом з можливістю бути індивідуально адаптованими. Одночасно було виділено необхідність комплексного підходу, який потребує залучення адміністрації, ІТ-відділів, педагогів, батьків, міцної сукупності навичок та широкого спектру різноманітних ролей та завдань, які здійснює вчитель під час уроків ігрового навчання. У якості висновку та вектору подальших досліджень було запропоновано організацію Лабораторії Навчального Дизайну як інтегральної частини сучасного освітнього закладу.

**Ключові слова**: навчальні цифрові ігри, ігрове навчання, переваги та виклики навчальних ігор, модель Лабораторії Навчального Дизайну.

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# Theoretical and methodical aspects of the organization of students' independent study activities together with the use of ICT and tools

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**Abstract**. In the article the possibilities and classification of ICTs and tools that can be used in organizing students' independent study activities of higher education institutions has been explored.

It is determined the students' independent study activities is individual, group, collective activity and is implemented within the process of education under the condition of no pedagogy's direct involvement. It complies with the requirements of the curriculum and syllabus and is aimed at students' acquisition of some social experiences in line with the learning objectives of vocational training.

The analysis of the latest information and technological approaches to the organization of students' independent study activities made it possible to determine the means of realization of the leading forms of organization for this activity (independent and research work, lectures, consultations and non-formal education), to characterize and classify the ICTs and tools that support presentation of teaching materials, electronic communication, mastering of learning material, monitoring of students' learning and cognitive activity, such as ones that serve for the sake of development and support of automated training courses, systems of remote virtual education with elements of artificial intelligence, which implement the principle of adaptive management of learning and the organization of students' independent study activities.

The paper provides the insight into the essence of the conducted investigation on the assesses of the effectiveness of ICTs and tools in the process of organizing students' independent study activities.

**Keywords**: students' independent study activity, process of activity's organization, ICT, ICTs and tools.

# 1 Introduction

## 1.1 Statement of the problem

The globalization and informatization processes are widely recognized to have led to a steady increase in the volume of information, have significantly raised the intensity and power of information flows, have highlighted the problem of content, volume, logic, means and ways of organizing the mastering of knowledge and experience of humans in the higher education institutions. The problem of organizing the students' independent study activities has become a matter of importance and significance in the conditions of changes in educational paradigms from the concept of knowledge-oriented education "for life" to education through life, that is, continuous education, that is mainly carried out on the basis of person's self-initiative and activism.

Obviously, the nominal increase in the volume of students' independent work without introducing changes in the structure and content of the educational process has resulted in most cases in a decrease in cognitive motivation among students, impedes the development of important personality traits and characteristics, impacts on the specialists' competitiveness and their professional mobility, doesn't ensure appropriate evolution of students' abilities in learning throughout their life and doesn't allow them to master new technologies. In terms of information society researchers are seeing new wide perspectives in the active introduction of modern information and communication and network technologies, computer based technology, tools of transfer and exchange of information. At the same time the development and mass application of ICTs is seem to have caused significant changes in the informational and educational spheres of a higher education institution.

Therefore, the introduction of a new structure, the latest ICT tools into the administration and self-management of the students' independent study activities requires investigation and research.

## 1.2 Analysis of recent research and publications

By the thorough researches of the scientists in the past and present days (Anatolii M. Aleksiuk [1], Ivan M. Bendera [3], Volodymyr I. Bondar [6], Volodymyr K. Buriak [7], Oleksandr H. Kolgatin [20], Vitalii A. Kozakov [22], Oleksandr V. Malykhin [28], Aleksandr G. Molibog [33], Pavel I. Pidkasistyi [38], Serhii V. Sharov [43], Mykola M. Soldatenko [46], Nataliia P. Volkova [36], Viktor I. Yevdokymov [40], etc.) it was found that the independent study activities are not only a continuation of the student's study work, but it is also conditioned and is means of forming the personality traits that are especially valuable for specialist-and-experts in their personal and professional self-improvement such as e.g. self-organization, self-actualization, self-identification, self-evaluation, self-control, self-reflection, etc. [3, 28].

Evidently, in the context of reforming the system of higher education in Ukraine, due to the need to bring it in line with the best world standards the problem of effective designing and organization of independent study activities is acquired of particular significance. The documents of the Bologna process, international research projects as well as the adoption of the "National Qualifications Framework" (2011), the Laws of Ukraine "On Higher Education" (2014) and "On Education" (2017), etc. have become a powerful foundation for the conceptual changes in national educational system. It caused the revision of the traditionally formed basis of students' study activities in the direction of increasing their personal and competent orientation, activity and independence in the choice of goals and priorities, orientation towards the construction of individual educational trajectories [5, 12, 13, 16, 39].

According to Yurii O. Zhuk, the mass ICT implementation in the educational process has required the development of special tools, which, according to the pedagogical situation, offer a certain set of options and means that extend the spectrum and enrich the students' study activity [59, p. 40].

Over and above, and also more extensive opportunities for academic mobility of teachers and students, the increasing role and importance of non-formal, distance and dual education [48], have led to the development of qualitatively new educational standards and programs as well as integrated and hybrid academic disciplines, which cannot be high-quality learnt without use of the modern ICT (Aleksandr A. Andreev [2], Valerii Yu. Bykov [9], Roman S. Hurevych [19], Maiia Yu. Kademiia [19], Petrus A. M. Kommers [21], Mykhailo M. Koziar [19], Volodymyr M. Kukharenko [23], Olekasndr V. Merzlykin [30], Natalia V. Morze [21], Serhiy O. Semerikov [42], Eugenia M. Smyrnova-Trybulska [21], Yurii V. Tryus [51], Ivan M. Tsidylo [8] and etc.).

It should be noted, nowadays in higher education institutions the gradual abandonment takes place to the widespread use of traditional non-electronic study technologies whereas the ICTs continuous implementation in all forms and types of students' independent study activities. However, a significant amount of information resources that has developed and is used by lecturers is usually applied unsystematically, and this fact does not contribute to the proper performance of vocational training's tasks.

### 1.3 The purpose of the article

The purpose of the article is to explore the possibilities and classification of ICTs and tools, as well as to analyze the degree of productivity of their application in organizing students' independent study activities in higher education institutions.

## 2 The theoretical backgrounds

Due to the results of the analysis of the primary sources, it has been established the *independent study activity* is such activity, which is a logical continuation of study work, it embodies the educational and cognitive minimum ensuring the autonomously mastery of students by determined level of professional competences. In line with its content, it is individual, group, collective activity and is implemented within the process of education under the condition of no lecturer's direct involvement. It complies with the requirements of the curriculum and syllabus and are aimed at students' acquisition of some societal practices in accordance with the learning objectives of vocational training (Anatolii M. Aleksiuk [1], Ivan M. Bendera [3], Nataliia I. Boiko [4], Volodymyr I. Bondar [6], Volodymyr K. Buriak [7], Vitalii A. Kozakov [22], Serhii M. Kustovskyi [24], Anatolii I. Kuzminskyi [25], Oleksandr V. Malykhin [28], Aleksandr G. Molibog [33], Pavel I. Pidkasistyi [38], Iia M. Shymko [44], Mykola M. Soldatenko [46], Oleh O. Tsys [52], Svitlana H. Zaskalieta [58], etc.).

By virtue of the content analysis of initial categories, such as "information technologies", "computer based technologies", "communication technologies", as well as existing numerous researches, in the context of the investigated problem of organizing students' independent study activities we consider the *ICT*s as a systematic range of techniques and forms of knowledge acquisition and ways of learning on the basis of lecturer-student and ICT tools interaction aimed at the achievement of expected accomplishments of the educational process (Svitlana M. Hryshchenko [34], Yevhenii O. Modlo [31, 32], Yurii L. Novikov [50], Polina A. Novikova [50], Ivan O. Petrytsyn [37], Tatiana V. Rudenko [41], Andrii M. Striuk [29], Valentyn M. Tomashevskyi [50], Ivan M. Tsidylo [8], Serhii M. Yashanov [56], Elena V. Zakharova [57], etc.).

The conducted our own research of the content and essence of organization of students' independent study activities with the use of ICT has made it possible to identify and characterize the *leading forms of its organization*: independent and research work, lectures (electronic, multimedia, video, audio ones), consultations (synchronous, asynchronous, delayed, remote, network, local, online, offline ones) and non-formal learning (electronic, user, distance learning courses) [52].

The essence of ICTs is represented as a system which includes: technical, methodological, substantive environment and software and hardware which accompany and support different aspects of the organization of students' independent study activities via appropriate ICT and tools (see Fig. 1).

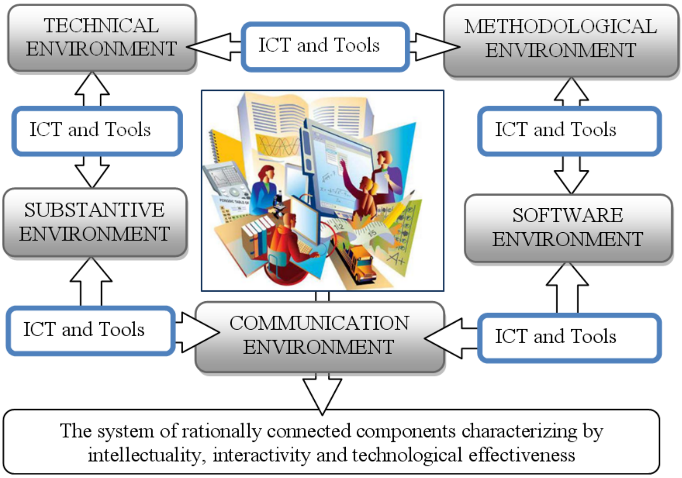


**Fig. 1.** Contents of information and communication technologies

Useful ICTs in the organization of students' independent study activities are multimedia, interactive, hypertext, cloud computing, telecommunication, Internet technologies, SMART technologies, web technologies, as well as technologies of virtual information space and automated library-and-information systems [52].

## 3 Findings

Nowadays there are many software products, widely available open author's apps, cloud and local services that offer a variety of ICT and tools. They can be embedded in existing forms and what's more caused perfect methods of students' self-learning without any significant additional time expenditures. In our study, we consider ICT and tools in the scope of minimal, desirable and predictive ones. First of all, the basic ICT and tools include the software and hardware part of multimedia. There are PC, the input, output and communication devices, the devices of storage and transmission of large amounts of information and their software, and over and above the tools of mobile ICT. Additionally, we take into account such ICT and tools that enable the recognition and synthesis of human speech together with multilingual support.

Consideration the specifics students' independent study activities in institutions of higher education, we present the ICT and tools' classification (see Fig. 2).

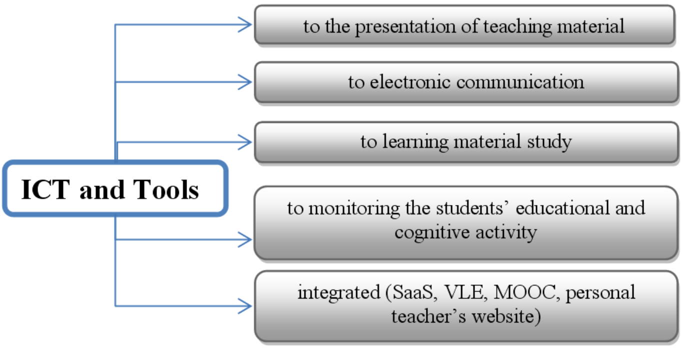


**Fig. 2.** The classification the ICTs and tools for organizing students' independent study activities

Offer you to consider further each group of ICT and tools in more detail.

### 3.1 ICT and tools for the presentation of teaching material

The all existing diversity of software and hardware tools for creating and presenting certain educational content and general methodological support that students could use in their own autonomous learning may be united in *ICT and tools for the presentation of teaching material.*

As just before computer occurrence and its widespread distribution now lecturer both creates a methodological support for leaning the discipline or its separate sections and develops educational content. With the use of ICT this process slowly but surely gets more automation and flexibility. The author's software products, prepared by the lecturer, are the result of processing a certain technology with using office packages, text and graphic editors, automated design tools. In fact, today the lecturer's relevant information competence is not only desirable, but is considered as demands of the times [55]. At the same time, the most trained in this regard, scientific-and-pedagogical personnel represents their educational and methodological text-books in the form of electronic lectures, study presentations, electronic teaching aids, they place educational information on the pages of personal websites and use thematic blogs of social networks.

To prepare the multimedia presentation today, the Microsoft PowerPoint product could be used, as well as applications for creating animated video presentations in the format of "hand drawn" (Algodoo, Sparcol VideoScribe, and PowToon), cloud services GoAnimate, Prezi, Google Slides, Zoho Show, Haiku Deck, Visme and many others that allow not only to make presentations but also receive real-time help to improve them [47].

It is generally accepted that a learning book remains the most important source of knowledge. Theoretically, an e-book can be prepared using a text editor and, by means of hypertext technology, it can be structured for the benefit of quick navigation on it. At the same time, modern ICT and tools enable the creation of full-time didactic means for students' self-learning activities. There are both the simple HTML documents (HTML Help Workshop, HTML Help ActiveX control, HTML Help Viewer, Microsoft HTML Help Image Editor, HTML Help Java applet, HTML Help compiler, HelpMaker) and full-fledged textbooks in such formats as html, chm, pdf and exe that support speech, animation, video and simulation (SunRav BookOffice, eBooksWriter LITE, Help & Manual, Sophie, ExeBook, Maestro STANDARD, HTML Book Maker, Document X), as well as other leaning materials, trainings, courses, demonstrations, help manuals (Adobe Captivate), etc. [2].

With the object of teaching materials' granting there are the repositories for data sharing and knowledge sharing, the educational resources, the electronic libraries, the file sharing networks (Usenet, Citrix), the knowledge bases, the distributed knowledge bases, the cloud storages (Dropbox, Google Drive, 4shared, Amazon S3, CloudMe, etc.) on the Internet [42].

The stream multimedia is far and away a great opportunity for students to organize their independent study activities by themselves. It means the information in a multimedia format that is continuously received by the user from the provider which offering streaming broadcasts (Internet radio, Internet-TV, video collections, educational programs, etc.) [42].

Significant advantages for the organization of student's independent study activities are next:

- thematic channels of YouTube, where there are collections of video tutorials, presentations, educational videos, multimedia lectures, created directly by teachers and individual training centers (https://www.youtube.com);

- TED (Technology Entertainment Design) presentations, they are lectures collection on topics of science, art, design, politics, culture, business, global issues, technology and entertainment industry (https://www.ted.com);
- the Khan Academy, it is open online platform featuring short video tutorials (5–15 minutes) on various subjects as well as tests helping visitors to measure the level consciousness of leaning information (https://www.khanacademy.org);
- Wolfram|Alpha, it is knowledge base, a set of computational knowledge engine and a question-based system, containing, in particular, the necessary information for the mastery of engineering, technical, technological, computer knowledge (http://www.wolframalpha.com);
- the services of corporate social networks (Podio, Yammer, Chatter, SocialCast, Bitrix24) that allow users to centrally store all working materials in one place, attach files and add comments;
- the services and tools for creating thematic websites for the demands of teachers and students (WordPress, Ucoz, Strikingly, Imcreator, etc.). They can build a site using a template set and in any case, they don't need web programming knowledge.

### 3.2 ICT and tools for electronic communication

The next step in organizing students' independent study activities is to establish feedback, planning and carrying out consultations. This process can be provided by *tools of electronic communication.*

The leading direction of consulting is the use of electronic network communicators and IP-telephony. The actual state of the development of network technologies allows to apply the free features of Skype, Viber, WhatsApp, Google Talk, Facebook Messenger, iMessages for the organization of study work both individually and in chat, as well as thanks to email and cellular communication.

Webinars, web-forums, web-conferences, teleconferences, which are implemented in both synchronous and asynchronous regimes, are effective means of communication organization; in particular within the framework of students' research work. It enables students to organize the communication on a specific topic of their interest in a convenient time. Such platforms as BigBlueButton, V-Class, GoToMeeting, iMind, WebEx [23] can be used for technical support of web-conferences.

It should be taken into account that the virtual boards (Padlet) are fairly well-approved in organizing students' independent study activities. These are web sites allowing to communicate with other students via text messages, photos, links, etc., that placed on such a virtual message board. This tool enables to set up equal access for multiple users who can view and add their materials.

What's more with the development of the Internet technologies, feedback and counseling in the system of students' independent study activities can be provided in thematic groups of social networks namely Facebook, Twitter, Instagram, etc.

### 3.3 ICT and tools for learning material study

It is well known ICTs provide exceptional opportunities for autonomous student learning. This quality is supported by *ICT and tools for learning material study.*

It should be noted the hardware and software capabilities of ICT can effectively organize independent carry out by students of multilevel educational tasks in virtual (digital) laboratories in a number of academic subjects, both technical and humanitarian [51].

In fact, the virtual lab has a complete set of properties typical of the traditional organization of scientific research. Its application in the learning process allows to expand the range of solved tasks, helps students to create mathematical models of devices, to test different modes of their work, to explore a wide range of phenomena and processes, to carry out an instrumental diagnostics and detailed analysis of the results with together using computer software — electronic calculators, graphs, summary tables, diagrams, models and others. In this case, the advantage of virtual laboratories is the possibility of independent and remote conducting of researches with significant saving of material equipment and training means, observance of the requirements of protection and occupational health [35].

Among the virtual labs, one can identify those that function on the basis of software emulators reproducing software or hardware, or a combination of the work of other programs or devices, and simulation programs simulating the state of the modeled system for executing the original machine code [37].

It is supposed the examples of ICT and tools for the creation of virtual research and teaching laboratories are STAR (Software Tools for Academics and Researchers), VirtualLab, Algodoo, PhET, Wolfram Demonstrations Project, there are also many cloud services that enable users to directly conduct both virtual laboratory researches and to process mathematical statistics with applying their results (MATLAB, Statistics). It should be noted that these tools let to development and functionate full-fledged pedagogical software means for the methodological provision of students' independent study activities [35].

An important place in the system of training specialists in technical area is engineering, design and technological activities. Their formation covers the assimilation and application of modern automatic designing systems, and not only during the study of certain academic subjects, but also in terms of supporting coursework and qualification design (drawing, sketching, animation of processes, preparation of sketches) [18].

CAD system is a program for designing and issuance of working project documentation allowing to study project ideas and visualize concepts through photorealistic visualization, as well as to model the behavior of products in real-world conditions [31]. There are the most commonly used CAD tools — AutoCAD, NanoCAD, Compass 3D, FreeCAD, T-FLEX CAD, SolidWorks, Simulink, on top of the animation programs — Maya, 3ds Max, Corel Draw, CorelCAD, University MD Motion Bundle, etc.

The students' supervision from the direction of lecturers can be provided through a project management system. The service enables the reproduction of a complete design cycle: objectives and results trees, project life structure phases, organizational structure of the project, matrix of distribution of responsibility and allocation of works between the performers (if the project is collective), network model of the sequence of project execution, resource tree, cost tree, description of project risks, etc. Among the ICT and tools supporting project management are Microsoft Project, Casual, Bullet Journal, Evernote, Trello, SCIM.ru and others [54].

Implementation of learning projects, conducting research in the network is being supported by Web 2.0 technology, through which such systems operate, that, by accounting for network interactions, they become the better, a lot of people use them [49]. These technologies, including the wiki, Google, Flickr, Digg.com, and blogging services, allow students to engage in self-search research on specialized sites as contributors, copywriters, critics, bloggers, commentators, etc. Therefore, together with the acquisition of educational information, this kind of independent study activity contributes to the formation of self-esteem, broadens the horizons, and develops students' communication skills.

### 3.4 ICT and tools for monitoring the students' educational and cognitive activity

The scientific based organization of students' independent study activity involves systematic control, self-control and correction. For this purpose the special means with ICTs for *monitoring the students' educational and cognitive activity* are being used.

Predictably the most successful and effective is test control appreciating the knowledge that students mastered by themselves, since it enables to objectively, impartially and promptly find out the quality of assimilation of learning information. The software market provides a wide range of ICT and tools for computer testing that let the user to select different test presentation formats, the test structure, and how to evaluate its execution (tempo, time, use of tips), styles of input and choice of answers, type of organization under time of testing knowledge (number of attempts, time limit, arbitrary choice of questions for the answer, the possibility to randomly select a certain number of questions from the general database of tasks, the introduction of statistics), the ways giving of the test results (in general, for each task with the demonstration of the correct answers, the formation of group information) [52].

The study-and-control programs of linear and branched-off character are considered to have the most widespread. The programmed learning's concept founded their expediency and optimality. The purpose of such programs is to prevent students' errors. If branched-off study-and-control programs are being used, after the test the student is provided with the analysis of the results, as appropriate the correct answers are shown, explanation to the assumed errors is given, the references to those aspects of the learning material that need to be finalized is pointed out. In that case the student has the opportunity to independently determine both the order of passing the test and studying portions of the learning material. In our opinion, such a variant of study-and-control programs is more adapted to the individual characteristics of students, but there is danger of losing control over the performance of independent work. So, each type of study control program must find its place in the system of students' independent study activities [55].

In a nutshell we would like to cite the ICTs and tools as an example that could be used to build testing control of students' knowledge. These are MyTest, MiniTest-SL, ExeTest-SL, OpenTEST, Quick Exam, FreeXTest, Assistant, Test Designer, etc.

Furthermore, the Internet offers a number of cloud-based services that create on-line quizzes by virtue of the principle of gamification. The quite professional and versatile services in this respect are Kahoot (https://getkahoot.com) and Quizizz (https://quizizz.com) that contribute to build and conduct quizzes and surveys, with the use of mobile devices. The tool lets the test organizer adjust the tempo, speed, time limits for each task, and add additional marks for the estimation of speed or sequence of tasks performed by each student [14].

Certainly, above we considered the most well-known and promising ICTs and tools in terms of organization of students' independent study activity.

### 3.5 Integrated ICT and tools

At the same time, we would like to emphasize specially created ICTs with educational purposes, they are *integrated ICT and tools* that cover all of the above listed aspects of organization students' independent study activities.

These include Internet technologies and SaaS (software as a service) cloud-based technologies [17]. They allow storing data and associated applications on specialist servers that let solving the tasks of organizing students' independent study activities. The most common are Microsoft Office 365 Education and Google Apps for Education, as well as cloud-based services have been made on their basis. Their benefits are next: they are either full or in a practical manner free as well as availability and widespread [23].

In particular, the Google Apps for Education cloud platform offers the following ICTs and tools: text, voice, and video, chat, email; Google Drive — a data warehouse (15 to 30 Gb) for storing files, setting access rights to them with the possibility to post to the Internet; as well as a number of tools — Google Docs for making documents, spreadsheets and presentations; Google Group to create mailing lists and discussion groups; Google Calendar — a calendar for planning and managing meetings, tasks, and event sharing; Google Forms for surveys and tests, Google Sites — for generation sites using templates. It should be taken into account the fact that the list of tools is constantly expanding.

According to experts, the use of ICT in the organization of study activities was based on general-purpose services. Then special services appeared and integrated the individual functions of e-learning (for example, the "virtual class" model); their evolution led to the creation of the concept of Virtual Learning Environments (VLE) [23]. Its main representatives are:

1. Learning Content Management System (LCMS) enabling the placement and manipulation of electronic teaching materials in various formats. This system is convenient in the case when the created system of educational courses uses a lot of common fragments of educational information;

2. Learning Management System (LMS) is mainly applied in distance learning.

In the educational process today, various platforms for managing integral training courses are being actively used, including Moodle, Claronline, ATutor, SharePointLMS, Live@EDU, eFront, Prometheus, Dokeos, etc. Their advantages and disadvantages are considered in detail in their publications of Bohdan A. Demyda [11], Halyna I. Haidur [55], Andrii I. Hladyr [11], Mykola P. Hnidenko [55], Oleh O. Ilin [55], Polina A. Novikova [50], Yurii L. Novikov [50], Serhii O. Sahaydak [11], Valentyn M. Tomashevskyi [50], Viktor V. Vyshnivskyi [55], Nataliia V. Zachepa [15] and many others [23].

Among the principles of social constructivism [49], which is the basis of the LMS project, we emphasize one very important for our study, it is the opinion that the learning environment should be flexible and should provide a simple tool for the participants in the educational process to fulfill their learning needs [55]. This certainly makes LMS a powerful tool for organizing students' independent study activities.

Any distance learning system is being based on the context-modular principle and covers, as indicated by Bohdan A. Demyda, Serhii O. Sahaydak and Irena Kopyl, such modules as: administration of the system; organization and support of the educational process; development and maintenance of testing; design and presentation of all kinds of learning materials in the system; export-import of their various formats; interactive user cooperation; user potency registry [11]. These sections, blocks and modules can be applied separately and together in line with specific goals and tasks of studying those or other subjects.

The analysis of the functional capabilities of these interactive modules makes it possible to identify their essential advantages for the organization of students' independent study activities in all its forms — independent and research work, types of consultations, as well as to build on its basis a functional electronic resource that reflects and supports academic discipline.

What's more, there are commercial Blackboard, WebCT, Microsoft Learning Gateway, Prometheus, WebTutor, Virtual University, and freeware ATutor, ILIAS, Sakai among widespread virtual learning environments [55]. The distance education functions on these platforms and creates chances for organizing students' non-formal education.

It is a peculiarity of online education that students and lecturers are separated in space and time, and the interaction between them takes place in a virtual environment [42]. Online Educational institutions are commonly referred to as “virtual universities”. Their functioning is being based on the four systemic principles of open education: they are formulated by Valerii Yu. Bykov, namely: mobility of subjects of the educational process; equal access to educational systems; providing quality education; formation of the structure and implementation of educational services [9, p. 55–56].

Massive open online courses (MOOC) allow students to be taught by lecturers from leading world universities, to join a multinational student community, and to receive a document confirming the successful completion of the entire course. The largest online platforms offer electronic lessons with subtitles and printed learning material; video materials; enable conduct a meaningful evaluation of the knowledge gained. To help the student methodical and reference material is given, the opportunity to discuss learning issues and tasks at the forum is added, credit for regulate the speed, the pace of training are taken. They are Coursera, Khan Academy, EdX, Udacity, Canvas Network, Udemy, FutureLearn, FUN, Prometheus on-line platforms that provide such user-friendly courses [11, 42].

When all’s said and done above we mark that the processes of ICTs’ unification and universalization of eventually ensured the development of various types’ separate universal training modules. Ones could be part of several technologies for the organization of students’ independent study activities [45, p. 85].

*The personal teacher’s website* is a means of interactive distance cooperation between participants in the educational process. It could be considered as the holistic ICTs that capable of providing pedagogical management to the organization of students’ independent study activities [26, p. 66]. It is an interactive didactic tool through which the cooperation between all participants in the pedagogical process — teachers, lecturers, students, potential entrants, employers, graduates, etc., is organized. An equally important aspect of such interaction is the possibility of individualization of independent study in the view of student’s cognitive or professional perspective.

On their content there are several types of teachers’ websites, in particular:

- the *business card site* presents the image of the teacher, his scientific interests, the most profound scientific and methodological works, photo-collections, it contains general information about him/her and the courses that he teaches. In addition, such a type of site enables the implementation of operative feedback with students for consulting and organizing their research work;

- *portfolio site* that usually includes general information about person, results of scientific and pedagogical activities, scientific and methodological works, lecture notes, electronic textbooks, examples, reference samples, and tasks for students' independent work, multimedia collections, leaning models, etc.;
- the *subjective site* that is a specialized online resource for the organization and control of students' independent study activities for a fixed educational discipline. Typically, the structure of such type of site is determined either by thematic lines of the course, or by types and forms of students' independent work (section for ongoing work, for conducting a study project, preparation of term paper, web-quest, for laboratory and practical classes, lead-up for exams or credits, etc.). The quality of subject site is determined by the presence in its structure of information relevant to students, dynamic and multimedia models of investigated phenomena, video materials, references to digital educational resources, cloud services; presentations, automated tools for self-control;
- the *educational site* is considered to have wider possibilities, in comparison with the above presented one, in the organization of students' independent study activities. Its main purpose is to help students build their own educational trajectories, to promote deepening and expanding knowledge in the chosen specialty. Here could will be found top news and announcements, latest video materials, links to educational, scientific, library and other resources, will be introduced to holistic self-education electronic courses, it will be possible to organize interest communication in specialized chats;
- the *combined site* that has two or more of the above types of sites in its structure [26].

The technological basis of such websites can serve as specially developed platforms for distance learning that are provided to the user almost for free: they are Moodle, Google services, Edmodo, Studyboard, etc., and moreover ordinary social networks. In their structure, the main features of management of students' independent study activities are laid.

When creating a site, a specialist programmer uses specially designed programming languages (PHP, HTML, JavaScript, etc.). However, a website builder tools can generate a site applying user-friendly simple settings. There is the possibility of making sites, both on the basis of Content Management Systems (CMS) and applying SaaS platforms, although in this case, the service is paid [55].

## 3.6 Criteria for the effectiveness organizing of students' independent study activities via the use of ICTs and tools

It is observed that the organizing of independent study activities with the use ICTs tools is considered an effective one if the students gain a certain amount of knowledge at the appropriate general scientific and professional level, forming the important features of their personality, necessary for further intellectual and professional development. At the same time, the independent study activities has been carried out on the basis of self-management by students and the systemic indirect mediated management by lecturers as well as rates of mental labor, sanitary and hygienic and ergonomic requirements in the application of ICTs have been taken into account.

The effectiveness of the organization of students' independent study activities can be assessed by a number of criteria. Obviously, the students' motives and motivation determine their personal meaning, are the main factors of one's effectiveness, especially in terms when the classroom training has been reducing. Starting independently, based on their needs, the student has put forward a specific goal. Therefore, the goal is being defined as a conscious need, as a marking of a desired result that is being directed the student's activity towards achievement it [53]. Thus, activating the students' cognitive interests, initiating their creative initiative, and the desire to perform the proposed learning tasks in a qualitative and timely manner, to master and apply for the sake of these newest ICTs is the first urgent step in organizing an effective students' independent study activity [3]. The next step is to build a content and instrumental basis for independent study activities. This involves, firstly, the formation of students' teaching and methodological knowledge for the organization of autonomous learning, as well as methods, techniques and skills for solving the set of educational tasks with the wide application of ICTs. In the end, the effectiveness of the functioning of such a system is assessed by educational, cognitive and personally significant products of students' independent study activities.

In that way, based by the structure and content of the system of students' independent study activities, *criteria for its effective organizing* are: *motivational*, *substantive*, *organizational* and *productive* one. At the same time, considering the general state of the effectiveness of the organization of the studied activities, one requires a separate study and investigates the *technological ability criterion* of the educational process. Thanks to it we could be estimate the motivational provision of the students' and lecturers' functioning in the organization of independent study activities together with the use ICTs and tools; make diagnostic and appreciate efficiency of the investigated process; design the content of independent study activity by way of a system of cognitive and practical tasks as well as an indicative basis and methods of their solution; achieve algorithmicity, optimality, integrity and controllability of the process organizing students' independent study activity with the use of ICT and tools; amount the effectiveness and developmental nature of students' self-study and whatever (Dmitrii V. Chernilevskii [10, p. 18–25] and others).

Describing the level of efficiency organizing of students' independent study activity via the use of ICTs and tools we proceed from the features of educational activity as a process that can have different degrees of implementation and the subject of management. Therefore, taking into account the above-mentioned, we distinguish four levels, these are insufficient, critical, sufficient and proficiency one.

### 3.7 Brief description of the content of the pilot-and-experimental study of the effectiveness the use of ICTs and tools in the organizing of students' independent study activities

Pilot work has been carrying out for the years 2016–2017 and has covered 240 students of 2–3-courses of technological and pedagogical area of expertise of 2 HEI of Ukraine; they were Kryvyi Rih State Pedagogical University and Poltava National Technical Yuri Kondratyuk University [27].

After a theoretical justification the components of the informational and educational environment of higher educational establishments aimed at satisfying the educational needs of students in the organizing of independent study activities have been defined and specified. They cover:

- the website of the institution, which includes presentation and teaching materials of the institution and individual specialties, library repository, automated library frames, built-in platforms for the use the Learning Management Systems (in particular, Moodle), systems for automated learning inspection;
- the departments' educational-methodical complexes;
- the specialized web-sites of departments and personal lecturers' web-sites for organizing students' independent study activities from disciplines of curriculum;
- the open electronic educational resources.

In the framework of the forming experiment, the selection of ICTs and tools as well as the corresponding technological models that described above has been carried out. The criteria for their choice were as follows:

- *the general didactical* ones providing scientific, professional orientation, systemic, consistency, connexion a theory with a practice, computer and "traditional" visualization of the educational information, consciousness, activeness and independence of students in knowledge acquisition;
- *the general psychological* ones that allow for friendly dialogue interface, quality of screen design (color, contrast, clarity, size, speed of change of information, etc.), taking into account the students' age and individual characteristics, bring in both of motivation means for their independent study activities, and pedagogical and computer support in organizing their autonomous learning;
- *the methodical* ones providing planned, algorithmic, staged and sequence in the study of learning information, as well as feedback between the lecturer and student, last and not least the unified approach to the organizing independent study activities in any learning environment;
- *the technical* ones, these are accordance hardware tools with software and operational documentation, the ability to create a seamless learning environment, produce a synchronous and asynchronous training communication mode, provide software stability for incorrect users actions;
- *the ergonomic* ones by virtue of them the functional comfort in work, correspondence of aesthetic design of certain learning objects to their functional purpose are being guaranteed [55].

We also took into account such specific requirements as the ability to use ICTs and tools on portable mobile and media devices without software interference in their content.

For the scientifically grounded management by students' independent study activities of technological and pedagogical area of expertise the steps to distribute the ICTs and tools according to the leading forms its organization have been taken; we means the independent and research work, lectures, consultations and non-formal learning (see Table 1).

In addition, the didactic supply of the organization of students' independent study activities of technological and pedagogical area of expertise with the use of ICTs and tools have been created and adapted.

**Table 1.** Ways of implementation the forms organizing the students' independent study activity via the use of ICTs and tools

| **The forms organizing the students' independent study activity** | | | | |
|---|---|---|---|---|
| **Independent work** | **Research work** | **Lectures** | **Consultations** | **Non-formal learning** |
| • Lecturer's Web-site<br>• Web-quest<br>• Portfolio<br>• Training project<br>• Virtual Laboratory Classes<br>• Training simulators<br>• Study-and-control programs<br>• Electronic educational resource<br>• CAD<br>• Systems for automatic control of objects and models<br>• Knowledge bases<br>• Databases<br><br>**ICTs and tools**: for the presentation and learning of teaching material, for monitoring the students' educational and cognitive activity | • Service projects<br>• Presentation portfolio<br>• Project's portfolio<br>• Web-forum<br>• Web-conference<br>• Webinars<br>• Network publications<br>• Wiki-projects<br>• Web-based programming<br>• Multi-design<br><br>**ICTs and tools**: for providing an electronic communication, for virtual education with elements of artificial intelligence | • Multimedia lectures<br>• E-lectures<br>• Lecture-and-visualization<br>• Video tutorials<br>• Micro-lessons<br>• Thematic blogs<br>• EBook<br>• Electronic library<br>• E-learning resources<br>• Useful educational resources<br>• Thematic library collections<br>• Knowledge bases<br>• Databases<br>• Infographics<br>• Virtual museum<br>• Video channels<br><br>**ICTs and tools**: for the presentation of teaching material | • Video tutorials<br>• Workshops<br>• IP telephony<br>• Interactive counseling<br>• Network consulting<br>• Correspondence<br>• Work in the list of links<br>• Chat<br>• Blog<br>• Video-chat<br>• Virtual bulletin board<br>• Useful educational resources<br>• Administration and management as a service<br>• Webinars<br>• Gamification (web-quests)<br>• SMART Table Training Center<br><br>**ICTs and tools**: for provide electronic communication | • User e-course<br>• On-line course<br>• Distant education<br>• Thematic educational channel<br>• Virtual universities<br>• Planetary classes<br>• MOOC<br><br>**ICTs and tools**: for creating and managing automated learning courses, remote virtual education systems with elements of artificial intelligence |

They were the electronic educational content, if in a nutshell — electronic lectures, electronic educational books, electronic educational kits and whatever. At last the electronic, mobile, combined, mixed learning technologies as well as ones of training, coaching, gaming, design, test, rating have been tested and endorsed.

It has been tested the models of blended learning. First of all, it was the stream model that via an educational web-site has concentrated in itself an invariant core of students' independent study activities and has integrated with traditional technologies through so called model “Flipped classroom”. The potentials of axial model that included user's custom electronic courses of curriculum disciplines as interactive educational modules on the Moodle platform has been studied. The variety of ways for mixed self-study learning has also been implemented.

### 3.8 Analysis of the effectiveness of the use of ICTs and tools in the organization of students' independent study activities

Focusing on this task we have investigated the changes that occurred in the levels organizing of students' independent study activities with the use of ICTs and tools on the grounds of productive and technological ability criteria. Such work meant the study of the quality of mastered by students the knowledge about disciplines of the curriculum, the specific types their professional activity in the system of independent work, research work and non-formal learning, as well as the degree of technological efficiency of these processes.

