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This volume represents the proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), held in Kryvyi Rih, Ukraine, in March 22, 2019. It comprises 19 contributed papers that were carefully peer-reviewed and selected from 25 submissions. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

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AREdu 2019 – How augmented reality transforms to augmented learning

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Abstract. This is an introductory text to a collection of papers from the AREdu 2019: The 2nd International Workshop on Augmented Reality in Education, which was held in Kryvyi Rih, Ukraine, on the March 22, 2019. It consists of short introduction, papers review and some observations about the event and its future.

Keywords: virtualization of learning, augmented reality gamification, design and implementation of augmented reality learning environments, mobile technology of augmented reality, augmented reality in science education, augmented reality in professional training and retraining, augmented reality social and technical issues.

1 AREdu 2019 at a glance

Augmented Reality in Education (AREdu) is a peer-reviewed international Computer Science workshop focusing on research advances, applications of augmented reality in education.

AREdu topics of interest:

- Virtualization of learning: principles, technologies, tools
- Augmented reality gamification
- Design and implementation of augmented reality learning environments
- Mobile technology of augmented reality
- Aspects of environmental augmented reality security and ethics
- Augmented reality in science education
- Augmented reality in professional training and retraining

- Augmented reality social and technical issues

This volume represents the proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), held in Kryvyi Rih, Ukraine, in March 22, 2019 (Fig. 1). It comprises 19 contributed papers that were carefully peer-reviewed and selected from 25 submissions. Each submission was reviewed by at least 3, and on the average 3.7, program committee members. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

Fig. 1. AREdu 2019 moments

The volume is structured in five parts, each presenting the contributions for a particular workshop track.

2 Session 1: Virtualization of learning: principles, technologies, tools

The article [1] of Olga V. Bondarenko, Olena V. Pakhomova and Włodzimierz Lewoniewski clarifies the concept of “virtual information educational environment” and examines the researchers’ views on its meaning exposed in the scientific literature. The article determines the didactic potential of the virtual information educational environment for the geography students training based on the analysis of the authors’ experience of blended learning by means of the Google Classroom. It also specifies the features (immersion, interactivity, and dynamism, sense of presence, continuity, and causality). The authors highlighted the advantages of virtual information educational environment implementation, such as: increase of the efficiency of the educational process by intensifying the process of cognition and interpersonal interactive communication; continuous access to multimedia content both in Google Classroom and beyond; saving student time due to the absence of necessity to work out the training material “manually”; availability of virtual pages of the virtual class; individualization of the educational process; formation of informational culture of the geography students; and more productive learning of the educational material at the expense of IT educational facilities. Among the disadvantages the article mentions low level of computerization, insignificant quantity and low quality of software products, underestimation of the role of virtual information educational environment in the professional training of geography students, and the lack of economic stimuli, etc.

Volodymyr H. Shamonia, Olena V. Semenikhina, Volodymyr V. Proshkin, Olha V. Lebid, Serhii Ya. Kharchenko and Oksana S. Lytvyn in [15] establish 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.

The article of Svitlana V. Symonenko, Nataliia V. Zaitseva, Viacheslav V. Osadchyi, Kateryna P. Osadcha and Ekaterina O. Shmeltser [18] deals with the urgent problem of application of virtual reality in foreign language training. Statistical data confirms that the number of smartphone users, Internet users, including wireless Internet users, has been increasing for recent years in Ukraine and tends to grow. The coherence of quick mobile Internet access and presence of supplementary equipment enables to get trained or to self-dependently advance due to usage of virtual reality possibilities for education in the stationary classrooms, at home and in motion. Several important features of virtual reality, its advantages for education are discussed. It is noted that virtual reality is remaining a relatively new technology in language learning. Benefits from virtual reality implementation into foreign language learning and teaching are given. The aspects of immersion and gamification in foreign language learning are considered. It is emphasized that virtual reality creates necessary preconditions for motivation increasing. The results of the survey at two higher education institution as to personal experience in using VR applications for learning foreign languages are presented. Most students at both universities have indicated quite a low virtual reality application usage. Six popular virtual reality applications for foreign language learning (Mondly, VRSpeech, VR Learn English, Gold Lotus, AltSpaceVR and VirtualSpeech) are analyzed. It is stated that the most preferred VR application for foreign language learning includes detailed virtual environment for maximal immersion, high-level visual effects similar to video games, simple avatar control, thorough material selection and complete complicity level accordance of every element and aspect, affordability, helpful and unobtrusive following up.

Michael S. Lvov and Halyna V. Popova in [7] argued that introduction of simulation technologies of virtual reality in the educational process of higher maritime educational institutions increases the efficiency of education, promotes the development of professional thinking of students, enhances the quality of professional competence development.

The article [19] of Tetiana A. Vakaliuk, Valerii V. Kontsedailo, Dmytro S. Antoniuk, Olha V. Korotun, Iryna S. Mintii and Andrey V. Pikilnyak presents the possibilities of using game simulator Sotware Inc in the training of future software engineer in higher education. Attention is drawn to some specific settings that need to be taken into account when training in the course of training future software engineers. The use of modern ICT, including game simulators, in the educational process, allows to improve the quality of educational material and to enhance the educational effects from the use of innovative pedagogical programs and methods, as it gives teachers additional opportunities for constructing individual educational trajectories of students. A feature of any software engineer is the need to understand the related subject area for which the software is being developed. Authors notes that when the real-world practice is impossible for students, game simulators that simulate real software development processes are an alternative.

3 Session 2: Augmented reality social and technical issues

Vladimir S. Morkun, Natalia V. Morkun and Andrey V. Pikilnyak in [11] argued that for programming the AR tools, interactive objects and creating the markers, the method of fiber spaces (*k*-space) for modeling of ultrasonic wave propagation in an inhomogeneous medium using coarse grids, with maintaining the required accuracy was used. The algorithm and AR tools are introduced by authors into the adaptive control system of the pulp gas phase in the iron ore flotation process using a control action based on high-energy ultrasound dynamic effects generated by ultrasonic phased arrays. The AR tools based on *k*-space methods allow facilitating wider adoption of ultrasound technology and visualizing the ultra-sound propagation in heterogeneous media by providing a specific correspondence between the ultrasound data acquired in real-time and a sufficiently detailed augmented 3D scene. Such tools allow also seeing the field of ultrasound propagation, its characteristics, as well as the effect of the dynamic effects of ultrasound on the change in the gas phase during the flotation process.

Svitlana I. Pochtoviuk, Tetiana A. Vakaliuk and Andrey V. Pikilnyak in [14] study presents the possibilities of using augmented reality in the learning mathematics, anatomy, physics, chemistry, architecture, as well as in other fields. The comparison of domestic and foreign proposals for augmented reality is presented.

4 Session 3: Augmented reality in science education

Article [17] of Mariya P. Shyshkina and Maiia V. Marienko presents the AR-based open science tools 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). 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 a component.

The article [16] of Viktor B. Shapovalov, Yevhenii B. Shapovalov, Zhanna I. Bilyk, Anna P. Megalinska and Ivan O. Muzyka 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.

Tetiana H. Kramarenko, Olha S. Pylypenko and Vladimir I. Zaselskiy in [5] improves the methodology of teaching Mathematics using cloud technologies and augmented reality, analyzing the peculiarities of the augmented reality technology implementing in teaching mathematics. 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.

Svitlana L. Malchenko, Davyd V. Mykoliuk and Arnold E. Kiv in [8] emphasize in astrophysics, a significant role is play the observations. During astronomy classes in the absence of surveillance tools interactive programmes such as Universe Sandbox[2] can be used. Using this programme students have an opportunity to get acquainted with the existence of stars with different masses, their differences, to observe changes in the physical characteristics of stars such as: mass, temperature, speed velocity, luminosity, radius and gravity. It will help to develop the ability to analyze, to compare, to form scientific worldview, to develop the attraction for research, to raise the interest for studying astronomy.

The purpose of the article [12] of Pavlo P. Nechypurenko, Viktoriia G. Stoliarenko, Tetiana V. Starova, Tetiana V. Selivanova, Oksana M. Markova, Yevhenii O. Modlo and Ekaterina O. Shmeltser is an analysis of opportunities and description of the experience of developing and implementing augmented reality technologies to support the teaching of chemistry in higher education institutions of Ukraine. The article is aimed at solving problems: generalization and analysis of the results of scientific research concerning the advantages of using the augmented reality in the teaching of chemistry, the characteristics of modern means of creating objects of augmented reality; discussion of practical achievements in the development and implementation of teaching materials on chemistry using the technologies of the augmented reality in the educational process. As a result of the study, it was found that technologies of augmented reality have enormous potential for increasing the efficiency of independent work of students in the study of chemistry, providing distance and continuous education. Often, the technologies of the augmented reality in chemistry teaching are used for 3D visualization of the structure of atoms, molecules, crystalline lattices, etc., but this range can be expanded considerably when creating its own educational products with the use of AR-technologies. The study provides an opportunity to draw conclusions about the presence of technologies in the added reality of a significant number of benefits, in particular, accessibility through mobile devices; availability of free, accessible and easy-to-use software for creating augmented-reality objects and high efficiency in using them as a means of visibility. The development and implementation of teaching materials with the use of AR-technologies in chemistry teaching at the Kryvy Rih State Pedagogical University has been started in the following areas: creation of a database of chemical dishes, creation of a virtual chemical laboratory for qualitative chemical analysis, creation of a set of methodical materials for the course “Physical and colloidal chemistry”.

5 Session 4: Augmented reality in professional training and retraining

The aim of the article [13] of Liubov F. Panchenko and Ivan O. Muzyka is to provide an analytical review of the content of massive open online courses about augmented reality and its use in education with the further intent to create a special course for the professional development system for the research and teaching personnel in postgraduate education. As results of the research the content and program of specialized course “Augmented Reality as a Storytelling Tool” for the professional development of teachers was developed. The purpose of the specialized course is to consider and discuss the possibilities of augmented reality as a new direction in the development of educational resources, to identify its benefits and constraints, as well as its components and the most appropriate tools for educators, to discuss the problems of teacher and student co-creation on the basis of the use of augmented reality, and to provide students with personal experience in designing their own stories and methodical tools in the form of augmented books and supplementary training aids with the help of modern digital services.