Diagnostics on a productive criterion has carried out on the basis of “Rating card of the student's self-study activities”. In this mean we have included such following positions: the standardized components of the basic level of organization of independent study activities (current student's learning progress, systematic independent work, accorded independent work (educational projects), work in the informational educational environment of higher educational establishments); components of an in-depth and professionally oriented level (student's research work, work with electronic educational resources of subjects); non-formal learning (study in user and additional electronic courses developed by both the lecturers and in the system of open distance education).

While the experimental research, we have been able to determine thanks to such the card, the degree of activity, autonomy and systematic, effectiveness and productive performance of each student's individual study activities. Due to this card we have standardized the performance of each type of work by virtue of addition to basic students' result both supplementary and penalty marks.

The obtained results are presented in the Table 2 as well as on Fig. 3.

As you can see the quantitative data analysis of Table 2 reflects the changes in the attitude of students in the experimental group to independent study activities with together use of ICTs and tools in its organization.

Predictably, the introduction of special control and diagnostic procedures, systematic differentiated inspection and evaluation have contributed to increasing the level of students' activity in research work, as well as the application of qualitative new forms of its organization into the system of the students' independent study activities. We mean the webinars, workshops, video tutorials, thematic websites, user courses, electronic educational resources, whatever.

**Table 2.** Comparative dynamics of levels organizing the students' independent study activities with use of ICTs and tools in line with productive criterion (%)

| **Levels** | **Experimental group** | | **Control group** | |
|---|---|---|---|---|
| | **Output Stage** | **Final Stage** | **Output Stage** | **Final Stage** |
| Insufficient | 15.0 | 3.3 | 13.3 | 11.6 |
| Critical | 25.0 | 13.3 | 23.3 | 20.0 |
| Sufficient | 43.3 | 55.0 | 45.1 | 48.4 |
| Proficiency | 16.7 | 28.4 | 18.3 | 20.0 |
| Pierson $\chi^2$-criterion | $25.9 > 11.3, \ \rho = 0.001$ | | $1.1 < 11.3, \ \rho = 0.001$ | |

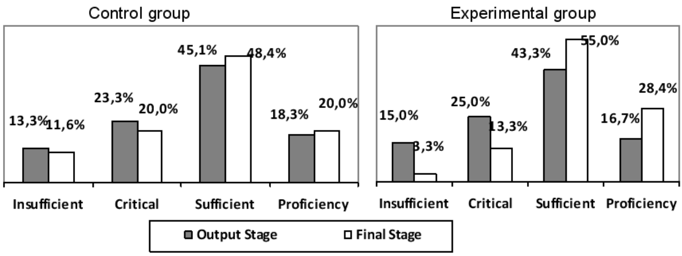


**Fig. 3.** Dynamics of the levels organization the students' independent study activity with the use of ICTs and tools according to productive criteria

The students have noted the expediency of developing a department's thematic website, the variety of offered courses for the acquisition of knowledge about ICTs and tools for educational and professional purposes, as well as orientation to opened online e-courses.

As you can see for data of Fig. 3, there is a positive, statistically significant dynamics in the levels organizing independent study activity for students in the experimental group in contrast to the students of the control group: 11.6% more students have shown the proficiency and sufficient levels of organization of the investigated activity via the use ICTs and tools.

The level of productivity of the organizing the students' independent study activities with together use of ICTs and tools has been estimated by the coefficient of efficiency:

$$K_t = \frac{K_c}{K_p}, \quad (1)$$

where $K_c$ and $K_p$ are in respectively coefficients of completeness of the fulfilled tasks by students with the used ICT and non-computer pedagogical technologies.

The data obtained are summarized in Table 3. We must notice, evaluating the efficiency, we did not take into account the use of ICT by students for text editing, automatic calculation, etc.

**Table 3.** The coefficient of effectiveness the use of ICTs and tools in the process of organizing students' independent study activities of technological and pedagogical area of expertise

| **Types of tasks** | **The coefficient** | |
|---|---|---|
| | **Output Stage** | **Final Stage** |
| Organization of educational communication in the "lecturer-student" system | 1.5 | 1.8 |
| Information search | 1.2 | 1.8 |
| Graphic, computational and practical tasks | 0.7 | 1.2 |
| Educational projects | 0.8 | 1.3 |
| Preparation of plans-synopsis of lessons for labor training and technologies | 0.6 | 1.1 |
| Laboratory and experimental research | 0.6 | 1.5 |
| Creation of portfolio | 0.5 | 1.1 |
| Creation of schemes, technological cards, consolidated tables, charts and diagrams | 0.7 | 1.5 |
| Self-monitoring, test control | 0.9 | 2.0 |
| Solving the technical creativity tasks | 0.6 | 1.1 |
| Working with the library catalog | 0.7 | 1.5 |
| Participation in the quest | 0.7 | 1.1 |

As you can see, in experimental groups there has been a significant increase in the use of ICTs and tools by students for solving educational problems. Such results were made possible by introducing into the educational process the varieties of ICTs and their technological models that have made it possible to integrate traditional and electronic tools into blended and mixed learning systems.

For the control group statistical analysis shows the changes in the level organizing students' independent study activities are being random and related to the general evolution of the individual students in the vocation training process.

## 4 Conclusions and prospects for further research

Consequently, the analysis of the latest information and technological approaches to the organization of students' independent study activities made it possible to determine the means of realization of the leading forms of organization for this activity (independent and research work, lectures, consultations and non-formal education).

In the current context, when the development and replication of educational software products becomes a business, the market is being filled with quite diverse and multiple products. Identification of the criteria for their quality and selection is getting increasingly issue of the day. Often, the criteria for such an assessment are the technical characteristics of software products that not directly related to the pedagogical and methodical terms for their creation. The quality of graphic design, reliability, availability and quality of documentation, etc. — all these criteria are definitely important, but in our opinion, they do not determine the main characteristics of educational software products. Therefore, the programmatic and methodological support of students' independent study activities based on ICT should include both software tools for teaching support and means that enable the lecturer to manage the learning process, its rational organization.

As for result of this study, the ICTs and tools for the organization of students' independent study activities have been characterized and classified. It was shown and described the ICTs and tools that support presentation of teaching materials, electronic communication, mastering of learning material, monitoring of students' learning and cognitive activity, such as ones that serve for the sake of development and support of automated training courses, systems of remote virtual education with elements of artificial intelligence, which implement the principle of adaptive management of learning and the organization of students' independent study activities.

In this publications the elements of the system of pedagogical work on the creation of informational educational environment of higher educational establishments functioning on the basis of the same educational principles in the process of organizing students' independent study activities with the use of ICTs and tools have been presented. The content and functional components of such a medium have been developed and tested in the framework of pilot-and-experimental work. They have enabled to effectively implement the leading forms and technologies via appropriate ICTs and tools, as well as have given statistically significant dynamics in the levels of organizing students' independent study activities in line with for productive and technological ability criteria.

Summarizing the analysis of the possibilities of integrating traditional and newest ICT into the organization of students' independent study activities, take credit that not only ICTs are important, but how their use serves the achievement of educational goals. Usually, the best educational result is being provided by a feasible combination of well-proven time traditional and innovative means of organizing students' self-study. Expediently, when ICT are being selected one should take into account their maximum compliance with the specifics of the students' training in a particular area of expertise.

Perspective in the development of this area, we consider the research content of students' independent study activities in the distance, dual and e-learning educational systems.

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## Теоретичні та методичні аспекти організації самостійної навчальної діяльності студентів з використанням інструментів ІКТ

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**Анотація**. У статті досліджуються можливості та класифікація ІКТ та їх інструментів, що можуть бути використані для організації самостійної навчальної діяльності студентів вищих навчальних закладів.

Визначено самостійну навчальну діяльність студентів як індивідуальну, групову та колективну діяльність, що здійснюється у процесі навчання за

умов відсутності прямого залучення педагога. Вона погоджена з вимогами навчального плану та програми і спрямована на досягнення учнями деякого соціального досвіду відповідно до навчальної мети професійної підготовки.

Аналіз останньої інформації та технологічних підходів до організації самостійного навчання студентів дає можливість визначити засоби виконання провідних форм організації цієї діяльності (самостійна та дослідницька робота, лекції, консультації та неформальне навчання), характеризувати та класифікувати ІКТ та їх інструменти, що підтримують презентацію навчальних матеріалів, електронної комунікації, опанування навчального матеріалу, моніторинг навчальної та когнітивної діяльності студентів, як-от тих, що служать заради розвитку та підтримки автоматичних підготовчих курсів, систем віддаленого віртуального навчання з елементами штучного інтелекту, які імплементують принцип адаптивного управління навчанням та організацією самостійної навчальної діяльності студентів.

Стаття забезпечує розуміння сутності проведеного дослідження стосовно оцінки ефективності ІКТ та їх інструментів у процесі організації самостійної навчальної діяльності студентів.

**Ключові слова**: самостійна навчальна діяльність студентів, процес організації діяльності, ІКТ, ІКТ та інструменти.

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# The areas of educational studies of the cloud-based learning systems

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**Abstract**. The article analyzes the current stage of educational studies of the cloud-based learning systems. The relationship between the notions of the cloud-based learning system and the cloud-based learning environment are investigated. It was found that the researchers paid most attention to the design of a cloud-based learning environment. However, in the process of a cloud-based environment design, the researchers consider a cloud-based system as a component within the cloud-based learning environment of as a stage in the process of design. It is shown that in the research literature there is no single interpretation of the concept of a cloud-based system for educational purposes. Still the number of basic approaches to the interpretation of the concept under investigation are revealed. The first approach is based on the understanding of the system, as a set of cloud services or cloud-based technologies. The second approach is to consider a separate cloud service as a cloud-based learning system. In this case, the cloud service tools should include such components that cover the content, the tools, the forms and the methods of learning. The structure of the cloud-based learning system within the interpretation of the latest works of Ukrainian researchers is considered.

**Keywords**: cloud-based training system, cloud services, cloud-based learning environment, structure of cloud-based training support system.

## 1 Introduction

### 1.1 The problem statement

The use of the cloud technologies and services in the educational process is a rather promising direction of modern educational research. At the same time, the cloud services have taken their place both in the educational process of secondary and also higher educational institutions (HEI). This is evidenced by numerous dissertations defended during the latest years devoted to the given topic: Georgii A. Aleksanian "Formation of independent activities of students of secondary vocational education in teaching mathematics using cloud technologies" (2014) [1], Liudmila S. Galkina "The methodology for the development of ICT competence of future economists and managers using cloud technologies in teaching the disciplines of the information cycle" (2017) [5], Serhii P. Kasian "Workflow Management institutions of postgraduate education based on cloud technology" (2016) [8], Maksym V. Khomutenko "A methodology of teaching senior students atomic and nuclear physics in a cloud oriented learning environment" (2018) [9], Olha V. Korotun "Use a cloud oriented environment to training future teachers of Information Science to master database" (2018) [14], Svitlana H. Lytvynova "Theoretical and methodological bases of designing cloud-oriented learning environment educational institution" (2016) [16], Oksana M. Markova "Cloud technologies as a learning tool of the foundations of mathematical informatics for students of technical universities" [18], Oleksandr V. Merzlykin "Cloud technologies as tools of high school students' research competencies forming in profile physics learning" (2017) [19], Serhii V. Palii "Cloud mechanisms of formation of information-organizational environment of pre-university training of students" (2014) [20], Maiia V. Popel "The cloud service SageMathCloud as a tool of mathematics teacher professional competencies formation" (2017) [23], Susana N. Seytveliyeva "Methods of teaching cloud future software engineers" (2017) [29], Viktoriia G. Shevchenko "Cloud technologies as a tools of forming ICT competence of future informatics teachers" (2016) [30], Mariya P. Shyshkina "Theoretical and methodological principles of formation and development of the cloud-based educational and research environment of higher educational institution" (2016) [31], Nataliia V. Skrynnik "Techniques of teaching Ukrainian literature in the $5^{th}$–$6^{th}$ classes using cloud technologies" (2017) [33], Mariia V. Stupina "Formation of students' competence in the field of using tools for developing information systems using cloud technologies (by example the training of future bachelors-developers of information systems)" (2018) [34], Tetiana J. Vdovychyn "The use of network technologies of open systems in the training of future bachelors of computer science" (2017) [39], Tetiana V. Voloshyna "The use of a hybrid cloud-based learning environment for forming the self-education competence of future IT specialists" (2018) [40] etc.

In addition, a number of planed research works were devoted to this topic: "Methodology of the cloud-based learning and research environment formation in the pedagogical educational institution" (SR No. 0115U002231, 2015–2017), "Adaptive cloud-based system of secondary schools teachers training and professional development" (SR No. 0118U003161, 2018–2020), "The development of information and communication competence of teachers in a cloud-based learning environment" (SR No. 0117U000198, 2017–

2019) etc. The interest of researchers for the cloud-based environments, cloud-based systems does not decrease despite the fundamental works made in this direction. Although such concepts for pedagogical science as "cloud technologies", "cloud services", "cloud-based systems", "cloud-based environments" are not new, but in research literature there is a certain mix of these concepts. In addition, the relationship between such concepts as "cloud-based systems" and "cloud-based environments" is not completely determined.

### 1.2 Literature review

Cloud computing provides rather new educational tools. They bring new digital resources, digital content, such as cloud-based teaching materials, multimedia learning content, virtual labs and administrative tools for educational institutions. They bring changes, progress and opportunities for HEI. By using cloud computing, the workload of IT staff is shrinking so that they can focus on strategies for more efficient use of IT infrastructure. Using cloud computing, students and teachers gain access to resources and collaborate with HEI, they can communicate and exchange resources and ideas with other students and teachers from various HEIs at any time and anywhere. Different educational institutions do not have the same software and hardware resources due to certain limitations such as financial and material and technical. The learners and staff can access these resources in the cloud by paying a nominal fee for cloud services. A HEI can access cloud resources according to the users needs, such as software, servers, computing machines, network devices, virtual labs, journals, textbooks, multimedia content, and other tools that are useful for their research and training. Thus, cloud computing is useful for HEI for conducting their research work and improving student learning as well as teaching and assessment practices of teachers [32].

Tetiana A. Vakaliuk in [38] gives the following interpretation of the "cloud-based learning support system" concept: "Under the cloud-based learning support system, we will understand a system in which the implementation of the didactic goals involves the use of cloud services and technologies, and ensures group collaboration of teachers and students, development, management, and distribution of educational materials with the provision of cloud-based technologies to the participants of the learning process" [38, p. 7]. The author defined in detail each component of the proposed model and their connections.

Maryna V. Rassovytska and Andrii M. Striuk do not give a clear definition of the concept of "system of cloud-based tools of learning".

However, the meaning of the term is given, rather descriptive. In the study [24], it is noted that those types of cloud-based learning tools defined by the authors constitute this system.

Although Svitlana H. Lytvynova does not specifically refers to the concept of a cloud-baseed system, the concept of a cloud-based learning environment is revealed through a system of cloud services: the cloud-based learning environment is an artificially constructed system that provides cloud-based learning with educational services mobility, group collaboration of teachers and students for effective, safe achievement of didactic goals [16].

Oleksandr M. Kryvonos and Olha V. Korotun clarify the notion of the cloud-based system of distance learning: "a cloud-based distance learning system is a cloud-based service for the organization of an educational process that allows the creation, management and dissemination of educational materials in electronic form, monitor and evaluate learning outcomes, and formulate accounting records" [15, p. 134–135].

In this case, Olha V. Korotun, emphasizes that such cloud-based system of distance learning should be as much easy to use and administrate as possible [13]. Problems that may occur during its use, as a rule, do not concern the user, they are taken by the company's developer. At the same time, the cloud-based system as well as any cloud services does not require additional installation on the device of third-party software, configuration and, moreover, powerful hardware. According to a Korotun's study it can be argued that such cloud-based systems, which represent software as a service, acquire the most popularity in Ukrainian HEIs in the educational process [12].

In further research, Korotun gives somewhat modified author's definition: "the cloud-based distance learning system is a distance learning system deployed within the cloud for organizing an educational process that allows the creation, management and dissemination of educational materials in electronic form, organisation of communication and collaborative work between learners, monitor and evaluate learning outcomes, and formulate accounting training documentation" [14].

Giving the analysis of recent studies of Tetiana A. Vakaliuk, Svitlana H. Lytvynova, Mariya P. Shyshkina and others, the design of the cloud-based learning environments their structure and composition are quite thoroughly considered. However, the cloud-based educational system represent a separate component of this environment structure (Tetiana A. Vakaliuk), or certain cloud-based services (Oleksandr M. Kryvonos and Olha V. Korotun) serve as the basis for further construction of the cloud oriented environment (Maryna V. Rassovytska and Andrii M. Striuk). Therefore, in order to outline different approaches to the definition of the concept of "cloud-based system for educational purposes" and its structure, it should be considered how Ukrainian and foreign scientists understand the notion of "cloud-based learning environments" and how these concepts relate.

### 1.3 The aim of the research

To outline the content of the concept "cloud-based system for educational purposes" and to define the main directions of pedagogical studies of cloud-based systems for educational purposes.

## 2 Research results

### 2.1 The different approaches to the notion of the cloud-based system for educational purposes

According to the Paul Pocatilu, Felician Alecu, Marius Vetrici [21] at the advanced level the development of the cloud-based learning systems is consistent with the same scheme as any other software development project. For designing of the cloud-based e-learning system, you can use the same methods of development as for any software products. This is a source management software, build scenarios to create a deployment package, and automated regression testing.

AlAlaa N. Tashkandi and Ibrahim M. Al-Jabri argue that the gradual introduction of cloud services is also recommended, starting from the traditional cloud computing systems. E-mail, e-learning systems, learning management systems are the starting point for the implementation of the cloud. Cloud services providers targeting the higher education segment should invest in priority systems. Systems related to training, backup and file storage, as well as university or institute websites are systems that must first be realised by means of cloud computing [36].

According to Ibrahim Arpaci the cloud computing services such as Google Drive, Dropbox, SkyDrive and iCloud can be easily integrated into educational systems. These services can provide students with the ability to save files, share files, view and access files synchronized between different devices. Cloud services can also provide easier and quicker access to data, allow students to store and share documents, offer a more flexible environment, providing widespread access to materials and facilitating student-teacher interaction. Therefore, these services can support the practice of managing educational materials, including the creation or search of data, storage, transmission and use of data [2].

Daniel Pop [22] examining machine learning explodes cloud technologies and gives examples of their combination. The cloud computing paradigm and cloud providers have proven to be valuable alternative to accelerate the work of the machine learning platforms. Thus, some popular statistical tools such as R, Octave, Python are also integrated into a cloud. There are two main areas for integrating them with cloud providers: creating a cluster in the cloud and downloading it using static tools, or increasing the statistical environments with plug-ins that allow users to create Hadoop clusters in the cloud and run tasks on them. Environments such as R, Octave, Mapple, and similar to the low-level infrastructure for data analysis, can be applied to large datasets when used by cloud-based suppliers. Machine learning makes it easy to get training materials from huge data sets for customers who do not have a statistical background, automatically deducing from models of "knowledge models" [10, 27, 28]. Similar projects can either be PaaS / SaaS platforms, or products that can be deployed in private environments [17, 22].

Gustavo Gutiérrez-Carreón, Thanasis Daradoumis and Josep Jorba propose the semantic mechanism for integrating the API of the Cloud-service with the educational system. Researchers focus on issues related to the ease of use and the cognitive loads theory — CLT, which should be considered holistically. This subsection is followed in order to determine whether the proposed solution for integrating cloud education services can benefit both systems and learning. On the one hand, the basic assertion of CLT is that any curriculum design should take into account the limits of working memory in order to prevent the overload of the working memory and, consequently, the deterioration of the training process. On the other hand, the degree to which a user can complete a task with an effective tool is determined; Moreover, the level of ease of use of a tool or program can be determined only in the context of specific users and specific tasks that need to be performed. Gutiérrez-Carreón, Daradoumis and Jorba presents the study of learning management system using the semantic description of services and outlines the results of its implementation [6].

Manuel Sanchez, Jose Aguilar, Jorge Cordero and Priscila Valdiviezo-Diaz exploring cloud-based learning, note that this is an educational model that uses all the digital resources available on the Internet to improve the learning process. In this type of training, a set of tools and services in the cloud that promote the student's learning process, without the need for students and teachers to be physically present in one audience is provided. The combination of cloud learning with Ambient Intelligence can provide great benefits to the learning process, since it will not only rely on cloud learning services but the environment will be able to determine when it is appropriate to use these services, as well as with which devices or objects, available in the environment to be integrated. Thus, they propose a new concept called Ambient Intelligence for cloud learning (AmICL), which is defined as: "An AmICLis an Intelligent Learning Environment that combines educational services available in the cloud with objects (which can be intelligent or not) in the educational ambiance, in order to adapt the learning process to the student's learning style" [26, p. 40].

### 2.2 The relationship of the notions of the cloud-based learning system and cloud-based learning environment

In the process of analysis of domestic works of scientists and then at the stage of designing a cloud-based learning environment, Tetiana A. Vakaliuk revealed that one of its components is the cloud-based system of education support (CBSES). Therefore, Tetiana A. Vakaliuk considers it necessary first to create a model of a cloud-based system for supporting the education of bachelors of computer science, since this system is necessary for the design of a cloud-based learning environment. Moreover, in other Vakaliuk's works [38] considers the cloud-based system of education support as one of the main components of the cloud-based learning environment.

The types of cloud-based teaching aids, which reveal in their work Maryna V. Rassovytska and Andrii M. Striuk [24] within the process of its systematic use, can be considered as components of the cloud-based environment. Also, researchers are guiding the use of cloud-based learning tools and illustrating the practical implementation of individual components as components of the system of cloud-based learning tools.

Although Oleksandr M. Kryvonos and Olha V. Korotun otherwise understand the meaning of the concept of "cloud-based system for educational purpose", in the Korotun's study [13] it is indicated that using Canvas an open learning environment may be created, as well as open and also closed electronic courses. In this case, the researcher considers Canvas as a cloud-based system of distance learning, including a learning management system.

The ultimate goal of the research team of Jeremy Fischer, Steven Tuecke, Ian Foster and Craig A. Stewart was to create virtual machines as a desktop environment that any researcher can use to facilitate the research work. Jetstream also included cloud services OpenStack and Jetstream to support multiple formats of virtual machines that can convert them to other supported formats, giving the ability to transfer images to any number of platforms that can read certain formats [4].

Toru Kobayashi, Kenichi Arai, Hiroyuki Sato, Shigeaki Tanimoto and Atsushi Kanai focused their studies on a cloud-based education, and cloud-based tools that can be used to help students understand complex technical terms using social media. Thus, a group of scientists linked their research with e-learning services, using cloud computing and e-learning support systems. Many cloud-based services are offered. Most of these systems involve the exchange of educational materials. The use of e-learning systems enables the delivery and exchange of materials managed by means of a cloud in a common, consistent format. This system also provides students with individual learning content by analyzing their preferences, learning styles and patterns of content usage. In addition, there is a security system for managing data access and cloud encryption. NEC also provides "Smart Education" cloud systems for solving problems arising in the implementation of e-learning; training support, teacher support, school support and PC/tablet management. These systems are related to the system of general educational support for the exchange of educational material or the management of the learning process and the learning environment. On the other hand, the approach merely focuses on the adaptation of the original e-learning material to the e-learning environment. The study was focused on a program aimed at improving the e-learning system. As the e-learning standart SCORM was used, which advocated a reference model of the object Sharable Content Object [11].

Wei Huang, Li Jin and Imtiaz Sandia propose the use of intelligent agents for visualization to manage resources, hardware, platforms, education programs and cloud-based services to coordinate learning activities. The modern concept of the agent itself is associated with distributed artificial intelligence; it can be defined as an autonomous computer system that is capable of flexible interaction with other agents to perform autonomous actions. Agents are based on the concept of distributed artificial intelligence (DAI) in conjunction with distributed computing. They are able to use flexible and manageable strategies to solve many challenging tasks, fully utilizing the benefits of diverse perspectives, distributed problem solving methods, and the benefits of complex interaction schemes. These software tools demonstrate that utilizing intelligent agents can solve methodological problems in an open cloud-based environment. An agent paradigm is well suited to provide flexibility and reduce the complexity of the organization and management of the training system [7].

### 2.3 The structure of the cloud-based learning system

Tetiana A. Vakaliuk in the model of the cloud-based system of supporting the education of bachelors of informatics outlines the following subjects of interaction: administrator, teacher and student. In this case, the researcher combines the traditional system of education and the cloud-based one, therefore, the existing purpose, the content of training, means, methods and forms are presented. However, it should be noted that due to the use of cloud services and cloud technologies, the means, methods and forms of training are expanding, becoming cloud-based. That is, traditional means, methods and forms of training are used along with the cloud-based (those based on the cloud services and cloud technologies). A certain adaptation of the traditional education system to the use of cloud learning technologies is demonstrated due to the introduction of cloud-based learning systems. Among the forms of educational activity of students within the cloud-based learning environment are indicated: practical training, training sessions, control activities, independent work and research work [6]. Particular attention is paid to the scholar's form of organization of educational activities, as a lecture, since this form serves as the basis for conducting training sessions in a cloud-based learning support system. In this case, a detailed analysis of the types of lectures was performed and those that are considered as cloud-based are outlined.

Since cloud-based learning system is intended for the organization of independent work of students, therefore it contains the tools for collecting, checking and evaluating of laboratory, practical or individual works performed by students. A separate component is the tool for protecting laboratory works supported by cloud technologies in online mode [6]. The tasks for independent work are formed by the teacher in advance, not automatically, and the period for which students must complete the task is indicated. In this process, each student can contact the teacher for advice, which can take the form of correspondence (student-teacher) or collective discussion between the teacher and all students of the group.

One of the types of independent work is the group online projects that are intended for a certain period of implementation. The completed project is sent by the students to the teacher for verification. Tasks, their implementation, division into groups, verification and evaluation by the project teacher is carried out only with the use of tools of the cloud-based system.

The organization of the control of learning activities can be implemented using test tasks. In particular, an intermediate control on the learner activity may be online testing. In this case, the student is not limited spatially (because online testing may be passed out off the class) and the score is displayed automatically [37]. As for modular tests, tests and exams, using the cloud-based system toolkit, it is best to check the theoretical part of the study material. To do this, the teacher should prepare practical tasks, tests, surveys. Checking the tasks performed, in this situation can be done both in face-to-face form and with the use of cloud services, online. The consultations before the exam may be also conducted online or in a joint discussion with a group of students. A similar form of work is possible in consultation with a scientific adviser in the process of writing articles, course papers or diploma papers by students.

Maryna V. Rassovytska and Andrii M. Striuk consider the system of cloud-based tools of training consisting of the following tools [24]:

- management training;
- communications;
- joint activity;
- provision of training materials;
- knowledge control.

While selecting cloud-based tools, the specifics of their use and educational purpose were taken into account. In addition, researchers pointed out the most important types of cloud services and tools and noted that these types form a system of cloud-based learning tools. A separate issue is the study of cloud services such as Google and Microsoft, a detailed analysis of their advantages and disadvantages in the learning process.

Although, Tetiana V. Voloshyna does not provide a clear definition of the cloud-based learning support system, but it is noticed that it may include tools for modeling and monitoring student achievement and academic achievement. The progress of the development of educational achievements is preserved in similar cloud-based systems for the further planning of the educational process, its pace. By analyzing significant data sets in which student learning achievements are accumulated, the teacher will be able to individualize the educational process according to the level of preparation of each individual student of the group [40].

As Olha V. Korotun considers the cloud-based system of distance learning as a cloud service, the object of its research is the cloud-based training management system Canvas [13], which belongs to the category of cloud-based services: SaaS. This cloud-based system is designed for both tertiary and higher education. Using the Canvas tool, the teacher will be able to organize: distance and group work of students (including the project), assessment of their academic achievements and monitoring, training sessions (in the form of lectures, consultations and discussions). Interesting is the integration of Canvas with the following services: Facebook, Twitter, Skype, LinkedIn.

Olha V. Korotun believes that the new forms of organization of the educational process, in particular, mixed learning [14], become simpler thanks to the cloud-based educational system. She emphasizes that cloud-based systems of distance learning appeared within the trend of cloud computing development. At the same time, investigating the structure of such cloud-based systems, the researcher believes that their implementation will be appropriate first of all in small educational institutions. However, if the cloud-based system is not part of the cloud-based environment of a university, then its implementation should be gradual (within the department, faculty, individual student groups) [14].

The researcher carried out a significant analysis of the foreign experience of implementation of cloud-based systems of distance learning, the feasibility of their use, in particular in the educational process of the HEI of Ukraine. Interesting is the composition of a cloud-based system defined in the work [14]:

- a toolkit for authentication;
- a toolkit for access rights hierarchy for individual users and system users;
- a toolkit for managing and debugging an electronic course, including as separate actions of its configuration, setting parameters, etc .;
- a toolkit for managing user accounts;
- a toolkit for the organization of the educational process of a group of students (and individual students);
- a toolkit for organizing and maintaining communication between users of the system;
- a toolkit for analyzing the dynamics of academic achievements as a separate student and user group;
- a toolkit for planning and adjusting the dynamics of the educational process;
- a toolkit for combining with other cloud systems, services, perhaps with social networks;
- tools for organizing collective and individual work of students for the use of various forms of organization of educational activities.

Mattias Bitar argued that IaaS resources could be used to provide an appropriate amount of memory, bandwidth and other tools that were explored in separate versions of e-learning. The researcher also proposed an architecture and cloud-based e-learning model with components that are related with infrastructure, resources, software, service, and applications. Each component has certain benefits that can be changed for various educational purposes. Software features may vary to meet user requirements [3].

An e-learning based on the cloud is explored by Ghazal Riahi, who proposed a general architecture model for the cloud-based e-learning system. The proposed model has five components, infrastructure, software level, resource management level, service level and, finally, the application layer. Each component has specific characteristics that can be used for personalized e-learning. Hardware and infrastructure levels consist of resources such as physical memory, RAM, storage and central processing. The software component consists of an operating system and software that can have different performance and interface, and also provide developers with tools for further refinement of the software product. The existing level of resource management at the request of self-service and distribution of software through the free communication of hardware and software resources. Resource management can also be used to provide users with the required amount of resources. The existing service level that includes IaaS, PaaS and SaaS, where the service provides a different level of service provider responsibility. The provider can differentiate the software product, depending on what functions the user requires. The latest component is the application layer, which in fact serves as a custom application in e-learning. The key differences between e-learning components and clouds are at the application level. The features of this component are content production, content delivery, education goals, management components, and ratings [25].

By examining the possibilities for improving the delivery of MOOC resources and experience and the potential benefits of cloud computing, Geng Sun, Tingru Cui, Jianming Yong, Jun Shen and Shiping Chen attempted to develop a cloud-based system that creates virtual learning environments for so that both students and teachers work through mobile devices. This system consists of several programs like SaaS and three functional web services. All services and applications in the virtual learning environments will work together and will be deployed through the cloud infrastructure to provide powerful computing capabilities for storage space with a versatile and intuitive interface [35].

## 3 Conclusions and prospects for further research

The proposed research shows that there are different approaches to the interpretation of the concept of "cloud-based system for educational purpose". Depending on the author's understanding of this notion, the structure of the cloud-based system is defined. Some researchers understand the system of certain cloud services under this notion. Another approach is that a separate cloud service acts as a cloud-based system. Also the cloud-based system may be considered as a computer program for training purposes, which is deployed on the cloud. However, all scientists in their studies have come to the conclusion that the cloud-based system is part of the cloud-based learning environment. That is, the concept of cloud-based environment is much wider. However, the way of the cloud-based system design within this environment and combination of its components in each study is described in accordance to the structure of the cloud-based learning environment. Therefore, it was necessary to investigate not only the content of the concept of "cloud-based system for educational purpose", but also the structure of a similar system. It has been found that in certain studies, the cloud-based system is taken as a separate component. In the studies of other scholars, it is believed that the structure of the cloud-based system is closely intertwined with other components of the cloud-based environment.

The main areas of pedagogical research of cloud-based educational systems are:

- the design of cloud-based training systems, and the methods for developing existing software products that can be applied;
- introduction of cloud services is recommended to begin with the cloud-based learning system;
- cloud services can be easily integrated into the education systems of HEI and secondary education;
- cloud computing has proven to be a valuable alternative to accelerating the work of the machine learning platforms;
- the semantic mechanism of integration of cloud services with the educational system is investigated;
- existing studies of intellectual learning environments combine educational services available in the cloud with the objects of the educational environment;
- researchers propose using intelligent agent technologies to manage resources, hardware, platforms, education programs and cloud-based services.

Further research will focus on the evolution of the formation and development of cloud-based systems and the identification of trends in the development and use of cloud-based systems in the training of teachers in European countries.

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## Сфери освітніх досліджень хмаро орієнтованих навчальних систем

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**Анотація**. Стаття аналізує сучасний стан освітніх досліджень хмаро орієнтованих навчальних систем. Було досліджено зв'язок між поняттями хмаро орієнтованих навчальних систем та хмаро орієнтованих навчальних середовищ. Було визначено, що дослідники приділяють більше уваги розробці хмаро орієнтованих навчальних середовищ. Однак, у процесі розробки хмаро орієнтованих середовищ, дослідники розглядають хмаро орієнтовані системи у якості компоненту в межах хмаро орієнтованих навчальних середовищ як етап процесу розробки. Надано інформацію стосовно того, що у дослідницькій літературі немає єдиного тлумачення концепту хмаро орієнтованих систем для навчальних цілей. Однак наведено певну кількість базових підходів до інтерпретації досліджуваної концепції. Перший підхід заснований на розумінні системи, як набору хмарних сервісів або хмаро орієнтованих технологій. Другий підхід розглядає окремий хмарний сервіс як хмаро орієнтовану навчальну систему. У цьому випадку, інструменти хмарного сервісу повинні включати такі компоненти, що висвітлюють зміст, інструменти, форми та методи навчання. Розглянуто структуру хмаро орієнтованих навчальних систем у інтерпретації останніх робіт українських дослідників.

**Ключові слова**: хмаро орієнтовані системи підготовки, хмарні сервіси, хмаро орієнтоване навчальне середовище, структура хмаро орієнтованої підтримки підготовчої системи.

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# Pedagogical techniques of Earth remote sensing data application into modern school practice

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**Abstract**. The article dwells upon the Earth remote sensing data as one of the basic directions of Geo-Information Science, a unique source of information on processes and phenomena occurring in almost all spheres of the Earth geographic shell (atmosphere, hydrosphere, lithosphere, etc.).

The authors argue that the use of aerospace images by means of the information and communication technologies involvement in the learning process allows not only to increase the information context value of learning, but also contributes to the formation of students' cognitive interest in such disciplines as geography, biology, history, physics, computer science, etc.

It has been grounded that remote sensing data form students' spatial, temporal and qualitative concepts, sensory support for the perception, knowledge and explanation of the specifics of objects and phenomena of geographical reality, which, in its turn, provides an increase in the level of educational achievements.

The techniques of aerospace images application into the modern school practice have been analyzed and illustrated in the examples: from using them as visual aids, to realization of practical and research orientation of training on the basis of remote sensing data.

Particular attention is paid to the practical component of the Earth remote sensing implementation into the modern school practice with the help of information and communication technologies.

**Keywords**: Earth remote sensing data, aerospace images, Geo-Information Science techniques.

# 1 Introduction

## 1.1 Scientific relevance of the research

Earth remote sensing data (RS) is a unique source of information about the processes occurring in the Earth's geographic shell, and therefore their role in the study of geography is constantly increasing. Aerospace images are more effective than the terrestrial information system in terms of their information, since they enable to obtain information with the required spatial-temporal resolution and the image of the Earth's surface in spectral ranges of various radiations.

Aerospace images are of undoubted interest for the educational process. Using remote sensing data, one can visualize the natural and anthropogenic processes and evaluate their dynamics; inform about the placement of objects on the Earth's surface; to monitor (constant monitoring) the state of geographic objects and processes, to formulate hypotheses or to identify patterns.

The unusual character and novelty of such information is of great interest in terms of new technologies, and as a consequence, and of a more in-depth study of basic educational subjects. According to Svetlana S. Karimova and Michael B. Veselov [8], the main educational advantages of remote sensing data are: a large degree of visibility, which is generally unattainable for traditional geographic maps; high resolution; high realism; reflection of their objective reality; great depth of consideration of the investigated object or phenomenon; increasing the possibilities of demonstrating the complexity and interconnection of the processes; increased attention to the physical foundations of the studied processes, etc.

The use of aerospace images in the school geography course began in the early 1950s, when the results of aerial photography appeared in the Soviet school atlases and textbooks. However, wide-ranging use of geospatial data did not receive the results of remote sensing, due to the lack of methods for using Earth images from space in the learning process, as well as the closure of most remote-sensing materials for open use.