Anna V. Iatsyshyn, Valeriia O. Kovach, Yevhen O. Romanenko, Iryna I. Deinega, Andrii V. Iatsyshyn, Oleksandr O. Popov, Yulii G. Kutsan, Volodymyr O. Artemchuk, Oleksandr Yu. Burov and Svitlana H. Lytvynova in [2] describe the application of augmented reality technologies for preparation of specialists of new technological era. Number of scientific studies on different aspects of augmented reality technology development and application is analyzed in the research. Practical examples of augmented reality technologies for various industries are described. Very often augmented reality technologies are used for: social interaction (communication, entertainment and games); education; tourism; areas of purchase/sale and presentation. There are various scientific and mass events in Ukraine, as well as specialized training to promote augmented reality technologies. There are following results of the research: main benefits that educational institutions would receive from introduction of augmented reality technology are highlighted; it is determined that application of augmented reality technologies in education would contribute to these technologies development and therefore need increase for specialists in the augmented reality; growth of students’ professional level due to application of augmented reality technologies is proved; adaptation features of augmented reality technologies in learning disciplines for students of different educational institutions are outlined; it is advisable to apply integrated approach in the process of preparing future professionals of new technological era; application of augmented reality technologies increases motivation to learn, increases level of information assimilation due to the variety and interactivity of its visual representation. Main difficulties of application of augmented reality technologies are financial, professional and methodical. Following factors are necessary for introduction of augmented reality technologies: state support for such projects and state procurement for development of augmented reality technologies; conduction of scientific research and experimental confirmation of effectiveness and pedagogical expediency of augmented reality technologies application for training of specialists of different specialties; systematic conduction of number of national and international events on dissemination and application of augmented reality technology. It is confirmed that application of augmented reality technologies is appropriate for training of future specialists of new technological era.

The article [6] of Olena O. Lavrentieva, Ihor O. Arkhypov, Olexander I. Kuchma and Aleksandr D. Uchitel discusses the theory and methods of simulation training, its significance in the context of training specialists for areas where the lack of primary qualification is critical. The most widespread hardware and software solutions for the organization welders' simulation training that use VR- and AR-technologies have been analyzed. A review of the technological infrastructure and software tools for the virtual teaching-and-production laboratory of electric welding has been made on the example of the achievements of Fronius, MIMBUS, Seabery. The features of creating a virtual simulation of the welding process using modern equipment based on studies of the behavioral reactions of the welder have been shown. It is found the simulators allow not only training, but also one can build neuro-fuzzy logic and design automated and robotized welding systems. The functioning peculiarities of welding's simulators with AR have been revealed. It is shown they make it possible to ensure the forming basic qualities of a future specialist, such as concentration, accuracy and agility. The psychological and technical aspects of the coaching programs for the training and retraining of qualified welders have been illustrated. The conclusions about the significant advantages of VR and AR technologies in comparison with traditional ones have been made. Possible directions of the development of simulation training for welders have been revealed. Among them the AR technologies have been presented as such that gaining wide popularity as allow to realize the idea of mass training in basic professional skills.

The article [10] of Yevhenii O. Modlo, Serhiy O. Semerikov, Stanislav L. Bondarevskyi, Stanislav T. Tolmachev, Oksana M. Markova and Pavlo P. Nechypurenko is devoted to the methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects. An analysis of the experience of professional training bachelors of electromechanics in Ukraine and abroad made it possible to determine that one of the leading trends in its modernization is the synergistic integration of various engineering branches (mechanical, electrical, electronic engineering and automation) in mechatronics for the purpose of design, manufacture, operation and maintenance electromechanical equipment. Teaching mechatronics provides for the meaningful integration of various disciplines of professional and practical training bachelors of electromechanics based on the concept of modeling and technological integration of various organizational forms and teaching methods based on the concept of mobility. Within this approach, the leading learning tools of bachelors of electromechanics are mobile Internet devices (MID) – a multimedia mobile devices that provide wireless access to information and communication Internet services for collecting, organizing, storing, processing, transmitting, presenting all kinds of messages and data. The competency structure of the bachelor of electromechanics in the modeling of technical objects is reflected in three groups of competencies: general scientific, general professional and specialized professional. The implementation of the technique of using MID in learning bachelors of electromechanics in modeling of technical objects is the appropriate methodic of using, the component of which is partial methods for using MID in the formation of the general scientific component of the bachelor of electromechanics competency in modeling of technical objects, are disclosed by example academic disciplines “Higher mathematics”, “Computers and programming”, “Engineering mechanics”, “Electrical machines”. The leading tools of formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects are augmented reality mobile tools (to visualize the objects’ structure and modeling results), mobile computer mathematical systems (universal tools used at all stages of modeling learning), cloud based spreadsheets (as modeling tools) and text editors (to make the program description of model), mobile computer-aided design systems (to create and view the physical properties of models of technical objects) and mobile communication tools (to organize a joint activity in modeling).

6 Session 5: Design and implementation of augmented reality learning environments

In the article [4] of Yaroslav M. Krainyk, Anzhela P. Boiko, Dmytro A. Poltavskyi and Vladimir I. Zaselskiy the development of historical guide based on Augmented Reality technology is considered. The developed guide application it targeted to be used in different scenarios, in particular, during history learning classes, for guidance of the tourists to exhibits both indoor and outdoor. Common features of all these scenarios are generalized and according to them main information and objects model for forming scene are identified. This part is followed by detailed description of objects and scene representation, markers usage, employment of additional services, etc. Finally, the developed historical guide application has been introduced. It harnesses A-Frame library for processing of models and their representation. The application is able to work with different markers so that it can be extended easily. In addition, one of the main benefits of the developed application is support of multiple platforms because it works from web-browser and does not require installation of additional software. The developed application can be effectively used for all provided scenarios and has potential for further extension.

Lilia Ya. Midak, Ivan V. Kravets, Olga V. Kuzyshyn, Jurij D. Pahomov, Victor M. Lutsyshyn and Aleksandr D. Uchitel in [9] creates an Android mobile application LiCo.STEM for visualization of chemical structure of water and to display video-data of laboratory experiments that can be used by the teacher and pupils for an effective background for learning natural cycle subjects and performance of laboratory experiments in the elementary school using lapbook. Representation of the developed video materials on the mobile gadgets is conducted by binding them to individual markers for every laboratory experiment. Applying such technologies gives an opportunity to establish educational activity, based on interference of adults with children, oriented on interests and abilities of each kid, development of curiosity, cognitive motivation and educational energy; development of imagination, creative initiative, including the speech, ability to chose the materials, types of work, participants of the common activity, promotion of conditions for parents participate in the common study activity.

Oleksandr V. Kanivets, Irina M. Kanivets, Natalia V. Kononets, Tetyana M. Gorda and Ekaterina O. Shmeltser in [3] conduct an analysis of training tools used at the study a general technical disciplines. This made it possible to draw an analogy between physical and electronic models and justify the mobile application development for tasks performing at projective drawing. Authors showed a technique for creating augmented reality mobile applications. The main stages of development an augmented reality application are shown electronic models development, Unity3D game engine installation, and mobile application development, testing and work demonstration. Particular attention is paid by the scripts use to rotate and move electronic models. The authors presents an augmented reality mobile application for help to performance tasks from projection drawing.

7 Conclusion

The second instalment of AREdu was organised by Kryvyi Rih National University (Ukraine), in collaboration with Kryvyi Rih State Pedagogical University, Institute of Information Technologies and Learning Tools of the NAES of Ukraine and Ben-Gurion University of the Negev (Israel).

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We are looking forward to excellent presentations and fruitful discussions, which will broaden our professional horizons. We hope all participants enjoy this workshop and meet again in more friendly, hilarious, and happiness of further AREdu 2020.

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The didactic potential of virtual information educational environment as a tool of geography students training

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Abstract. The article clarifies the concept of “virtual information educational environment” (VIEE) and examines the researchers’ views on its meaning exposed in the scientific literature. The article determines the didactic potential of the virtual information educational environment for the geography students training based on the analysis of the authors’ experience of blended learning by means of the Google Classroom. It also specifies the features (immersion, interactivity, and dynamism, sense of presence, continuity, and causality). The authors highlighted the advantages of virtual information educational environment implementation, such as: increase of the efficiency of the educational process by intensifying the process of cognition and interpersonal interactive communication; continuous access to multimedia content both in Google Classroom and beyond; saving student time due to the absence of necessity to work out the training material “manually”; availability of virtual pages of the virtual class; individualization of the educational process; formation of informational culture of the geography students; and more productive learning of the educational material at the expense of IT educational facilities. Among the disadvantages the article mentions low level of computerization, insignificant quantity and low quality of software products, underestimation of the role of VIEE in the professional training of geography students, and the lack of economic stimuli, etc.

Keywords: teacher training, students, virtual information educational environment, Google Classroom.

1 Introduction

1.1 The Problem Statement

The Ukrainian educational policy aims at training a competitive professional who can work effectively and efficiently in the context of rapidly changing information society. Nowadays its focus is on the transition to a virtual model of education. The geography students are required to be fluent in navigating the global information space, be able to analyze large volumes of information, be capable of life-long education [6].

However, some inconsistencies prevent the process of modernization of teacher training going smoothly. Among them, we can highlight the contradiction between contemporary social requirements and the actual preparedness of geography students to study in a virtual information educational environment (VIEE); the incompatibility of the didactic potential of information educational environment and the lack of systematic outlook on its implementation in professional teacher training.

1.2 Theoretical background

The analysis of scientific literature confirms the relevance of the problem under study. Thus, Mykola I. Murashko and Svitlana O. Nazarko [23] study the virtualization of the education market. Olena S. Holovnia [11] researches the systematization of the virtualization of technologies, while Irina A. Belysheva [3] studies informational and learning environment as a means of developing student cognitive autonomy. Aleksandr A. Andreev [1], Mariia A. Kyslova [16], Liubov F. Panchenko [25], Kateryna I. Slovak [26], Olha A. Obdalova [24] analyze the systematization of the virtualization of technologies. Tetiana V. Zhuravel and Nataliia I. Khaidari [38] consider the virtual educational environment as a means of formation of the student competencies. The virtual learning environment as a component of distance learning was the subject under study in Yuliia V. Falshtynska's research [9]. The advantages and disadvantages of the virtual learning environment is illuminated by Olena M. Arkhipova [2], the virtual educational environment as the innovative educational high school component is presented in the scientific researches by Maryna O. Skurativska and Serhii S. Popadiuk [31].

Some aspects of our chosen theme are considered in the studies devoted to distance education and blended learning (Myroslav I. Zhaldak [37], Volodymyr M. Kukharenko [8], Yukhym I. Mashbyts [22], Natalia V. Rashevska [26; 27], Serhiy O. Semerikov [26; 28], Andrii M. Striuk [28; 33], Yurii V. Tryus [35], Bohdan I. Shunevych [30]).

The geography study by means of the virtual educational environment and blended learning, we ground our research on, is widely presented in foreign publications. Vertual reality as an efficient way in GIS classroom teaching is studied by Jiangfan Feng [10]. The development of virtual geographic environments is researched by Fengru Huang, Hui Lin, Bin Chen [12]. Kenneth David Lynch, Bob Bednarz, James Boxall, Julie Kesby [19] work on e-learning for geography's teaching and learning spaces. Application of virtual reality in geography teaching is highlighted in works of Ivan Stojšić, Anjelija Ivkov Dzigurski, Olja Maričić, Ljubica Ivanović Bibić, Smiljana

Đukičin Vučković [32], Adem Sezer [29] considers geography teachers' usage of the internet for education purposes.