Since the mid-80s of the last century, theoretical and practical researches based on modern technologies have been actively conducted abroad, using remote sensing data as educational resources.

At the beginning of the third millennium, qualitative changes in the use of remote sensing data for educational purposes began to take place. Openness and accessibility of information, active computerization of the educational process and the widespread use of Internet technologies contributed to the formation of a new pedagogical direction — space geography. Space geography makes a special emphasis on the formation of the most complete and close to the true reality of the visual image of various geographic objects through the study of their portrait space models. In the process of decoding these models, an understanding of the inter-component natural connections, the economy and the population with the natural environment is fixed [3, 10, 13, 16, 17].

The main mechanism for the introduction of satellite imagery in school practice is the various educational programs initiated by large space companies and organizations (NASA, OSC, Rocketdyne, etc.). Their essence is to encourage the pedagogues of some certain educational institutions to integrate the application of remote sensing data into the school curriculum. For this purpose, educational establishments are provided with the necessary programs and software, computer equipment and receivers of satellite signals.

### 1.2 Recent research and publications analysis

A significant contribution to the development of the theory and methodology of aerospace images use as an educational resource belongs to such scholars as: Alexander V. Barladin [1] (preparation of remote sensing data for using in multimedia presentations), Alexander M. Berlyant [2] theoretical foundations of geoinformatics), David Richard Green [7] (using GIS technologies at school), Lyudmila M. Datsenko and Vitaliy I. Ostroukh [4] (studying the foundations of geoinformation systems and technologies in special-field profile education), Nakis Z. Khasanshina [9] (the potential of geo-informational technologies in teaching geography), Ihor V. Kholoshin [11] (pedagogical techniques of Earth remote sensing data application into modern school practice), Rimma D. Kulibekova [12] (geoinformation technology as a means of information culture formation with the future geography teacher), Witold Lenart, Anna Wozniak, Malgorzata Witecka [19] (GIS at school), Vladimir S. Morkun, Serhiy O. Semerikov and Svitlana M. Hryshchenko [14] (methods of using geoinformation technologies in mining engineers' training), S. Simone Naumann, Alexander Siegmund, Raimund Ditter and Michelle Haspel [15] (theory and practice of the Earth's remote sensing), Oleh M. Topuzov [18] (informatization of geographic education) and others.

However, the question in what form, with the use of information and communication technologies and methodical techniques, the use of remote sensing in the teaching of the school geography course is possible, remains open.

### 1.3 Article objective

The objective of the proposed study is to analyze pedagogical techniques for the introduction of Earth remote sensing data into the practice of a modern school using ICT.

## 2 Research results

Aerospace images have all the necessary features that are characteristic of geography training [6]. Let us describe some of them. First, they contain training information that allows them to be used as a source of knowledge, and secondly, they can be used during practical work to develop skills and abilities.

**Table 1.** Patterns of students' skills formation and pedagogical result due to the remote sensing data characteristics

| **Earth remote sensing data characteristics** | **Skills formation** | **Pedagogical result** |
|---|---|---|
| Real image of the objects being studied | Formation of the investigated object (phenomenon) image on the basis of decoding aerospace images | It makes learning more figurative, bright and memorable |
| Complex character of information read from aerospace images | Mastering the methods of analysis and synthesis, the ability to build logical inferences and draw conclusions. | It activates the student's creative activity, increases motivation to acquire new knowledge |
| Monitoring the territory in time and space | Analysis of spatial and temporal information, modeling and predicting situations | It develops the potential of students' cognitive activity, involves them in research work |
| Great practical value of the information obtained when decoding aerospace images | Assessment of the studied areas state (accounting for the dynamics of changes in natural and anthropogenic factors) | It strengthens the influence that brings up training, forms practical skills and an active life position |

The information obtained in the study of aerospace images determines the specifics of their use in the learning process and opens new opportunities for remote sensing data as educational resources (Table 1). For example, the opportunity to see how geographic objects look in real form from a height in the range of 100 meters to tens of thousands of kilometers significantly increases the visibility of learning, making it more figurative, bright and memorable.

The complex nature of the information that is read from aerospace images (relief, fauna and flora, meteorological factors, socio-economic aspects) provides a comprehensive approach to information analysis, through the acquisition of knowledge on related disciplines: biology, geology, medicine, ecology and etc. As a result, the students master such methods as analysis and synthesis, make logical generalization and conclusions that significantly activate the student's creative activity, increase their motivation to acquire new knowledge.

One of the advantages of remote sensing data is the ability to monitor the territories for a long time, to provide the learning process with the sources of knowledge and the means necessary to carry out practical training. Based on these data, students are given the opportunity to study objects and phenomena in space and time, modeling and predicting the situation. It develops the potential to cognitive activity, involves them in research work.

Remote sensing data is a source of unique information of great practical significance. By its very nature, the aerospace image is a spatial model that replaces real objects and phenomena. At the same time, the picture performs a dual role: it is a means of research, on the one hand, and an object of research, on the other. A detailed study of the images helps to form an objective holistic image of the studied areas with their spatial-temporal characteristics, which is necessary for a comprehensive assessment of their state. Realizing the reality by analyzing airborne images in the process of studying geography proceeds in several stages [11] (Fig. 1).

The first stage — the understanding of aerospace images, involves the formation of knowledge among students about the main characteristics of images, the main features of reflecting various geographical objects, processes and phenomena on them. In fact, at this stage, the students lay the foundation for the practical use of remote sensing data.

The second stage — images decoding, is the ability to distinguish and recognize geographical objects (phenomena), as well as to identify their qualitative and quantitative indicators. This is the main focus in realizing reality through aerospace imagery, because it is at this stage that students learn about the basic characteristics of reality.

The third stage — the reading of aerospace images involves mastering the means of compiling descriptions of geographical objects and phenomena based on the results of decoding Earth images from outer space. At this stage, the students form the basis of images decoding in terms of their location, state, interconnection and dynamics of real objects and phenomena. Creating an image, analyzing and interpreting it using inductive and deductive generalizations leads to the expansion and enrichment of knowledge about the investigated reality, which promotes the formation of practical skills and active life position. At the same time, the teacher must be able to explain to students that the image created by them may differ significantly from reality, since the picture only conveys a part of it.

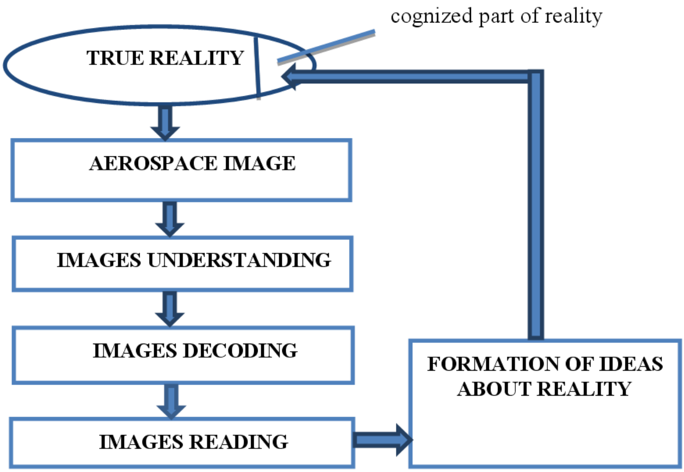


**Fig. 1.** Scheme of reality cognition by studying aerospace images in the process of geography training

In the learning process, Earth remote sensing can perform various functions.

### 2.1 Earth remote sensing data as a means of visual aids

The main visual guide when studying geography is the map. Given its advantages, it should be noted at the same time that the cartographic representation of objects is very arbitrary and does not accurately reflect the objective reality. Aerial imagery forms students' visual image of the objects and phenomena studied, which contributes to a more specific perception of their essence and a more qualitative memory of the of the educational material contents.

In the process of geographical representations visual formation, the means of remote sensing can be divided into four stages:

1. visual representation of definite geographical objects and phenomena characteristics;
2. occurrence of representations about geographical objects and phenomena;
3. preservation and reproduction of representations about geographical objects, phenomena or their certain characteristics;
4. regular application of the received ideas into the process of concepts formation.

It is possible to apply several ways of presenting remote sensing data using information and communication technologies. The most convenient, expedient and obsolete form of aerospace images is their presentation on various digital media. Low cost, saving a large amount of information, and most importantly, high visual characteristics, contribute to the dominance of this form of data representation of remote sensing data. The image is displayed on the computer monitor screen, although the use of the computer-plus-projection device demonstration is particularly effective. Designing aerospace images on a large screen greatly enhances the visibility of learning, as well as increases motivation to mastering it.

It is important that the teacher uses aerospace images not only as static information, but also creates the foundation for mental operations. Thus, using multi-dimensional space images, historical or geological materials, students can be taught elements of geographic modeling and predicting.

Aerospace images make it possible to grasp the role of geography as an actual contemporary science, which, while studying the environment, can significantly affect the development of many aspects of human activity and the interaction of man with nature. The teacher by specific examples (Aral Photos, Gulf Coast catastrophe, etc.) demonstrates how remote sensing data can monitor the anthropogenic impact on nature.

Aerospace images as visual aids can be used at different stages of the lesson for different purposes. The most typical is the use of shots when explaining the learning material by a teacher to form a geographic image of objects and phenomena. It is also advisable to use the remote sensing data before studying the topic. In this case, they will act as a means of forming initial ideas and motivating cognitive activity. In addition, photos can be used to fix the training material and to control the data received.

Fig. 2 shows an example of the MyTest program, which is a consortium of electronic tests. As a means of visualizing test questions, aerospace images are used.

With MyTest (and the like, e.g., Test Designer), you can organize and test students' knowledge of both single topics and entire school geography courses. No less effective is the use of the program for educational purposes. In this case, the educational mode of the program's operation is used.

Taking into account the simplicity of the program, a teacher with basic information preparation can independently develop tests for lessons with the use of remote sensing data.

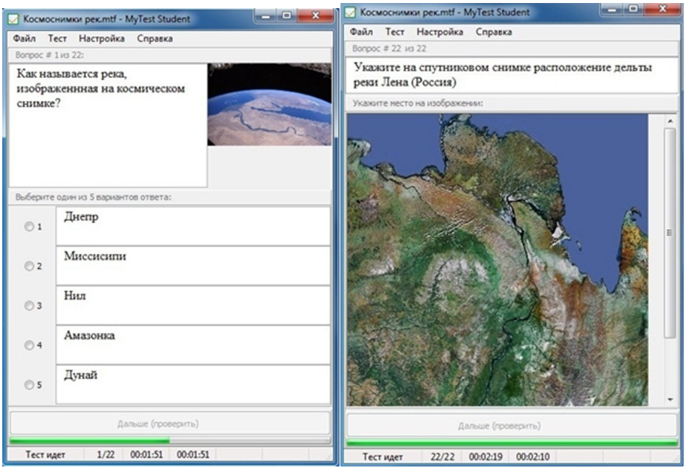


**Fig. 2.** MyTest program windows with different types of questions on the theme "Rivers" with the use of satellite images

Generally speaking, the methodology for using aerospace images as a means of visualizing geographic information is largely similar to the method of working with graphical visual aids such as pictures and photographs [5]. Let us note the basic requirements that need to be taken into account when using images as high-quality visual aids:

- the content of aerospace images must be consistent with the content of the material being studied and illustrated at the appropriate time of the lesson;
- the visibility of the images should be used with a reasonable dose of the transmitted information;
- images should be of high quality;
- the remote sensing data collection should be organized on the principle of "from simple to complex" during the study of geography;

- the objects or phenomena depicted in the photographs are to have a geographic binding;
- the information transmitted by the images should not affect the integrity of the lesson;
- the teacher should think over the explanations and comments on the aerospace images.

### 2.2 Earth remote sensing data as an interactive learning tool (ILT) on geography

Electronic georesources, developed on the basis of satellite images of the Earth, are unfolding new opportunities in the process of geographical education — interactive learning, i.e., learning with feedback, bilateral exchange of information between the subject and the object of the learning process.

Currently, a significant number of interactive learning tools (ILTs) are known in pedagogical practice and geography is one of the leaders in their use [9]. Earth Remote Sensing Data is a unique basis for the creation of interactive geoservices, the skillful use of which allows them to be considered as an ILT with unique educational functions. As an example, we can name the following satellite-based interactive geoservices: Google Earth, Google Maps, NASA World Wind, EINGANA, etc.

By the nature of the transmitted spatially-bound information, all interactive geoservices based on remote sensing data, can be divided into two groups: complex and thematic.

Complex resources (Google Earth, Google Maps, NASA, World Wind, etc.) contain different geoinformation layers (weather conditions, ocean conditions, firewalls, earthquakes, etc.). Thematic georesources (Gismeteo, Meteoweb, Map of Life and etc.) are mono-informational and devoted to certain processes or phenomena (atmospheric processes, traffic flows, migration of animals, etc.). This also includes various spatially-bound social networks.

Wide functionality of such georesources allows them to be used in all the courses of school geography, in various forms of organization of the in-study process, with the involvement of different teaching methods. The most common form of application of ILT based on remote sensing data — classroom, it fits into a traditional lesson, and allows you to organize new types of educational activities. Here are the main types of lessons:

*A. Lesson to learn new teaching material.* The teacher creates in advance labels with information layers that allow you to consistently display static aerospace images, interactive terrain models, photos and video materials on the screen (interactive whiteboard). Unconventional types of lessons in the formation of new knowledge using ILT can include lessons, integrated lessons or research lessons. The basic organizational form of this kind of lessons is working with the class.

*B. Lesson of skills and abilities formation and improvement.* The teacher develops applications in which, using interactive georesourses functions, each student performs individual practical work. The main organizational form is to work with georesources in small groups, although using an interactive whiteboard, the students can work in class collectively.

*C. Lesson of knowledge generalization and systematization.* At the lessons of this type, the teacher offers students creative tasks for laboratory work in the computer class. Independent work on the task, reinforces the cognitive interests of the students, makes their work creative, and in some cases brings it closer to the nature of the research. Unconventional types of lessons of knowledge generalization and systematization can be attributed to students' workshop conferences using data remote sensing and other types of geoinformational technologies.

*D. Lesson of knowledge, skills and abilities control and correction.* The lessons of this type are to control the level of students' assimilation of theoretical material, the formation of skills and abilities; correction of knowledge, accumulated skills and abilities. To this end, the teacher develops control interactive questions based on the use of Google Earth georesourse. An individual or group survey can be as well used in the classroom.

The choice of a lesson form and type depends on its purpose, features of the given class, the studied topic, etc. Of course, extra-curricular work greatly expands the educational potential of the ILT on the basis of remote sensing data. Independent work, optional classes and classes allow students to bring their educational work with interactive aerospace imagery to a completely new level.

### 2.3 Earth remote sensing data as a source of geographic knowledge and skills

The knowledge obtained by analyzing aerospace images, for example, includes such as: spatial position of geographic objects; their morphometric characteristics; qualitative and quantitative indicators; the establishment of causal relationships, patterns, etc. This information is the basis for conducting practical and laboratory classes, as well as students' research work.

The most characteristic feature of the remote sensing data use during the practical work is thorough the images study, with qualitative and quantitative characterization. The knowledge gained during the work with aerospace images within the scope of practical work includes the following: definition of geographical objects size (length, width, perimeter, area, volume) and distances in the area; identification of quantitative and structural indicators (the Earth surface temperature, the spectral brightness of the vegetation, the composition of the forest fund, etc.). It is extremely important that the analysis of aerospace images is to be combined with the use of the whole set of geographic knowledge, including geographic maps, statistical indicators, and field observations.

Laboratory work is a more complex form of practical and research orientation of training realization with the use of remote sensing data. The complication of dealing with aerospace images enhances the influence on the schoolchildren's way of thinking. Tasks performed during laboratory work with the use of geoinformational technologies, promote the students' cognitive activity through the integration of theoretical knowledge and practical skills.

One of the main tasks of laboratory work is to master working skills with aerospace images: their reading and decoding. Of course, laboratory classes should be multileveled, that is, to differ in the complexity of solvable subject and didactic tasks or the method of their conduct.

The complexity of the work to be carried out should gradually increase. At the same time, the design of a series of laboratory works using these remote sensing data should be elaborated taking into account the main areas of students' practical activity.

The Earth image from space for aerial photography is a special means of studying geography, which allows you to create skills about the actual outlines of geographical objects and processes, describe their spatial position, compare different mapping of the terrestrial surface in aerospace images with other sources of geographic information (plan, map, etc.); perform spatial-temporal analysis and so on, thus enriching the world view of the student.

Students can realize the acquired skills by creating a map of the dynamics of the natural environment. The environment is changing: new settlements are emerging and the existing ones disappear; new roads, engineering structures are emerging, new mining areas are being developed; forests are cut down and land use structures are changing. Under the influence of natural and anthropogenic factors shore lines, vegetation and new objects arise. In this regard, the great practical significance is the creation of maps, the main thematic load of which are the boundaries of areas of the territory, exposed to natural or anthropogenic character and, as a consequence, determine the long-term changes in landscapes. The maps of the dynamics are intended to solve tasks connected with the monitoring of the territory and obtaining information about the activity that takes place in the territory.

To create maps of dynamics space images that capture the mapping area received with a certain time interval have been used.

The main purpose of research work organization is the discovery and support of gifted bright students, as well as the development of their intellectual and creative abilities. It is extremely important to choose the right topic for the research. It should be noted that the purpose of the work must be concrete, understandable and accessible. It is necessary that the student in the process of performing the work would realize the practical significance of their research. Taking into account the specificity of the information that is provided by the Earth's observation data, it is necessary to outline the range of issues that could lay the basis for the student's research work.

First and foremost, it is territorial research aimed at solving specific problems in a particular region (for example, monitoring natural and anthropogenic areas). Analyzing time-varying images of the same territory allows students to create dynamic maps that reflect environmental changes: environmental violations, human-induced changes, deforestation, etc.

The second vector of students' research activity is the compilation and refinement of cartographic materials, as well as the registration of the land fund. These works are more applicable and are of great particular interest.

The third direction of the Earth remote sensing data use as a basis for conducting pre-research work is a detailed study of space images in order to identify atypical or unique objects and processes on the Earth's surface.

## 3 Conclusion

1. Earth remote sensing data represent an inexhaustible source of unique information, which opens to the students the door to the world of unknown before. The teacher's task is to enable students to open these doors, since the use of remote sensing data during geography studies has a number of advantages over the traditional teaching materials (e.g. high resolution, high degree of visibility, realism, etc.).
2. The prospects of further scientific research in the use of GIS technologies during the study of geography in profile school and extra-curricular work are regarded as those of top priority.

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# Педагогічні методи використання даних дистанційного зондування Землі у сучасній шкільній практиці

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**Анотація**. Стаття зупиняється на даних дистанційного зондування Землі, як одного з основних напрямків Гео-Інформаційної Науки, унікального джерела інформації про процеси та феномени, що відбуваються майже в усіх сферах географічних оболонок Землі (атмосфері, гідросфері, літосфері тощо).

Автори доводять, що використання аерокосмічних знімків за допомогою включення до навчального процесу інформаційних і комунікативних технологій, дозволяє не лише підвищити об'єм інформаційного контексту навчання, але також сприяє формуванню когнітивного інтересу учнів до таких дисциплін як географія, біологія, історія, фізика, комп'ютерні науки тощо.

Було обґрунтовано, що дані дистанційного зондування формують у учнів концепти простору, часу та якості, сенсорну підтримку для сприйняття, знань та пояснень специфічних об'єктів та явищ географічної дійсності, що, у свою чергу, призводить до підвищення рівня навчальних досягнень.

Було проаналізовано та проілюстровано на прикладах прийоми використання аерокосмічних знімків у сучасній шкільній практиці: від використання їх у якості візуальної підтримки, до проведення практичних та дослідницьких спрямувань підготовки на базі даних дистанційного зондування.

Окрема увага приділяється практичному компоненту включення дистанційного зондування Землі до сучасної шкільної практики за допомогою інформаційних та комунікативних технологій.

**Ключові слова**: дані дистанційного зондування Землі, аерокосмічні знімки, прийоми Гео-Інформаційної Науки.

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# Cloud calculations within the optional course *Optimization Problems* for 10th–11th graders

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**Abstract**. The article deals with the problem of introducing cloud calculations into 10th–11th graders' training to solve optimization problems in the context of the STEM-education concept. After analyzing existing programmes of optional courses on optimization problems, the programme of the optional course *Optimization Problems* has been developed and substantiated implying solution of problems by the cloud environment CoCalc. It is a routine calculating operation and not a mathematical model that is accentuated in the programme. It allows considering more problems which are close to reality without adapting the material while training 10th–11th graders. Besides, the mathematical apparatus of the course which is partially known to students as the knowledge acquired from such mathematics sections as the theory of probability, mathematical statistics, mathematical analysis and linear algebra is enough to master the suggested course. The developed course deals with a whole class of problems of conventional optimization which vary greatly. They can be associated with designing devices and technological processes, distributing limited resources and planning business functioning as well as with everyday problems of people. Devices, processes and situations to which a model of optimization problem is applied are called optimization problems. Optimization methods enable optimal solutions for mathematical models. The developed course is noted for building mathematical models and defining a method to be applied to finding an efficient solution.

**Keywords**: optimization problem, cloud calculation, CoCalc.

## 1 Introduction

### 1.1 Problem statement and its topicality substantiation

Modern society is evolving fast. The character of current changes is conditioned, first of all, by rapid informatization of people's life. The scientific-technical and informational advance of the 20th–21st centuries has caused transition from the industrial society to the informational one.

These changes are going on. Experts predict the so-called smart society appearing in the nearest decade. Rapid paces of life dictate their terms of success to people.

A person has to be able to make his/her activity and surrounding processes efficient in terms of time expenditures for study, work and transport losses. The problems of optimizing control over a small group of classmates working on a project or managing a business, etc. should also be solved.

### 1.2 Analysis of the latest researches and publications

Development of optional and selective courses with the inter-subject integral content is one of the most urgent issues of subject-oriented instruction of senior school students. These courses allow students, on the one hand, to better visualize prospects of a chosen future profession, on the other hand, — to satisfy their educational needs to the fullest.

It is worth noting that in solving optimization problems, the notion of an optimization problem model is as important as that of an optimization problem. Correspondingly, a target function is a mathematical function to be optimized in a problem, while limitation is a set of requirements to problem parameters in the form of equations or inequalities. If the target function is linear and linear limitations are imposed on its arguments, a corresponding optimization problem refers to the problem class of linear programming.

From the practical point of view, optimization problem solution means that a person in his/her activity aimed at achieving a set goal always strives for the best or the most efficient ways of action if there is an opportunity to choose out of an endless variety of methods the one that helps to achieve it. Ways of action or strategies are often characterized by a value. In this case, the problem of choosing the best strategy implies finding an extremum — the minimum or the maximum of this value.

It is also important to admit that the mathematical apparatus of optimization problem solution is used not only as a tool of ordinary calculation. It is also essential for decision making while choosing the most efficient variant to achieve the best result.

It is essential to accentuate the importance of optimization problem solution aimed at demonstrating applicability of inter-subject connections between mathematics and other subjects. It should be noted that complex optimization problems associated with long calculations should be solved professionally, while $10^{\text{th}}$–$11^{\text{th}}$ graders are able to deal with less complicated ones. Such problems include those of the external ballistics theory (determining the maximum missile range, building a safety parabola equation), optimization problems in studying the topic *Percentage*, etc.

Thus, optional courses dealing with optimization problems allow showing $10^{th}$–$11^{th}$ graders how to formalize decision making problems, solve them by applying mathematical tools and how to apply obtained solutions to practice.

At present, there are not so many authors' optional courses dealing with optimization problems. Yet, the available ones do not accentuate application of information technologies to providing instruction which is a sign of meeting modern requirements to training organization under the STEM concept. Some researchers [2, 4–7, 9–11] think that CoCalc can be one of software tools to be applicable to solving optimization problems.

### 1.3 Research methods

Research methods include theoretical analysis and synthesis of data from research and scientific-pedagogical literature concerning the research problem, analysis of regulatory and legal documents in education that regulate optional courses, investigation into training programmes, teaching aids, programmes of standard and optional courses for $10^{th}$–$11^{th}$ graders in similar subjects.

## 2 Inside the optional course *Optimization Problems*

The STEM-concept in education is aimed at forming students' basic ideas of understanding unity of informational principles of building and functioning of various systems and management processes in nature, engineering and society.

Considering these postulates, we have developed the course *Optimization Problems*. Its relevance is explained by rapid updating of science-intensive technologies calling for highly-qualified specialists of a new type — active, creative, able to enrich their knowledge on elaborating and mastering new generations of machines and industrial processes. According to the competence-oriented approach, there appears a necessity for new interpretation of subject instruction and new conditions of incorporating instruction into formation of students' competences. Therefore, it is required to find critically new characteristics of subject instruction. New educational standards aimed at self-development, self-identity and self-realization make educators look for new approaches and forms of training organization as well as new content of traditional training forms. In view of this, principles of training organization are changing. Out-of-class forms of training are prioritized, while principles of independent work organization are becoming more extensive. Independent work is a cognitive activity associated not only with knowledge acquisition, but also with practical experience in the context of competences.

The developed course considers the whole class of conventional optimization problems that vary in their content. They can be associated with designing devices and technological processes, distributing limited resources and planning business functioning as well as with everyday problems of people. Devices, processes and situations to which a model of optimization problem is applied are called optimization objects. Optimization methods enable optimal solutions to mathematical models. The developed course is noted for building mathematical models and defining the method to be applied to finding an efficient solution.

The specific feature of the suggested course is simple presentation of the training material based on concrete examples and problems. Studying linear programming by applying mathematical materials and solving optimization problems which are understandable for senior school students is of particular interest in this course. In this case, optimization problems are treated as those reduced to finding the maximum or the minimum value. These problems are also called extremal ones as finding the maximum and the minimum value is neither more nor less than finding an extremum — the maximum or the minimum of a function.

While solving such problems, scientific thinking and the ability to see a situation as a whole are formed. Cognitive interests and abilities to find a way out of critical situations with minimum losses are also developed. It is evident that an employee possessing these qualities is much more valuable for society.

Basic principles of optimization problem solution by using computer technologies can be taught at Informatics classes with enhanced mathematics study as they require fundamental mathematical training. As the range of topics is very wide, it is reasonable to treat solving even one of them as a project.

Let us look into some variants of projects to be proposed to students within the optional course *Optimization Problems*. First, students should be provided with basic algorithms in CoCalc [4, 8]. While doing a project, students get acquainted with methods of optimization problem solution. One should accentuate the recommendations for improving functioning of a process to be simulated while discussing project results.

There are several stages in teaching optimization problem solution.

***Optimization problem 1***. *Any port in a storm* [1]: there is significant danger to boats caught out in the open sea during a storm. Ideally, boats will dock before the storm hits and wait it out. The map above shows 20 orange boats out at sea. With a storm approaching, each boat needs to be directed to one of three docks. Docks have a limited number of spaces available for boats (indicated by the rectangular spaces). Altogether, there are 20 boat spaces available. The boats are clustered into three areas and each area varies in distance to the docks (as indicated by the black arrows). All boats must be assigned to one space in a dock. **Question: What is the minimum possible total distance traveled by all boats?** More detailed information is presented in Fig. 1.

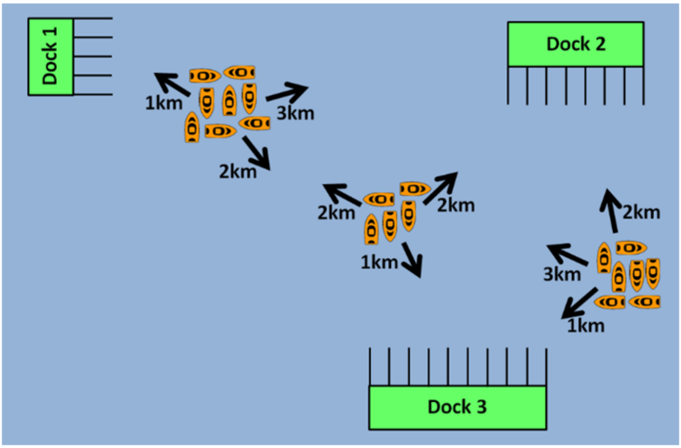


**Fig. 1.** Figure to the Optimization problem 1

Students must build a mathematical model of the problem. To solve the problem we offer students the following code in CoCalc [8]:

```
A=matrix(QQ, [[...,...,...],[...,...,...]],[...,...,...]]); A
m=A.nrows()    #p
n=A.ncols()    #q
isoptimal=0
isunbounded=0
XVar=[]
TVar=[]
for i in range(n-1):
  XVar.append('X'+`i+1`)
```

```
for j in range(m-1):
  TVar.append('T'+`j+1`)
p=-1
q=-1
isfeasible=1
problemfeasible=0
#Atemp=matrix(QQ, m,n)
while (isoptimal==0 and isunbounded==0):
  isoptimal=1
  isunbounded=1
  isfeasible=1
  problemfeasible=1
  p=-1
  q=-1
  #checks to see if current position is feasible
  for i in range(m-1):
    if A[i,n-1]<0 and p<0:
      p=i
      isfeasible=0
      isoptimal=0
      isunbounded=0
  #Checks to see if problem is feasible
  if isfeasible==0:
    problemfeasible=0
    for k in range(n-1):
      if A[p,k]<0 and q<0:
        q=k
        problemfeasible=1
  if problemfeasible==0:
    print('The problem has no feasible solutions')
    p
    q
  else:
    #checking last row to see if optimal (step 1),
    #it's optimal when all are negative
    for i in range(n-1):
      if A[m-1,i]>0:
        isoptimal=0
    if isoptimal==1 and isfeasible==1:
      print('This is optimal, ignore everything after this')
```

```
#finding the right [p,q] to pivot on and will only
# pivot if point is feasible
if isoptimal!=1 and isfeasible==1:
  q=-1
  #finding position q to pivot on
  for i in range(n-1):
    if A[m-1,i]>0 and q<0:
      q=i; q

  #checking column q to see if all negative (step 4)
  for k in range(m-1):
    #A[k,q]
    if A[k,q]>0:
      isunbounded=0

  if isunbounded==1:
    print('This is unbounded')
  p=-1
  #finding position p to pivot on (step 5)
  for j in range(m-1):
    if A[j,q]!=0:
      if A[j,n-1]/A[j,q]>=0 and A[j,q]>0:
        if p<0:
          p=j; p
        if p>=0 and A[j,n-1]/A[j,q]<A[p,n-1]/A[p,q]:
          p=j; p
  print('pivot on position')
  p
  q
#the temporary matrix pivots on [p,q]
Atemp=matrix(QQ, m,n)
for i in range(m):
  for j in range(n):
    if i==p and j==q:
      Atemp[i,j]=1/A[p,q]
    if i==p and j!=q:
      Atemp[i,j]=A[i,j]/A[p,q]
    if i!=p and j==q:
      Atemp[i,j]=-1*A[i,j]/A[p,q]
```

```
    if i!=p and j!=q:
      Atemp[i,j]=(A[i,j]*A[p,q]-A[i,q]*A[p,j])/A[p,q]
Xp=XVar[q];Xp
Tp=TVar[p];Tp
XVar[q]=Tp
TVar[p]=Xp
Atemp
A=Atemp
XVar
TVar
```

***Optimization problem 2***. *Cell Towers* [3]: as the head of analytics for a cell phone company, you have been asked to optimize the location of cell towers in a new area where your company wants to provide service. The new area is made up of several neighborhoods. Each neighborhood is represented by a black house icon in the accompanying image. A cell tower can be placed on any square (including squares with or without a neighborhood). Once placed, a cell tower provides service to 9 squares (the 8 adjacent squares surrounding it and the 1 it sits on). For example, if you placed a cell tower in B2, it would provide service to A1, B1, C1, A2, B2, C2, A3, B3, and C3. The company recognizes that it may not be worthwhile to cover all neighborhoods, so it has instructed you that it needs to cover only 70% of the neighborhoods in the new area. Each cell tower is expensive to construct and maintain so it is in your best interest to only use the minimum number of cell towers.

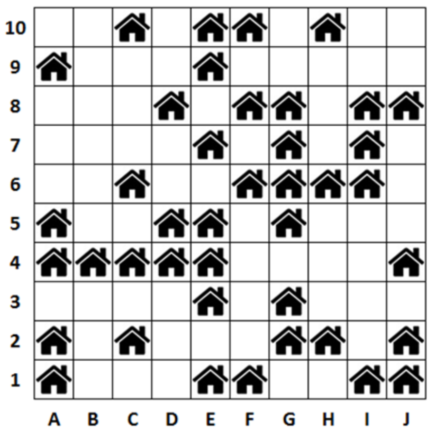


**Fig. 2.** Figure to the Optimization problem 2

**Question: What is the minimum number of cell towers needed to provide service to at least 70% of the neighborhoods?** More detailed information is presented in Fig. 2.

Students must build a mathematical model of the problem. To solve the problem, we offer students the same code as in optimization problem 1.

***Optimization problem 3***. For the project, students can be offered the task of finding the optimal route with restrictions. More detailed information is presented in Table 1 and Fig. 3. There are a certain number of containers in each quarter, each with a capacity $1{,}1\,\mathrm{m}^3$. Just such containers 110. The following additional conditions are met: the volume of the truck body is limited and equal $43\,\mathrm{m}^3$. The point of departure of a filled truck is point B. The truck starts its journey from Base to Point A. The following flights provide a quarterly cycle (from Point B to Point B). The last point of arrival van-tag with an empty body — Point A. Students should independently ask questions and solve the problem.

**Table 1.** The number of containers in the area

| № | Number of containers | № | Number of containers |
|---|---|---|---|
| 1 | 4 | 16 | 1 |
| 2 | 5 | 17 | 3 |
| 3 | 6 | 18 | 3 |
| 4 | 4 | 19 | 2 |
| 5 | 5 | 20 | 4 |
| 6 | 3 | 21 | 5 |
| 7 | 2 | 22 | 2 |
| 8 | 5 | 23 | 6 |
| 9 | 4 | 24 | 2 |
| 10 | 3 | 25 | 1 |
| 11 | 6 | 26 | 1 |
| 12 | 3 | 27 | 4 |
| 13 | 3 | 28 | 3 |
| 14 | 7 | 29 | 5 |
| 15 | 8 | | |

To solve the problem, we offer students the following code in CoCalc:

```
g = graphs.ChvatalGraph()
g = g.minimum_outdegree_orientation()
p = MixedIntegerLinearProgram()
f = p.new_variable(real=True, nonnegative=True)
s, t = 0, 2
for v in g:
  if v != s and v != t:
    p.add_constraint(
      sum(f[(v,u)] for u in g.neighbors_out(v))
      - sum(f[(u,v)] for u in g.neighbors_in(v)) == 0)
for e in g.edges(labels=False):
  p.add_constraint(f[e] <= 1)
p.set_objective(sum(f[(s,u)] for u in g.neighbors_out(s)))
p.solve()  # rel tol 2e-11
```

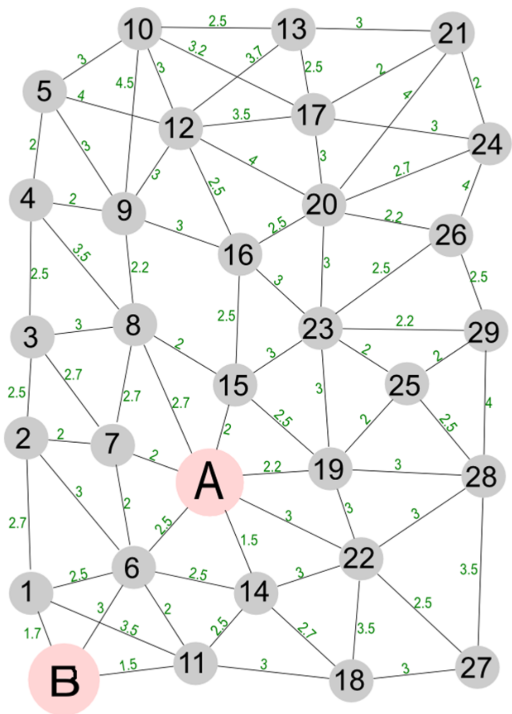


**Fig. 3.** Figure to the Optimization problem 3

**Stage 1**. Studying theoretical principles. It includes the notion of an optimization problem and the necessity to solve such problems in modern life. There are some problem examples provided.

Various situations require absolutely different solutions depending on the chosen or set criterion.

For example, it is possible to spend 50 minutes driving from one city to another. But if part of the route is covered by railway and then by bus, it will take 30 minutes only. It is evident that the latter solution is better if it is necessary to get to one's destination in the shortest time possible. In other words, this solution is the best by the criterion of time minimization. According to another criterion (for example, reduction of expenditures or the number of changes), the former solution is better. Thus, to solve problems, it is essential to analyze quantitative parameters — minimum expenditures, minimum deviations from the standard, maximum speeds, revenues, etc.

**Stage 2** is studying the general plan of optimization problem solution. Here, the notions of a target function, admissible solutions, and the system of limitations are introduced.