Currently the topicality of implementation of VIEE and its didactic potential for geography student training are not fully recognized in the Ukrainian scientific writings. Now there are some electronic information resources such as Google Earth, LearningApps.org, World Map Quiz, Redigo, etc. that are mostly used to study geography than to train geography students [13; 14]. In addition, some elements of the virtual educational environment, for example: e-mail, chats, forums, blogs, computer multimedia programs, electronic manuals, simulators, media resources, etc., are applied in distance and full-time studies, but due to the lack of a scientific and methodological basis, the results achieved have a fragmentary unsystematic character.

1.3 The objective of the article

The objective of the article is to specify the concept definition of "virtual information educational environment" and to summarize the researchers' understanding of it, and to consider its didactic potential for the training of geography students.

2 Results and discussion

The gradual transition of education from the knowledge to the virtual pattern reflects the process of its rapid informatization and boosts the introduction of some new terms into the scientific discourse. The comparative analysis of the meaning of the newly coined terms such as "virtual educational environment", "virtual learning environment", "information educational environment", etc., is presented in the following research (Table 1).

Table 1. The comparative analysis of the terms meaning

Term	Researchers	Definition
Virtual education environment	Marina E. Vaindorf-Sysoeva [36]	the amount of information and means of communication of local, corporate and global computer networks, which are made and used for educational purposes by all participants in the educational process
	Tatiana V. Zhura-vel and Natalia I. Haydari [38]	an open system enabling effective interactive self-education, based on the virtual reality technologies
	Maryna O. Skurativska and Serhii S. Popadiuk [31]	the organized system of informational, technological, didactic resources, various forms of computer and telecommunication interaction used by educators and students
Virtual learning environment	Olena M. Arkhipova [2]	a software system designed to support distance learning with an emphasis on learning, in contrast to a managed learning environment, with the emphasis on the management of the learning process
	Yuliia V.	a system for the learning process management created for

Term	Researchers	Definition
	Falshtynska [9]	students' learning activities, and provides the necessary replenishment and resources for successful learning and knowledge acquisition
Virtual learning environment / Virtual reality learning environment	Jiangfan Feng [10]	is the simulation of teaching method, thinking model, cognition manner and control means in the actual learning environment
Information educational environment	Olha A. Obdalova [24]	the conditions for information exchange, which are provided with the special software, aimed at satisfying the educational needs of users, usually created by cooperatively interconnected educational institutions with information exchange
	Liubov F. Panchenko [25]	open, nonlinear, holistic system of innovation orientation
Information learning environment	Irina A. Belysheva [3]	the system that reflects the interconnection of conditions and has such features as: the availability of information resources, the interactive nature of communication environment, saturation with educational resources, the possibility to change goals, methods, forms of learning organization, asynchronous use, the ability to store and accumulate information
	Svitlana H. Lytvynova [20]	an open system accumulating in itself deliberately created organizational-pedagogical, procedural-technological, informational resources, and with a single value-purpose basis provides innovation as a means and mechanism for the formation of components of the pedagogical culture, the formation of the professional position of teachers and the content of the forms, methods and techniques, technologies, aimed at forming a pedagogical culture of students – future teachers
Learning information environment	Svitlana O. Leshchuk [18]	a system of information communication and traditional means aimed at organizing and conducting a learning process focused on personal learning in the information society
Cloud-based learning environment	Svitlana H. Lytvynova [20]	an artificially constructed system that provides learning mobility, group collaboration between teachers and students and uses cloud technologies for effective and safe achievement of didactic goals
E-space / E-learning environment	Kenneth David Lynch, Bob Bednarz, James Boxall, Julie Kesby [19]	Online course materials used to support traditional campus based learning that are delivered entirely online, or provide complementary support in the form of learning materials. There are four main types of e-learning: web-supplemented, web-dependant, mixed mode, fully online.
Virtual environment / Virtual geographic environment	Fengru Huang, Hui Lin, Bin Chen [12]	a concept of a virtual world that was referenced to the real world, which had five types of space, namely Internet space, data space, 3D graphical space, personal perceptual and cognitive space, and social space.

Table 1 shows that the environment is sometimes interpreted as “information exchange”, “information space”. Although, most of the definitions are made in the domain of the system approach, according to which the environment is a system of interconnected, interdependent components that form a single entity performing qualitatively new function, not inherent in its separate elements. This means that the environment under study “is formed rather by educational subjects, than by technical means or electronic guides, therefore its existence is impossible beyond the communication of students, faculty, facilitators, administrators, developers of distance courses, etc.” [31].

Let us consider to use the term “virtual information educational environment” in the context of geography student training.

In such an environment, the nature of the interaction of all participants of learning (a student, a student group, a teacher) is fundamentally changing. We deliberately do not use the term “study” for we interpret it as a cognitive activity of students who under the guidance of a teacher master knowledge, skills, and develop cognitive abilities. The involvement of the geography students in the information educational environment means that a teacher changes his role of a head and mentor to a tutor, facilitator, and moderator. Teacher strives to help a student find an individual educational route (an individual way of personal potential realization as a student that is made taking into account his abilities, interests, needs, motivation, opportunities and experience).

Geography, socio-economic geography in particular, is a discipline with dynamic content. So the knowledge received by former student at the higher school in the past can become “out of date for one day” in relation to the present one. That is why it is of great importance to teach a student to collect and analyze the necessary information by his/her own using available statistical sources such as countrymeters.info, ukrstat.gov.ua; to process the records and statistics of international organizations such as UN, WHO, etc.; to use information in the form of self-created cartographic works, schemes, drawings based on DataGraf, QuickMap, and Google Earth; to work with interactive maps such as MigrationsMap, kartograph.org, Setera.org, World Map Quiz, Redigo, Mapillary, etc.

Modern students live in a media environment where the use of computers, Internet resources and mobile devices is the part of their everyday life. They are, according to Aleksander Kuleshov “digitally born”, and this fact cannot be ignored. Therefore, “key properties” [15] VIEE, which can realize its didactic potential to some extent, should be taken into account while training of geography students. They are in particular:

- Immersion, the ability to be an active doer instead of a passive viewer (for example, not to state and percept the volume of world's population, but try on a role of an expert UNFPA, who is capable of predicting the dynamics of the population over the coming decades);
- Interactivity, the active interaction of education process participants among each other and with an artificial environment (for example, to be able to carry on a peer survey in order to find out the family and childbirth plans). Interpretation of the results implies finding out the nature of demographic behavior of the population in countries and regions with different types of reproduction of the population);

- Dynamism, variability, transience of events (for example, the skill of comparative analysis of content and processes for the creation of medieval and modern digital geographic maps);
- Sense of presence (for example, to be able to role-play the characteristics of demographic behavior of representatives of various social strata of Africa);
- Continuity, the ability for continuous interaction of participants in the educational process (off-line, on-line, etc.);
- Causality, the ability to identify the causal relationships among physical and geographical, socio-economic, cultural-historical phenomena and processes, and to visualize them with multimedia.

Moreover, global informatization of society has caused the problem of cognitive overload (when the number of operations that human brain must perform exceeds its capacity) [21]. This problem concerns geography students as well, because their training involves the memorization of a significant amount of factual material (geographical nomenclature, quantitative and qualitative parameters of the population of the world and regions, indicators of socio-economic development of countries, algorithms of work with geodetic instruments, trends and patterns of physical development geographic, socio-economic, cultural-historical phenomena and processes, etc.). On the other hand, the VIEE enables a student to visualize information, choose the form and rate of education, the level of complexity of the task, methods and means of training. Its creation encourages a student to make more personalized educational and practice-oriented objectives. Aleksei N. Leontiev emphasize the importance of personal sense of learning objectives and identify the later as the reflection of the relation of an activity motive to the purpose of an action in the mind of an individual [17].

As the scientific works do not share the commonly accepted definition of the term "virtual information educational environment", there is an urgent need to define our own one taking into account the definitions given by other authors, and the specifics of teacher work and the requirements for the personality of the geography teacher. Basing on the researches of Maryna O. Skurativska and Serhii S. Popadiuk [31], we define the "virtual information educational environment" as a holistic, organized system of various resources (informational, didactic, technological) and forms of interaction of teachers and students (synchronous, asynchronous, full-time, remote, computer and telecommunication), aimed at creating student individual educational trajectory.

Any platforms as commercial as free suitable for blended learning such as Blackboard, Bodington, CloudSchool, Edmodo, Google Classroom, Moodle, etc. can serve as the basis for creating a virtual information educational environment.

The authors of this article have the experience in scaffolding of blended learning of geography students by using Google Classroom [4; 5; 7], Fig. 1.

It should be noted that the educational process organized in the VIEE, based on the Google Classroom, is similar in its structure to the traditional one and embraces the objective-motivational, content-operational, emotional-volitional, evaluative-productive components. Although, all of them are fulfilled with the specific technologies and tools (IT communication tools and IT educational facilities).

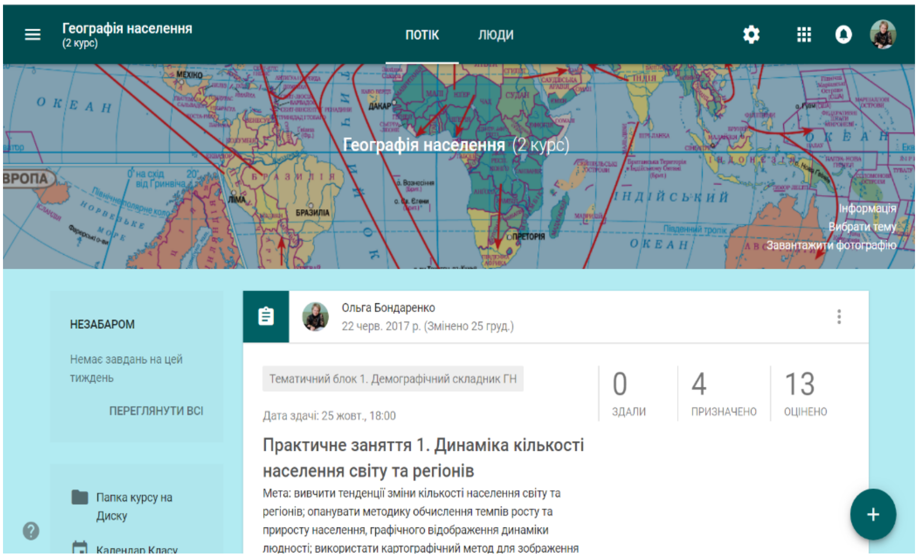

Fig. 1. The main page view of the course “Population Geography”

3 Conclusion

1. To summarize the stated above we may claim the advantages of VIEE:

- increase of the efficiency of the educational process by intensifying the process of cognition and interpersonal interactive communication [23; 34];
- continuous access to multimedia content both in Google Classroom and beyond;
- saving student time due to the absence of necessity to work out the training material “manually”;
- availability of virtual pages of the virtual class;
- individualization of the educational process;
- formation of informational culture of the geography students;
- more productive learning of the educational material at the expense of IT educational facilities.