The general plan of optimization problem solution includes:

- investigation into an object to define parameters required to solve the problem;
- descriptive simulation, i.e. determining basic connections and dependencies between parameters;
- mathematical simulation;
- choice or development of the method for solving the problem;
- computerized implementation of the solution;
- analysis of the solution obtained.

One of the problems is considered in the form of a mathematical model as a theoretical basis to receive practical solutions on the computer. Next, a practical method is selected and implemented. After obtaining the result, one should analyze it considering various variants of optimizing the process by the ready-made algorithm with initial data changed.

**Stage 3**. Theoretical and practical implementation of solving any optimization problem by applying systems of computer mathematics or other tools.

The ability to solve optimization problems is essential for modern people. This should be taught. Introduction of the project course *Optimization Problem* could be a way out.

If the current variant of training is used without any chance of introducing an optional course like this, the work can be organized as follows. Mathematical models can be created at Mathematics classes, while algorithms of solving these problems by means of CoCalc can be implemented at Informatics classes. Abilities acquired through studying under this mode will help students become successful in new social conditions.

The course programme was based on existing programmes of optional courses of similar character as well as teaching aids and programmes of optional courses.

The developed course is connected with secondary school basic courses of *Mathematics* (sections Linear Equations and Inequities, Solution of Systems of Linear Equations and Inequities) and *Informatics* (Mathematical Simulation, Spreadsheets).

The developed course is aimed at theoretical and practical study of basic notions and methods of optimization as well as basic principles of the decision making theory to form students' ideas of applying the mathematical apparatus to solving problems of finding efficient solutions. While achieving the set aim, a number of tasks are solved:

- getting students acquainted with basic principles of the decision making theory and optimization methods;
- demonstrating application of optimization methods to practical activities;
- introducing methods of solving linear programming problems and their application to students;
- forming students' abilities of solving decision making problems by applying studied optimization methods.

The optional course *Optimization Problems* comprises 35 hours designed for a semester. The recommended number of hours per week in the $10^{th}$ grade is 2, in the $11^{th}$ grade — 1.

The course consists of two main content modules:

1. The role of the theory and methods of decision making in the modern world (17 hours);
2. Linear optimization (17 hours).

The content of the first module includes general statement of the decision making problem in various spheres of human activity as well as some decision making methods. Presentation of theoretical materials of this section should be illustrated by concrete examples and problems. This module covers the following topics:

- The decision making theory (basic notions and definitions);
- The decision making theory in economics;
- Mathematical simulation of decision making;
- Collective decision making. Models of collective choice;
- Decision making in the organization theory.

The second module includes the most important, yet at the same time, simple section of the decision making theory — linear programming. It enables students to comprehend applicability of systems of linear equations and inequities, methods of studying and building function diagrams, mathematical modules of real-life objects and processes to human activity. Presentation of theoretical materials of this section should also be illustrated by concrete examples and problems. This module covers the following topics:

- Basic principles of linear programming;
- Linear optimization problems;
- The graphical method of solving linear programming problems;
- The simplex-method of solving linear programming problems;
- Solving linear programming problems by means of CoCalc.

The suggested programme of the optional course is of a rough character and open to changes to enable a teacher to correct and modify the course depending on the type of an educational institution where the course is taught. It should be noted that the course programme includes some modules and topics that can be used as independent optional courses if their content is expanded.

The course programme provides theoretical and practical classes and independent work (solo work on problem solution). The distance mode of training is recommended.

After mastering the programme material, a student can get an idea of practical application of the decision making theory and optimization methods to everyday life and professional activity. Besides, there are the following requirements to students' knowledge and abilities to be formed after mastering the course:

- The student knows basic notions of the decision making theory, methods of decision making and optimization, basic problems of linear programming, the simplex-method of solving linear programming problems;
- The student is able to correctly choose a relevant solving method to optimize a problem and implement it;

- The student possesses methods of solving problems of linear programming, abilities of applying CoCalc and modern mathematical tools to solving practical problems.

## 3 Conclusions

After analyzing existing programmes of optional courses on optimization problems, the programme of the optional course *Optimization Problems* has been developed and substantiated implying solution of problems by the cloud environment CoCalc. It is a routine calculating operation and not a mathematical model that is accentuated in the programme. It allows considering more problems which are close to reality without adapting the material while training $10^{\text{th}}$–$11^{\text{th}}$ graders. Besides, the mathematical apparatus of the course which is partially known to students as the knowledge acquired from such mathematics sections as the theory of probability, mathematical statistics, mathematical analysis and linear algebra is enough to master the suggested course. The developed course deals with a whole class of problems of conventional optimization which vary greatly. They can be associated with designing devices and technological processes, distributing limited resources and planning business functioning as well as with everyday problems of people. Devices, processes and situations to which a model of optimization problem is applied are called optimization problems. Optimization methods enable optimal solutions for mathematical models. The developed course is noted for building mathematical models and defining a method to be applied to finding an efficient solution.

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# Хмарні обчислення у факультативному курсі «Задачі оптимізації» для учнів 10–11 класів

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**Анотація**. Стаття стосується проблеми представлення хмарних обчислень під час підготовки учнів 10–11 класів задля розв'язання задач оптимізації у контексті концепту STEM-освіти. Після аналізу існуючих програм факультативних курсів стосовно задач оптимізації, було розроблено програму курсу «Задачі оптимізації», а також було обґрунтовано використання хмарного середовища CoCalc для вирішення задач. У програмі наголошується на звичайні операції підрахунку, а не математичні моделі. Вона дозволяє розглядати більше задач, які знаходяться ближче до об'єктивної реальності, без адаптування матеріалу під час підготовки учнів 10–11 класів. Крім того, математичний апарат курсу, частково відомий студентам у якості знань, отриманих з таких розділів математики як теорія ймовірності, математична статистика, математичний аналіз та лінійна алгебра, є достатнім для опанування запропонованого курсу. Розроблений курс має справу з цілим класом звичайних задач оптимізації, які можуть сильно різнитися. Вони можуть бути пов'язані як з проектуванням пристроїв та технологічних процесів, розподіленням обмежених ресурсів та плануванням функціонування бізнесу, так і з повсякденними людськими проблемами. Пристрої, процеси та ситуації, до яких застосовується модель задач оптимізації, називаються задачами оптимізації. Методи оптимізації роблять можливими розв'язки для математичних моделей. Розроблений курс відзначається побудовою математичних моделей та визначенням методу, який має бути використаний для знаходження ефективного розв'язку.

**Ключові слова**: задача оптимізації, хмарні обчислення, CoCalc.

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# Import test questions into Moodle LMS

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**Abstract**. The purpose of the study is to highlight the theoretical and methodological aspects of preparing the test questions of the most common types in the form of text files for further import into learning management system (LMS) Moodle. The subject of the research is the automated filling of the Moodle LMS test database.

The objectives of the study: to analyze the import files of test questions, their advantages and disadvantages; to develop guidelines for the preparation of test questions of common types in the form of text files for further import into Moodle LMS.

The action algorithms for importing questions and instructions for submitting question files in such formats as Aiken, GIFT, Moodle XML, "True/False" questions, "Multiple Choice" (one of many and many of many), "Matching", with an open answer — "Numerical" or "Short answer" and "Essay" are offered in this article. The formats for submitting questions, examples of its designing and developed questions were demonstrated in view mode in Moodle LMS.

**Keywords**: Moodle LMS, Import Questions, Aiken, GIFT, Moodle XML, Moodle Quiz.

## 1 Introduction

Pedagogical testing, due to its high technological and informative content, has surely become a leading method of research into the structure of educational achievement [3, p. 13]. Evidence of it is the introduction in the system of general secondary education external independent assessment and state final certification [6]. Computer-based testing is considered to be the most standardized and objective method of monitoring and evaluating learning outcomes [8]. Requirements for computer testing include:

1. testing variability;
2. prompt submission of student diagnostic results;
3. prompt processing of test results;
4. application of adaptive testing algorithm;
5. accumulation of test results and analysis of their dynamics;
6. dynamic design of tests [3, p. 18].

Computerized testing at Moodle LMS enables to meet most of these requirements — generating test questions randomly from an existing bank, automatically mixing the order of test questions and answer options (alternatives), having different assessment options ("adaptive mode", "deferred feedback", "immediate feedback", etc.), recording the results of each test attempt at evaluation logs and more.

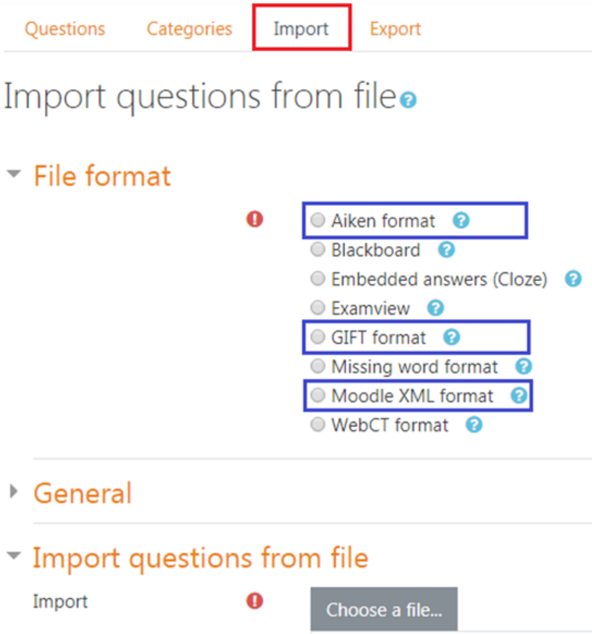



**Fig. 1.** Import page of questions from the file

A considerable number of questions are required to provide meaningful validity for the test. However, developing of such questions in Moodle LMS directly in the browser is time consuming — it takes a lot of time and attention. You can significantly reduce the time for filling a bank of test questions of considerable volume by preparing and importing questions in the form of a text file that corresponds to one of the modern formats for the exchange of test tasks — Aiken format, Blackboard, Embedded answers (Cloze), Examview, GIFT format, Missing word format, Moodle XML format and etc.

The purpose of this article is to highlight the theoretical and methodological aspects of preparing the test questions of the most common types in the form of text files for further import into Moodle LMS.

## 2 Import questions from file

This article examines the peculiarities of preparing for import test questions of the most commonly used types — "True/False", "Multiple Choice" ("one of many" and "many of many"), the question of "Matching", an open-ended question ("Numerical" or "Short answer") or "Essay" in Aiken, GIFT and Moodle XML formats (Fig. 1).

The Aiken format is extremely simple [1]. However, only "Multiple Choice" questions can be prepared in this format with one correct answer. The detailed algorithm for preparing and importing questions in Aiken format is shown in Table 1.

**Table 1.** The algorithm of actions for import in Aiken format

| Step 1 |
|---|
| Open the window for any text editor (or processor) to work |
| Step 2 |
| Make a list of test questions and answer options consistently (one after another) strictly in the format:<br>`The text of the question`<br>`A. correct answer`<br>`B. wrong answer 1`<br>`C. wrong answer 2`<br>`D. wrong answer 3`<br>`ANSWER: A`<br>*Note.*<br>1. The number of alternatives to choose the correct answer cannot exceed 10<br>2. There is no need to waste time choosing the correct answer (variation A, B, C, or D), since in Moodle, mixing or not mixing alternatives is configured and performed automatically on the test options page |

| Step 3 |
|---|
| Save the file as a text document *, ** in Unicode encoding mode (UTF-8)<br><br>*Note.*<br>* In text editor Notepad: File → Save → File type: Text documents; Encoding: Unicode (UTF-8)<br>** In text processor MS Word: File → Save → File Type: Plain Text; Encoding: Unicode (UTF-8) |
| Step 4 |
| In Moodle (on the relevant course page), import the saved file to the bank issues by selecting the format of the Aiken file (Fig. 1):<br>4.1. Control Panel → Bank Issues → Import<br>4.2. File format: Aiken<br>4.3. Import questions from a file: Import → Select file . . . → . . .<br>4.4. After the message is resolved from the import file and the successful import of all issues is completed, click Continue |

The GIFT format is much more powerful than Aiken, because besides preparing different types of questions ("True/False", "Multiple Choice", "Matching", "Numerical", "Short Answer", "Essay", etc.), it also has the ability to add question names, percentages, graphics, comments [2], and etc.

The detailed algorithm for preparing and importing questions in GIFT format is shown in Table 2.

**Table 2.** The algorithm of actions for import in GIFT format

| Step 1 |
|---|
| Open the window for any text editor (or processor) to work. |
| Step 2 |
| Make a list of test questions and answer options according to the sample and instructions in Table 4:<br><br>`The text of the question`<br>`{`<br>`answers`<br>`}`<br><br>or (if necessary, enter the name of the question): |

| |
|---|
| `:: The title of the question :: The text of the question`<br>`{`<br>`answers`<br>`}` |
| Step 3 |
| Save the file as a text document in Unicode encoding mode (UTF-8) |
| Step 4 |
| Import saved file (in case of use of images — archive) to the bank of questions, choosing the format of the file GIFT (Fig. 1) |

Preparing Moodle XML questions is not easy at first sight. An example of a file fragment (resulting from export) is shown in Fig. 2.

```
<question type="truefalse">
        <questiontext format="html">
                <text>Для створення публікацій використовують MS Publisher?</text>
        </questiontext>
        <image></image>
        <image_base64></image_base64>
        <generalfeedback>
                <text></text>
        </generalfeedback>
        <penalty>0.1</penalty>
        <hidden>0</hidden>
        <answer fraction="100">
                <text>true</text>
                <feedback>
                        <text>
                        </text>
                </feedback>
        </answer>
        <answer fraction="0">
                <text>false</text>
                <feedback>
                        <text>
                        </text>
                </feedback>
        </answer>
        <name>
                <text>Питання Так/Ні - відповідь Так</text>
        </name>
</question>
```

**Fig. 2.** The fragment of the file in Moodle XML format

The ability to work with an intuitive interface while creating questions of various types (with the addition of images, question names, comments, category creation, etc.) in the MS Word text processor environment necessitates the use of the Moodle Quiz macro (Fig.3) [5].

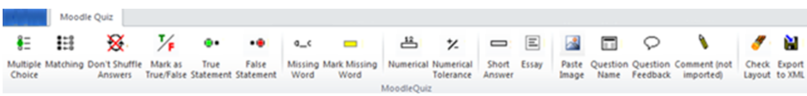



**Fig. 3.** The Moodle Quiz tab

The detailed algorithm for preparing and importing questions in Moodle XML format using the Word template with the Moodle Quiz macro is shown in Table 3.

**Table 3.** The algorithm of actions for import in the format of Moodle XML

| Step 1 |
|---|
| Open the template with the macro moodle_quiz_v_21 [4, 5] in the MS Word processor window, if necessary, unlock the macros. For successful execution of actions in the tab of tabs MS Word will appear tab Moodle Quiz (Fig. 3) |
| Step 2 |
| Make a question using the appropriate tools of the Moodle Quiz tab (see Table 4) |
| Step 3 |
| Use the tool Check Layout (Fig. 3) to verify the correct test pattern |
| Step 4 |
| Use the tool Export to XML (Fig. 3) to export the doc file to the XML format |
| Step 5 |
| Import the saved file to the bank by selecting the format of the Moodle XML file (Fig. 1) |

Table 4 provides standards (protocols) and examples of processing different types of questions in text files-documents for importing test questions in GIFT and Moodle XML formats.

**Table 4.** Instructions for submitting questions files in GIFT and Moodle XML formats

| **GIFT format** | **Moodle XML Format (using Moodle Quiz in MS Word)** |
|---|---|
| The question “True/False” (Fig. 4) | |
| Format:<br><br>`Question {TRUE}`<br><br>or else<br><br>`Question {FALSE}`<br>`Question Yes/No?`<br>`{TRUE}` | The tool True Statement (Fig. 3) — for the answer to the question Yes. And False Statement (Fig. 3) — for the answer to the question No. |

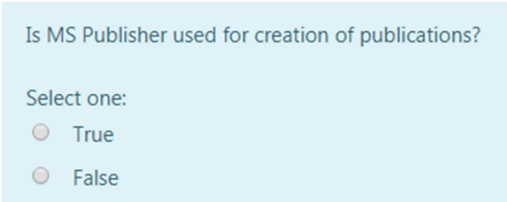
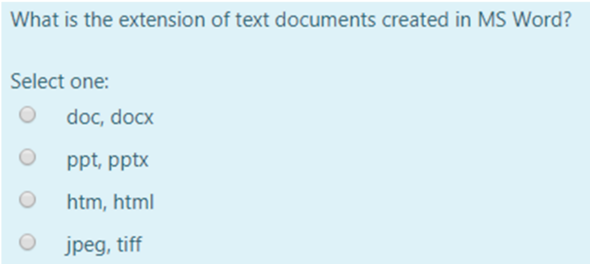
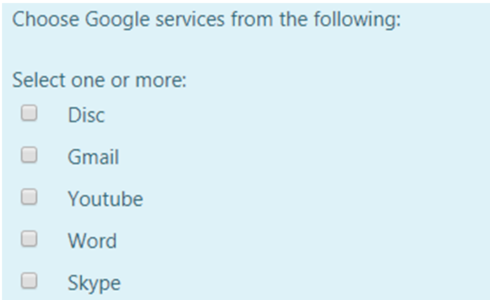
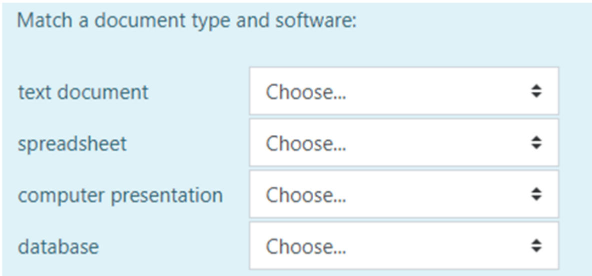
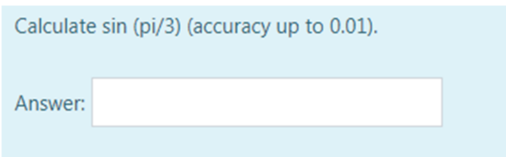
<table>
<tr><th>GIFT format</th><th>Moodle XML Format (using Moodle Quiz in MS Word)</th></tr>
<tr><td colspan="2">

Fig. 4. Example of the question “True/False”</td></tr>
<tr><td colspan="2">The question “Multiple Choice” (Fig. 5, 6)</td></tr>
<tr><td>Format:<br><br><code>Question {= ~ ~~}</code><br><br>Example:<br><br><code>The question with one correct answer?</code><br><code>{</code><br><code>= The correct answer</code><br><code>~ Wrong answer 1</code><br><code>~ Wrong answer 2</code><br><code>~ Wrong answer 3</code><br><code>}</code><br><br>Format:<br><br><code>Question {~% number% ~% number% ~}</code><br><br><code>The questions with several correct answers?</code><br><code>{</code><br><code>~% 50% Correct answer 1</code><br><code>~% 50% Correct answer 2</code><br><code>~% -50% Wrong answer 1</code><br><code>~% -50% Wrong answer 2</code><br><code>}</code><br><br>Note: if there are three correct answers to the question, then each of them should add %33.333%, if four — %25%, etc.</td><td>The tool Multiple Choice (Fig. 3)<br><br><code>The question with one correct answer?</code><br><code>Correct answer</code><br><code>Wrong answer 1</code><br><code>Wrong answer 2</code><br><code>Wrong answer 3</code><br><br><code>The questions with several correct answers?</code><br><code>Correct answer 1</code><br><code>Correct answer 2</code><br><code>Wrong answer 1</code><br><code>Wrong answer 2</code><br><br>Note: You can see the answer to the opposite (from right to wrong) using the tool Mark as True/False (Fig. 3).</td></tr>
</table>

<table>
<tr><th>GIFT format</th><th>Moodle XML Format (using Moodle Quiz in MS Word)</th></tr>
<tr><td colspan="2">


<br>
Fig. 5. Example of the question “Multiple Choice” (one of many)
<br>


<br>
Fig. 6. Example of the question “Multiple Choice” (many of many)
</td></tr>
<tr><td colspan="2">The question “Matching” (Fig. 7)</td></tr>
<tr><td>Format:<br><br><code>Question {= Questions -> Answer}</code><br><br><code>Questions about matching:</code><br><code>{</code><br><code>= Question 1 -> Answer 1</code><br><code>= Question 2 -> Answer 2</code><br><code>= Question 3 -> Answer 3</code><br><code>= Question 4 -> Answer 4</code><br><code>= -> Answer 5</code><br><code>}</code></td>
<td>The tool is Matching (Fig. 3). Pressing the Enter key means the beginning of the introduction of question 1, pressing Enter again — the beginning of the input Answers 1, etc.<br>In the end, leave one question blank and enter an additional answer.<br><br><code>Questions about matching:</code><br><code>Question 1</code><br><code>Answer 1</code><br><code>Question 2</code><br><code>Answer 2</code><br><code>Question 3</code></td></tr>
</table>

| **GIFT format** | **Moodle XML Format (using Moodle Quiz in MS Word)** |
|---|---|
| | `Answer 3`<br>`Question 4`<br>`Answer 4`<br><br>`Answer 5` |
| <br><br>**Fig. 7.** Example of the question "Matching" | |
| The question "Numerical" (Fig. 8) | |
| Format 1:<br><br>`Question {# number}`<br><br>Format 2:<br><br>`Question {#min value..max value}`<br><br>`Numerical question 2 + 2?`<br>`{# 4}` | The tool Numerical (Fig. 3). To enter an answer — Enter. To enter accuracy — the tool Numerical Tolerance (Fig. 3).<br><br>`Numerical question 2 + 2?`<br>`4` |
| <br><br>**Fig. 8.** Example of the question "Numerical" | |
| The question "Short Answer" (Fig. 9) | |
| Format:<br><br>`Question {= answer}` | The tool Short Answer (Fig. 3). Pressing the Enter key means entering the answer. |

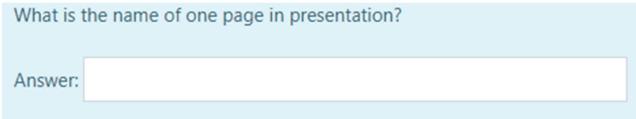
<table>
<tr><th>GIFT format</th><th>Moodle XML Format (using Moodle Quiz in MS Word)</th></tr>
<tr><td><code>The question with a short answer?</code><br><code>{</code><br><code>= yes</code><br><code>}</code></td><td><code>The question with a short answer?</code><br><code>Yes</code></td></tr>
<tr><td colspan="2">

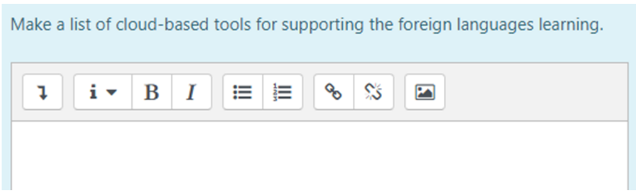
Fig. 9. Example of the question “Short Answer”</td></tr>
<tr><td colspan="2">The question “Essay” (Fig. 10)</td></tr>
<tr><td>Format:<br><code>Question {}</code><br>Example:<br><code>Task -- essay.</code><br><code>{</code><br><code>}</code></td><td>The tool Essay (Fig. 3).<br><code>Task -- essay.</code></td></tr>
<tr><td colspan="2">

Fig. 10. Example of the question “Essay”</td></tr>
<tr><td colspan="2">Adding images (in the text of the question or answer variants)</td></tr>
<tr><td>1. All the images used in this file are saved in the folder (case sensitive)<br>2. Place the <code><img src \= "@@PLUGINFILE @@ / folder / name.png»</code> tag on the image, where name is the name of the image<br>3. When you finish editing, create a zip archive containing the folder and the file with the questions<br>4. The format for importing questions in Moodle LMS — GIFT with medials format (choose zip-archive)</td><td>Tool Paste Image (Fig. 3) (pre-copy the image to the clipboard)</td></tr>
</table>

Note (for GIFT files).

1. Questions are separated by an empty line, the question itself can not contain empty lines.
2. The text of the question should not contain special characters ({,}, =, ~, #) since they divide the parts of the question. If necessary, they must be preceded by the symbol "\" before each of these characters. It will be deleted when it is imported.
3. If it is necessary to write certain explanations for test users, developers can write a comment starting with the characters "//". The starting point for commenting on answer options is the "#" character.
4. Formatting the text of questions or variants:

```
[html] <p> Questions about formatting </ p>
{
}
```

The main tags for formatting are given in Table 5.

**Table 5.** Tags for formatting text (GIFT format, [7])

| Syntax | Action |
|---|---|
| <h1> Text </h1> | heading 1 level |
| <p> Text </p> | text paragraph |
| <br> | new line |
| <hr> | horizontal line |
| <b> Text </b> | bold text |
| <i> Text </i> | text outline in italics |
| <sub> Text </sub> | lower index |
| <sup> Text </sup> | top index |
| <ol><br><li> List item 1 </li><br><li> List item 2 </li><br><li> ... </li><br></ol> | numbered list |
| <ul><br><li> List item 1 </li><br><li> List item 2 </li><br><li> ... </li><br></ul> | marked list |
| <a href="URL-link" > hyperlink text </a> | hyperlinks |

## 3 Conclusions

The choice of file format for importing questions depends on the needs of the test developer, and may vary depending on the situation (Table 6).

**Table 6.** Compare file characteristics for importing issues

| **Characteristic** | **Format** | | |
|---|---|---|---|
| | **Aiken** | **GIFT** | **Moodle XML (macro Moodle Quiz)** |
| Minimalistic interface | + | + | – |
| Different types of questions | – | + | + |
| Images, sounds | – | + (GIFT with media format) | + |
| Automatically formatting | – | – | + |
| Free software | + | + | – |

Yes, the undeniable advantage of the Aiken format is its simplicity, but the questions prepared in this format are the same. The GIFT format, like Moodle XML, provides the ability to fill questions with different types of questions; however, in GIFT format, all tags should be manually written. The downside of the moodle_quiz_v_21 macro is development for commercial software — MS Word.

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## Імпортування тестових питань до системи управління навчання Moodle

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**Анотація**. Мета дослідження полягає у висвітленні теоретичних та методологічних аспектів підготовки найпоширеніших типів тестових питань у формі текстових файлів для подальшого імпортування їх у систему управління навчанням (LMS) Moodle. Предметом дослідження є автоматичне заповнення бази даних з тестами у Moodle LMS.

Завдання дослідження: проаналізувати імпортування файлів з тестовими питаннями, їх переваги та недоліки; розробити вказівки для підготовки тестових питань поширених типів у формі текстових файлів для подальшого імпортування їх до Moodle LMS.

У статті надається алгоритм дій імпортування питань та інструкцій для подання файлів з питаннями у таких форматах як Aiken, GIFT, Moodle XML, питання типу «Вірно / Не вірно», «Множинний вибір» (одна відповідь з набору варіантів або декілька відповідей з набору варіантів), «Вибір відповідності», питань відкритої форми — «Числова відповідь» або «Коротка відповідь» та «Есе». Було продемонстровано формати для подання питань, приклади проектування та розробки питань у режимі перегляду Moodle LMS.

**Ключові слова**: Moodle LMS, імпортування питань, Aiken, GIFT, Moodle XML, Moodle Quiz.

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УДК 378.147:004

# Дослідження процесу використання мобільних ІКТ студентами університетів: мобільні тестові системи та мобільні засоби розробки мультимедіа

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**Анотація**. Мета дослідження: теоретичне обґрунтування, розробка та експериментальна перевірка методики використання мобільних технологій студентами університетів. Завдання дослідження: адаптація мобільних тестових систем та мобільних засобів розробки мультимедіа до використання на аудиторних заняттях в університеті. Об'єкт дослідження: процес використання мобільних ІКТ у навчальному процесі. Предмет дослідження: методика використання мобільних тестових систем та мобільних засобів розробки мультимедіа під час аудиторних занять в університеті. Результати дослідження. Проаналізовано вітчизняні та зарубіжні дослідження, присвячені проблемі використання мобільних ІКТ у навчальному процесі університету. Мобільні тестові системи визначено як різновид мобільного програмного забезпечення для вимірювання навчальних досягнень студентів, що надає можливість автоматизувати процес поточного та підсумкового контролю на основі сучасних засобів тестування та комплексно інтенсифікувати процес навчання. Встановлено, що мобільні засоби розробки мультимедіа мають задовольняти принципам мультимедійності, просторового сусідства, часової суміжності, когерентності, модальності, надмірності, персоналізації, інтерактивності, сигналізації та індивідуальних відмінностей. Розроблено методику використання мобільних тестових систем на прикладі системи Plickers, що надає можливість реалізувати швидкий зворотний зв'язок викладача та академічної групи, а також окремих студентів; проводити мобільне голосування, фронтальні опитування під час навчальних занять; здійснювати миттєвий контроль відвідування занять. Розроблено методику використання мобільних засобів розробки мультимедіа (на прикладі засобів розробки мультимедіа із доповненою реальністю). Здійснено порівняльну оцінку функціональності мобільних тестових систем та мобільних засобів розробки мультимедіа із доповненою реальністю. Експериментально перевірено та доведено ефективність розробленої методики.

**Ключові слова**: студенти університетів, мобільні технології, мобільні тестові системи, мобільні засоби розробки мультимедіа.

## 1 Вступ

Розробка, упровадження та ефективне використання технологій Індустрії 4.0 в Україні вимагає посилення уваги до професій інформаційного суспільства, головною характеристикою якого є високий рівень розвитку ІКТ, розвинені інфраструктури, що забезпечують виробництво інформаційних ресурсів і можливості доступу до них, процеси прискореної автоматизації й роботизації всіх галузей виробництва та управління, радикальні зміни соціально-професійних структур, наслідком яких є розширення сфери інформаційної діяльності та впровадження мобільних технологій.

Використання мобільних ІКТ досліджували М. А. Кислова, Н. В. Рашевська та К. І. Словак (у навчанні вищої математики), А. П. Авраменко, М. Е. Джантджис, К. В. Капранчикова, О. В. Мардаренко та Ф. Фотухі-Газвані (у навчанні мов), М. О. Григор'єва та С. О. Семеріков (у навчанні інформатики), А. Абу-Аль-Аїш, С. С. Бахаром, П. В. Берд, К. Біллінгтон, Е. А. Валі, Р. С. Наговіцин, М. Е. Резаїрад, Дж. Дж. Тріндер та М. Хепберн (у системі вищої освіти), В. О. Куклєв та І. Шао (у відкритій освіті), А. А. Зухре, В. Джотем та Н. Н. Чень (у повсякденному житті). Незважаючи на те, що мобільні ІКТ активно використовують інженери-педагоги, методику їх використання розглянуто лише в розвідці О. В. Жукова, присвяченій професійній підготовці фахівців з автосервісу.

Використовуючи мобільні тестові системи, описані в роботі [1], автор зазначає, що завдання для тестування можуть бути розроблені викладачами та поширені через мережу. Проведене опитування свідчить про те, що студенти віддають перевагу автоматизованому тестуванню у порівнянні із традиційним. Автоматизоване тестування покращує ІТ-навички користувачів, на відміну від традиційного письмового тестування.

Дослідники [2] описали ефективність тестування за допомогою мобільних пристроїв у хімічній лабораторії. Розглянуті у статті педагогічні інновації, пов'язані із використанням смартфонів, дають учителям можливість створити в лабораторіях навчальне середовище. Автори в загальних рисах описують власний досвід із використання мобільної тестової системи Socrative Response Student by Mastery Connect. Вони припустили, що використання цього додатка для тестування може підвищити якість навчання і виявити прогалини в знаннях студентів з хімії. Щоб дослідити освітню ефективність Socrative, автори статті проаналізували дані, отримані під час навчання курсу хімії студентів магістратури. До та після лабораторних занять студенти проходили тестування, використовуючи мобільну тестову систему Socrative на своїх мобільних пристроях. У результатах було відмічено, що, на думку студентів, тестування із використання мобільних пристроїв сприяє інтенсифікації навчального процесу, тоді як викладачі повідомили, що такий вид тестування поліпшує успішність і відносини між викладачами та студентами.

У дослідженні [3] подано звіт про досвід використання мобільних пристроїв в навчальній аудиторії, а також обґрунтовано, що для того, щоб залучити якомога більше студентів до активної діяльності у лекційній аудиторії, лекції повинні містити мотивуючі та активізуючі елементи. До таких можна віднести, зокрема, тестові запитання, на які студенти відповідають анонімно за допомогою власного смартфона. Тестування з використанням мобільних пристроїв також дозволяє лектору слідкувати на навчальною успішністю студентів.

Автори статті [4] досліджували вплив мобільних тестових систем на використання мобільного телефону в студентами в аудиторії, оскільки мобільні телефони — це засіб потенційного відволікання уваги від таких інтенсивних розумових дій, як навчання. Однак мобільний телефон можна розглядати і як потужний інструмент для посилення деяких з цих дій. Мобільні тестові системи являють собою такий тип засобів навчання, який дозволяє викладачам опитувати аудиторію в реальному часі. Мобільні телефони все частіше використовуються для опитування, що робить опитування більш універсальними і доступними. Оскільки мобільні телефони та інші персональні електронні пристрої (планшети, ноутбуки) стають все більш поширеними засобами аудиторного навчання, дослідники прагнули з’ясувати, як ці зміни вплинуть на використання мобільних телефонів студентів. Окрім того, вони визначили, як розташування місця студента в аудиторії впливає на використання мобільного телефону студентами протягом семестру. Для цього авторами проводились спостереження на лекціях із хімії та біології в університеті Вашингтона. Автори виявили, що у студентів, які сидять в задній частині аудиторії, з більшою ймовірністю не буде мобільного телефону. Однак, всупереч очікуванням, студенти, які використовують технологію опитувань на основі персональних пристроїв (мобільних телефонів), з більшою ймовірністю будуть використовувати телефони під час лекції, ніж їхні однолітки, що використовують традиційні (паперові) тести. Автори припускають, що недоліки використання мобільних телефонів в якості навчального посібника можуть бути обмежені.

## 2 Використання мобільних ІКТ у навчальному процесі

### 2.1. Методика використання мобільних тестових систем

Одним з різновидів мобільних програмних засобів ІКТ навчання інформатичних дисциплін є засоби діагностики — моніторингу, контролю та оцінювання навчальних досягнень.

У процесі діагностики рівня сформованості ІК-компетентностей студентів використовуються різні засоби діагностики, серед яких чільне місце посідає тестовий контроль знань. Засоби оцінювання навчальних досягнень студентів представлені мобільними тестовими системами.

Мобільні тестові системи — різновид мобільного програмного забезпечення для вимірювання навчальних досягнень студентів, що надає можливість автоматизувати процес поточного та підсумкового контролю на основі сучасних засобів тестування та комплексно інтенсифікувати процес навчання завдяки:

- забезпеченню мобільності, економічності (ефективності) та конфіденційності процесу тестування шляхом розробки та реалізації технології зберігання та використання короткочасного сеансу передавання бази тестових завдань із серверу, що розміщений у мережі Internet, засобами бездротового зв'язку;
- вирішенню проблеми наявності обмежень із точки зору технічних характеристик, а також дистанційного розмежування комп'ютерів викладача та студентів у процесі організації тестового сеансу [5].

Мобільні тестові системи, що відповідають даному визначенню: ClassMarker, EasyTestMaker, Google Forms, iSpring QuizMaker, Kahoot!, MyTestXpro, Plickers, ProProfs та ін.

У нашому дослідженні ми виділили мобільну тестову систему Plickers, оскільки вона надає можливість реалізувати швидкий зворотний зв'язок викладача та академічної групи, а також окремих студентів; проводити мобільне голосування, фронтальні опитування під час навчальних занять; здійснювати миттєвий контроль відвідування занять. Перевагою цієї системи є висока ефективність роботи, оскільки виконання зазначених дій потребує лише декількох хвилин; крім цього, наявність смартфонів або комп'ютерів у студентів не обов'язкова, достатньо мобільного пристрою викладача.

Plickers можна використовувати на різних операційних системах стаціонарних комп'ютерів та мобільних пристроїв. Система розрахована на одночасне тестування до 63 студентів. Особливістю системи є можливість негайного сканування відповідей студентів за допомогою мобільного пристрою викладача. Система також надає можливість переглядати в табличній формі результати тестування студентів (як групи в цілому, так і кожного студента окремо).

Для роботи із Plickers викладачеві необхідно зареєструватися на сайті https://www.plickers.com/ та створити бібліотеку тестів із різних дисциплін (Рис. 1).

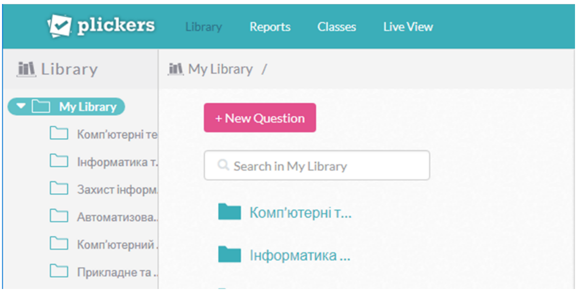


**Рис. 1.** Бібліотека тестів з інформатичних дисциплін у мобільній тестовій системі Plickers

Система надає можливість використовувати створений список академічної групи у процесі тестування з різних дисциплін (Рис. 2).