2. On the basis of the analysis of scientific literature (Olena M. Arkhipova [2], Yuliia V. Falshtynska [9], Mykola I. Murashko and Svitlana O. Nazarko [23], and own pedagogical experience we can state that despite the obvious number of advantages of VIEE, its adoption among the students and teaching community is slow in Ukraine. To a certain extent, this situation has arisen because of the low level of computerization of institutions of higher education and the lack of economic stimuli. Depending on the specifics of the discipline, the quantity and quality of the necessary software products can be quite low. The underestimation of the role of VIEE in the professional formation of geography students also prevents its adoption to certain extend.

3. We anticipate the further study of the problem in the development of the systems of electronic courses on Google Classroom platforms and Moodle for the organization of distance learning of the geography students of the correspondence department and people with special educational needs.

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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 software-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.

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.

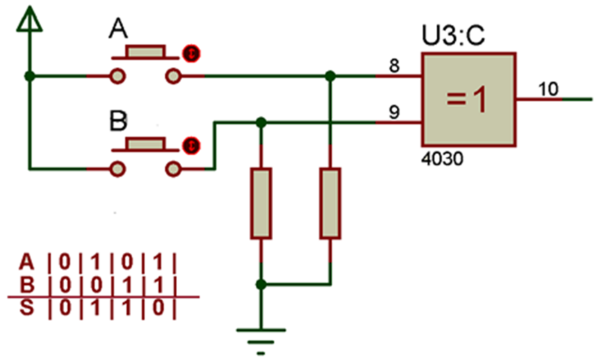

Fig. 1. The truth table for the states of the module adder 2 and a diagram of its construction in Proteus

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

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).

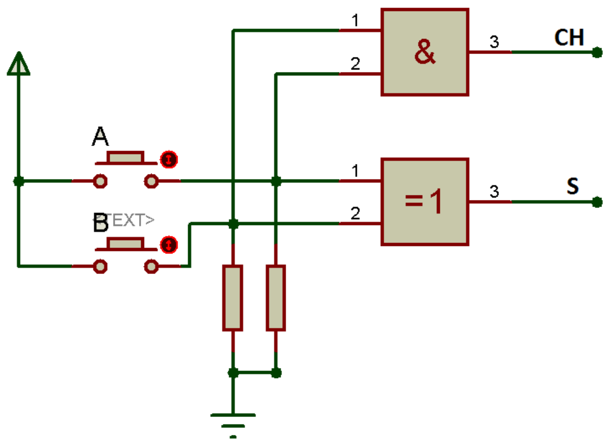

Fig. 2. Schematic of element connections for constructing a half adder

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)⊕CL	0	1	1	0	1	0	0	1
	CH(out)	0	0	0	1	0	1	1	1

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) ⊕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:

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

Using the rules of logic algebra, we obtain:

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

The forming element (A∧B) is already involved (U1: C), we supplement the scheme with the element *AND* (U1: D) to form the product (A⊕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).

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).

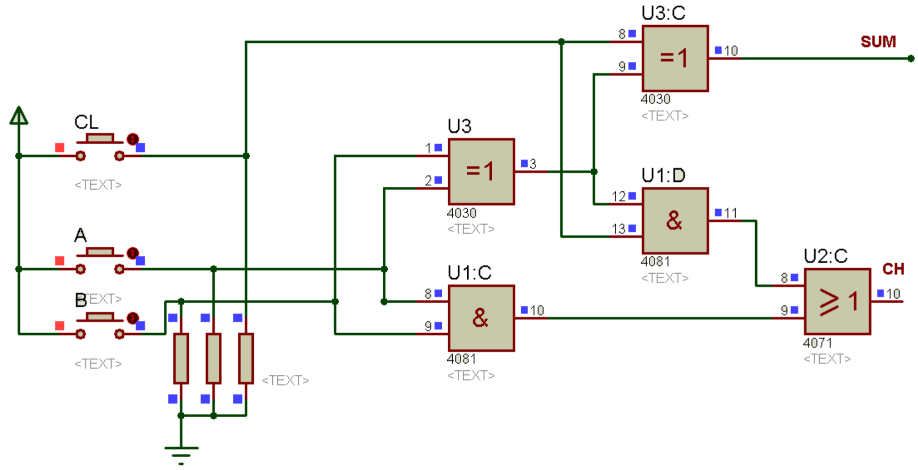

Fig. 3. Simulation of the complete adder in Proteus (inputs: A = 0, B = 0, CL = 0, outputs: S = 0, CH = 0)

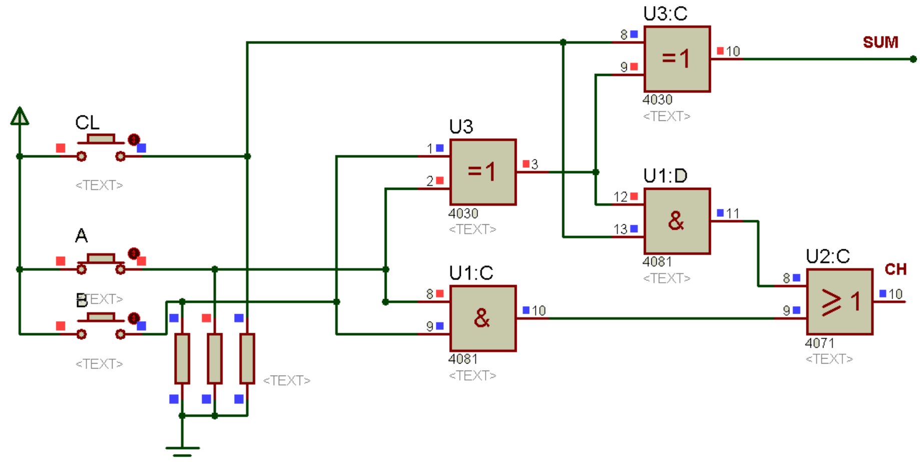

Fig. 4. Simulation of the complete adder in Proteus (inputs: A = 1, B = 0, CL = 0, outputs S = 1, CH = 0)

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.

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.

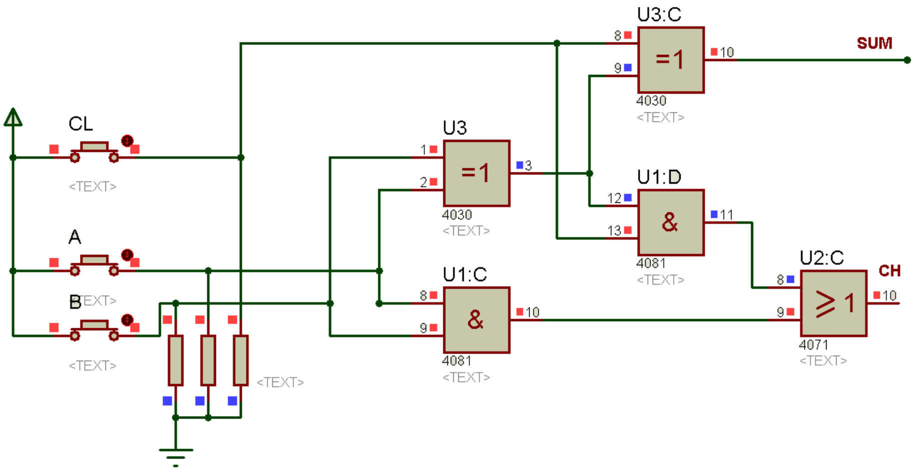

Fig. 5. Simulation of the complete adder in Proteus (inputs: A = 1, B = 1, CL = 1, outputs S = 1, CH = 1)

Table 3. Results of the double poll

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

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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Virtual reality in foreign language training at higher educational institutions

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Abstract. The paper deals with the urgent problem of application of virtual reality in foreign language training. Statistical data confirms that the number of smartphone users, Internet users, including wireless Internet users, has been increasing for recent years in Ukraine and tends to grow. The coherence of quick mobile Internet access and presence of supplementary equipment enables to get trained or to self-dependently advance due to usage of virtual reality possibilities for education in the stationary classrooms, at home and in motion. Several important features of virtual reality, its advantages for education are discussed. It is noted that virtual reality is remaining a relatively new technology in language learning. Benefits from virtual reality implementation into foreign language learning and teaching are given. The aspects of immersion and gamification in foreign language learning are considered. It is emphasized that virtual reality creates necessary preconditions for motivation increasing. The results of the survey at two higher education institution as to personal experience in using VR applications for learning foreign languages are presented. Most students at both universities have indicated quite a low virtual reality application usage. Six popular virtual reality applications for foreign language learning (Mondly, VRSpeech, VR Learn English, Gold Lotus, AltSpaceVR and VirtualSpeech) are analyzed. It is stated that the most preferred VR application for foreign language learning includes detailed virtual environment for maximal immersion, high-level visual effects similar to video games, simple avatar control, thorough material selection and complete complicity level accordance of every element and aspect, affordability, helpful and unobtrusive following up.

Keywords: Virtual Reality, Foreign Language Learning, Virtual Reality Application, Immersion, Gamification.

1 Introduction

Information and communication technology (ICT) is an inseparable part of lifestyles of modern people, especially of adolescents and young adults. In Ukraine, dependence on its benefits has been limited to person-to-person communication and information acquisition for decades. Nowadays, Ukrainians tend to enlarge the list of their demands towards IT due to massive switch to smartphone usage and because of the mobile Internet services have been rapidly advancing and expanding recently.

As it is reported by RBC-Ukraine with reference to the State Statistics Service, the number of mobile subscribers in Ukraine was 53.9 million people (January 1, 2019). According to the statistics, the number of Internet subscribers increased by 10.3% (by 2.435 million) to 26.067 million for one year. The number of subscribers of wireless Internet access has risen by 14.4% (by 2.515 million) within the year to 20,024 million people [31].

The findings of the Kantar TNS Founding Study confirm that the number of Internet users in Ukraine has increased by 7%: currently 70% of Ukrainians use the World Wide Web (compared to 63% as of December 2017). According to the survey, 74% of Internet users use a smartphone to access the Internet, and 45% of users call the smartphone their primary device. Compared to 2017, these figures have increased by 18%. In 2017, 56% of users used the smartphone to access the Internet, and they were the main devices for 27% of users [12].

The statistical data given above confirm that the number of smartphone users, Internet users, including wireless Internet users, has been increasing for recent years in Ukraine and tends to grow. Availability of the Internet access allows users to get necessary information in every professional, academic and business sphere, e.g. to telework, to keep in touch with their partners and to study independently both inland and abroad. The coherence of quick mobile Internet subscription and presence of supplementary equipment (such as headsets, gamepads, frontiers) enables to spare both time and money to get trained or to self-dependently advance due to usage of virtual reality possibilities for education in the stationary classrooms, at home and in motion.

2 Virtual reality in education

The main feature of virtual reality is its dual nature: it is used both for reproducing real environments and creating invented scenarios which in turn enables the combination and recombination techniques for VR implementation in study and entertainment.

Carl Machover, past president of the National Computer Graphics Association, defines virtual reality as “an industry in its infancy’ [16]. He analyses several important VR features, it is important to stress the following ones to support the relevance of VR benefits in education:

- ability to evoke fiery discussions in the technical community;
- ability to trigger passionate involvement of the humanities resulting from tight connection to the human senses;

- uniqueness in its emphasis on the experience of the human participant;
- focusing the user's attention on the experience while suspending disbelief about the method of creating it.

All mentioned above features are student-focused and enhance study results due to motivation and the interest increase.

Mehraza Alizadeh outlines even more advantages of using virtual reality in education: 1) providing numerous reality representations by immersing learners in virtual learning environments; 2) representing the natural complexity of the real world by exposing learners to immersive content; 3) focusing on knowledge construction by interaction between learners for finding out the facts on their own; 4) presenting tasks by virtually putting learners to different contexts; 5) providing real-world, case-based learning environments by allowing for personalized learning of different learning styles, paces, individual learning paths; 6) fostering reflective practice by appealing to visual, aural, tactile, and other different senses; 7) enabling context- and content-dependent knowledge construction by providing context-rich content and gamified problem-solving tasks [2].

According to Jeremy Bailenson, Founding Director of Stanford University's Virtual Human Interaction Lab, the training of focusing a participant's attention on the definite subject or principle is exactly one of numerous benefits of VR application: "Unlike learning from a book, video or lecture, in the immersive environment that VR provides, you learn firsthand where to direct your attention, what consequences your actions will have and even how to talk to another person" [4].

Researchers Lesia Dashko and Oksan Dubytska put forward the idea of VR irreplaceability within educational process and its superiority over traditional teaching methods. VR enables a student not to imagine but to feel scenarios, situations, subjects which are not affordable or even possible to be recreated in a classroom [7].

Taking into account numerous benefits of its application, virtual reality is being widely used for numerous education purposes and studying different disciplines: virtual traveling, language learning by immersion, practical skills training and experimenting, philosophical theory testing, architecture modeling and design, education for people with specific needs, distance learning, improvement of collaboration, game-based learning, and virtual campus visiting [29].

Virtual reality is remaining a relatively new technology in language learning. Euan Bonner and Hayo Reinder insist that slow rates of virtual reality introduction into the language education are "to the fact that teachers are reluctant or intimidated by incorporating VR-powered learning tools and resources into their classes" [5].

This situation can be explained by a lack of literacies or a low level of certain literacies, which both teachers and students possess. Howard Rheingold puts emphasis on the significance of digital literacies for human personal empowerment, learning efficiency and further professional successfulness. According to Rheingold, "literacies are where the human brain, human sociality and communication technologies meet" [26]. Two of the mentioned above (human brain and communication technology) have pivotal role in VR functioning. The third component is the desired result from

VR application into foreign language teaching – students' ability to socialize in everyday, professional and business-like situations.

Rheingold also names five fundamental digital literacies: critical consumption of information, network smarts, participation, collaboration and attention [25]. All of them are either required for complete VR immersion or are trained in simulated environments.

The award-winning education technology specialist Paul Driver enlists benefits from VR implementation into language learning and teaching as following:

- VR links learning with the demanded context and makes learning activities situated;
- physical activities of the body within VR are as much important as current mental processes; Paul Driver names this coherence as "Embodied interaction";
- VR ensures users' active control over their moves and directions;
- VR and digital games provide "Spatial Affordance" hence they are the most spatial form of media available to use in language training [10].

Viktorija Dobrova and Polina Labzina emphasize the following features of VR they consider to be crucial for opting for using it in foreign language teaching:

- relevance: virtual objects exist only in the current virtual framework;
- autonomy: the laws of virtual objects existence do not coincide with the existence laws of reality that generates them;
- derivativeness: objects of VR are produced by the activity of some other reality external to them, and exist only as long as original activity lasts;
- interactivity: virtual objects can interact with the reality that generates them as ontologically independent of it;
- ephemerality: virtual objects are artificial and mutable;
- non-material impact: not being material, virtual objects can produce effects similar in their characteristics to material objects;
- fragmentation: freedom of entry into virtual reality and freedom of exit from it provides the possibility of voluntary interruption and resumption of its existence [9].

The practice of immersion into virtual environment in foreign language learning will enable students to feel themselves an integral part of the professionally oriented situation which is designed specifically to prepare the course participants for communication within. Having their legends and terms of existence within VR task students both get used to psychological challenges and apply existing speaking skills in a foreign language to perform their roles stipulated by the tasks. Educational activities in VR encourage spontaneity and therefore entail the maximum possible immersion of every single or multi-user within virtual environments. If successful, promising task performance increases students' interest in following tasks and their motivation to achieve better results in a training course expands.

VR application solves the problem of immersion in the language environment, psychologically prepares students to use existing professional skills and knowledge and motivates their further study. VR based tasks also clearly demonstrate situational models of possible daily life circumstances for foreign language communication.

The recent study analysis indicates that the most effective way of learning a foreign language is the method of complete immersion. This statement is relevant for acquiring trendy vocabulary and adequate syntax constructions, for pronunciation adjustment in compliance with geographical or social preconditions. Moreover, improving one's communication skills is one of the most wanted benefits of immersion into interaction with presumable partners because of resemblance of emotions and feelings got by native speakers when communicating with each other within their natural language environment. Nowadays, when English is learned as an end in itself course only by linguists, a long-term immersion into a foreign culture abroad means becoming unfocused for a professional to be. It suggests parting their time for evolving in a foreign language at the expense of other professional skill improvement.

In order to integrate foreign language learning into other spheres of a future professional's life different options have been introduced into vocational training: short-term language courses abroad, bilingual education, international projects on academic mobility. However, all mentioned above choices still demand considerable amount of time and advancement. The alternative ways of immersion can be implemented into foreign language training: audio and video-based problem situations, online courses and business games. The gamification needs meticulous preparation and perfect timing, which demand high-level qualification teachers. On the other hand, professionally oriented and business games are always welcome by students.

The following gamification features support advancing in foreign language training:

1. Gamification combines working out prearranged input data and legends with improvisation.
2. It is an active form of training – students are involved in the process all the time.
3. It stimulates developing an independent creative way of problem solving by participants.
4. It encourages group discussion and team work.
5. It reveals students' linguistic, professional and leadership potential.
6. It supports positive effect both as a routine learning aspect and as a final trial.
7. It increases student motivation and activity within the course.

The motivation aspect is a very important factor for using the game method and virtual reality technologies on a substantial scale in teaching languages, as motivation is one of the main driving forces in human behavior and independent activity.

As it applies to training engineers and computer specialists-to-be VR applications create necessary preconditions for motivation increasing [14; 15; 27]. Students of these specialities demonstrate initiative in presenting their professional background, creativeness, and cognitive independence. In respect of language learning, gamification through VR educational projects is a powerful learning tool. It meets the mentioned above terms of student voluntary involvement. Gamification also supports instructors in purposeful engaging their students into active, conscious cognitive activity [6].

Nowadays, one of the undeniable motivation factors with the students is innovative technology introduction, and namely augmented reality facilities [13; 17; 21; 22; 28].

3 VR tools for foreign language learning

The importance of using mobile devices and applications as education media tends to increase continuously [18; 19; 23; 24; 30]. Nevertheless, students themselves are not aware of the time amount and percentage of using namely online learning facilities. In order to estimate exact activities and to demonstrate students their involvement into online learning the survey has been conducted. In January 2019, students of Dmytro Motornyi Tavria State Agrotechnological University and Bogdan Khmelnitsky Melitopol State Pedagogical University, Melitopol, Ukraine (further referred to as university 1 and university 2 respectively) were invited to share their personal experience in using VR applications for learning foreign languages and to agree or disagree with four statements given below:

1. You use a smartphone not a cellphone.
2. You mostly access your university website from mobile devices than from desktop computers.
3. You are rather a mobile than a desktop user of the learning management system (Moodle).
4. You use more than three AR/VR applications for learning English.
5. Name AR/VR applications for learning foreign languages you use.

The first group of responders consisted of Computer Science undergraduate students (2-4 years) and postgraduate students at university 1. Curricula of these student groups include 20 credits and 4 credits of English and Business English respectively. Therefore, they have been used to regular media and e-learning implementation into English syllabi of every term. Online facilities for their foreign language communication competence development include wide range of resources within distant learning courses on the Moodle platform and numerous links and recommendations on the Foreign Languages Department website [8].

The second group of the survey participants included undergraduate and postgraduate students of university 2. They major in Computer Science either. At the pedagogical university curricula limit English as an academic discipline to 6 credits. The syllabi shift focus from direct in-class instruction to independent learning due to smaller amount of the study load.

The results of the survey are represented in the diagrams (Figures 1, 2, 3, 4).

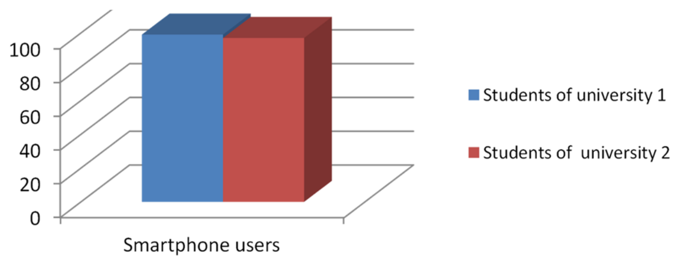

Fig. 1. The percentage of smartphone users at universities 1 and 2 (according to the survey).

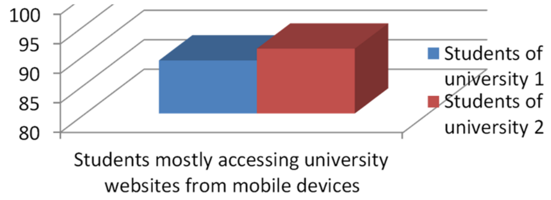

Fig. 2. The percentage of students accessing university websites from mobile devices at universities 1 and 2 (according to the survey).