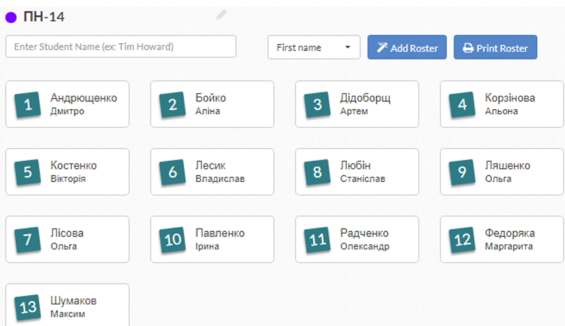


**Рис. 2.** Список академічної групи у Plickers

Для проведення тестування студентам видаються спеціальні картки із QR-кодами (https://www.plickers.com/PlickersCards_2up.pdf), що містять варіанти відповідей A, B, C і D (Рис. 3); прочитавши питання, студенти піднімають картки з обраним варіантом відповіді, які викладач сканує камерою мобільного пристрою.

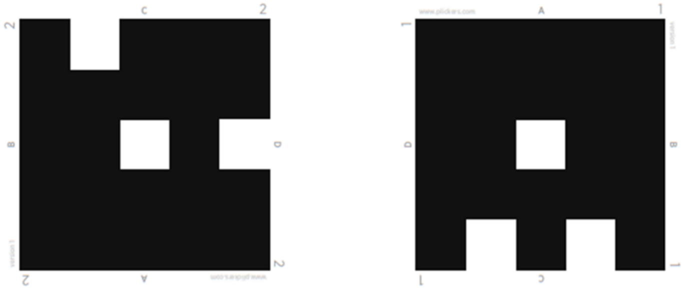

**Рис. 3.** Картки Plickers із QR-кодами

Після сканування QR-кодів із карток студентів інформація з мобільного пристрою викладача передається у хмару Plickers, де вона опрацьовується і зберігається. Plickers надає можливість аналізувати результати окремого студента або вивчати загальну статистику групи.

Для організації опитування викладач працює із сайтом Plickers у розділі «LiveView» (Рис. 4) — це спеціальний режим показу питань, яким можна керувати за допомогою мобільного пристрою.

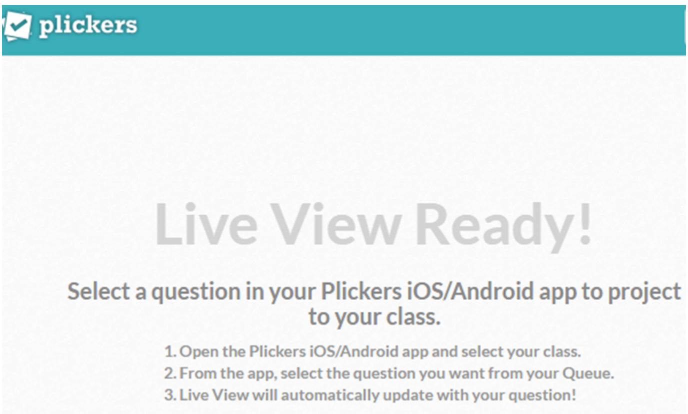


**Рис. 4.** Режим роботи з LiveView

Для того, щоб відсканувати відповіді студентів, у мобільному пристрої слід відкрити Plickers, на головному екрані якого обрати академічну групу (Рис. 5).

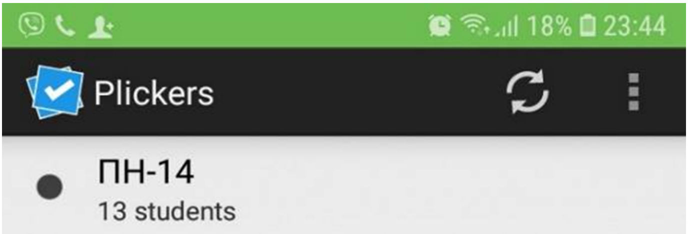


**Рис. 5.** Головна сторінка мобільної тестової системи Plickers

До кожної дисципліни викладач заздалегідь розробляє тести з вибором однієї вірної відповіді з чотирьох варіантів (Рис. 6).

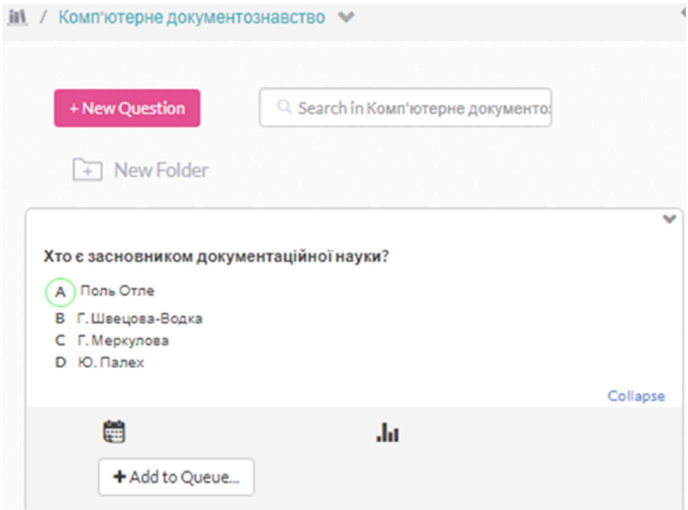


**Рис. 6.** Питання до заліку, розроблені у Plickers

Статистика відповідей на кожне запитання відображається на екрані в реальному часі (Рис. 7).

Інші мобільні тестові системи мають схожу функціональність, проте надають можливість використання інших типів тестових питань та ін. (Таблиця 1).

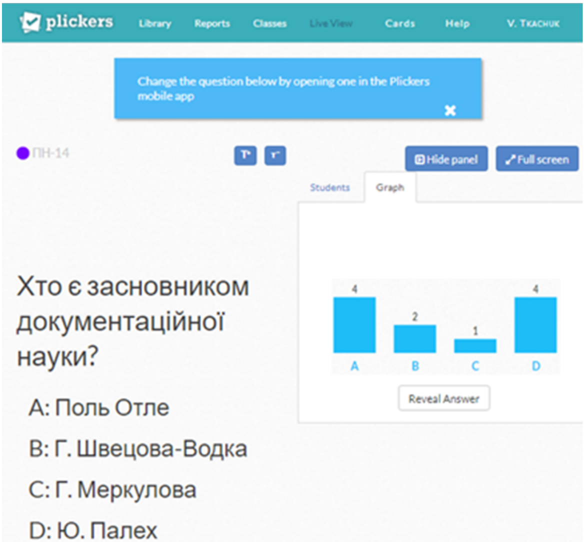


**Рис. 7.** Результати відповідей студентів на запитання тесту

Незважаючи на недостатньо високу оцінку функціональності, Plickers надає можливість проведення швидкого масового тестування студентів під час лекції за відсутності 100% доступу студентів до мобільних Інтернет-пристроїв. Картки, що використовуються при роботі з Plickers, можуть бути застосовані для ідентифікації студентів (Рис. 8).

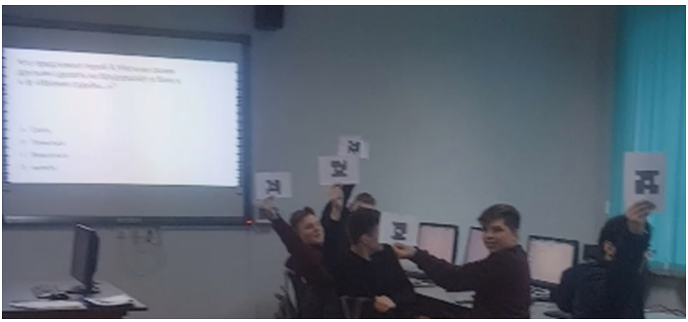

**Рис. 8.** Методика використання мобільних засобів розробки мультимедіа

**Таблиця 1.** Оцінка функціональності мобільних тестових систем

| Характеристики | Мобільна тестова система | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **ClassMarker** | **EasyTestMaker** | **Google Forms** | **iSpring QuizMaker** | **Kahoot!** | **MyTestXpro** | **Plickers** | **ProProfs** |
| **Типи тестових запитань** | | | | | | | | |
| вибір одного з двох протилежних | + | + | + | + | + | + | − | + |
| вибір одного з багатьох | + | + | + | + | + | + | + | + |
| множинний вибір | + | + | + | + | + | + | − | + |
| відповідність | + | + | + | + | + | + | − | + |
| відкрита відповідь | + | + | + | + | + | + | − | + |
| **Інше** | | | | | | | | |
| наявність веб-версії | + | − | + | − | + | − | + | − |
| можливість автономної роботи | + | − | + | − | − | − | − | − |
| локалізація українською мовою | − | − | + | − | − | − | − | − |
| iPhone OS та Android. | + | + | + | + | + | + | + | + |
| наявність повнофункціональної безкоштовної версії | − | − | + | − | + | + | + | + |
| наявність хмарного сховища | + | − | + | − | + | − | + | − |
| мінімальні вимоги до мобільного пристрою | + | − | − | − | + | − | + | − |
| **Рейтинг** | 10 | 6 | 11 | 6 | 10 | 7 | 6 | 7 |

### 2.2. Методика використання мобільних засобів розробки мультимедіа

Об’єднання різних способів подання даних є основою теорії мультимедійного навчання Р. Е. Майєра, який виділяє чотири різні види когнітивних процесів: вибір, організація, перетворення та інтеграція даних [6, с. 118]. Вибрані текстові та графічні дані спочатку опрацьовуються окремо. Далі обрані дані організуються у дві окремі моделі: для словесних даних та графічних. Під час опрацювання даних словесні подання можуть бути перетворені на графічні (наприклад, шляхом побудови розумових образів) і навпаки (наприклад, шляхом внутрішньої вербалізації зображень). Для того, щоб мультимедійне навчання було успішним, обидві моделі повинні бути інтегровані та пов'язані з попередніми знаннями [6].

Згідно Р. Е. Майєра [7], можна виділити три основні підходи до подання мультимедійних матеріалів:

1) за каналами передавання матеріалів — за допомогою двох або більше пристроїв (наприклад, екран та гучномовці);
2) за режимом подання — текстове та графічне (екранні текст та анімація);
3) за модальністю сприйняття — аудіальна та візуальна (анімація, що супроводжується розповіддю).

Кожному із цих підходів відповідає окремий клас засобів розробки мультимедіа: першому — засоби розробки відеоматеріалів, другому — засоби розробки презентацій, третьому — засоби розробки доповненої реальності (такі як Augment, Blippar, Amazon Sumerian, Anatomy 4D, AR Flashcards Space Lite, AR Freedom Stories, AR-3D Science, Chromville, Elements 4D, HP Reveal, Google Lens). За будь-якого підходу Р. Е. Майєр вважає необхідним дотримуватися наступних принципів розробки мультимедіа [7, с. 59–60]:

1. Мультимедійний принцип: люди краще навчаються за допомогою слів та зображень, ніж лише за допомогою слів.
2. Принцип просторового сусідства: люди навчаються краще, коли відповідні слова та зображення подаються поруч, а не далеко один від одного на сторінці або на екрані.
3. Принцип часової суміжності: люди навчаються краще, коли відповідні слова та зображення подаються одночасно, а не послідовно.
4. Принцип когерентності: люди навчаються краще, коли сторонні слова, картини та звуки виключаються, а не включаються.
5. Принцип модальності: люди навчаються краще за допомогою анімації та розповіді, ніж за допомогою анімації та екранного тексту.

6. Принцип надмірності: люди краще навчаються за допомогою анімації та розповіді, ніж за допомогою анімації, розповіді та тексту на екрані.
7. Принцип персоналізації: люди навчаються краще, коли слова подаються у розмовному стилі, а не у формальному.
8. Принцип інтерактивності: люди навчаються краще, коли вони контролюють темп презентації.
9. Принцип сигналізації: люди навчаються краще, коли слова містять маркери про організацію презентації.
10. Принцип індивідуальних відмінностей: мультимедійні ефекти більше впливають на студентів з низьким рівнем знань, ніж на студентів з високим рівнем знань. Мультимедійні ефекти більше впливають на високопрофесійних студентів, ніж на низькопрофесійних студентів.

Дотримання цих принципів надає можливість стверджувати, що будь-яка система, що їх задовольняє, є мобільним засобом розробки мультимедіа.

Використання мобільних засобів розробки мультимедіа надає можливість підвищити ефективність управління увагою та мотивацією студентів.


**Рис. 9.** Модель використання Blippar у процесі професійної підготовки (за [8])

Ураховуючи, що методику використання засобів доповненої реальності розкрито у дослідженнях [8–10], розглянемо більш детально мобільні засоби розробки доповненої реальності.

Так, для організації роботи студентів з дисципліни «Комп'ютерні технології в освіті» нами було використано систему Blippar [11], яка надає можливість реалізувати мультимедійні проєкти із доповненою реальністю. Узагальнену модель використання Blippar у процесі професійної підготовки подано на Рис. 9.

Перед створенням мультимедійного проєкту із доповненою реальністю у Blippar зареєструватись на офіційному сайті за посиланням https://accounts.blippar.com/signup/free (Рис. 10).

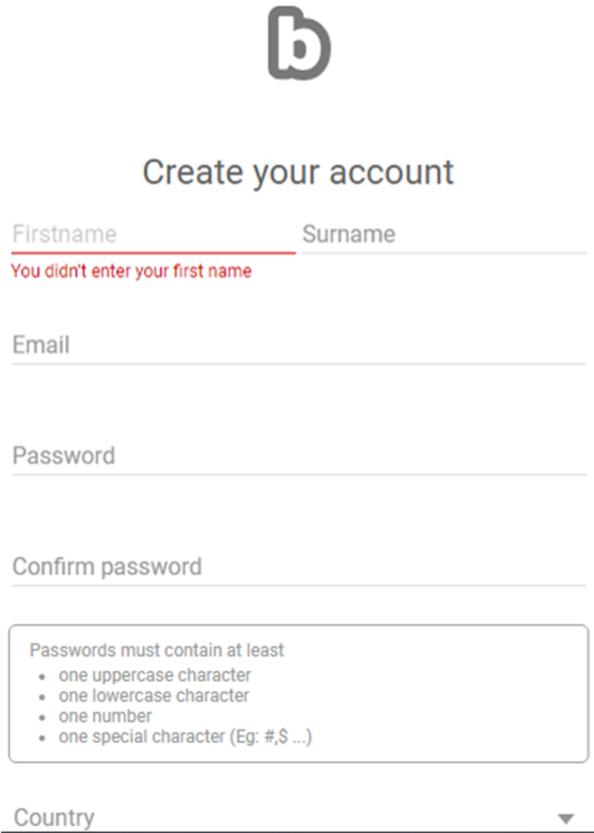


**Рис. 10.** Реєстрація на сайті Blippar

Blipp — об'єкт Blippar, що містить елементи сцени та пов'язаний з ними маркер. Для створення об'єкту Blippar необхідно собрати «Create Blipp» у меню «My Blipps» або створити новий проєкт, у якому цей об'єкт буде міститись (Рис. 11). Об'єкт Blippar може бути створений візуально за допомогою комбінування 3D об'єктів та анімацій або за допомогою JavaScript (Рис. 12). Найпростіший спосіб — візуальний.

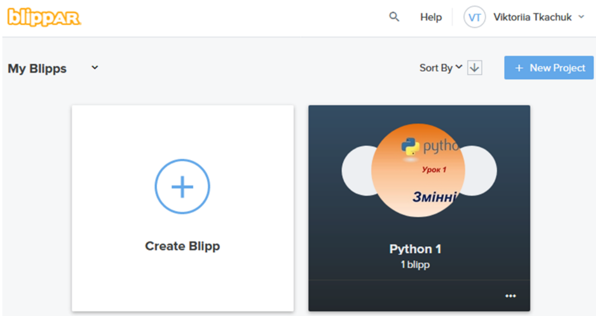


**Рис. 11.** Створення об'єкту Blippar

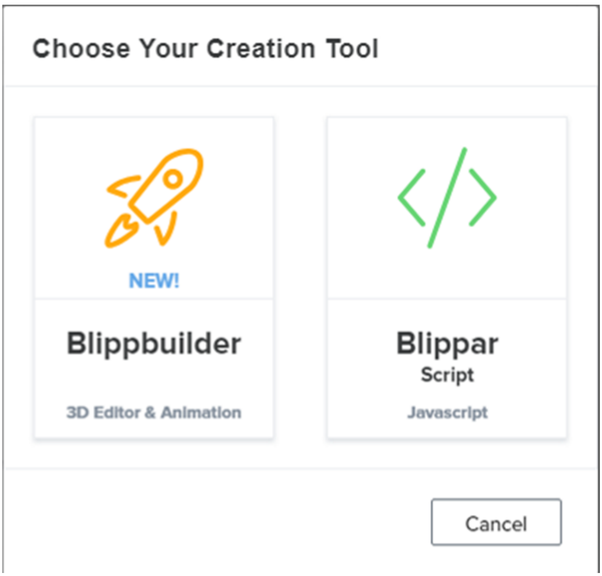


**Рис. 12.** Створення об'єкту Blippar

Перший крок — завантаження або генерування зображення, що виконуватиме роль маркеру (Рис. 13).

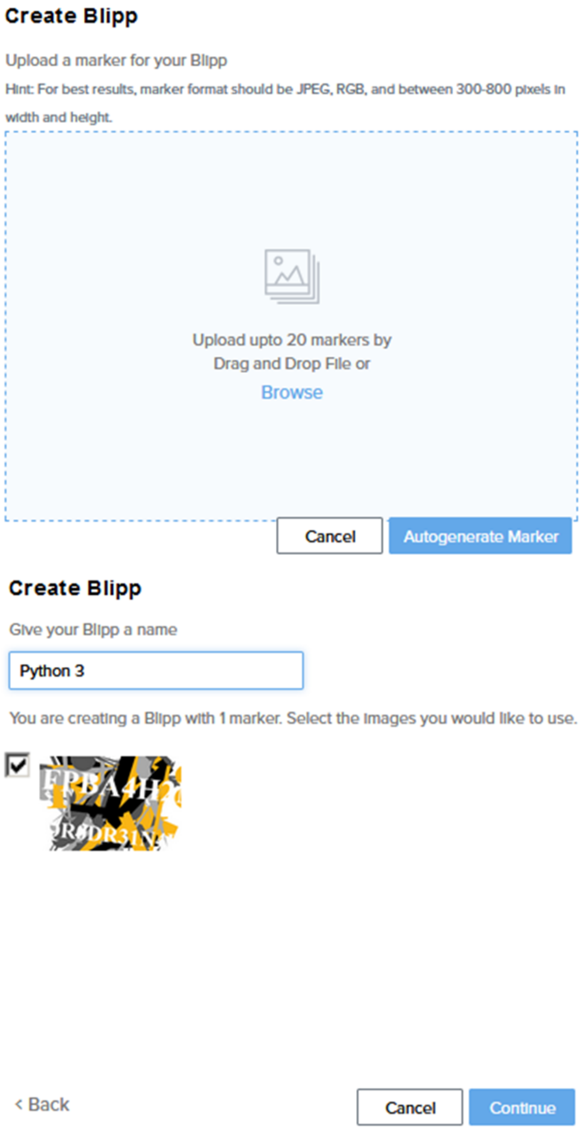


**Рис. 13.** Вибір методу створення маркеру

На другому кроці відбувається створення сцени за допомогою візуального редактору BlippBuilder (Рис. 14), що надає користувачу панелі «Elements» (прості геометричні 3D об'єкти та текст), «Widgets» та «Uploads» (для завантаження моделей у форматі FBX).

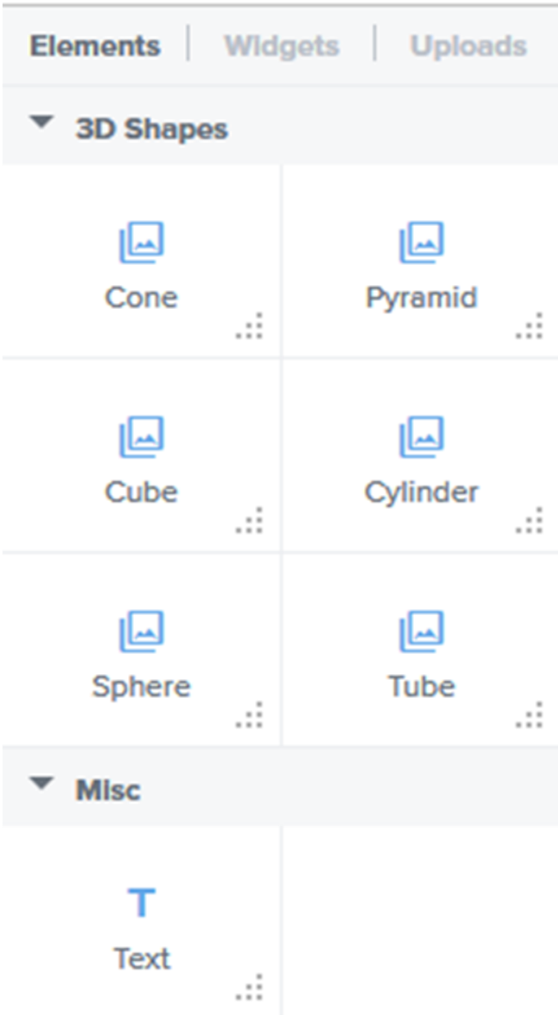


**Рис. 14.** Панелі редагування BlippBuilder

Так, у вікні редагування можна додати фігури та текст, через меню надати їм активний чи не активний стан, змінити шрифт, колір (обрати з того, що є, або задати колір числом, наприклад: #778899), прозорість, розмір, позицію та обертання (Рис. 15), додати зовнішні посилання, завантажити відео або аудіо тощо (Рис. 16).

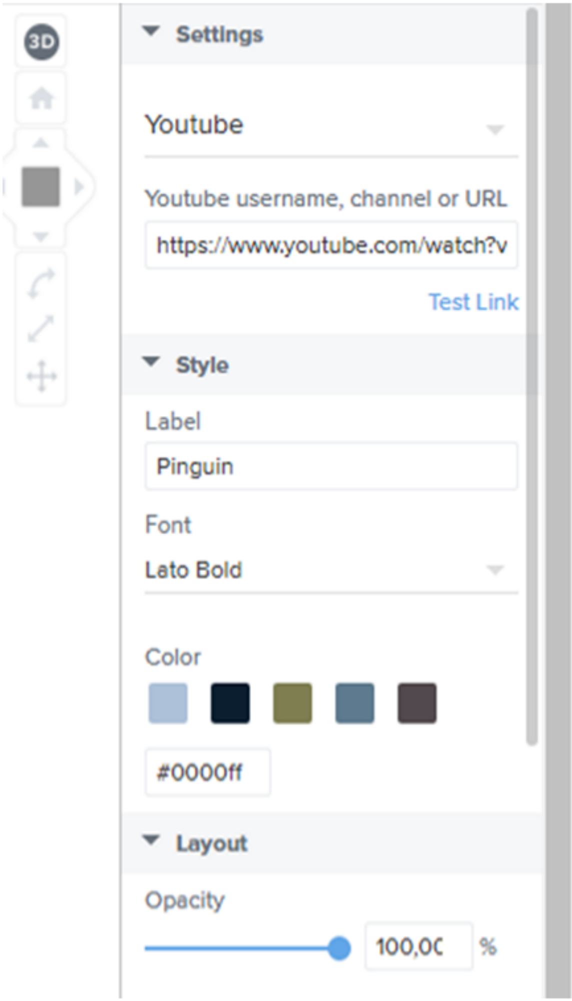


**Рис. 15.** Налаштування елементів сцени Blippar

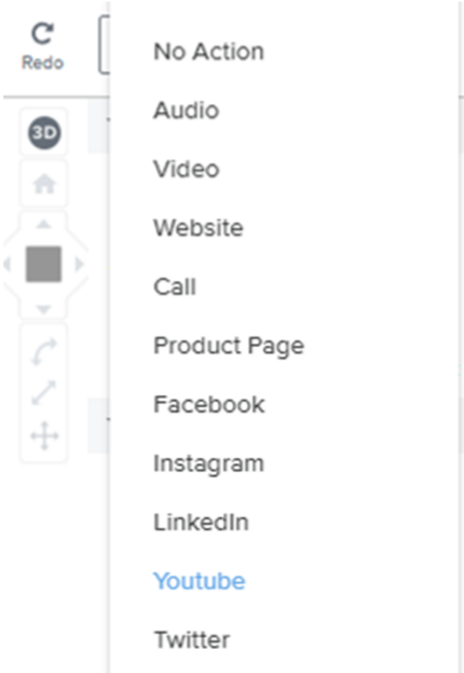


**Рис. 16.** Додавання дій до елементів сцени

На третьому кроці після завершення налаштування сцени об'єкт Blippar попередньо переглядається та оприлюднюється (Рис. 17).


**Рис. 17.** Попередній перегляд/оприлюднення об'єкту Blippar

Для кожного об'єкта Blippar генерується унікальний код, за яким його можна переглянути на мобільному пристрої (Рис. 18). Для перегляду об'єкту Blippar необхідно завантажити браузер доповненої реальності Blippar на мобільний пристрій, у налаштуваннях якого вводиться код об'єкту Blippar (Рис. 19). Після цього браузер Blippar буде розпізнавати маркер об'єкту та завантажувати пов'язану з ним сцену.

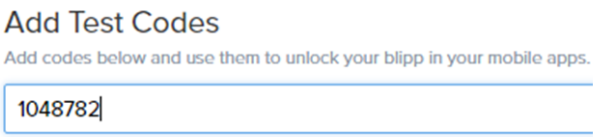


**Рис. 18.** Код для перегляду Blippar об'єкту

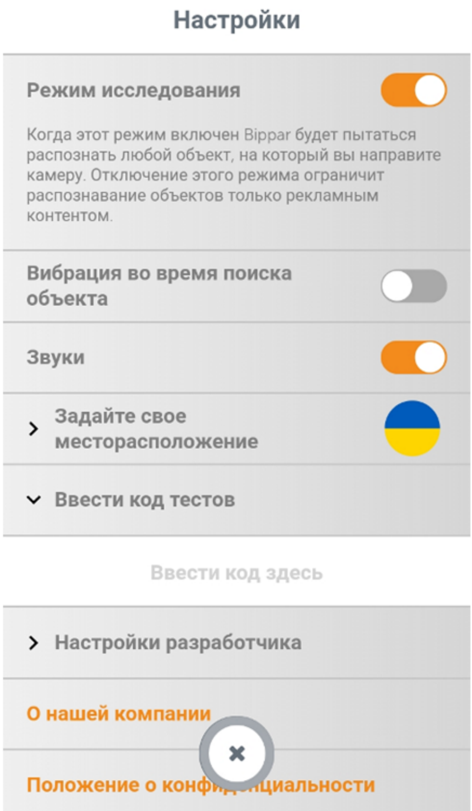


**Рис. 19.** Налаштування браузера доповненої реальності Blippar

На Рис. 20 показано маркер для коду 1048782, пов'язаний із відеоуроком на тему «Змінні у мові програмування Python».


**Рис. 20.** Приклад маркеру об'єкта Blippar

**Таблиця 2.** Оцінка функціональності мобільних засобів розробки мультимедіа із доповненою реальністю

| **Характеристики** | **Мобільні засоби розробки мультимедіа із доповненою реальністю** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Amazon Sumerian** | **AR Flashcards Space** | **AR-3D Science** | **Augment** | **Blippar** | **Chromville** | **Elements 4D** | **HP Reveal** |
| Безкоштовне поширення | ± | − | ± | ± | + | + | + | ± |
| Можливість розробки власних об'єктів | + | + | − | + | + | − | − | + |
| Локалізація українською мовою | − | − | − | − | − | − | − | − |
| Підтримка різних платформ | + | − | − | + | + | + | + | + |
| Підтримка візуального редагування об'єктів | + | + | + | + | + | + | + | + |
| Підтримка різних галузей науки | + | + | − | + | + | − | − | + |
| **Рейтинг** | 4,5 | 3 | 1,5 | 4,5 | 5 | 3 | 3 | 4 |

У Таблиці 2 наведено порівняння функціональності мобільних засобів розробки мультимедіа із доповненою реальністю. Серед проаналізованих засобів звертаємо увагу на Amazon Sumerian, що надає можливість об'єднання засобів віртуальної та доповненої реальності у єдиному мультимедійному середовищі на основі веб-браузера з підтримкою WebGL 2.0 та WebXR 1.0.

## 3 Висновки

У процесі дослідження можливостей використання мобільних технологій студентами університетів, ми отримали наступні результати:

1) проаналізовано вітчизняні та зарубіжні дослідження, присвячені проблемі використання мобільних технологій на аудиторних заняттях;
2) розроблено методику використання мобільних тестових систем (на прикладі Plickers) та мобільних засобів розробки мультимедіа (на прикладі засобів розробки мультимедіа із доповненою реальністю);
3) здійснено порівняльну оцінку функціональності мобільних тестових систем та мобільних засобів розробки мультимедіа із доповненою реальністю;
4) експериментально перевірено та доведено ефективність розробленої методики.

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# The research of process of applying mobile ICT by university students: mobile testing systems and mobile means of multimedia development

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**Abstract**. The study is aimed at theoretical substantiation, development and experimental testing of methods of applying mobile technologies by university students. The objectives of the study imply adapting mobile testing systems and mobile means of multimedia development for using in the classroom environment at universities. The research object is application of mobile ICT to the educational process. The research subject is methods of applying mobile testing systems and mobile means to conduct practical classes at the University. The studies of Ukrainian and foreign researchers dedicated to the question of using mobile ICT for the university educational process were analyzed. Mobile testing systems are defined as a variety of mobile software support aimed firstly to measure students' academic results, which enables to automatize the process of both current and final control through applying modern testing means, and secondly to intensify the educational process comprehensively. It is found that mobile means of multimedia development are to fulfill the principles of multimedia, space vicinity, time contiguity, coherence, modality, excessiveness, personalization, interactivity signalization and individual distinctions. The authors have developed the methods of applying mobile testing systems by taking *Plickers* system, as the one providing the opportunity to arrange a rapid feedback between a lecturer and both an academic group and an individual student. The system also allows conducting mobile surveys, in-class general questioning and instant control of students' attendance. The authors have developed methods of applying mobile tools of multimedia development through using augmented reality. The comparative assessment of functionality of mobile testing systems and mobile means of developing augmented reality multimedia was held. Efficiency of the developed technology was experimentally tested and confirmed.

**Keywords**: university students, mobile technologies, mobile audience response systems, mobile tools of multimedia development.

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# Augmented reality as a tool for open science platform by research collaboration in virtual teams

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**Abstract**. The provision of open science is defined as a general policy aimed at overcoming the barriers that hinder the implementation of the European Research Area (ERA). An open science foundation seeks to capture all the elements needed for the functioning of ERA: research data, scientific instruments, ICT services (connections, calculations, platforms, and specific studies such as portals). Managing shared resources for the community of scholars maximizes the benefits to society. In the field of digital infrastructure, this has already demonstrated great benefits. It is expected that applying this principle to an open science process will improve management by funding organizations in collaboration with stakeholders through mechanisms such as public consultation. This will increase the perception of joint ownership of the infrastructure. It will also create clear and non-discriminatory access rules, along with a sense of joint ownership that stimulates a higher level of participation, collaboration and social reciprocity. The article deals with the concept of open science. The concept of the European cloud of open science and its structure are presented. According to the study, it has been shown that the structure of the cloud of open science includes an augmented reality as an open-science platform. An example of the practical application of this tool is the general description of MaxWhere, developed by Hungarian scientists, and is a platform of aggregates of individual 3D spaces.

**Keywords**: ERA, EGI, EOSC-hub, EOSC, European Open Science Cloud.

## 1 Introduction

In order for researchers to be able to focus on their work, newly developed electronic computing resources and cloud services should not only offer the functions necessary to solve the problems of large data, but also work smoothly and intuitively, without emphasizing the technical details of the cloud-based environments Thus, today's demands of the research and education community require a holistic approach in the development of the next generation of intelligent networks, which should work in concert with the components of distributed application.

### 1.1 The problem statement

Calculations that are traditionally used to store and process large amounts of data remain difficult to use, both in terms of programming and in terms of data management. This is especially emphasized by the latest trends in modern research, which are becoming more and more manageable and associated with big data [10]. The latter require the processing of a huge amount of distributed computing in an easy way. Most of the current high-tech data tasks can easily be rolled into a list of independent tasks that can be handled in parallel (for example, using a cloud platform and do not require additional software), while the problem of distributed computing, storage and fast data remains unresolved.

In order to focus on their research, researchers need to be able to analyze and process data specific to the program intuitively. Users do not need to understand the core cloud infrastructure software blocks that need to deal with distributed computing, storage, and interconnection issues. The examples that cover these problems can be found in virtually all branches of science, such as bioinformatics, geological science, high-quality streaming video and real-time processing, or the design work of a large group of scientists geographically distant from one another [4].

Cloud computing in all of its available models, such as IaaS, PaaS and SaaS [5], plays an important role in this attempt to facilitate collaborative research by not exploring and managing the details of the underlying infrastructure in order to be able to use it for joint data processing. By providing abstraction of resources and simple automation tools, modern cloud platforms simplify most routing tasks such as installation, maintenance, backup, security, and more. Thus, cloud applications have become an important tool for modern researchers. Moreover, today, they are, as a rule, the best way to solve the problem of big data [4].

To solve research-related problems, modern science needs support from computing infrastructures, so many European and national initiatives deal with distributed, networked and cloud-based infrastructures. One of them is the Helix-Nebula project, the European Network Infrastructure (EGI), the European Open Cloud of Science (EOSC-hub). Due to the high demand for research applications, similar services related to data storage, for the processing of a huge amount of data are increasing interest from the scientific community. It is expected that these services will provide both productivity and features that allow more flexible and cost-effective use of such services. Easy multi-platform data access, long-term storage, performance support, and cost of data access are elements that can be differentiated into one system. In order to meet the needs of the scientific community regarding infrastructure in Poland, several national projects were also launched. The results of the PL-Grid family of projects provide a computing infrastructure for large-scale simulations and calculations at high-performance computing clusters supported by domain-based services, solutions and environments. Pioneer's infrastructure serves high-bandwidth optical networks that connect the main computer centers used in the infrastructure of PL-Grid. Since the scientific data obtained through simulation, sensors or devices used by scientific applications should be stored for further research in appropriate repositories, such services are in high demand [7]. Some requirements put forward by users relate to aspects of service quality and its proper level [8].

### 1.2 Analysis of recent research and publications

For Ukrainian science, issues relating to the European cloud of open science are new and little studied. However, certain work is already being met and scientists are actively interested in the issues. Olekcey O. Petrenko [9] investigated the changes taking place in service-oriented architectures in connection with the transfer of applied applications in the cloud environment, in particular, to the European cloud of open science.

Valerii Yu. Bykov [2] investigated the scientific and methodological basis for the creation and development of a cloud-based environment in the context of open scientific priorities and the formation of the European Research Area (ERA). Their work outlines the conceptual and terminological justification of cloud computing, as well as the main features of such a medium. Ukrainian scientists describe the main methodological principles of designing and developing the environment, on the example of the principles of open science, open education, as well as the specific principles inherent in cloud-based systems.

### 1.3 The purpose of the article

On the basis of analysis of the structure of an open science platform, it is shown that complemented reality serves as its tool and on a separate software product to determine its practical value in scientific research.

## 2 Theoretical background

Scientists around the world are increasingly using cloud-based technologies to perform computational tasks. Cloud resources can be distributed on demand, scaled according to different usage patterns, and reduced costs for individual groups of scientists to support their own infrastructure.

Olekcey O. Petrenko in [9, p. 13–14] notes that service-oriented approach that is based on the present-day largest European project for the creation of the European Open Science Cloud for Research (EOS), which began in 2017 and which motivates research into the technology of hosting many SOA applications in the cloud, which will soon serve 1,7 million scientists and 80 million professionals from various fields of science and technology.

Major research infrastructures are planned on an EU-wide scale in the context of the ESFRI roadmap, aimed at providing scientists with the appropriate tools for research. More and more demands on data volumes and computing power are put forward.

Projects such as Indigo-Datacloud, EGI, European Cloud Science, HelixNebula, are considering the introduction of cloud services for the European academic community [1].

Indigo-DataCloud develops intermediate software for implementing a variety of cloud-based services, from authentication, workload and data management, and collects a catalog of cloud services. The project just released the second software, ElectricIndigo.

The Indigo project is primarily aimed at bridging the gap between cloud-developers and the services provided by existing cloud service providers, instead of providing their own cloud-based services.