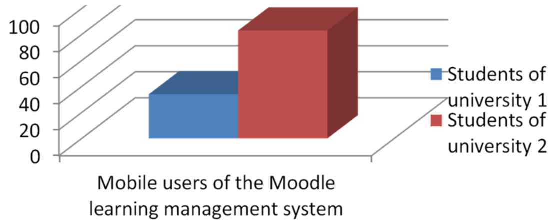

Fig. 3. The percentage of mobile users of the Moodle learning management system at universities 1 and 2 (according to the survey).

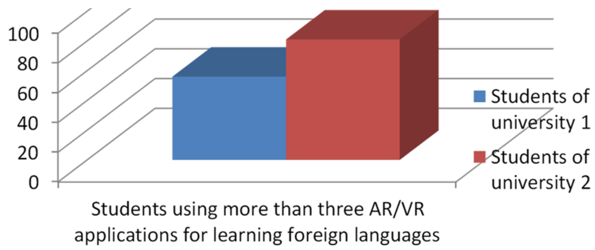

Fig. 4. The percentage of students using more than three AR/VR applications for foreign language learning at universities 1 and 2 (according to the survey).

Among 58 students of university 1 (99% of responders) use smartphones, 97% of 59 students of university 2 having participated in the survey have opted for smartphones either. The follow-up discussion has revealed that the benefits which are most frequently appealed to are the operating speed and online-application access.

The analysis of the answers to the second question has shown that the polled students mostly access university websites from their mobile devices. The students of university 1 (89%) appreciate both information amount and news urgency on the site and the website adjustment for mobile view. The responders from university 2 (91%) noted quick search option respond and numerous requisite external links added to the main page of their university website. Students from university 2 have also mentioned their attachment to the website of the Informatics and Cybernetics department within the university domain [11]. According to responders' own estimation they use it even more willingly than the university 2 website due to both relevant content and visuals easily accessed and downloaded.

The third question has demonstrated significant differences in the percentage of mobile device usage for access to the learning management system and revealed the distinct patterns of operation while e-learning courses are created. Both universities place e-learning courses in Moodle using multiple evaluation options. Students of university 1 use mobile devices less often (34% vs. 83%) than responders from university 2. According to the responders' feedback, the difference is that at university 1 the matching question type in Moodle quizzes is chosen, which is not responsive to the mobile view. Most mentioned above matching tests are based on the drag-and-drop option, which functions only on desktop. Quizzes consisting of 10 pair matching drop-down box questions are rather widespread which requires switching from mobile to desktop view. At university 2 a conventional type of matching questions are common: the content area and a list of statements that students must match correctly are used.

Statement number four appeared to be controversial to responders. Most students (65%) at both universities have indicated quite a low VR application usage. The reasons are high prices for VR mobile headsets of high quality and purchasing access to simulated environments.

Nevertheless, students of both universities easily listed at least three VR applications for learning English. Responders from university 1 (56%) mostly named Mondly, VRSpeech and AltspaceVR. Students of university 2 (81%) mentioned on average five applications (Mondly, VRSpeech, VR Learn English, Gold Lotus and VirtualSpeech). The proficiency of students from university 2 in immersing themselves in a virtual English speaking world arises from their wider experience in regular using educational VR applications, as the pedagogical university has such a valuable asset as a VR laboratory. The laboratory is mostly used by the instructors of the Informatics and Cybernetics department to improve student professional skills. But since communication in English is one of the most demanded skills of modern specialists in the IT sphere, students themselves volunteer to subscribe and to test VR applications for learning English. Having formed their opinion about definite simulated environments as users and CS specialists they share their experience and either disapprove or recommend the tested app.

The subsequent discussion with students of both polled groups has revealed a lot of common features in student dual impression from testing VR and the thorough analysis conducted by the English teachers from the department of foreign languages. The most referred to by Internet users VR applications for English learning have been tested and analyzed both by instructors and students while using smartphones. The user friendliness, self-sufficiency and user's independence in application, advance and support of the apps were studied. The specifications of 6 popular virtual reality applications for foreign language learning are reproduced below.

VR Learn English [33] is the application for English vocabulary study. A user moving around the rooms can listen to the pronunciation of the names of the objects inside these rooms, learn and memorize them.

Gold Lotus [1] is similar to VR Learn English, but the places are more varied: shops, parks and famous cities. The learning materials include vocabulary and grammar.

Mondly [20] is the first application using augmented reality with the chatbot technology and speech recognition for studying foreign languages, engaging into conversation with users and giving feedback on their pronunciation. The application is aimed at studying thirty-three foreign languages. Mondly has similar features with the applications described above, but comprises reading, listening, writing and speaking activities. The distinguishing feature of the application is the possibility of taking part in the conversation with virtual characters on the given topic of real-life situations (making friends, ordering dinner, taking a taxi ride etc.).

VRSpeech [34] is the application for vocabulary acquisition and speaking training in two modes: the learning mode and the situation mode. All the situations a user is engaged are real-life ones: making orders in restaurants, job interviews, presentations etc. High quality speech-recognition and context-specific interaction are specific features of the application.

VirtualSpeech application [32] allows users to use different scenarios which are of crucial importance for forming key language skills. The components of VirtualSpeech scenarios are public speaking, promotions, networking, presentations and media training. Main peculiarities of the application are its realistic venues, such as virtual rooms with audience, presence of noise and distractions to fully immerse a user into the event. The function of speech analysis allows participants of the event to get feedback on their speeches, record all the speeches and have the progress results. The application can be used in the course of Business English for undergraduate and postgraduate students.

AltspaceVR [3] which is reasonable called as the place for events allows users to attend, participate in and organize numerous events like live shows, meetups, classes on different disciplines, presentations, performances, talk shows, and watch-parties.

The main features of the virtual reality applications for foreign language learning described above are given in Table 1.

Table 1. Main features of the virtual reality applications for foreign language learning

	Vocabulary acquisition	**Grammar learning**	**Speech recognition**	**Real-life situations**	**Speaking**
VR Learn English	+		+		
Gold Lotus	+	+	+		
Mondly	+	+	+	+	+
VRSpeech	+		+	+	+
VirtualSpeech	+		+	+	+
AltspaceVR	+		+	+	+

The poll and the testing have revealed that the least preferred VR application among the mentioned above is VR Learn English. Along with only two learning aspects the visual effects and the virtual environment are rather poor – it actually is a panoramic view of a place connected to the theme of the lesson, e.g. a clothes shop photo as a background with pop-up word definitions in white square boxes. The negative aspect is that the narrative text is of much more advanced level than the word explained and being processed. The pace of the narration is also inappropriate for the intended vocabulary complexity level. Another challenging feature of VR Learn English is imperative of fixing a user's look on objects for several seconds in order to move on. Multiply repeated instructions to look left or right and to find the next object (as well as inevitable follow-up questions if a user has found the object) have been noted both by students and instructors as irritating.

The most appealing VR application for foreign language learning according to the table is Mondly designed by ATi Studios. The numerous benefits listed above are enlarged by user friendly technical support and customization.

The price policy includes regular reductions and lifetime access with one-time purchase at 95% off which is extremely inviting for Ukrainian students. The system requirements for smartphones are minimal, the Android app file size is 75 MB and updates are included. Every week a user is notified about a successive individually arranged lesson in their personal account. The virtual environment is colourful and vivid. The application characters are young adults and thus favourable for students, the conversational chatbot replies with a human voice. Although characters look cartoonish it cannot be estimated as a disadvantage because students appreciate the visuals. Moreover, the application is level graded in spite of the fact that designers intend the basic version for users 3 years old and over. Another positive aspect noted by instructors is motivation to self-reliant error correction, e.g. in the event of the user demonstrating incorrect word order within a dialogue a partner character politely asks to repeat the phrase to continue the conversation without indicating the sentence has been built wrong and without pointing out the mistake.

As the study shows, the most efficient methods, practices and techniques for learning foreign languages have been put in the basis of virtual reality applications and resources for foreign language studying methods: immersion, gamification, real-life situation simulation and others.

4 Conclusions

In conclusion it should be stated that VR is an inevitable tool in education of the nearest decades. It is going to be specifically demanded in under-graduate training, due to its attraction and motivation aspects for young adults who are proficient in information technology, relying on and being dependent on their smartphones. VR applications offer bright opportunities for both involvement students into foreign language learning process and achieving three main goals of this discipline successfully: enhancing foreign language learning, preparing under-graduates for real life and professional situations outside the native language environment, improving student communication skills.

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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.

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

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].

Fig. 1. Full-function navigational bridge

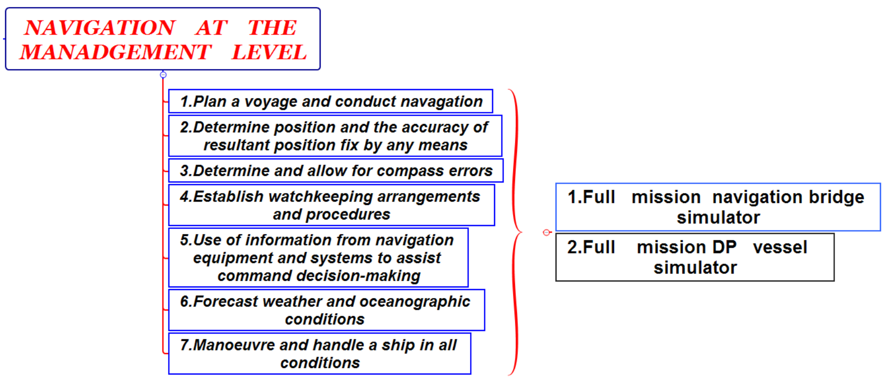

Fig. 2. VR laboratories of KSMA

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.

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.

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

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* Thorough knowledge of the content, application and intent of the International Regulations for Preventing Collisions at Sea, 1972, as amended. 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).