EGI coordinates a unified cloud, originally based on OCCI and CDMI, as web services interfaces to access OpenNebula and OpenStack cluster resources or public service providers. This approach is to provide an additional level of abstraction over the resources provided by national energy conservation programs and remain separate and independent of each other.

HelixNebula explores how best to use commercial cloud service providers in the purchase of cloud infrastructure for research and education. This approach is to create a private-government partnership for the purchase of hybrid clouds.

The third phase of the prototype, which involves three contract consortia, has recently begun. The European Commission promotes the European cloud of open science as a common basis for supporting open science and research, covering a wide range of issues ranging from technical, accessible and managerial to building infrastructure. Many of these projects are funded by research or meet the needs of specific communities, such as providing prototype or pilot-level services to a limited group of users, with limited resources, as well as groups within the EGI Federated Cloud Initiative.

Moving from the prototype stage to the production stage, offering large volumes of resources for a large community, is a challenge in terms of efforts and resources. Creating a well-equipped and supported platform for cloud computing requires a significant investment of large commercial cloud providers or public organizations that decide to invest in creating a real cloud infrastructure for science. One of the possible alternatives to a central approach to large-scale financing is the federative approach, where the infrastructure is built up from the bottom up, combining medium / large objects into large ones, to reach the appropriate scale [1].

Within the framework of the European Commission's strategy for creating a single digital market, the European Commission officially launched the European Open Educational Initiative (EOSC) in April 2016. EOSC promotes not only scientific excellence and data reuse, but also job creation and competitiveness in Europe, as well as contributing to pan-European cost efficiencies in scientific infrastructures by promoting unprecedented scale.

The experts outlined the basic principles of the cloud of open science [3]:

1. EOSC needs to integrate with other electronic infrastructures and initiatives in the world by introducing a light, interconnected system of services and data that fits the federal model.
2. The term "open" refers to the availability of services and data in accordance with the appropriate non-discriminatory policy ("not all data and tools may be open", and "free data and services do not exist").
3. The EOSC should include all academic disciplines.
4. The term "cloud" should not relate to ICT infrastructure, but to universal access to data, software, standards, expertise and policy frameworks for science and innovation-driven data.

The general view of most relevant stakeholders for the European cloud of open science lies in the fact that this cloud should [9]:

- to be a system of services provided by different suppliers;
- relying on existing electronic infrastructures, so developer efforts should focus on the integration / interoperability of cloud services;
- continuously develop and integrate new services and tools as soon as they become available, freely distributed to users;
- to take into account the needs of users as a leading motive for the development of the European cloud of open science.

In the vision of experts, EOSC will be an accessible infrastructure for modern research and innovation that employs the Internet of accessible data and interoperability and reusable services. It should be based on standards, best practices and infrastructures supplemented by adequate human experience. The fair principles should be maintained, and particular attention should be paid to the reuse of open and confidential data. Data should be with a multitude of elements (standard, tools, protocols) that provide the possibility and ease of reuse. In addition, there is a need to implement a science data processing profession to ensure professional data management and long-term management. In Europe, European research infrastructures specializing in the domain, and cross-sectoral ICT electronic infrastructures as well as other disciplinary and interdisciplinary collaborations and services have already been established. They can be considered the basis for EOSC. However, the implementation of ambitions to increase unimpeded access, reliable reuse of data and other digital research objects, as well as cooperation between different services and infrastructures (which guarantees non-discriminatory access and reuse of data both to the public and to the public and private sector), requires further improvement of this landscape in order to transform the ever-increasing amount of data on knowledge as a renewable, sustainable ground for innovation in turn to meet the global needs. EOSC is an instrument defined by the European Commission to facilitate such development towards the implementation of the Open Science. This idea highlights the strong link between ERA implementation through Open Science, Open Science and EOSC. In this context, the High-Level Expert Group, developed by the European Commission, reported on the list of key trends of Open Science that should be taken into account in the EOSC project. They cover several aspects, such as new ways of scientific communication (for example, programs, software conveyors and data itself), new incentives for promoting data dissemination and sharing of tools, facilitating the formation of data processing professionals, interdisciplinary collaboration, support for innovative SMEs, the creation of ecosystems, methodologies and tools for the reproduction of current published research, etc. [3].

## 3 Research methodology

The ERA was endorsed by the European Council in 2000 as a way of building a single, open-world research area based on a domestic market in which researchers, scientific knowledge and technology circulate freely and through which the European Union and its members strengthen their scientific and technological bases, their competitiveness and the ability to collectively address the challenges of today [3].

According to Olekcey O. Petrenko, EOSC is an interdisciplinary environment for research, innovation and educational goals [9, p. 59].

According to the first report of the High-Level Expert Group on the EOSC appointed by the European Commission, EOSC was identified as an open source support environment for accelerating the transition to more effective open science and open innovation in digital the single market by removing technical, legislative and human barriers to reuse data and research tools. Indeed, the term "cloud" was interpreted as a metaphor that helps convey the idea of fidelity and community [3].

## 4 About Open Science platform

Now consider the platforms and tools of one of the major European electronic infrastructures, EGI, which will cover how they can be the basis for an open science fund and then EOSC. EGI, an advanced computing engine for research, is a federated electronic infrastructure created to provide advanced computing services for research and innovation. EGI's infrastructure is primarily state-funded and has over 300 data centers and cloud providers throughout Europe and around the world. Its principles are based on an open academic community, and its mission is to create and provide open solutions for research and research infrastructures by combining digital capabilities, resources and expertise between communities and across national boundaries. EGI architecture is organized in platforms [3]:

- Basic Infrastructure Platform for Managed Distributed Infrastructure;
- Cloud infrastructure for managing the unified regional infrastructure;
- An open data platform that provides easy access to large and distributed data sets;
- A platform for cooperation, for the exchange of information and community coordination,
- Joint platforms, specialized service portfolios designed for specific academic communities.

The platform architecture allows any type and any number of shared platforms to coexist on physical infrastructure.

### 4.1 Augmented reality platform as a tool for open science

EGI launched the production phase of the cloud federation to serve research communities in May 2014, the EGI Federated Cloud. It integrates community, private and/or public clouds into a scalable computing platform for data and/or computing applications and services. Its architecture is based on the concept of an abstract cloud management environment (CMF), which supports a set of cloud interfaces for communities. Each Infrastructure Resource Center manages an instance of this CMF according to its own technological advantage and integrates it with the federation by interacting with the EGI's core infrastructure [3]. This integration is carried out using public interfaces supported by CMF, which minimizes the impact on the work of the site. Suppliers are organized in the area that uncover homogeneous interfaces and group resources dedicated to serving specific communities and/or platforms.

EGI Federated Cloud is based on a hybrid model where private, community, and public clouds can be integrated and already offer some tools that a service center must provide, such as virtualization and easy sharing and reuse of tools.

Each Infrastructure Resource Center manages an CMF instance according to its own technological advantage and integrates it with the federation by interacting with the EGI core infrastructure. Suppliers are organized in the areas of homogeneous interfaces (IaaS). Community platforms can use resources from one or more areas using these interfaces. AppDB VMOps enables the automatic deployment of virtual devices at all resource centers that support a specific community.

Olekcey O. Petrenko [9] explores the FIWARE directory as the main tool for creating web services for EOSC. Some of the services included in the FIWARE directory can be linked to the augmented reality:

- AEON Cloud Messaging: Real-time service provides cloud services (channels) for the transfer of unlimited number of entities, sharing unlimited amount of information, as well as services for managing actors involved in cloud environments.
- Complex Event Processing (CEP) — Proactive Technology Online: CEP analyzes real-time events by responding to situations rather than on individual events. Situations include composite events (for example, sequential), operator distribution by events (e. g., aggregation), and lack of operators.
- Cloud Rendering: The service defines a common way of requesting, receiving, and managing the video stream of a remote 3D application.

**4.2 Practical application of augmented reality**

Today, the Institute of Information Technologies and Training of the NAES of Ukraine is a partner of Visegrad Fund's Strategic Grant No. 21810100 "V4 + Academic Research Consortium for the Integration of Databases, Robotics and Language Technologies" [2]. As an example, let's look at one of the services developed by one of the partners of this project (Óbuda University Budapest, Magyarország), which can be included in the open science platform: MaxWhere (Hungary). MaxWhere combines several new technologies. The cognitive navigation technology (CogiNav) allows users to navigate smoothly across 3D spaces using only a laptop and mouse [5].

MaxWhere is the platform for managing all forms of digital content in 3D spaces. The main product — MaxWhere, which is largely similar to graphics engines (like Unity, Unreal), however, differs from them, since it has been optimized not for gaming applications, but for everyday digital life and professional industry. MaxWhere can be used in education and research.

Maxwhere [6] includes fast and innovative interfaces. This allows you to switch projects and go to different scientific communities, distribute research results in the fastest way. This is a combination of other applications that exist to organize the teamwork of scholars. 3D graphics will diversify your work without compromising performance. It can also be used by students to increase productivity and study data research.

Browser23 introduces a new web surfing philosophy: instead of having a limited number of tabs next to users, limiting their ability to switch between them and searching now, it allows you to set browser windows in 3D space, grouped by topics that are scaled for size and significance. The newly developed Ultra Sharing technology, which allows users to create VR offices that contain a large number of documents, and even complete the workflows of the project, and split these offices with one click [6]. Research shows that all these solutions combine an extremely effective way of visualizing, exchanging and manipulating large volumes of information while maintaining low cognitive load — a huge asset for understanding, configuring and managing large digital networking systems.

In 2017, MaxWhere was released as a tool for presenting 3D slides in interactive spaces. This solution is a blend between PowerPoint and Prezi, expanded with 3D objects. From a technological point of view, MaxWhere combines 3D space with web technologies. In this way, the world of open-source software (for example, Node. js, NPM and Node-RED) can be directed to MaxWhere applications.

## 5 Conclusions and prospects for further research

To date, the implementation of the European Research Area (ERA), as depicted by the European Council, can not be considered fully achieved. The implementation of an open and integrated environment for cross-border unimpeded access to advanced digital resources, services and opportunities facilitating the reuse of data and research services is accelerated by the initiative of the European Commission "European Open Science Cloud". Open science is seen as a natural paradigm for the promotion and development of such events. It can remove the barrier between neighboring communities, provide interdisciplinary cooperation, reinforce the need for knowledge sharing and allow free and unrestricted access. The advantages of the approach to open science and, in particular, the advantages of joint resources for the introduction of European infrastructure and the management of European open science were considered. We have analyzed the possible approach to the implementation of EOSC through open scientific communities. The EOSC architecture is based on the cloud hub federation, where the cloud hub provides data, services and features in a standard and consistent way. Hubs support the cloud provisioning paradigm to facilitate sharing, reuse, and combined data and tooling with virtualization. In addition, the federation of hubs provides a multi-layered organizational structure that complies with European policies, norms, restrictions and business models, and allows the creation of a community that can combine the various types of experiences available in each center. That is, an existing environment with several suppliers

EOSC is governed by special tools, processes and tools that determine the EOSC integration and management system owned, maintained, and developed by EOSC in accordance with the Commons management model. EOSC cloud nodes services are provided by many stakeholders: data providers, European research infrastructures, electronic infrastructures, research and local, regional and national institutions. The use of data directly benefits EOSC and the acceptance of open academic communities, using technologies, services and resources provided in the context of existing European electronic infrastructures. EOSC and electronic infrastructures can become a pole of engagement for designing and implementing appropriate solutions for managing and using a large number of data sets. This will allow you to create an integrated environment for rapid development, prototyping and service delivery for service platforms and scientific applications.

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## Доповнена реальність як інструмент відкритої наукової платформи за рахунок дослідницької співпраці у віртуальних командах

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**Анотація**. Положення відкритої науки визначається як загальна політика, яка спрямована на подолання бар'єрів, що перешкоджають реалізації Європейського дослідницького простору (ЄДП). Відкритий науковий фонд прагне охопити всі елементи, необхідні для функціонування ЄДП: дані дослідження, наукові інструменти, ІКТ-послуги (зв'язок, розрахунки, платформи та конкретні дослідження, такі як портали).

Управління спільними ресурсами для спільноти науковців максимізує користь для суспільства. Це вже мало великі переваги у галузі цифрової інфраструктури. Очікується, що застосування цього принципу у відкритому науковому процесі покращить управління організаціями, що фінансують, у співпраці із зацікавленими сторонами через такі механізми, як громадські консультації. Це збільшить уявлення про спільну власність на інфраструктуру. Це також створить чіткі та недискримінаційні правила доступу, а також почуття спільної власності, що стимулює більш високий рівень участі, співпраці та соціальної взаємності.

У статті розглядається концепція відкритої науки. Надано концепцію європейської хмари відкритої науки та її структуру. Згідно з дослідженням, було продемонстровано, що структура хмари відкритої науки включає доповнену реальність як платформу відкритої науки. Прикладом практичного застосування цього інструменту є загальний опис MaxWhere, який розроблений угорськими вченими і являє собою платформу сукупностей окремих 3D-просторів.

**Ключові слова**: ЄДП, ЄМІ, центр ЄХВН, ЄХВН, Європейська хмара відкритої науки.

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# Simulation technologies of virtual reality usage in the training of future ship navigators

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**Abstract**. *Research goal*: the research is aimed at the theoretical substantiation of the application of virtual reality technology simulators and their features in higher maritime educational institutions. *Research objectives*: to determine the role and place of simulation technology in the educational process in the training of future ship navigators in order to form the professional competence of navigation. *Object of research*: professional training of future ship navigators in higher maritime educational institutions. *Subject of research*: simulation technologies of virtual reality as a component of the educational process at higher educational maritime establishments. *Research methods used*: theoretical methods containing the analysis of scientific sources; empirical methods involving study and observation of the educational process. *Research results*: the analysis of scientific publications allows to define the concept of virtual reality simulators, their application in the training of future navigators, their use for assessing the acquired professional competence of navigation. *Main conclusions*: introduction of simulation technologies of virtual reality in the educational process in higher maritime educational institutions increases the efficiency of education, promotes the development of professional thinking of students, enhances the quality of professional competence development.

**Keywords**: professional training of ship navigators, simulator training, simulation technology, simulators, virtual reality.

## 1 Introduction

### 1.1 The problem statement

Ensuring the development of the professional competence of future navigators should take place in accordance with the requirements of the International Maritime Organization (IMO), which defined the training and introduced it into the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers with the Manila Amendments of 2010 [10]. The STCW Convention defines the operational requirements for a number of simulators that are used in the process of developing the professional competencies of future marine specialists, and for the first time in international regulatory practice the assessment of professional competencies by simulators has been introduced. The normative document defines the operational requirements for a number of simulators and for the first time in the international normative practice training and assessment of competencies with simulators has been introduced.

World practice shows that in connection with the development of digital technologies, designing and creating software products is the most effective tools of professional training of ship navigators, which are simulators of the modern generation using virtual and augmented reality (VR and AR). Such simulators allow to bring the training conditions to the conditions of the reality for the ship navigators when navigating the vessel, and navigational simulators to a large extent ensure fulfillment of psychological and didactic requirements to the process of skills and abilities formation.

### 1.2 Theoretical background

In the context of our research, we analyzed the current vision of the role and place of VR simulators in the professional scientific discourse from the standpoint of taking into account the specifics of the subject field of professional activity of future marine specialists.

VR simulators are quite widely used in the training of students of maritime professions all over the world. Ukraine has no deep experience in the use of simulation technologies in the higher maritime education system, and therefore the approval in 2018 of a new standard of higher maritime education for the first (Bachelor level), aimed at developing competencies of the XXI century [10] has set the benchmarks for changing the educational paradigm for optimization and practical training process, integration of training in the educational process in order to effectively form the professional competencies of future marine specialists.

Among the works devoted to training and practical training of cadets in marine schools should be identified works of Asghar Ali [1], Djelloul Bouras [6], Olle Lindmark [15], Charlott Sellberg [30].

Olle Lindmark, studying simulators in maritime education, noted that in 1994, the IMO created a simulator working group that was created to structure training information for inclusion in the STCW, and this group identified the simulation as "realistic simulation", in real time, any handling of a ship, radar and navigation, propellant, cargo/ballast or other ship system, including an interface suitable for interactive use by a student or candidate both within and outside the operating environment. Higher, and compliance with the standards set out in the relevant sections of this section of the STCW Code [15].

Yaser H. Sendi classifies simulators on real, virtual and constructive, and determines that the constructive ones contain a virtual reality and is the highest level of complexity of simulators for the formation of professional competencies and their evaluation [31].

Constructive simulators — held in a virtual reality environment, it is considered a very complex level of simulators for the purposes of allowing instructors (i. e. captains) to analyze the performance of apprentices and evaluate their master of skills after using the simulation.

VR simulation technologies are new forms of professional competence development for marine specialists who, through the creation of quasi-professional situations, can form professional thinking and develop the necessary skills without risk to life and save time and resources. But it should be borne in mind that in most marine higher educational establishments of Ukraine, traditional approaches to teaching still prevail, therefore, a promising direction for improving the educational process in maritime institutions of higher education is the creation of simulation (training) centers in order to systematically approach the formation of professional competencies.

In the NMC Horizon project, VR technologies are part of the promising direction of the tools and processes of visual imaging technology that are used to combine the efforts of the brain's ability to quickly process visual information and to find order in difficult situations. Visualization technologies are used to improve teaching, learning, creative search and have a great prospect of use and effectiveness in the future [23]

Introduction of the concept of "Virtual University", which represents the use of modern development platforms virtual reality, takes place in the experimental process by industry in many authoritative implementations such as Massachusetts Institute of Technology, Yale University, Lund University, IBM, Microsoft.

Submitted by various researchers, the generalized results of the use of simulators with VR in the systems of training specialists of different directions can make a reasonable opinion on the feasibility of using VR technology in the system of training future mariners, taking into account the peculiarities of the organization of educational process in higher maritime educational institutions and the specifics of professional maritime activity sailors merchant fleet.

### 1.3 The objective of the study

The purpose of the article is to substantiate the essence of simulation technologies of the VR used in the process of training of marine specialists, and to determine the specifics of the application of simulation technologies of VR in the formation of professional competencies of future marine specialists.

## 2 Results and discussion

The use of e-learning is based on and used in the learning process of virtual environments [5, 18, 24], complemented by the reality of computer simulations, virtual 3D worlds with the effect of immersion. According to the numerous studies [11, 12, 14, 19, 25, 35, 44], the virtual environment is a quality educational tool, and the task of the teacher is to reorient modern virtual technologies to learning.

Virtual reality (VR) and augmented reality (AR) represent a new direction in the development of information technology. VR and AR are two closely related technologies that have certain differences.

VR is a similitude of the real world created by technical tools in digital form. The created effects through the projection onto the human eyes and cause the feeling that they are as close as possible to the real ones.

VR allows users to immerse themselves in the world created by the computer, and get the sensory experience there. Augmented reality (AR) is an image that is imposed on objects of the real world. Augmented reality is characterized by the inclusion of digital information (images, video and audio) in real space, trying to combine reality with the virtual environment, allowing users to interact with both physical and digital objects [7, 9, 13, 16, 17, 21, 22, 26, 28, 32, 33, 36, 39, 41, 45].

Consumer Technology Association at CTA-2069 standard highlights the mixed reality (MR), a seamless combination of the real environment and digital content, where both environment exists to create experience [27].

Virtual technologies for educational purposes began to be used as early as in the 1960s as airplane simulators [38], and in the 80s, in the form of systems for dialogue management with machine-generating images [42].

The most common means of immersion in VR are specialized helmets / glasses, the display of which outputs 3D video, and the sensors capture the head turns and change the image on the display.

From the point of view of cybernetics, the essence of virtual reality is reduced to the following characteristics: 1) creating means of programming three-dimensional images of objects that are as close as possible to real, models of real objects, like holographic; 2) the possibility of animation; 3) network data processing, which occurs in real time; 4) creation of means of programming of the effect of presence [29].

Today, using a web browser or smartphone, it's possible to switch from the Amazon to the library (Google), to your personal space (Facebook). There are virtual spaces for meetings (Skype) and even game arenas (Steam Valve) as teleportation in the digital sense. But none of these services will be able to simulate the real world due to limitations of 2D screens.

Many VR technologies are just 360-videos, which format provides a sense of presence: the one who browses himself chooses, where to look, exploring the space, and is an active participant in everything that's happening. Immersion is achieved even in the absence of a screen frame, through which so everyone is accustomed to watch the news, reality show. Video review of VR requires photorealistic and real-time environments to create unity with the browser and presence phenomenon and joining the situation.

There are many classifications of virtual simulators using a variety of criteria, such as the degree of realism, hardware, the scale of the virtual space that is being created.

The advantages of virtual simulators are:

- the possibility of creating a safe for the student working space in which he can work out various skills without risk for his life;
- the creation of an educational space, built on the needs of those who study;
- the possibility of repeated repetition to achieve automatism;
- compatible scenarios and actions;
- the possibility of immersion in a situation in which it is necessary to quickly make decisions and act [37].

Also, the advantages of using simulators and virtual simulators include the possibility of using them for both individual work of the student and for organization of group training.

For the first time simulations and virtual simulators began to be used in medicine.

A virtual simulator is a modern learning tool that provides a clear idea of the object of the research and work with it without direct contact with the object [30].

A virtual simulator can be defined as an interactive component of e-learning to study and consolidate a variety of practical skills when working with real objects in the subject area.

There are three types of VR simulators:

1. Those which teach (electronic textbooks).
2. Those which control (testing systems).
3. Those which teach skills (multimedia and / or animated simulators of reality with subjects of the subject area).

The first simulators were similar to computer classes, where simulation of situations took place, but the lack of them was an unnatural presentation of objects. Ideal simulators are those that combine ("mix") the real and virtual world and where the visual series is almost entirely true reality. These simulators completely allow you to work out scenarios of real professional situations in a completely realistic three-dimensional space.

Virtual simulators can be used primarily where it is necessary to work out the sequence of actions, as well as the formation of sustainable skills for the prevention and elimination of emergencies, accidents.

The virtual training complex significantly reduces the operating load on a real object (vessel element), reduces the probability of errors, increases the inter-repair resource. The main advantage of virtual simulators is that for a minimum amount of time the student receives a maximum of practical experience.

In the traditional scheme of training, students receive profound knowledge only from individual disciplines, and combining this knowledge in practice is given the opportunity only after several years of work as a responsible decision-maker, virtual simulators give the opportunity to feel like a person directly in the learning process of certain scenarios [8].

There is a phenomenon of kinetheus in the VR — the indicators of the vestibular apparatus and organs of sensation are different, because a person sees movement, but the body remains at rest. The brain perceives visual information as hallucination, which may be felt by poisoning, and nausea occurs. Similar feelings also exist when creating the effect of staying at sea. The effect of the sea sickness is very similar to the real feelings, getting used to it can even help future carriers in future work

An important element in achieving the effect of a psychological presence is theory of embodied cognition [40], which explains the fact that people are better at perceiving information when acting, rather than when they are watching what others do or listening to or reading about it [4].

That is, in fact, the main purpose of the use of VR simulators is to provide the new quality of professional training of future specialists by immersing the students in the real atmosphere of solving quasi-professional tasks, optimal for the formation of professional competencies and personal qualities of future professionals in conditions that are as close as possible to the conditions of future professional activity.

For the first time marine simulators were used in Sweden in 1967 (Goteborg) with a research purpose to analyze the prediction of the behavior of the crew [6].

Today, the traditional training of sailors has changed the emphasis on practical orientation and the use of simulators for the formation of professional competencies without the need to be on the vessel [43].

Simulation technology in a navigational system is a modern technology of training, assessment of practical knowledge, skills based on the use of computer models of navigation processes that are as close as possible to the conditions, simulation of communication interaction in specific situations.

The pedagogical advantage of using simulators in maritime education is that it is possible to develop such scenarios or exercises that are designed to study and evaluate specific learning outcomes [30].

The use of training technology in the educational process allows you to work out the interaction of the crew with each other and with other participants in the navigation; to simulate emergency and crisis situations; to check psychological readiness of cadets for actions in extreme conditions; reduce the risk of making wrong decisions, etc. [2].

Charlott Sellberg [30] in her doctoral thesis experimentally proves that work on simulators meets the requirements of STCW, and all training in these simulators contributes to the formation of professional competencies of marine specialists.

Kherson State Maritime Academy has the experience of implementing the model of a competent approach to training according to the program of experimental activity on the topic “Theoretical and methodical principles of implementation of the competence approach in the system of graduation of maritime industry specialists training” in accordance with the order of the Ministry of Education and Science of Ukraine No. 1148 dated October 7, 2014.

In order to systematically approach the development of professional competencies of marine specialists and through the support of partner companies and central and local authorities, a training complex (simulation center) was opened in October 2016, which included 19 laboratories, 16 simulators and 21 training room.

All these laboratories, training bases and complexes were combined into a single training complex, which was named “Virtual-Real Ship”. Several dozen cadets have the opportunity to simultaneously undergo training on such a vessel, and the preparation itself is carried out not only in conditions that are as close as possible to the real, but also in the conditions of direct bearing of the ship's watch.

KSMA "Virtual-Real Ship" is a separate structural innovation unit in the education system — a full-fledged simulation vessel — combining educational continuity between the pre-practical and practical stages of training and is a powerful tool for building the professional competencies of future marine specialists. Thus, in the center, the development and implementation of methodological and normative provision of the educational process, the formation of an individual educational trajectory, standardization of criteria for assessing knowledge, skills, competencies, and high-tech emergency response standards that meet the requirements of the STCW are being developed.

All simulators meet the requirements of international and national standards and regulations (including STCW, SOLAS, IMO model courses), as well as certificates of leading classification societies. They provide effective training and assessment of professional competencies of the cadet, which corresponds to the concept of evidence-based competence in the marine industry in accordance with the requirements of the STCW.

Educational training on "Virtual-Real Ship" is carried out in two directions:

- professional training with the priority of special professional knowledge;
- sequence of actions and group training with an emphasis on the human factor-coordination of teamwork and resource management in crisis situations.

In the educational process of the KSMA simulation complexes, VR simulators are used, on the basis of which educational programs are implemented. The appropriate platform, thanks to realistic interactive scenarios and opportunities for immersion, provides the following capabilities: acquisition of knowledge and skills with sophisticated techniques, gaining knowledge about reducing the probability of occurrence of extraordinary situations, getting experience of troubleshooting and restoring normal working conditions in the event of an emergency situation.

The purpose of training in VR simulators is:

1. Acquisition, improvement and practical use of the acquired skills of navigation
2. Formation of professional thinking, reflection of their activities.
3. Practical understanding of their role in the team.

So, in the KSMA there are two laboratories with VR simulators (Fig. 1):

- Full-function navigational bridge;
- Full-function simulator of a vessel with a dynamic positioning system.

**Fig. 1.** Full-function navigational bridge

The scheme (Fig. 2) defines professional competencies according to the STCW, which are formed in these laboratories.

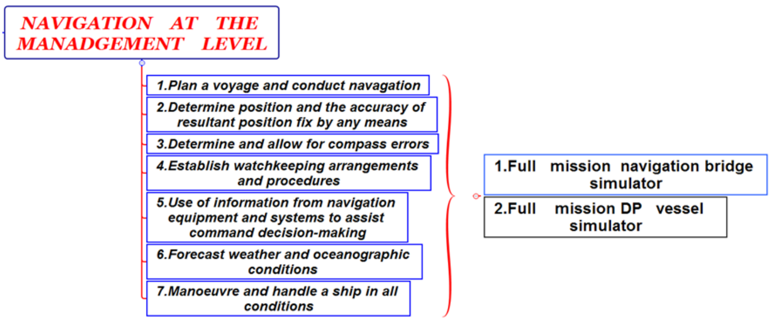


**Fig. 2.** VR laboratories of KSMA

Teachers of special professional disciplines develop exercises on simulators that must be performed by students in accordance with the program of discipline and define their goals according to the general objectives of the training defined for the particular discipline. Training objectives, simulators, tasks and evaluation criteria are described and defined in accordance with the requirements of the STCW [10]. Before approving by the corresponding heads of the department, exercises on the simulators are tested by instructors in order to ensure that they are consistent with the objectives of training. Instructors familiarize students with a simulator before undertaking any exercise, including goals, tasks to be performed, assessment criteria, and arrange a discussion session after completing the exercise, in which the instructor and students discussed the exercise and its outcome. During the exercise on the simulator, the instructors evaluate students' activities [34].

Training laboratory "Full-function navigational bridge" is equipped with a simulation of the navigating vessel with a circular visualization of the navigational environment with an angle of the visible horizon of 210 degrees horizontally and 35 degrees vertically, a simulator of the integrated navigation system with two ARPA stations, two ECDIS stations, software and hardware controls a vessel, a sound simulation system, means for controlling and monitoring a marine propulsion system, an imitation of a maritime system. The training laboratory "Full-function navigational bridge" meets the requirements for the A1-grade classes in the DNV/IMO classification.

The algorithm of the simulator though similar to modern computer games, which consist of passing of missions (tasks), but unlike them, there are no levels of complexity — the simulation always occurs in the mode of maximum realism.

The purpose and tasks of training on this simulator, as defined in the model course 1.22, is to gain experience in working with ships in different conditions and to make a more efficient contribution to the bridge crew when maneuvering ships in normal and emergency situations.

In particular, the aim of the course is to acquire the following competencies:

- familiarization with the use of engines and steering for maneuvering vessels;
- understanding of the effects of wind on vessel behavior, shallow water flow, shallow, narrow channels, and loading conditions;
- a deeper understanding of the importance of planning a transition or maneuver and the need for an alternative plan;

- a deeper understanding and awareness of the effective procedure for bridge and crew work during the navigational watch, in normal and emergency situations;
- a deeper understanding and understanding of high-quality interactive communication and the benefits of creating a common mental model for a planned transition.

The results of training are written in specific skills, which after the completion of the course will be able to perform the cadets:

- Form a bridge team, using all available resources, enforcing official responsibilities and creating a sense of responsibility for all crew members
- Make a detailed plan for the transition and track the progress of the vessel in accordance with the plan
- Assess the situation and make decisions to ensure the safety of the ship
- Support pilots and track their actions
- Determine the need for a contingency plan in a high-risk area
- Recognize the sequence of actions leading to an error and effectively interrupt such sequence
- Interpret and effectively use data on maneuvering the vessel.

**Table 1.** Division of hours into lectural and practical ones

| **1**. Ship Management | | | | | |
|---|---|---|---|---|---|
| **Course** | **II** | | **III** | **IV** | **Total** |
| Semesters | 3 | 4 | 6 | 8 | |
| Lectures | 20 | 20 | 18 | 16 | 74 |
| Practical works | 16 | 20 | 18 | 16 | 70 |
| **2**. International rules for preventing collisions of ships at sea | | | | | |
| Lectures | – | – | – | 20 | 20 |
| Practical works | – | 14 | – | – | 14 |

In the course of an experimental work, the training was integrated into the curriculum of bachelors and masters. Thus, in the laboratory there are practical classes in the disciplines "Ship management" and "International rules for preventing collisions of ships at sea". The distribution of hours into lectures and practical works (Table 1) indicates that 48.6% of hours and 41% of the hours have been allocated for practical training.

The STCW [10] defines minimum requirements for the content, criteria and assessment of professional competencies, which should be more clearly specified by each higher education institution on its own.

Teachers have developed working programs of disciplines that contain requirements for the formation of professional competencies, methods of demonstrating competencies. Thus, in Table 2, the competence requirements for skills of the specialists from the work program “International rules for preventing collision of ships at sea” are presented, which meets the standards of the Ministry of Education and Science of Ukraine, requirements of section AI/12, Section BI/12 of SNCW and IMO Model Course 1.07, “Radar Observation and Planning and Operational Use of Automatic Radar Plotting Aids” (ARPA).

**Table 2.** Competency requirements for the skills of specialists in the working program of discipline

| **Competence** | **Skills** | **Methods of competency demonstration** |
|---|---|---|
| Maintain a safe navigational watch | *Watchkeeping*<br>Thorough knowledge of the content, application and intent of the International Regulations for Preventing Collisions at Sea, 1972, as amended.<br>Thorough knowledge of the Principles to be observed in keeping a navigational watch. | Evaluation of radar simulator and ARPA results, and work experience |

Framework of competencies is also used on the LMS Moodle electronic platform, which allows you to retrieve individual trajectories and form professional competencies [20].

The training takes place in small groups (4–5 cadets), which allows each cadet to actively participate in the educational process, demonstrate their knowledge and acquired competencies. A permanent working relationship is formed between a teacher and a cadet, resulting in a significant increase in the degree of mastery of both theoretical and practical knowledge [3].

Stages of classes consist of the following stages:

- Training (briefing), which assesses the situation, equipment, determines the object and purpose.
- Simulation process itself, in which an important condition is the maximum sense of the reality of the situation.
- Summaries, analysis (debriefing).

Successful formation of professional competence is considered when the cadet reaches certain set of points. The level of competence development can be evaluated automatically by special software, and the assessment of the teacher-instructor who has the appropriate certificates of permission rating-by average (execution time, accuracy, absence of errors) is possible.

When comparing grades for discipline in 2018, until the introduction of integrated training plans between the training center and academy, and in 2019, there is a significant improvement in the quality of knowledge of students, which indicates the effectiveness of the use of technology VR in the educational process in the training of marine specialists to improve the quality of the formation of professional competencies (Fig. 3).

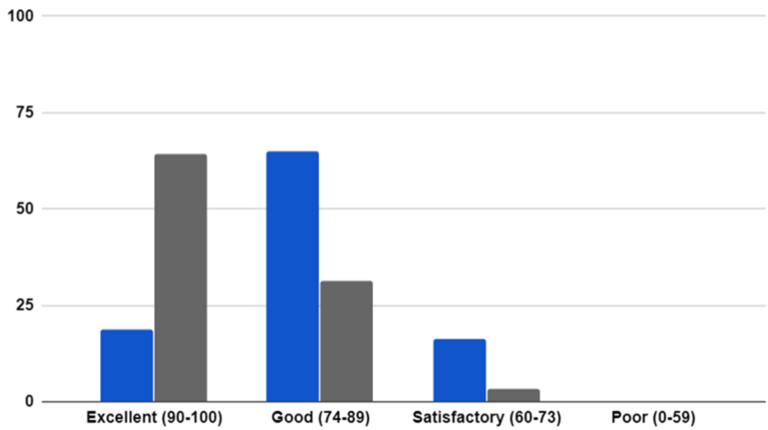


**Fig. 3.** Comparative chart of examination marks

## 3 Conclusions and prospects

The search for the latest and effective technologies for the formation of professional competencies in higher maritime vocational education is conditioned by the requirements of normative documents, rapid informatization of navigation and requirements of employers.

It is the use of modern VR simulators helps to find new approaches in shaping the professional competencies of future ship navigators with the departure from traditional teaching, in favor of the requirements of time and achievements of science and technology.

The main objective of using simulation technologies is to provide the new quality of the professional training of future navigators by immersing the students in the real atmosphere of solving quasi-professional tasks, optimal for the formation of professional competencies and personal qualities of future ship navigators in conditions that are as close as possible to the conditions of future professional activity.

The following research on the use of VR simulators in order to develop the professional competencies of marine specialists will include the development of methodological support, which will be reflected in subsequent publications.

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# Симуляційні технології використання віртуальної реальності у процесі підготовки майбутніх судноводіїв

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**Анотація**. *Мета*: дослідження спрямоване на теоретичне обґрунтування застосування симуляційних технологій віртуальної реальності та їх особливостей у вищих морських навчальних закладах. *Завдання дослідження*: визначити роль та місце симуляційної технології в навчальному процесі у підготовці майбутніх судноводіїв з метою формування професійної компетентності судноплавства. *Об'єкт дослідження*: професійна підготовка майбутніх судноводіїв у вищих морських навчальних закладах. *Предмет дослідження*: симуляційні технології віртуальної реальності як складова навчального процесу у вищих морських навчальних закладах. *Методи дослідження*: теоретичні методи, які включають аналіз наукових джерел; емпіричні методи, що передбачають вивчення та спостереження за навчальним процесом. *Результати досліджень*: аналіз наукових публікацій дозволяє визначити поняття симуляторів віртуальної реальності, їх застосування у процесі підготовки майбутніх водіїв, їх використання для оцінки набутої професійної навігаційної компетентності. *Основні висновки*: впровадження симуляційних технологій віртуальної реальності у навчальний процес у вищих морських навчальних закладах підвищує ефективність навчання, сприяє розвитку професійного мислення студентів, підвищує якість розвитку професійної компетентності.

**Ключові слова**: професійна підготовка судноводіїв, симуляційне навчання, симуляційна технологія, симулятори, віртуальна реальність.

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# Using the Proteus virtual environment to train future IT professionals

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**Abstract**. Based on literature review it was established that the use of augmented reality as an innovative technology of student training occurs in following directions: 3D image rendering; recognition and marking of real objects; interaction of a virtual object with a person in real time. The main advantages of using AR and VR in the educational process are highlighted: clarity, ability to simulate processes and phenomena, integration of educational disciplines, building an open education system, increasing motivation for learning, etc. It has been found that in the field of physical process modelling the Proteus Physics Laboratory is a popular example of augmented reality. Using the Proteus environment allows to visualize the functioning of the functional nodes of the computing system at the micro level. This is especially important for programming systems with limited resources, such as microcontrollers in the process of training future IT professionals. Experiment took place at Borys Grinchenko Kyiv University and Sumy State Pedagogical University named after A. S. Makarenko with students majoring in Computer Science (field of knowledge is Secondary Education (Informatics)). It was found that computer modelling has a positive effect on mastering the basics of microelectronics. The ways of further scientific researches for grounding, development and experimental verification of forms, methods and augmented reality, and can be used in the professional training of future IT specialists are outlined in the article.

**Keywords**: augmented reality, virtual environment, Proteus, training, future IT professionals.

## 1 Introduction

The rapid development of the modern information space is inextricably linked to the modernization of the education system, the effectiveness of which depends largely on involvement of students and teachers into digital information environment. Recently, progressive educators are increasingly turning to augmented reality (AR) as an opportunity to supplement the physical world, including the educational space, through digital information. This process is provided by computer devices such as smartphones, tablets and AR glasses in real time.

No wonder leading methodologists perceive augmented reality as an innovative technology of training students, including IT professionals. It is a well-established fact that augmented reality, unlike VR (Virtual Reality), which requires a complete immersion in the virtual environment, uses the educational environment around us and imposes on it a certain piece of virtual information. This information is usually attributed to graphics, sounds, or touch responses.

As the virtual and real worlds coexist in harmony, users with augmented reality experiences are able to experience a new world where virtual information is used as an additional useful tool to assist in the daily educational process. Therefore, it can be argued that computer visualization of the educational process is a necessary and important component of augmented reality. Its implementation is possible, for example, through the use of virtual laboratories.

In the field of modelling of physical processes the Proteus Physical Laboratory may be as augmented reality because its micro-level instrumentation allows tracking the features of the information system.

The analysis of the real practice of realization of educational process at Borys Grinchenko Kyiv University and Sumy State Pedagogical University named after A. S. Makarenko testifies that the features of using the Proteus virtual environment as augmented reality in the preparation of future IT specialists (students of the specialty “Computer Sciences”, field of knowledge “Secondary Education” (Informatics)) are still insufficiently developed.

## 2 Analysis of previous results

Various aspects of augmented reality application in the digital educational space have been the subject of research by a number of scholars. Noteworthy results of studies of Ukrainian scientists. Thus, Svitlana O. Sysoieva and Kateryna P. Osadcha have explored the possibilities of virtual, augmented and hybrid reality for the use of remote technologies at higher educational institutions [17]. Halyna V. Tkachuk outlined features of unique mobile content as augmented reality at the level of perspectives, advantages and disadvantages [18]. Maiia V. Marienko [15] and Mariya P. Shyshkina [13] considered augmented reality as a component of a cloud-oriented environment. Oleksandr V. Syrovatskyi [16], Serhiy O. Semerikov [9], Yevhenii O. Modlo [10], Yuliia V. Yechkalo [21], and Snizhana O. Zelinska [22] have characterized software for designing augmented reality in the preparation of future computer science teachers.

The analysis of the outlined works shows that modern authors highly appreciate the relevance of the introduction of augmented reality technologies in the educational process. Such activities are aimed at increasing students' motivation for learning, improving the quality of assimilation of information due to the variety and interactivity of its visual presentation, etc.

It is worth to mention about researches about forms, methods and conditions of using augmented reality when teaching physics in higher education (Tetiana V. Hruntova [5], Andrey V. Pikilnyak [5], Andrii M. Striuk [5], Yuliia V. Yechkalo [5]), in the study of chemical disciplines (Oksana M. Markova [12], Yevhenii O. Modlo [12], Pavlo P. Nechypurenko [11, 12], Tetiana V. Selivanova [8, 11], Ekaterina O. Shmeltser [12], Tetiana V. Starova [8, 11], Viktoriia G. Stoliarenko [12], Anna O. Tomilina [11], Aleksandr D. Uchitel [11]), geography (Elizabeth FitzGerald [4]), as well as in the educational space of the secondary school (Artem I. Atamas [14], Zhanna I. Bilyk [14], Viktoriia L. Buzko [1], Alla V. Bonk [1], Olexandr V. Merzlykin [7], Viktor B. Shapovalov [14], Yevhenii B. Shapovalov [14], Iryna Yu. Topolova [7], Vitaliy V. Tron [1, 7], Aleksandr D. Uchitel [14]).

We also distinguish the principles, approaches and working conditions of virtual laboratories. Thus, research on the application of Proteus simulation software in the teaching of electronic information specialty (Zhong-jian Cai [2] and Shi-bin Tong [2]) was carried out. Research on the application of simulation bench in experimental teaching of electrical engineering and electronics (Rongli Wang [19], Xiaojing Li [19] and Hongyue Liu [19]) is presented. A softwar-in-the-loop approach for automation and supervisory systems education (Antonio José Calderón [3] and Isaías González [3]) is considered. The PI-based implementation for modeling and simulation of the continuous-time LTI system and its Matlab-Simulink-based application (Zong-Chang Yang [20]) are outlined.

The purpose of this article is to use Proteus virtual environment as augmented reality in the training of future IT professionals.

## 3 Research methodology

The achievement of the goal of the research was facilitated by the use of a set of appropriate methods: scientific literature analysis in order to establish the state of elaboration of the problem under study, determination of the categorical and conceptual apparatus of the research; synthesis, generalization, systematization for theoretical substantiation and practical elaboration of research problem, including playback in the simulator environment of work of adders; modelling method for visualization of physical processes; empirical: diagnostic (conversation, content analysis, testing) to track the dynamics of professional training of students; a pedagogical experiment to prove the effectiveness of using the Proteus virtual environment; mathematical methods (McNemar's test) to assess the significance of improvements on the results of experimental work.

The research was performed within the framework of the complex scientific theme of the Department of Computer Science and Mathematics of Borys Grinchenko Kyiv University "Theoretical and practical aspects of the use of mathematical methods and information technologies in education and science" (SR No. 0116U004625) and the scientific topic of Department of Informatics of Sumy State Pedagogical University named after A. S. Makarenko "Development of intellectual skills and creative thinking of pupils and students in the study of mathematics, physics, computer science" (SR No. 0112U003078).

We have used the experience of teaching "Basics of Microelectronics" and "Computer Architecture", the study of which involved the involvement of specialized tools to model the work of individual components of the computer system.

## 4 Results and discussion

One of the major problems of professional training of future IT professionals is the low level of students' motivation to study. As noted by scientists [16, 17], it is possible to increase students' interest in learning through updated forms and methods of the educational process, in particular those based on the use of information technologies, first and foremost, augmented reality. The experience of professional training of IT specialists shows that the existing level of psychological, methodological training of students and teachers for use in the augmented reality in educational process, as well as the corresponding technical equipment in the vast majority of educational institutions do not meet the requirements of today. At the same time, we believe that the active use of augmented reality in the educational process is only a matter of time.

There are many approaches to using augmented reality technology in education today. Such mobile learning systems are conventionally divided into three main areas by modern researchers [8]:

1. 3D image rendering for visual presentation of training material.
2. Recognition and marking of real objects. Such capabilities make it possible to implement mobile, space-oriented learning systems.
3. Interaction of a virtual object built by a computer (smartphone) with a person in real time.

These directions of augmented reality help students through simulations and models to better understand the course material, create and manage tasks, evaluate, comment, and organize effective communication with teachers and other students.

To implement augmented reality technology in the learning process can be used:

1. Tutorials that contain special augmented reality objects; special mobile applications, printed illustrations are transformed into animated, three-dimensional animated objects that can perform certain movements and be accompanied by sound information.
2. Educational games. Best practice shows that in many cases the information provided in the form of interactive games is positively received by the students, activates motivation to participate in the process and promotes the development of learning materials.
3. Simulation of objects and situations. Creating graphic objects and constructing certain situations that can be used to learn the material, saves considerable material and financial resources, as well as conduct practical classes directly in classes.
4. Skills training supplements. When teaching certain subjects, it is possible to create content in augmented reality format, which can be

used as a tool for acquiring certain professional skills. It can be used by students for self-testing [6].

To date, the main technical advantages of using AR and VR in education are highlighted in scientific sources. Consider them in detail.

Start with clarity. Indeed, 3D graphics make it possible to reproduce detail of even the most complex processes invisible to the human eye, and it is also possible to increase the level of detail. Virtual and augmented reality allows you to reproduce or simulate almost any process or phenomenon. Next one is a security. The practical aspects of any activity can be safely practiced on a virtual or augmented reality device. In terms of engagement, AR and VR technologies make it possible to simulate any mechanics of action or behavior of an object, to solve complex mathematical problems. Among the benefits are focusing, so space modelled in VR can be easily viewed in a 360 degree panoramic range without being distracted by external factors, and etc.

Equally important are the organizational benefits of using augmented reality in education: the integration of different disciplines and visualization of the learning process; construction of an open system of education that provides an opportunity for each student to create a personal learning trajectory; expanding the boundaries of study through the use of study materials from leading universities in the world; improving the quality of students' independent work; increasing motivation for learning.

The analysis of real practice shows that in the field of modelling of physical processes as a popular example of augmented reality is the Proteus Physical Laboratory.

Scientific sources analysis for the training of IT specialists allows us to say that the fulfilment of professional tasks in the field of IT necessitates mastering the architecture of the computer and the basics of microelectronics, which is not trivial for many reasons, one of them is the inability to see the features of circuit design, implemented at the micro level. At the same time, acquaintance with them is the basis not only for understanding the processes that take place inside the computer system, but also for finding new, non-existing, approaches in the organization of its work.

Visualization of circuit solutions implemented at the micro level is possible based on a simulation method that is based on the replacement of real objects by their conditional samples. Modelling can describe the structural components of the object, their interaction and performance. With a well-constructed model, you can estimate the state of the object, predict the consequences.

Since all the processes that take place in the middle of the computing system are based on the operation of physical devices, it is advisable to perform their simulations in a physical process simulator environment. Among the variety of software (Electronics Workbench, LabVIEW, Micro-Cap, NI Multisim, Proteus, etc.), we choose Proteus, where you are able to create wiring diagrams, edit the parameters of their components, use different virtual devices (generators, meters, etc.), which are implemented as mathematical models that simulate the operation of various functional nodes.

The computer tools available in Proteus, in our view, can best visualize the temporal and spectral characteristics of the signals, the transient and transmitting characteristics of the four-pole, the logical states of the inputs and outputs of the digital elements, including the demonstration of the operation of the adders — nodes of the computing system determine the sum of two operands (a digital scheme that performs adding numbers).

No computer system can be built without a central processor, which is responsible for responding to external and internal events. This response is made possible by the correct and interconnected work of a large number of basic elements. In modern processors, both arithmetic and logic operations are performed by ALU (Arithmetic Logic Unit), a device whose operation is based on combinatorial elements. It should be noted that the adder is the basis for constructing hardware solutions of arithmetic and logic operations: subtraction, multiplication, division, comparison, bit operations, etc. That is why we consider it important to be aware of the ideas that underpin the work of summary devices.

The group of adders include:

1. module adder 2;
2. half adder;
3. complete adder.

The adder of Module 2 differs from the half adder only by the presence of the transfer output, and from the total adder by the presence of the transfer output for the higher digit and the transfer input from the lower digit. These inputs and outputs are designed to build a multi-bit adder based on a single-bit adder.

Below is a demonstration of the work of adders in the Proteus environment.

1. *Modulator adder 2*

Modulator 2 is often called an *XOR* element because its operation is based on the use of the logic function "exclusive OR" — the result will be false if and only if its two input elements are the same.

$$Y = \left(A\overline{B} \vee B\overline{A}\right) = (A \oplus B)$$

The simplest demonstration of its features in the Proteus environment is by "manually" controlling the state of the appendices A and B with the keys (Fig. 1). The status of the output is monitored by the color of the indicators.

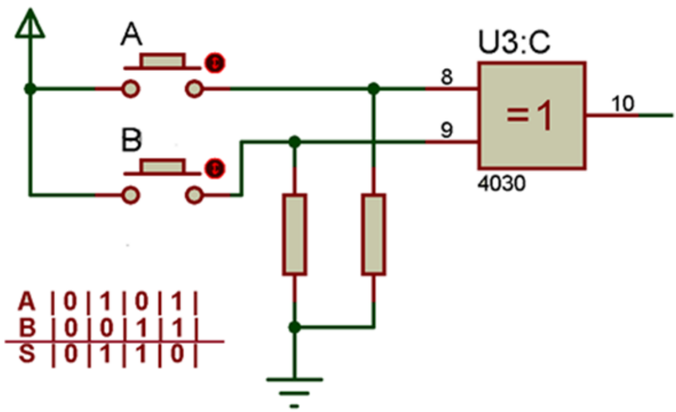


**Fig. 1.** The truth table for the states of the module adder 2 and a diagram of its construction in Proteus

2. *The half adder*

The half adder is slightly more complicated in structure: it calculates, in addition to the sum, also the state of the CH (Carry High) signal of the transfer (the transfer signal to the next (higher) category, if such transfer is required).

The truth table for the half adder is shown in table 1.

It is easy to notice that the state "1" at the output of CH is a conjunction of the additives $A * B$, and the state of the output of the sum S is the same as that of the module 2. We use this feature to build a circuit of element connections for constructing a half adder in ISIS Proteus environment (Fig. 2).

**Table 1.** Truth table for the half adder

| | | | | | |
|---|---|---|---|---|---|
| Inputs | A | 0 | 1 | 0 | 1 |
| | B | 0 | 0 | 1 | 1 |
| Outputs | S, the sum | 0 | 1 | 1 | 0 |
| | CH, transfer signal to the higher category | 0 | 0 | 0 | 1 |

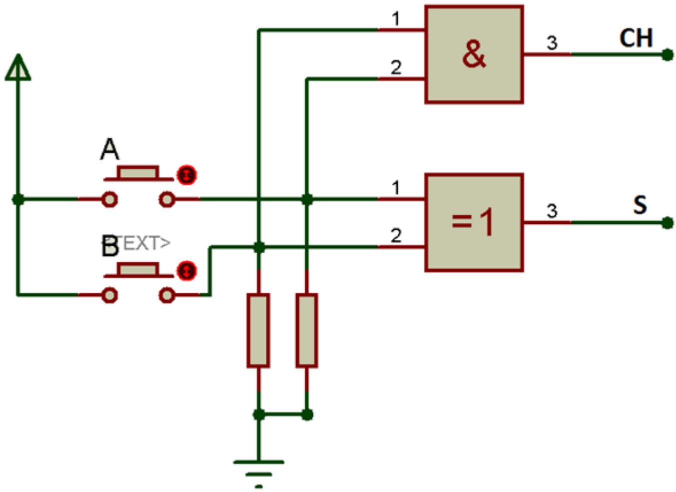


**Fig. 2.** Schematic of element connections for constructing a half adder

3. *Complete adder*

The complete adder is characterized by the presence of three inputs, which serve the same digits of two additions and the transfer signal from the lower digit, and two outputs: one realizes the arithmetic sum of the module 2 in this category, and the other — the transfer signal to the next (higher) category. Note that such adders are oriented to positional numerical systems.

Let us construct a truth table for him, supplementing Table 1 with another line of inputs — the transfer signal from the lower order — CL (Table 2). This will extend Table 1 to eight columns, of which the first four (1..4 for which SL = 0) are already implemented hardware.

**Table 2.** The truth table for the complete adder

| | Column number | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|
| Inputs | A | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| | B | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| | $A \oplus B$ | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| | CL(in) | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| Outputs | $S = (A + B) \oplus CL$ | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| | CH(out) | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |

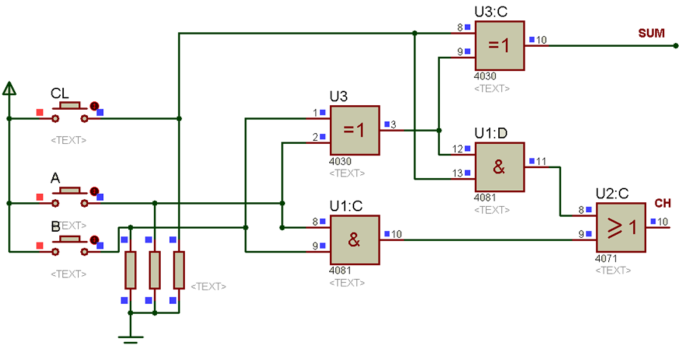


**Fig. 3.** Simulation of the complete adder in Proteus
(inputs: A = 0, B = 0, CL = 0, outputs: S = 0, CH = 0)

Consider the formation of output signals: sums — S and transfer to the highest digit — CH. To simplify the considerations, add the table to the auxiliary row “A + B”. It is obvious that $S = (A + B) \oplus CL$, so we use the element *XOR* (U3: C, Fig. 3) to generate the sum signal. Generate a carry signal using the Perfect Disjunctive Normal Form:

$$CH = \left(A \wedge B \wedge \overline{CL}\right) \vee \left(A \wedge \overline{B} \wedge CL\right) \vee \left(\overline{A} \wedge B \wedge CL\right) \vee (A \wedge B \wedge CL).$$

Using the rules of logic algebra, we obtain:

$$CH = (A \wedge B) \vee (A \oplus B) \wedge CL.$$

The forming element $(A \wedge B)$ is already involved (U1: C), we supplement the scheme with the element *AND* (U1: D) to form the product $(A \oplus B) * C$ and form a transfer signal with the element *OR* (U2: C, Fig. 3).

Let's show the implementation of the complete adder in Proteus. The status of the outputs can be easily traced by logical indicators (Fig. 3–5).

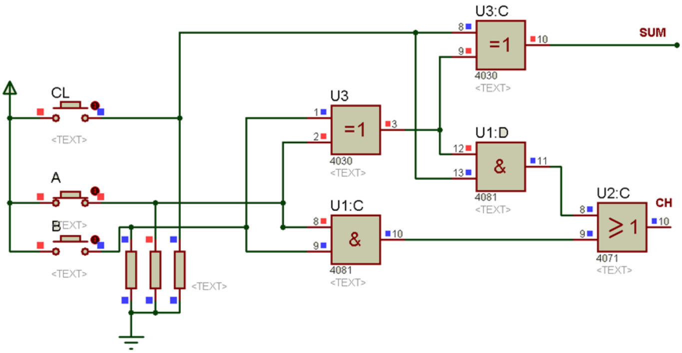


**Fig. 4.** Simulation of the complete adder in Proteus
(inputs: A = 1, B = 0, CL = 0, outputs S = 1, CH = 0)

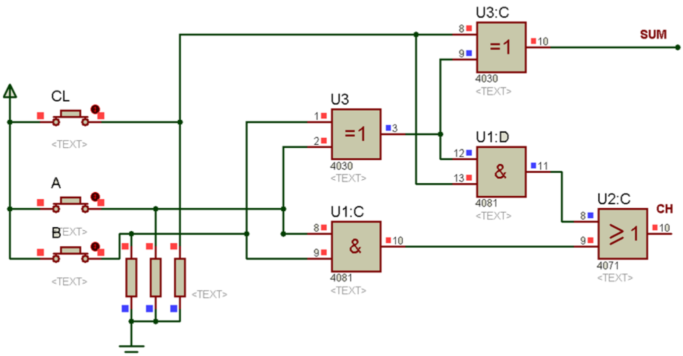


**Fig. 5.** Simulation of the complete adder in Proteus
(inputs: A = 1, B = 1, CL = 1, outputs S = 1, CH = 1)

The simulation confirms the correct operation of the circuit for all eight input variants.

The use of the Proteus virtual environment for simulation of the work of the adders took place on the basis of Borys Grinchenko Kyiv University and Sumy State Pedagogical University named after A. S. Makarenko during 2017–2019. Until 2017, the study of the basics of microelectronics was only at a theoretical level. In order to determine the appropriateness of using computer simulation in the training of IT professionals and computer science teachers, we conducted a double survey of students' attitudes toward conducting a laboratory workshop. The following question was asked: "Do you need to use computer simulation to study the basics of microelectronics?" ("Yes" and "No" answers).

Of the 58 students who participated in the experiment, a random sample of 20 people was randomized. The results of the dual survey responses were evaluated according to the McNemar's test, which provides a scale of 1 or 0 ("Yes" or "No", respectively).

Under these conditions, it is possible to determine the impact on students' perceptions of computer modelling as a means of mastering the basics of microelectronics. The results of the survey are given in Table 3.

**Table 3.** Results of the double poll

| the first poll | the second poll | | |
|---|---|---|---|
| | Yes | No | The sum |
| Yes | A=2 | **B=3** | 5 |
| No | **C=12** | D=3 | 15 |
| The sum | 14 | 6 | 20 |

Tested hypothesis $H_0$: computer simulation does not affect the learning of microelectronics basics according to the subjective estimates of students. According to the results obtained ($B < C$), an alternative hypothesis $H_1$ is built: computer simulation has a positive effect on the learning of microelectronics. The McNemar's test is used for $n = B + C = 15 < 20$, so the value of the statistics is $T = 3$ (least of $B$ and $C$). The probability of occurrence of values not exceeding $T$ is 0.018, which, in turn, is less than half the established significance level of 0.05. This means rejecting hypothesis $H_0$ and accepting $H_1$. Therefore, according to the results of the experiment, we can conclude that it is advisable to use the Proteus virtual environment as augmented reality in computer simulation (the work of the adders described in the article) for students to study the basics of microelectronics.

In addition, an analysis of the results of a survey of teachers (12 people) and students (58 people) on the use of augmented reality in the educational process makes it possible to find out the following. According to the respondents, the use of augmented reality in education significantly increases the interest of students. 93% of respondents answered this question in the affirmative. According to 82% of respondents, the use of augmented reality can improve the level of competence formation. For example, students and teachers have often referred to the following competencies: mastering system information and basic knowledge of computer graphics, the ability to build graphic objects, including three-dimensional ones, and create computer animation to perform professional tasks effectively; knowledge and understanding of the architecture and software of high-performance parallel and distributed computing systems, numerical methods and algorithms for parallel structures. In addition, according to the majority of experts (87%), the educational process has significantly succeeded in diversifying innovative forms of work with the audience. Yes, a series of master classes was implemented within the framework of the activities of the student scientific group "Computer Systems", which operates at Borys Grinchenko Kyiv University.

## 5 Conclusions

1. It is established that the application of augmented reality as an innovative technology of students' training comes in the following directions: 3D image visualization; recognition and marking of real objects; interaction of a virtual object with a person in real time. The main advantages of using AR and VR in the educational process are highlighted: clarity, ability to simulate processes and phenomena, integration of educational disciplines, building an open education system, increasing motivation for learning, and etc.

2. It has been found that in the field of physical process modeling, the Proteus Physics Laboratory is a popular example of augmented reality. Using the Proteus environment allows to visualize the functioning of the functional nodes of the computing system at the micro level. This is especially important for programming systems with limited resources, such as microcontrollers. The experiment found that computer modelling had a positive effect on the acquisition of microelectronics.

3. Research perspectives include the following: identifying effective augmented reality forms, methods, and tools that can be used in the professional training of future IT professionals.

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# Використання віртуального середовища “Proteus” для підготовки майбутніх фахівців у галузі інформаційних технологій

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**Анотація**. На основі огляду літератури було встановлено, що використання доповненої реальності як інноваційної технології навчання студентів відбувається у таких напрямках: 3D-рендерінг зображень; розпізнавання та маркування реальних об'єктів; взаємодія віртуального об'єкта з людиною в режимі реального часу. Висвітлено основні переваги використання доповненої та віртуальної реальності у навчальному процесі: чіткість, вміння моделювати процеси та явища, інтеграція навчальних дисциплін, побудова відкритої системи освіти, підвищення мотивації до навчання тощо. Виявлено, що в цій галузі моделювання фізичного процесу, лабораторія фізики "Proteus" є популярним прикладом доповненої реальності. Використання середовища "Proteus" дозволяє візуалізувати роботу функціональних вузлів обчислювальної системи на мікрорівні. Це особливо важливо для систем програмування з обмеженими ресурсами, наприклад для мікроконтролерів у процесі підготовки майбутніх фахівців у галузі інформаційних технологій. Експеримент проходив у Київському університеті імені Бориса Грінченка та Сумському державному педагогічному університеті імені А. С. Макаренка зі студентами спеціальності "Інформатика" (галузь знань — середня освіта (інформатика)). Було встановлено, що комп'ютерне моделювання позитивно впливає на оволодіння основами мікроелектроніки. У статті окреслено шляхи подальших наукових досліджень щодо обґрунтування, розробки та експериментальної перевірки форм, методів та доповненої реальності, які можуть бути використані у професійній підготовці майбутніх фахівців у галузі інформаційних технологій.

**Ключові слова**: доповнена реальність, віртуальне середовище, "Proteus", підготовка, майбутні фахівці у галузі інформаційних технологій.

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# Prospects of using the augmented reality application in STEM-based Mathematics teaching

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**Abstract**. The purpose of the study is improving the methodology of teaching Mathematics using cloud technologies and augmented reality, analyzing the peculiarities of the augmented reality technology implementing in the educational process. Attention is paid to the study of adaptation of Augmented Reality technology implementing in teaching mathematical disciplines for students. The task of the study is to identify the problems requiring theoretical and experimental solutions. The object of the study is the process of teaching Mathematics in higher and secondary education institutions. The subject of the study is augmented reality technology in STEM-based Mathematics learning. In the result of the study an overview of modern augmented reality tools and their application practices was carried out. The peculiarities of the mobile application 3D Calculator with Augmented reality of Dynamic Mathematics GeoGebra system usage in Mathematics teaching are revealed.

**Keywords**: Augmented Reality, GeoGebra 3D Graphing Calculator, Geometry, Probability theory, STEM-competence, teaching methods of Mathematics, cloud technology in education.

## 1 Introduction

Teaching aids visualization during lectures and practical classes, in particular in Mathematics, allows students to understand the learning material better, to increase the applied orientation of learning and the communication competence both learners and teachers. One of the ways to improve the abstractions visualization in Mathematics is a pedagogically sound and appropriate application in the teaching the modern ICT.

Gartner attributes Artificial Intelligence Education Applications, Conversational User Interfaces, Blockchain in Education, Immersive Technology Applications in Education, Design Thinking, Competency-Based Education Platforms and Adaptive Learning Platforms to the main tendencies of using ICT in education [25].

Since augmented reality technology already has an important place in innovative development, it can also have significant potential for implementation in Mathematics learning. That is why this technology needs more detailed study. Because augmented reality is intrinsically linked to 3D construction, its usage in conjunction with Dynamic Mathematics systems like GeoGebra, can significantly increase the level of visualization in Mathematics and enhance students learning. In addition, Augmented Reality can become a tool for enhancing STEM-based learning for students majoring in Mathematics and Computer Science.

At present, the use of augmented reality technology in teaching, including Mathematics, requires development, research, and testing. Therefore, the review of tools for developing augmented reality and current practices is relevant. It is important the new technologies usage contribute to improving the quality of education.

## 2 Materials and methods

A number of works of scientists and software developers are devoted to the research of integration issues of the augmented reality technology into the educational process. In particular, Tim Brzezinski [2], James Purnama [29], Serhiy O. Semerikov [22, 34], Svitlana V. Shokaliuk [33], Iryna S. Mintii [21], Andrii M. Striuk [9], Yuliia V. Yechkalo [35], Maiia V. Marienko [27] focus on the general trends and special issues of the augmented reality application in education. Pavlo P. Nechypurenko [23, 24] shares her experience of using AR in teaching chemistry pupils and future chemistry teachers. Svitlana L. Malchenko raises the issue of the AR application to the astronomy teaching and others [18].

The problems of STEM-training, in particular the training of staff for STEM-education in the modern innovative educational and research environment are covered by Mariya P. Shyshkina. The aim of the article [31] is to describe the problems of personnel training that arise in view of extension of the STEM approach to education, development of innovative technologies, in particular, virtualization, augmented reality, the use of ICT outsourcing in educational systems design. The results of the research are the next: the concepts and the model of the cloud-based environment of STEM education is substantiated, the problems of personnel training at the present stage are outlined. Recently in the field of STEM education the following ICT trends have been developed, such as new interfaces, screenless displays, 3D technologies, augmented reality, "emotional" computing, wearable technologies (devices) and others. All these areas are united under the common name of "new opportunities" (emerging technologies) [31].

Having analyzed the state of research into the problem of STEM-education in the secondary education institutions in psycho-pedagogical, methodical and educational literature, we can conclude that in Ukraine the educational landscape is aimed at the innovative student. Teaching a student to learn for life, to think critically, to set goals and achieve them, to work in a team, to communicate in a multicultural environment — all this is the urgency of the present, which forms the basis of a specialist's competitiveness in the labour market.

The issues of using GeoGebra were highlighted by us in a teaching manual designed to train mathematics teachers in higher education institutions [12]. The methodological recommendations were presented there, which teach how to create and apply for the tool of different topics in elementary mathematics. The visuals are hosted in a file repository GeoGebra. They can be accessed either via traditional links or via QR codes.

STEM approach in teaching mathematics to students using GeoGebra have been partially covered in our publication [11]. However, the problems of using the augmented reality tools in mathematics teaching are covered by us for the first time.

The purpose of this publication is the overview of the augmented reality tools practices in the educational process, analysis of application prospects in STEM-training of mathematics and to train mathematics teachers. In order to use the new technologies to improve the quality of education.

## 3 Results

### 3.1 Augmented reality toolkit overview

The article [31] discusses the prospects of the augmented reality using as a component of a cloud-based environment. It is revealed that the attraction of the augmented reality for the educators requires the development of new methodologies, didactic materials, updating and updating of the curriculum. The main conclusions and recommendations: the main principles of augmented reality use in the learning process are: designing of the environment that is flexible enough, attention should be paid to the teaching and didactic issues; adjusting the educational content for mastering the material provided by the curriculum; the research methods that can be used in training along with the elements of augmented reality are to be elaborated; development of adaptive materials; training of teachers, which will include augmented reality in educational practice.

Olga Yu. Chubukova and Igor V. Ponomarenko article [5] is devoted to the study of the augmented reality technology use to meet the needs of modern society. The peculiarities of the augmented reality realization as an innovative product that has significant prospects for integration into the real economy are considered. The role of this technology in improving the teaching subjects process in Ukraine's higher educational institutions is determined. The main directions of communication intensification with students during conducting of classes with the help of using the augmented reality are given. The key benefits for the national education system from implementation of the augmented reality into the educational process are highlighted.

In paper [17] Hong-Quan Le and Jee-In Kim propose a framework for learning geometry using a software tool based on augmented reality (AR) and hand gestures recognition technologies. These technologies are combined into a system that can address some current issues in geometry education and provide students with an easier way for studying geometry. They compare the speed of development and the quality of the developed geometry training using Cabri and GeoGebra.

The objective of research is to develop an AR and hand gesture based application for learning 3D geometry. This paper aims to present a novel approach for effective learning 3D geometry in school. The research basically focused on two main technologies: AR and hand gesture recognition to build up a hands-on learning method for students. With AR, the students can understand the basic concepts of 3D geometrical shapes, their relationships and ways to construct the 3D shapes and the objects in 3D space. Importantly, AR can provide a dynamic visualization of 3D structures of geometrical shapes. This feature helps the students to understand a comprehensive background of 3D geometrical shapes and improve the abilities of geometrical structures. Moreover, the hand gesture based interactions furnish an intuitive and convenient way for the students to directly control and interact with geometrical shapes in 3D space. With the experiences of interacting with the 3D shapes using their own hand gestures, the students can improve their own awareness of the relationships of the 3D shapes and easily remember or retain the knowledge about the 3D shapes.

### 3.2 Application practices GeoGebra AR technology

A number of examples that can be used in mathematics training are offered by the developers of the GeoGebra Dynamic Mathematics system [6] on the YouTube page [7].

GeoGebra is a free software, dynamic mathematics system for all levels of education that integrates geometry, algebra, tables, graphs, statistics and calculations in one easy-to-use package [30]. GeoGebra has become a leading provider of dynamic mathematics programs used to support Science, Technology, Engineering and Mathematics (STEM), education and innovation in teaching and learning worldwide.

We can highlight the benefits of GeoGebra, such as free distribution; easy-to-use interface with powerful functionality; availability in many languages, including Ukrainian; a number of freeware developments, models, exercises, lessons and games for math, as well as video tutorials and courses to help you use GeoGebra applications.

GeoGebra is a few free offline apps for iOS, Android, Windows, Mac, Chromebook and Linux. Among these mobile phone applications there is the 3D Graphics application (3D-feature graphs, surface, and 3D-geometry) that can be used while developing the visuals with AR. Today, the app is only available to users of gadgets on the iOS operating system. This program includes some examples of 3D mathematical objects that can be placed, such as on a desktop, floor, or any other flat surface. Today, the app is only available to users of gadgets on the iOS operating system. This program includes some examples of 3D mathematical objects that can be placed, such as on a desktop, floor, or any other flat surface. The fixed models will be managed. They can be resized. Such visualization will allow you to see more mathematics in the surrounding world.

With AR you can build polyhedra, surfaces (Fig. 1), rotation bodies, visualize their rotation, and show cross 3D sections.

GeoGebra developers note that they created this application to explore the AR potential for mathematics training and teaching. This is just the beginning for GeoGebra AR. In the future, the application will be improved, supplemented with new ideas for 3D models, which will allow to see and explore 3D mathematics in the environment more.

Let's see what kind of manipulation can be done using the AR app. We can, for example, write down the surface equations and examine the result, change individual parameters, and observe changes in real time. We can also "scan" the objects around us, get the appropriate models, and further explore them. Before researching we have to place mathematical objects on any surface. Built and fixed models can be "bypassed" from all sides, "look" in the middle, take screenshots of internal structures.

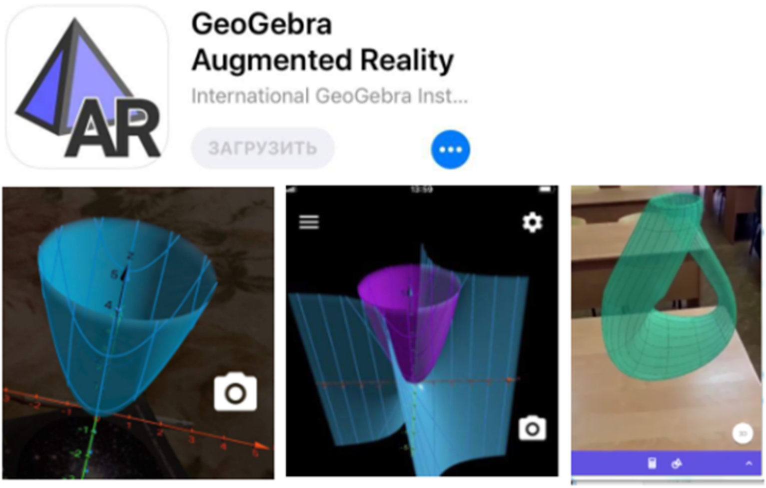



**Fig. 1.** The surfaces in AR

3D Graphics mode is designed to work with 3D objects. You can create objects using Algebra or Tools tabs. In Algebra mode, we add objects using mathematical functions, and in Tools mode, we use a toolbar that offers a large set of tools for creating three-dimensional objects. In addition to the well-known tools: creating points, segments, straight lines, angles and polygons — there are also specialized tools for constructing bulk bodies such as: sphere, pyramid, prism, cone, cylinder. You can build cross sections of volumetric figures and form a sweep.

Tim Brzezinski closely uses the 3D Graphics AR application in his activities. Based on his research, we can conclude that the using AR is a powerful tool for the explore and formatively assess student constructions. Brzezinski offers some developed GeoGebraBook, targeted at both teachers and students. His collections provide ideas for lessons and various means by which math teachers can use GeoGebra 3D Grapher with AR (iOS) to create dynamic, learner-centered learning environments [2]. In the mathematics teaching it is advisable to use some of his works [1, 3, 4].

In the workshop on mastering the package of dynamic mathematics GeoGebra Liudmyla E. Gryzun, Valentyna V. Pikalova, Iryna D. Rusina and Valentyna A. Tsybulka [8] focused on the training and retraining of mathematics teachers, as well as on extracurricular work with students. Because the training is based on examples and models that can be attributed to the objects of mathematical art, this allowed the authors to present GeoGebra as a powerful tool for realizing STEAM education. One of the sections of the practicum is AR. The authors present the brief information about the AR application and provide examples of its use.

### 3.3 Development of visibility tools with GeoGebra 3D Graphics and AR

To create a mathematical model in the AR application, first of all, you need to create a model in 3D Graphics using appropriate tools (Table 1), and then using the button "AR" to project into the real world. To place an object in the real world, you must select a location, point it at the camera, and tap the screen on your phone. Then the figure locks in the selected location. To change the size, color of the object, we use a touch screen.