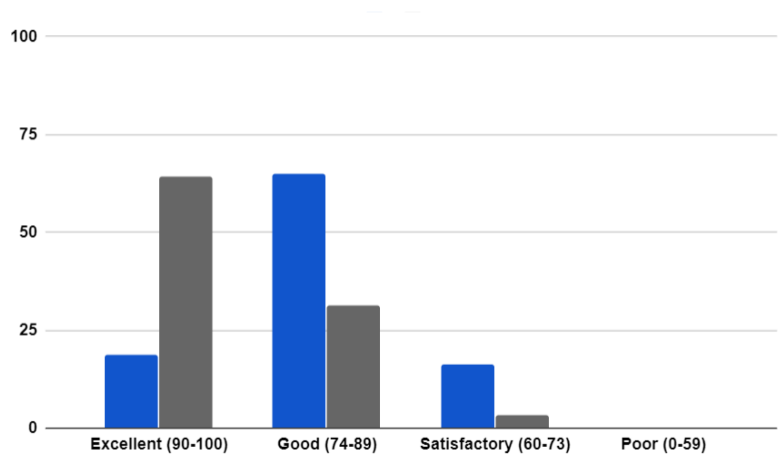

Fig. 3. Comparative chart of examination marks

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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Using game simulator Software Inc in the Software Engineering education

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Abstract. The article presents the possibilities of using game simulator Sotware Inc in the training of future software engineer in higher education. Attention is drawn to some specific settings that need to be taken into account when training in the course of training future software engineers. More and more educational institutions are introducing new teaching methods, which result in the use of engineering students, in particular, future software engineers, to deal with real professional situations in the learning process. The use of modern ICT, including game simulators, in the educational process, allows to improve the quality of educational material and to enhance the educational effects from the use of innovative pedagogical programs and methods, as it gives teachers additional opportunities for constructing individual educational trajectories of students. The use of ICT allows for a differentiated approach to students with different levels of readiness to study. A feature of any software engineer is the need to understand the related subject area for which the software is being developed. An important condition for the preparation of a highly qualified specialist is the independent fulfillment by the student of scientific research, the generation, and implementation of his idea into a finished commercial product. In the process of research, students gain knowledge, skills of the future IT specialist and competences of the legal protection of the results of intellectual activity, technological audit, marketing, product realization in the market of innovations. Note that when the real-world practice is impossible for students, game simulators that simulate real software development processes are an alternative.

Keywords: simulator, game simulator, training, software engineers.

More and more educational institutions are introducing new teaching methods, which result in the use of engineering students, in particular, majoring in software engineering, to deal with real professional situations in the learning process [30, p. 547; 41, p. 150].

The use of modern ICT, including game simulators, in the educational process [31; 37; 13; 19; 24; 29; 60], allows to improve the quality of educational material and to enhance the educational effects from the use of innovative pedagogical programs and methods, as it gives teachers additional opportunities for constructing individual educational trajectories of students [55]. The use of ICT allows for a differentiated approach to students with different levels of readiness to study.

A feature of any software engineer is the need to understand the related subject area for which the software is being developed [57]. An important condition for the preparation of a highly qualified specialist is the independent fulfillment by the student of scientific research, the generation, and implementation of his idea into a finished commercial product. In the process of research, students gain knowledge and skills of the future IT specialist among with the competences of the legal protection of the results of intellectual activity, technological audit, marketing, product realization in the market of innovations. Note that when the real-world practice is impossible for students, game simulators that simulate real software development processes are an alternative.

This topic is dedicated to the research of Liudmyla I. Bilousova [6], Yevhenii O. Modlo [39], Ivan O. Muzyka [28], Pavlo P. Nechypurenko [38], Olga P. Pinchuk [50], Andrii M. Striuk [61], and others. In particular, computerization and informatization of the education system were considered by Oleksandr Yu. Burov [50], Arnold E. Kiv [25], Oleksandr H. Kolgatin [27], Maiia V. Marienko [51], Liubov F. Panchenko [48], Svitlana V. Shokaliuk [35], Vladimir N. Soloviev [17], Tetiana V. Starova [44], Viktoriia V. Tkachuk [59], Snizhana O. Zelinska [58], and others; Olga V. Bondarenko [7], Svitlana H. Lytvynova [32], Pavlo P. Nechypurenko [43], Yuliya H. Nosenko [46], Maiia V. Marienko [33], Oksana M. Markova [45], Maryna V. Rassovytska [53], Serhiy O. Semerikov [40], Mariya P. Shyshkina [56], Andrii M. Striuk [34], and others, paid attention to the use of electronic learning tools.

Importance and necessity of introduction of information and communication technologies (ICT), including game simulators, in training are substantiated by Faheem Ahmed [1], Ritika Atal [4], Alex Baker [5], Bassam Baroudi [49], Márcio Barros [12], Kunal Bedse [23], Salah Bouktif [1], Noel Burchell [20], Alejandro Calderón [9], Piers Campbell [1], Luiz Fernando Capretz [1], Craig Caulfield [10], Paul Clarke [11], Alexandre Dantas [12], Khaled El Emam [15], Ayesha Farooq [52], Dave Hodges [20], André van der Hoek [5], Mehdi Jazayeri [22], Hashem Salarzadeh Jenatabadi [47], Shanika Karunasekera [23], A. Günes Koru [15], Stanislaw Paul Maj [10], Emily Oh Navarro [42], Ali Noudoostbeni [47], Rory V. O'Connor [11], Ira Pant [49], Sanghamitra Patnaik [52], Goparaju Purna Sudhakar [52], Lise Renaud [54], Mercedes Ruiz [9], Louise Sauvé [54], Ashish Sureka [4], David Veal [10], Cláudia Werner [12], Jianhong Xia [10], Norizan Mohd Yasin [47]. ICTs are part of every area of human activity and have a positive impact on education, as they open up opportunities for the introduction of completely new teaching and learning methods.

A significant contribution to the theory of educational games was made by Daniil B. Elkonin [16], Eric Klopfer [26], David R. Michael [36], Lev S. Vygotskii [63], and others. At the same time, game technologies of teaching and use of interactive games in high school were investigated by Ayşe Alkan [2], Mohammad Hasan Al-Tarawneh [3], Viktoriia L. Buzko [8], Muhammet Demirbilek [14], Glenda A. Gunter [18],

G. Tanner Jackson [21], Estela Aparecida Oliveira Vieira [62], Nataliia P. Volkova [60], and other modern scholars and pedagogues. However, the question of the use of game simulators in the training of future software engineers remains poorly understood.

That is why the purpose of this article is to describe the features of working with the game simulator Software Inc in the software engineering training.

Game simulators are interactive programs that fully or partially simulate certain real processes or systems that capture and motivate students through fun and interesting game experiences, where students can perform different roles in a variety of realistic circumstances and are used in the educational process when real practice is impossible or inaccessible.

Software Inc is a game simulator that allows students to try their hand at running a software development company.

To start the game you need to press the “New Game” button, then the corresponding screen, shown in Fig. 1.

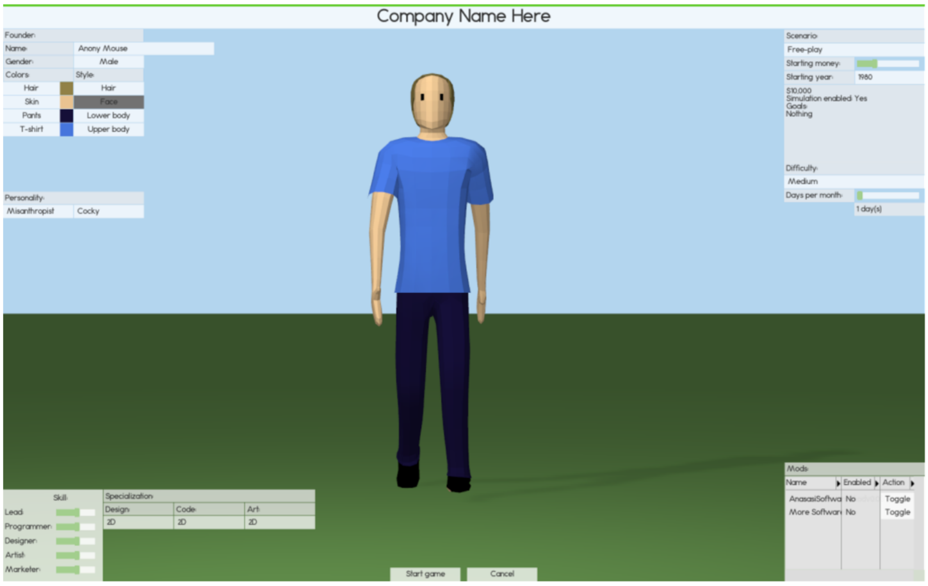

Fig. 1. Starting a game simulation in Software Inc

In the first stages, students should use a manual to provide detailed information about the gameplay and the various individual stages of the game. Beginners are encouraged to choose Optimism and Generosity as the main features when creating a company founder, without necessarily changing the settings of the sliders located on the left in the user interface.

In the panel on the right, you need to increase the startup capital of the company to $ 20,000 or move the slider one mark if the game is in a different currency (the currency can be changed in the options menu). Set to default 1980 as the year the company was founded, there is no need to change, but at the stage of getting acquainted with the game the difficulty level must be set to "Easy".

The Days per month parameter sets the number of days in a month. By default, it is set to 1 day, meaning one game day will count as a month. With this setting, you can change the speed of the game (most of them set 4 days, but first you need to set the value to 1 or 2 days).

After that, the student needs to change the founding person's settings and choose a name for their company, such as "SpaceTech" or "Aperture Cake Production", after which the students will see the next window (see Figure 2).

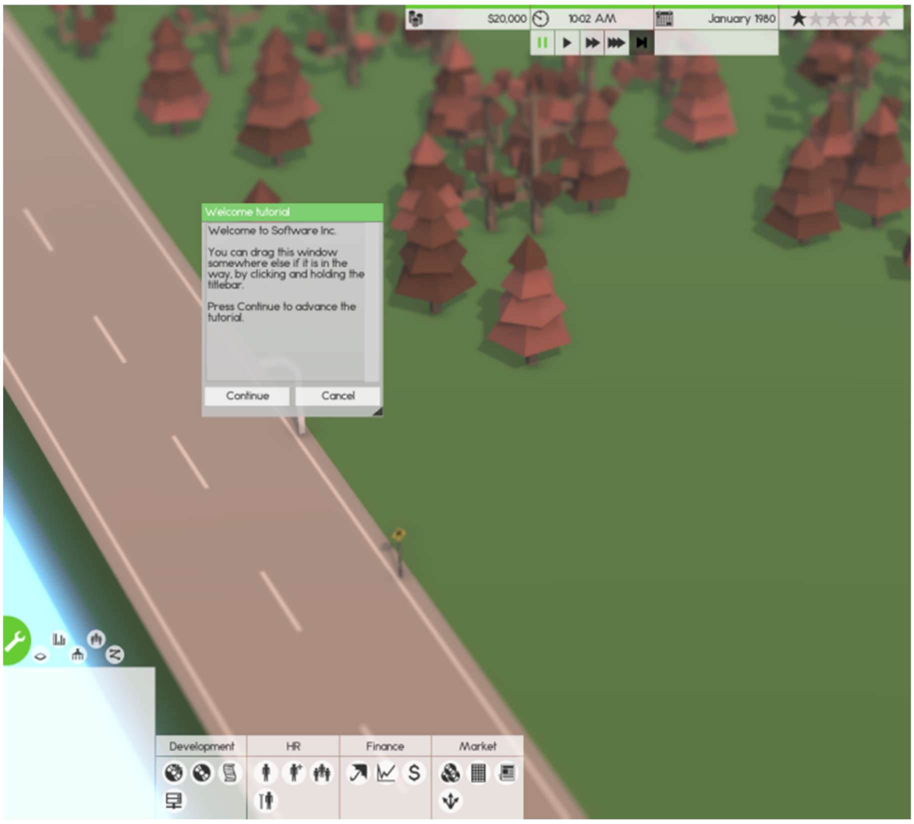

Fig. 2. Welcome dialog in Software Inc

You can move the instruction box around the screen and resize it. You have to press the "Continue" button to flip through the manual. To start creating the premises of a future virtual company for a student, it is necessary to go into construction mode by clicking on the green button with the image of a wrench on the user interface.