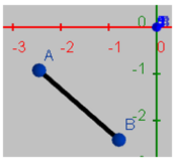
**Table 1.** Examples of tools for 3D Graphics implementation

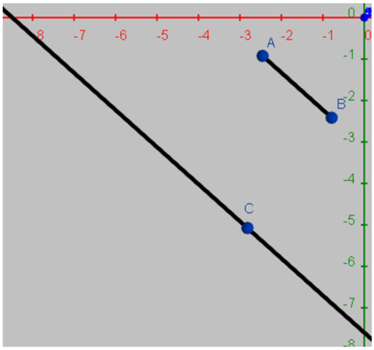
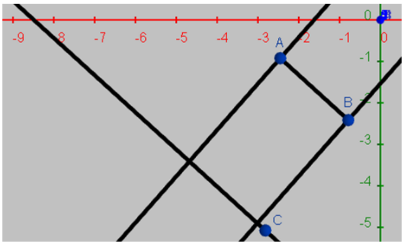
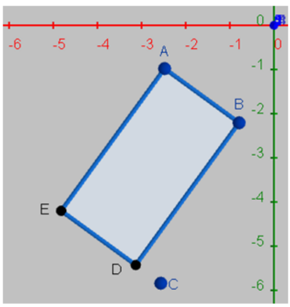
| Icon | Tool | Application |
|---|---|---|
|  | *Cube* | double-click in the 3D view to create points that set the rib of the cube |
|  | *Move* | allows you to move objects, the first click on the point will change its position in the $xOy$ plane, the second click — the coordinate along the $z$ axis |
|  | *Extrude to Pyramid* | allows you to construct a pyramid from a polygon or a cone from a circle |
|  | *Rotate 3D Graphics View* | allows rotation in three-dimensional space |
|  | *Net* | allows you to build a sweep to the specified polyhedron |

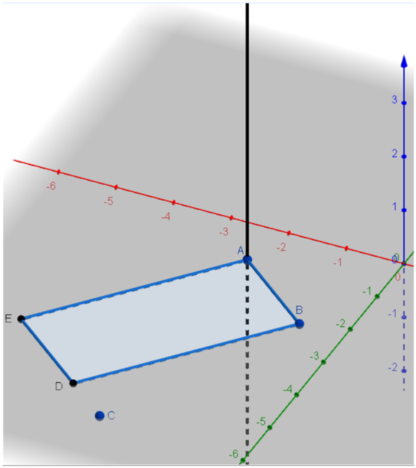
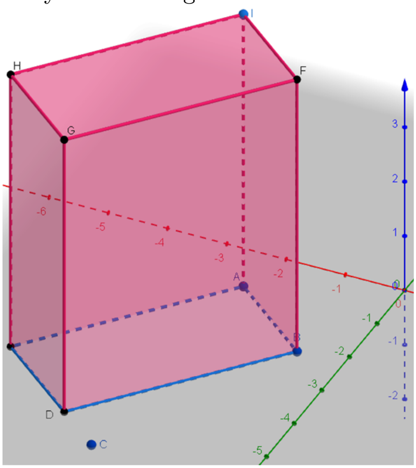
| | | |
|---|---|---|
|  | *Sphere: Centre and Point* | allows you to construct a sphere by selecting the center point and any point of the surface |
|  | *Plane through 3 Points* | constructing a plane by successively selecting three points |
|  | *Reflect in Plane* | select the object you want to display and then specify the display plane |
|  | *View in front of* | select an object to move the point of view of the construction in front of the selected object |

Because the application has the ability to build a prism, the difficulties can arise while creating certain types of prisms. Consider in detail the example of a straight prism, the basis of which is a rectangle (Table 2).

**Table 2.** An algorithm for creating a rectangular parallelepiped in 3D graphics

| **№** | **Stage** | **Instruction and drawing** |
|---|---|---|
| | *Construction of a dynamic rectangle* | |
| 1 | Build a segment | In order to plot a segment in the $XOYU$ plane, you need to select the "View in front of" (located in the Edit group) and specify this plane. Then select the "Segment" tool and specify the two points through which the segment AB is automatically constructed.   |
| 2 | Construct a line that is parallel to the segment | Use the "Point" tool to put a point in any place (point C). We select the "Parallel Line" tool, point to the constructed segment and point, and automatically construct a line g. |

<table>
<tr><td></td><td></td><td>
</td></tr>
<tr><td>3</td><td>Construct perpendiculars to the line passing through the ends of the segment</td><td>Select the tool “Perpendicular line”, point to a straight line g and point A — get a straight line perpendicular to the line g passing through the point A (denote i). Similarly, we construct a line through point B (denote j).<br>
</td></tr>
<tr><td>4</td><td>Construct a rectangle</td><td>We select the “Polygon” tool and point to the intersection points of straight lines and segments. In the Algebra tab, we remove the visibility of unnecessary straight lines, change the color of objects if desired. We can resize the rectangle by moving the points A, B, C.<br>
</td></tr>
</table>

| *Construction of a rectangular prism* | | |
|---|---|---|
| 5 | Construct a straight line perpendicular to the rectangle | Select the “Perpendicular Line” tool, point to the rectangle and its vertex. Received a line h that is perpendicular to the rectangle ABDE and passes through its vertex.   |
| 6 | Build a prism | Select the “Prism” tool, point to a rectangle and a straight line h. The prism is built, you can resize it using points A, B, C, I. In the Algebra tab we remove the visibility of the straight h.   |

After constructing a prism in GeoGebra 3D Calculator [28], we press the "AR" button. Next, you need to use the camera to select the environment in which we plan to move the object. For example, on the table. By tapping on the screen, the figure will be transferred to the real world [13] where it can be explored. The phone camera will serve our eyes. Immersing the phone in a virtual figure we will see it from the inside, we can bypass it, also the application allows you to resize, color. Due to the AR with GeoGebra you can see that we are surrounded by mathematical objects, shapes everywhere [14–16] we can explore them, walk around them, peek in, or step inside a figure.

We can insert real objects that have the shape of a rectangular parallelepiped into a fixed figure (see Fig. 2).

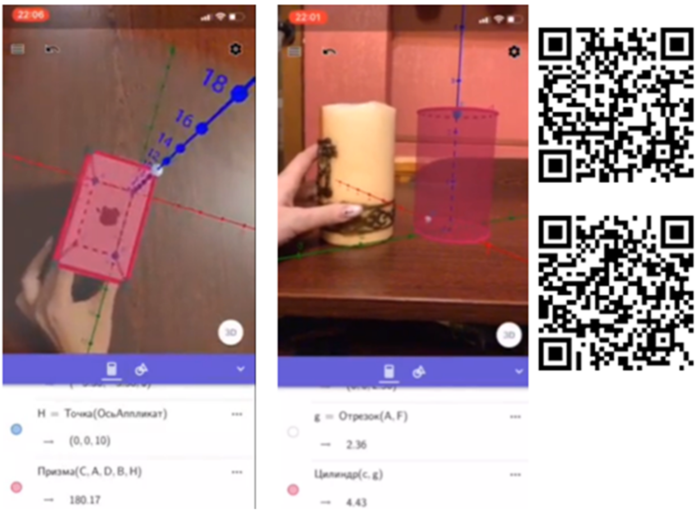



**Fig. 2.** GeoGebra AR demos

Considering the creating a geometric body, the prism automatically calculates its volume, we can determine the relationship between the volume of the real body and the result that is offered by the software. In this case, the student must have the apparatus to apply the properties of such bodies.

Previously, we offered students a STEM approach in addition to the traditional formula output when learning the topic of "Body volumes". The approach was that the students were asked to propose some hypothesis how the volumes of a prism and a pyramid, a cylinder, and a cone correlate.

For this purpose, made models of these geometric bodies were used and poured dry matter from the cone into the cylinder, from the prism into the pyramid.

### 3.4 Perspectives of using AR application in teaching calculus and probability theory

An analysis of the studies conducted to date indicates that the greatest effectiveness in teaching elementary mathematics, calculus, probability theory is achieved through a complex combination of traditional tools, forms and methods of teaching with computer-oriented. For plotting functions, surfaces are quite convenient to use software tools, including CoCalc, GeoGebra, Wolfram|Alpha [10, 19, 20, 26, 32].

With GeoGebra we can construct a surface, examine it from different sides, examine the change of values of a function at one of the fixed independent variables, or at certain relationships between independent variables. Similar observations are useful in the study of the function of many variables for continuity. However, we cannot calculate extrema by symbolic transformations, although partial derivatives can be calculated.

With GeoGebra 3D Calculator and AR the visualization capabilities for solving the types of tasks outlined above are greatly enhanced.

Particularly effective can be the use of a 3D Calculator with AR when studying the topic of "Multiple integrals" (Fig. 3). Students often have difficulty with constructing bodies that are restricted to certain surfaces.

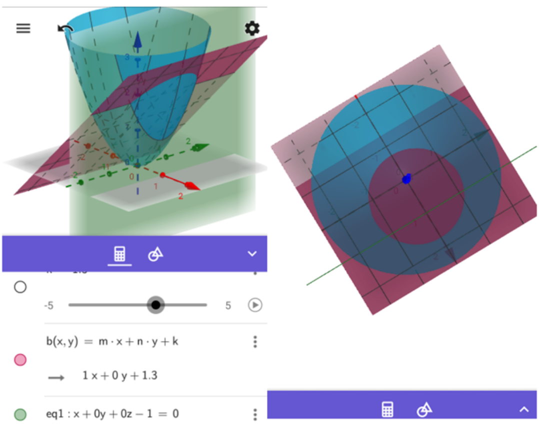



**Fig. 3.** a) a geometric body constructed in parallel projection, b) a projection on the $Ox$ plane

Using AR, you can not only see the built body, but also “travel” inside. Today, the construction of surfaces is available with the application. Often, students have problems in calculating the boundary of the function of two variables, while substantiating continuity.

It is advisable to use the software tools for both the construction of surfaces and the search for extrema of functions.

Here is an example of a problem where, when investigating the function of many variables, additional research is needed. An interesting example is the function $z = 1 - \sqrt{x^2 + y^2}$. At point (0; 0) partial derivatives of the first order do not exist. To investigate a function on extremum, we examine the increment of the function at this point. As the gain is negative, we can conclude that the function acquires the maximum value at this point.

In the teaching of probability theory, it is possible to visualize such concepts as the probability distribution function and the probability distribution density function for a two-dimensional continuous random variable. By constructing the respective planes, it will be possible to demonstrate graphs of the probability density functions for each of the components.

For example, by plotting the probability distribution function by the formula, we can consider the surface formed in more detail. Next, we cross the surface with the planes $x = const$ or $y = const$. We can view the graphs of the probability density functions for each of the components of a two-dimensional continuous random variable (see Fig. 4).

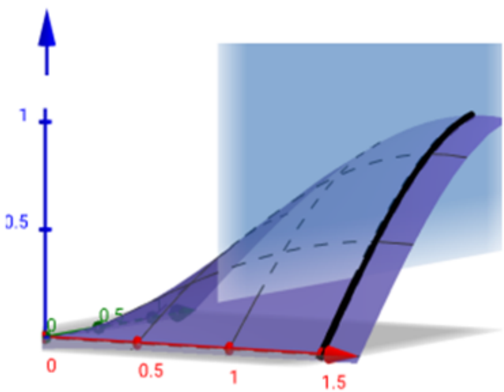



**Fig. 4.** Graph of the probability distribution function of two-dimensional random variable

## 4 Conclusions and prospects for further researches

Researches show that the GeoGebra AR should be used both in the profile teaching of mathematics students, and in the train of future mathematics teachers of higher mathematics, probability theory, calculus, analytical geometry.

At the same time, one of the major problems today in using the GeoGebra 3D Graphing Calculator with AR is that it is designed for iOS. Available mobile phones with Android operating system have become widespread in Ukraine.

Investigating the possibilities of using GeoGebra in the learning calculus and geometry, found out that engaging students to research using GeoGebra helps to expand the range of educational tasks, including STEM problems. This allow to achieve the high level of learning motivation and individualize the learning process.

Implementation of applied aspect in teaching mathematics using GeoGebra 3D Calculator with AR will help to solve one of the main problems of STEM education — individualization. We can explore AR objects because this application brings 3D math to the real world.

Systematic using of GeoGebra 3D Calculator with AR can help to develop students' research skills, enhance their socialization opportunities through the acquisition of ICT, which should lead to the systematic development of universal STEM competencies.

Having looked at a number of forms and methods and tried out some of them, we found that the goal of every STEM teacher should be to motivate and involve students into research activity. Then more varied and interesting the lessons will be, then more students will admire the subject. Implementation of the STEM education in mathematics teaching makes it possible to improve the quality of learning, which will further enhance the students' academic competences.

We see the prospect of further research in the development and investigation of the effectiveness of the use of AR-based tools in both elementary and higher mathematics.

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# Перспективи використання програми доповненої реальності у навчанні математики на основі STEM-підходу

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**Анотація**. Метою дослідження є вдосконалення методики викладання математики з використанням хмарних технологій та доповненої реальності, аналіз особливостей впровадження в навчальний процес технології доповненої реальності. Увагу приділено вивченню адаптації технології доповненої реальності, що реалізується у викладанні математичних дисциплін для студентів. Завдання дослідження — виявити проблеми, що потребують теоретичних та експериментальних рішень. Об'єктом дослідження є процес викладання математики у вищих та середніх навчальних закладах. Предметом дослідження виступають технології доповненої реальності у вивчанні математики на основі STEM підходу. В результаті дослідження було проведено огляд сучасних засобів доповненої реальності та практик їх застосування. Розкрито особливості використання мобільного додатку 3D графічний калькулятор із доповненою реальністю динамічної математики GeoGebra у навчанні математики.

**Ключові слова**: доповнена реальність, GeoGebra 3D графічний калькулятор, геометрія, теорія ймовірностей, STEM-компетентність, методи навчання математики, хмарні технології в освіті.

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# The Google Lens analyzing quality: an analysis of the possibility to use in the educational process

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**Abstract**. Biology is a fairly complicated initial subject because it involves knowledge of biodiversity. Google Lens is a unique, mobile software that allows you to recognition species and genus of the plant student looking for. The article devoted to the analysis of the efficiency of the functioning of the Google Lens related to botanical objects. In order to perform the analysis, botanical objects were classified by type of the plant (grass, tree, bush) and by part of the plant (stem, flower, fruit) which is represented on the analyzed photo. It was shown that Google Lens correctly identified plant species in 92.6% cases. This is a quite high result, which allows recommending this program using during the teaching. The greatest accuracy of Google Lens was observed under analyzing trees and plants stems. The worst accuracy was characterized to Google Lens results of fruits and stems of the bushes recognizing. However, the accuracy was still high and Google Lens can help to provide the researches even in those cases. Google Lens wasn't able to analyze the local endemic Ukrainian flora. It has been shown that the recognition efficiency depends more on the resolution of the photo than on the physical characteristics of the camera through which they are made. In the article shown the possibility of using the Google Lens in the educational process is a simple way to include principles of STEM-education and "New Ukrainian school" in classes.

**Keywords**: Google Lens, plant recognition, New Ukrainian school, STEM-education, augmented reality, digital education.

## 1 Introduction

The school biology course is quite complicated because it includes a huge number of abstract concepts and terms [4]. In addition, the school biology course also involves the study of species diversity learning [7]. Ukraine has a rich biota with more than 25,000 species of plants (5,100 vascular plants, more than 15,000 mushrooms and mollusks, more than 1,000 lichens, almost 800 mosses and about 4,000 algae) and 45,000 species of animals (more than 35 000 insects, almost 3 500 other arthropods, 1800 protozoa, 1600 roundworms, 1280 flatworms and 440 ringworms among more than 44 thousand invertebrates, about 200 fish and roundworms, 17 amphibians, 21 reptiles, about 400 birds and 108 mammals from the vertebrates) and is characterized by a certain endemism. A school teacher cannot perfectly know all kinds of species. He may face the problem: "the students brought a photo of a plant or animal and want to determine the species of this plant or animal". One of the ways to solve it is the use of a Google Lens. The absence of the answer will lead to decreasing of student's motivation which is even more important than the fact of absence of the answer.

According to the concept of a new Ukrainian school, students need to develop information and digital competencies, which involves the confident and meaningful use of information technology to receive, transmit information [3]. Google Lens allows students to set their own, in their convenient mode, during field or classroom classes, with both informational competence as well as competence in science and technology.

## 2 Literature review and problem statement

### 2.1 General situation on the necessity of Google Lens in curricula

The world is becoming digital and technological, which directly affects the learning process and it creates challenges to education. The classical educational environment is stable, based on pedagogical traditions, involves the formation of hard skills. In Ukraine, the classical educational environment is represented by curricula on various subjects that are required for the performance of all teachers, a list of textbooks that are recommended for use during the educational process and a number of legislative acts of the Ministry of Education and Science. However, considering the New Ukrainian school concept, educational society faces challenges on the implementation of virtual instruments (learning environment) [2, 3].

Unlike classical educational environment, virtual learning environment is constantly changing in connection with the constant scientific and technical process, it is aimed at the development of creativity [12]. Virtual learning environments include digital programs and websites. The most program helps to analyze experimental data, mathematically process them. Thanks to them, you can successfully apply a learning model through a study in which a student analyzes the results obtained by himself or others by establishing experimental data as if discovering the basic laws of nature. Special and most modern of them are those which include elements of virtual and augmented reality due to their ability to increase student's motivation [6, 19]. Previously, we substantiated the need to implement Google Lens approach in the educational process [16]. However, there wasn't shown the efficiency of Google Lens. Therefore, this work aims to analyze the possibility of Google Lens using in educational institutions to provide STEM-research projects on botany. To achieve the aims next tasks were indicated:

1. To evaluate the general quality of the Google Lens's recognition technology related to plants.
2. To understand and show the main factors which effect on the recognition in real-life research to give advice in the process.
3. To modify the pedagogical method of the plant's analysis based on the obtained knowledge.
4. To summarize up and analyze the results and evaluate the possibility of Google Lens implementation in the school botany research.

Thus, the object of the research is the pedagogical method of plant kind determination. The mechanism of plant determination by Google Lens was the subject of the study.

### 2.2 Description of the Google Lens and its role in education

Mobile phone nowadays is a powerful scientific instrument [13]. However, the potential of it still not fully understood and presented. One of the companies who are creating new digital software which can be used in education is Google who creates instruments such as Google Lens. Google Lens is an image recognition technology based on neural networks and developed by Google. Having determined the species of animal or plant, one can further study its biological properties. The main positive aspects of using Google Lens in our opinion are:

1. Provided by the possibility to use personal phones any time of the research.

2. Interaction with any objects include biological
3. The possibility of research any object any time including during expeditionary researches
4. Creation of interaction between real and virtual worlds.

Google lens is integrated into both Google Photos and Google camera which can be used on any Android devices with Android 4.4 or higher or IOS. The access to Google Lens instrument is presented in Figure 1.

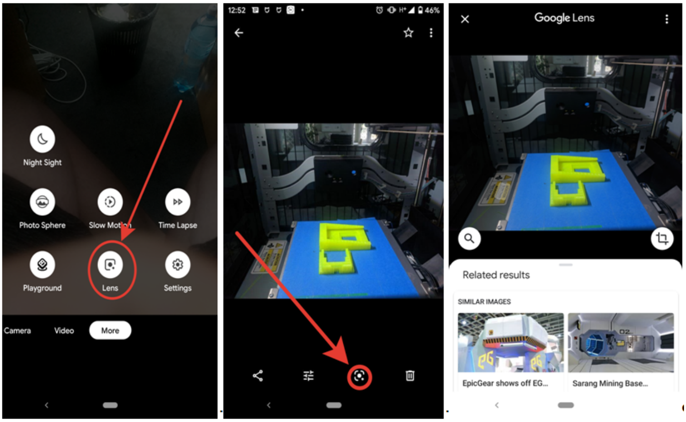


**Fig. 1.** Google Lens instrument access

Google Lens can be used in different parts of education such as Biology, Mineralogy, Architecture and history and Marketing to achieve additional information about the object and increase the motivation of the students (table 1).

**Table 1.** Using Google Lens in different fields of education

| **Field of science** | **Way of using** |
|---|---|
| Biology | Nowadays Google Lens is characterized by the possibility of biology objects recognition (animals, plants, etc.) |
| Mineralogy | Google lens can use the color and the structure of the minerals to analyze it (not available now, but we think it will be provided in the future) |
| Architecture and history | Analyzing the building and monuments |
| Marketing | Analyzing and searching for different real-life products such as clothes |

## 3 Materials and methods

### 3.1 Model experiment

To provide experiment and compare results with keys for each plant, 500 photos from online-classifier "The list of plants of the Dneprovskiy district of Kiev" (Fig. 2) were taken. The online-classifier contains the pictures of each kind of the plants and its determination names. Photos were characterized by the method described in 3.2 due to the different quality of the photos and collected by a method described in 3.3.


**Fig. 2.** The list of plants of the Dneprovskiy district of Kiev

### 3.2 The general method of photo analysis

Photo's quality is an important factor to Google Lens. Therefore, it is necessary to classify each photo by main quality components — composition, resolution, digital noise. Main photos quality criteria are presented in table 2.

**Table 2.** Main photos quality criteria

| Quality | Analyzed object's resolution, Mpx | Gray noise | Color noise | Analyzing object |
|---|---|---|---|---|
| Bad | < 0.3 | High | High | Not clearly visible |
| Middle | 0.3 – 3 | Middle | Middle | Clearly visible |
| Good | > 3 | Low | Low | Perfectly visible |

### 3.3 Data collection and analysis

To collect data, we developed the database with front-end and back-end development. Each photo was classified by the image quality using the method described in 3.2 and its characteristics such as type (tree, bush, grass) and presented part of the plant (flower, leaf, stem, fruit). The mark of the analyzing process was inputted too. The input interface is presented on Fig. 3.

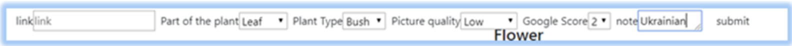


**Fig. 3.** The input interface

The output interface looked like a table to provide the visualization and dynamic of the research process. The output interface is presented in Fig. 4.

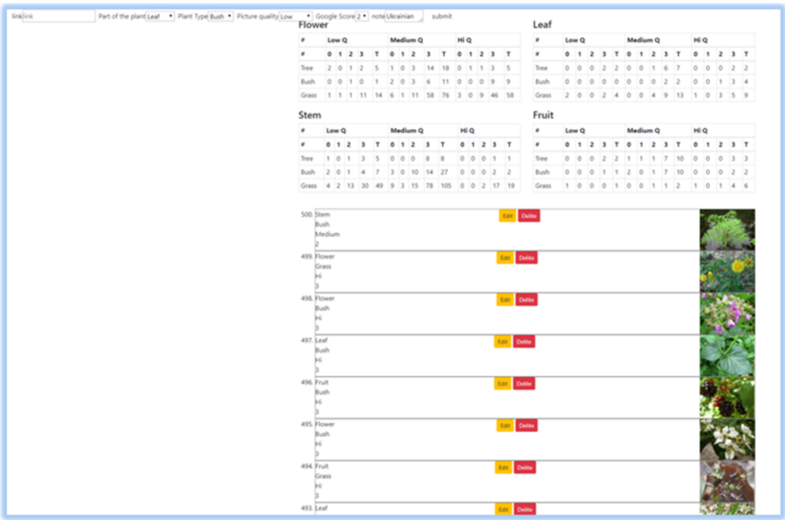


**Fig. 4.** The output interface

Google Lens propose a few results of the analysis to the user. Therefore, the results of Google Lens were classified on 0, 1, 2 or 3 points. Sometimes cropping of the photos was used, in this case, one point was deducted. The keys of Google Lens results evaluation are presented in table 3.

**Table 3.** Main photos quality criteria

| Points | Description |
|---|---|
| 0 | The object wasn't detected at all |
| 1 | A genus of the object was recognized and presented in top 6 results but species wasn't correctly recognized |
| 2 | a) a genus of the object was recognized and presented in top 3 results but species wasn't correctly recognized<br>b) Genus and species of the object was recognized and presented in top 6 results |
| 3 | Genus and species of the object was recognized and presented in top 3 results |

Results were collected on the database. To provide an analysis of the requests to a database prepared and provided. The requests were prepared to take into account the aims of the work. To process the results MS Excel 365 was used.

# 4 Results and discussion

## 4.1 The general accuracy of the Google Lens

The general inaccuracy of Google Lens analysis was 8.4% on the modeling experiment. This result proves the possibility of Google Lens using in the educational process and it can help pupils to conduct their own researches; in 92.6% of cases, it can help to find the right answer. It is worth note that this accuracy is much higher than the accuracy of the teacher's answers.

In 72.8% of cases, Google Lens gives a totally correct answer (finding object was in the top 3 of results) which is high. In 17% of cases, it shows the correct results in the top 6 of the results and just in 1.8 analysis results were not so much correct (in the top 6 of the results without correct genus recognizing but with correct species recognizing). General results are presented on Fig. 5.

## 4.2 Analyzing the importance of the criteria

***Photos quality***. As it was expected, as higher quality of the photo than better analysis results. However, even the low quality of the photos has a huge chance to be rightly analyzed. Just 14.3% of photos with low quality weren't recognized compared to 4.2 % of incorrect results in the case of high-quality photos. Google lens was totally accurate in 80.83, 72.7, 62.6%

of cases with high, medium and low quality, respectively. The dependency of the accuracy of Google Lens analysis quality of photo's quality is presented in Figure 6.

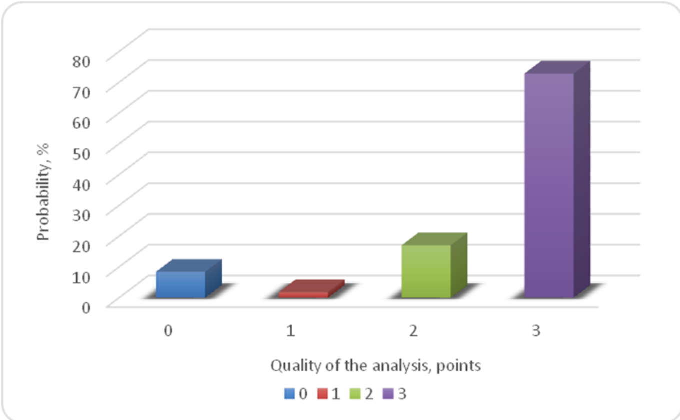


**Fig. 5.** General Google Lens accuracy

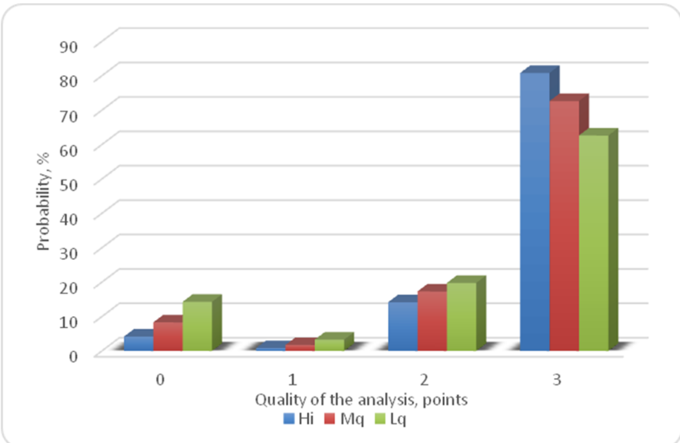


**Fig. 6.** The dependency of the accuracy of Google Lens analysis quality of photo's quality

Therefore, using a better camera and making a better photo can increase analysis quality, however, Google Lens algorithms work with low-quality photos enough fine and it means that Google Lens instrument can be used on any device even with a bad camera which can afford each student.

***Parts of a plant***. Google Lens algorithms better analyze flowers of the plants than other parts and it was characterized by an inaccuracy level of 7.1%. The worst result of the Google Lens analysis was observed under fruit analysis. It may be related to the similarity of some fruits between each other. It was characterized by inaccuracy level of 16.2%. However, totally correct analysis results were similar for steams, leaves and fruits of the plants and it was 70.9, 70.5, 70.3%, respectively. Significantly higher was the level of the totally correct analysis results in cases of flower analysis with an indicator of 76.0%. Therefore, to obtain better results if it possible provide analysis of the flowers of the plants. The dependency of the accuracy of Google Lens analysis quality of analyzing part of the plant is presented in Figure 7.

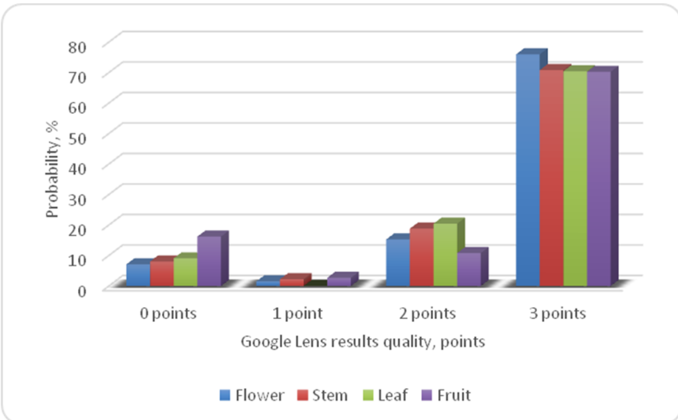


**Fig. 7.** The dependency of the accuracy of Google Lens analysis quality of analyzing part of the plant

***Plant type***. Google Lens analysis shows similar results for both totally accurate and inaccuracy for grass and trees and they were 74.4 and 7.8% for grass, respectively, and 76.4 and 8.3% for trees, respectively. Much worse Google Lens results were characterized for bushes. The inaccuracy of it was 10.4% and the quantity of totally correct results was 64.6%. Dependency of the accuracy of Google Lens analysis quality of analyzing plant type is presented in Figure 8.

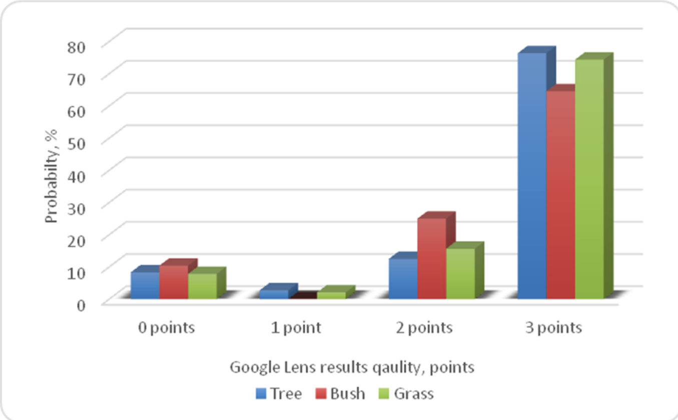


**Fig. 8.** The dependency of the accuracy of Google Lens analysis quality of analyzing plant type

### 4.3 Discussion

**General specific of analysis**.

It's worth note, that there were some examples of Ukrainian species of plants weren't recognized at all. This fact was obtained due to the integration of the Lens with different internet services where wasn't information about specifically kinds of plants. Thus, the results will be even better in the regions where more information about the plants in English.

High analyzing results were obtained under analyzing of the flowers of grasses (for example, Taraxacum officinale) where the quantity of inaccuracy analyzed samples were 0% and quantity of totally successfully analyzed samples was 93%.

Not surprisingly, the results of the brush's analysis at all were bad. However, the worsted was characterized for fruits and stems of the bushes and level of inaccuracy was 22.2% of them. The lowest level of total accuracy analyzed results were characterized for stems of the bushes. For all other samples, results were close to average. This means that using Google Lens for fruits and stems of the bushes do not guarantee the perfect results. However, it still characterized by a respectively high level of analyzing the accuracy and it can be used to obtaining information. General results of Google Lens analysis are presented on the fig. 9.

Google Lens isn't analyzing the environment; therefore, it can make mistakes based on this fact. For example, this fact was obtained under analyzing of the water mint photos.

Low indicator of analysis quality on the fruit analysis may be explained by an algorithm of analyzing a shape of the fruit firstly and then looking on its specific. Therefore, for example, guelder-rose was analyzed as grapefruit. Some photos where colors were differed compared to real-life samples and in those cases, Lens makes mistakes to. It was observed under analyzing of Gladiolus where colors were less saturated than in real-life and Heliopsis helianthoides where samples were more saturated. In those cases, Google Lens makes mistakes in the species not in the genus.

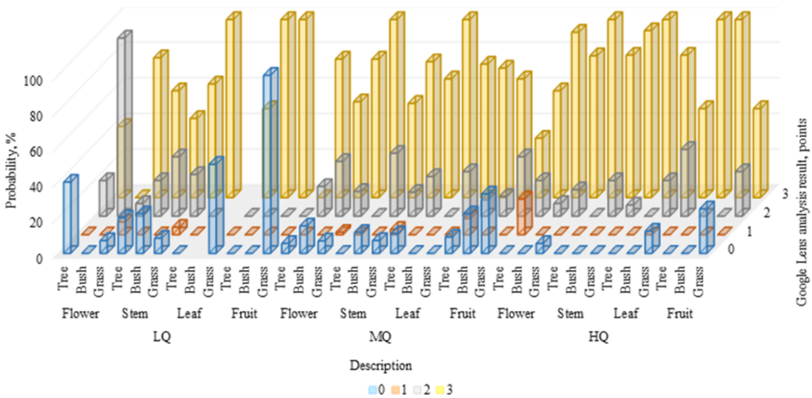


**Fig. 9.** General results

Therefore, it seems like, a shape is an effect on the genus determination. Color and specific of the plant parts are rather affected on the species determination of genus.

Google Lens is looking for eye-catching object and there were cases where plant part was less eye-catching than other objects and Lens makes mistakes. And this effect even more affected than other photo quality aspects. It means that even not camera or its lens plays the most important role in photo quality but photography skills. To decrease its effect cropping photo may be used. However, this fact will stimulate students to increase their photography skills.

**Google Lens in STEM-education**.

Google Lens is a powerful STEM-instrument which can provide increasing of knowledge quantity and quality and can increase motivation to education for students-visuals [5, 6]. As was noted before, it has a huge potential of implementation in different educational fields and can provide transdisciplinarity of the educational process through the integration of it with Wikipedia (default) and other resources (by picture search).

The teacher can achieve even better results by providing “find-mistakes” challenge with excellent students. Under it, students will try to find mistakes in the analyzing of the Google Lens.

It is worth note that one of the priorities of the Ukrainian secondary school is STEM-education [1, 15, 17, 18] and the New Ukrainian school principals implementation which can be easily achieved by using Google Lens using in classes.

Nowadays each teacher in Ukraine can easily use those methods based on Google Lens through using online-guides located in stemua.science open-source web-portal and can share own methods based on it [14]. In additions, STEM-principles nowadays are being introduced in university courses due to their efficiency [8–11, 15].

## 5 Conclusions

1. Google Lens shows the high results of analyzing which gives reason to recommend its implementation in the educational process.
2. It is better to plan classes on the gardens due to the fact that Google Lens shows better results on the grass and trees analysis.
3. Based on the results of the article we modernize methods located in the stemua.science.
4. Using of Google Lens in the educational process is a simple way to include principles of STEM-education and “New Ukrainian school” in classes.

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## Аналіз якості за допомогою Google Lens: можливості його використання в навчальному процесі

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**Анотація**. Біологія є досить складним початковим предметом, оскільки передбачає знання біологічного різноманіття. Google Lens — це унікальне мобільне програмне забезпечення, яке дозволяє розпізнавати види та рід рослини, яку студент шукає. Стаття присвячена аналізу ефективності функціонування Google Lens, пов'язаного з ботанічними об'єктами. Для проведення аналізу ботанічні об'єкти були класифіковані за типом рослини (трава, дерево, кущ) та за частиною рослини (стебло, квітка, плід), яка представлена на фото, яке аналізується. Було показано, що Google Lens правильно визначив види рослин у 92,6% випадків. Це досить високий результат, який дозволяє рекомендувати цю програму для використання під час навчання. Найбільша точність Google Lens спостерігалася під час аналізу дерев та стебел рослин. Найгірша точність Google Lens характеризувалася результатами розпізнавання плодів та стебел кущів. Однак точність все ще була високою, і Google Lens може допомогти забезпечити дослідження навіть у останньому випадку. Google Lens не здатний проаналізувати місцеву ендемічну флору України. Було продемонстровано, що ефективність розпізнавання залежить більше від роздільної здатності фотографії, ніж від фізичних характеристик камери, за допомогою якої вони зроблені. У статті зазначено, що можливість використання Google Lens у навчальному процесі — це простий спосіб включити принципи STEM-освіти та «Нової української школи» у класах.

**Ключові слова**: Google Lens, розпізнавання рослин, Нова українська школа, STEM-освіта, доповнена реальність, цифрова освіта.

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Наукове видання

# ОСВІТНІЙ ВИМІР

## ЗБІРНИК НАУКОВИХ ПРАЦЬ

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