Game Simulator Software Inc offers three build modes:

– "Construct" – construction of rooms, installation of windows and doors;

- “Furnish” – room furniture, choice of tables, chairs, coffee machine;
- “Roads” – road construction, parking, but initially this mode is not used.

Once enabled, the student must first build a small room for the virtual company. To do this, you need to use the Room Builder tool in the Construct mode menu. The initial size of the first room should be approximately 5x5 to accommodate the table and chair for the founder of the company.

To make the room light enough, you must select the windows and doors in the Construct mode menu and install them in the room.

Then students have to go into Furnish mode and have a desk, chair, and computer installed in the room. Use Shift + left mouse button to set multiple items at once. Chairs will automatically be installed near the tables they are closest to, but you may need to turn your computer over.

Students need to click on and hold the computer, turning it in the required direction. After that, the room will look something like this (see Figure 3).

Fig. 3. A room built-in game simulator Software Inc

Once the room has been created, the founder of the company can start working there.

After reading the instructions, you must press the Tab key to exit the build mode.

The process of making money and working on contracts.

The first way that allows companies to make money is to work on contracts. Contracts are projects that are offered to companies for execution, and each of them has their requirements.

To find a contract, the participant must go to the “Development” menu by clicking the button with the image of a piece of paper (A). Then a pop-up window will appear on the screen (see Figure 4).

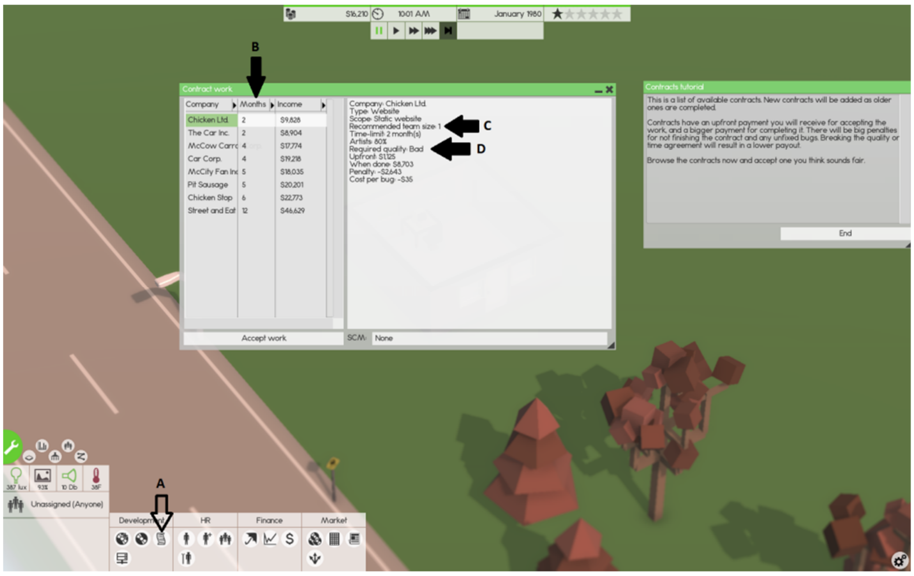

Fig. 4. Software search contract simulator popup window

Players need to sort the list by “Months” (B) to ensure that contracts that require the least number of months are at the top of the list. Typically, contracts with 1 or 2 (C) contracts will have a performance period of 1 or 2 months. The company does not receive big profits for working on such contracts, but in the beginning, it is a great source of financial income.

Regarding the quality of contract work, students must set the value to “Bad” or “Horrible” (D), which allows the initial stages not to take quality but quantity.

Students need to find a contract for their virtual company with a minimum work requirement for a team of 1 or 2 people for a maximum of two months and click the "Accept Work" button.

Contract work.

After the participants have selected a contract for their company, a project management pop-up window (A) will appear to the right in the user interface (see Figure 5). There are 4 stages of project implementation. The first stage is the development of the design. The product design specified in the contract is developed by the virtual company designer (s).

When pointing the mouse at the project management window, students can see the progress scale of a specific job by a company employee (B). The task is considered completed when the scale reaches its maximum value. However, students need to be careful and not delay the contracting process at the design development stage so as not to waste the time allotted for the contract.

Players must then click on the “Develop” (C) button in the project management window to proceed to the next stage – “Alpha”. At this stage, the software engineers create the product according to the design developed by the designer in the first stage. Students can monitor the completion of the assignment using the progress bar. When the task is completed, you must click on the “Promote” button to proceed to the next step.

Fig. 5. The project management popup in the game simulator Software Inc

The next stage is called “Delay” and is only an intermediate stage, which lasts a certain amount of time depending on the skill level of the company’s employees. The higher the skill level of the employees, the less time the Delay stage takes.

The project then proceeds to the “Beta” stage, which is to test and prepare for the product release. The company may release a product that is not ready for completion, but it is important to remember that the presence of errors and defects in the product will adversely affect its sales and contract payments.

Building for employees and first employee.

When building premises, students need to remember that employees are first and foremost people who have basic needs (want to eat, go to the restroom, drink coffee, prefer quiet, comfortable rooms with sufficient lighting, comfortable air temperature, and a comfortable environment). Therefore, you should build a facility that addresses all these needs, and do not forget to build small facilities for restrooms and rest areas.

Make sure you also have a fridge and coffee table in the lounge. Windows, lighting, and doors between rooms are required. It is important to keep in mind that indoor plants will have a positive effect on employee productivity and mood. Elements such as heat radiators and ventilation in the main room are also very important as they provide comfortable air temperatures.

How to hire employees?

After the company has reached a certain level of development, students need to hire new employees in the team.

When looking for a new employee, you first need to answer two questions:

1. In what position to open a vacancy?

- team lead;
- programmer;
- designer;
- creative manager;
- marketer.

2. How much time and resources can be spent on finding a new employee?

Then more time is spent in searching, then more applications from candidates will be considered. At the same time, it is necessary to consider the insurance policy of the company. Having a solid insurance fund will be an attractive factor for skilled workers. Therefore, every time after the completion of contract work and products, students need to invest in improving the insurance fund to attract highly qualified employees to the company.

After the list of candidates is created, you can go to the interviewing stage, during which you need to determine who should be hired and who should be better off. Keep in mind that you need to hire those who can be part of the team, as this will have a positive effect on the performance of the company and help you get things done faster.

The following is an example of a candidate whose compatibility with an existing team is low (see Figure 6).

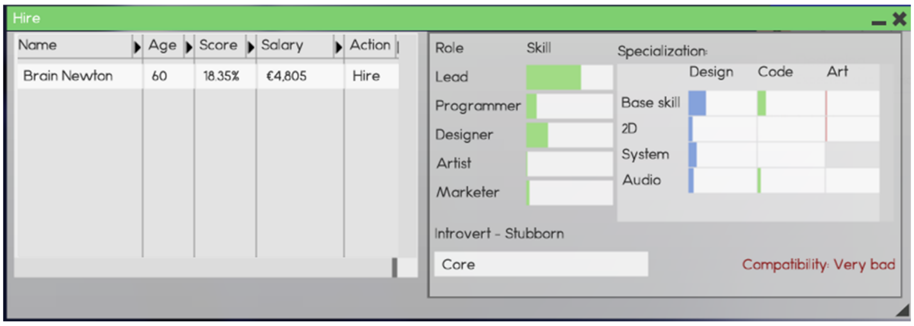

Fig. 6. Example of showing poor candidate compatibility with an existing team in a game simulator Software Inc

At the same time, there is a candidate whose compatibility with the team is sufficient (see Figure 7).

By finding a candidate with sufficient compatibility with the development team, as well as sufficient professional performance, players can hire a suitable candidate for their development team. They can then focus on managing software development or, if they see fit, continue to hire employees.

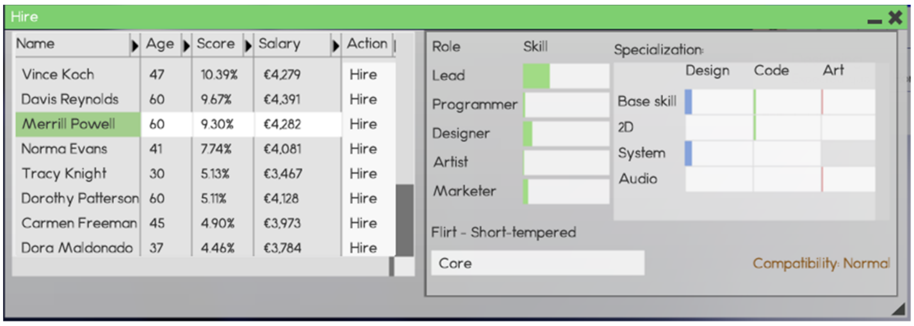

Fig. 7. An example of showing good candidate compatibility with an existing team in a simulator Software Inc

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Augmented reality as a tool for visualization of ultrasound propagation in heterogeneous media based on the *k*-space method

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Abstract. For programming the AR tools, interactive objects and creating the markers, the method of fiber spaces (*k*-space) for modeling of ultrasonic wave propagation in an inhomogeneous medium using coarse grids, with maintaining the required accuracy was used. The algorithm and tools of augmented reality were introduced into the adaptive control system of the pulp gas phase in the iron ore flotation process using a control action on the basis of high-energy ultrasound dynamic effects generated by ultrasonic phased arrays. The tools of augmented reality based on *k*-space methods allow to facilitate wider adoption of ultrasound technology and visualize the ultra-sound propagation in heterogeneous media by providing a specific correspondence between the ultrasound data acquired in real-time and a sufficiently detailed augmented 3D scene. The tools of augmented reality allow seeing the field of ultrasound propagation, its characteristics, as well as the effect of the dynamic effects of ultrasound on the change in the gas phase during the flotation process.

Keywords: Augmented reality, ultrasound propagation, *k*-space method.

1 Introduction

Nowadays, the growth of applications of augmented reality (AR) can be attributed to solutions, which allow to visualize products and their characteristics, add some interactive objects which allow looking inside the processes, etc.

Every year applications using augmented reality are gaining more and more popularity. It is used in various fields of activity: production, repair [20], training [21], sales [7], marketing, exhibitions, user guides [8], remote maintenance [17], and navigation [4]. To build a functioning system, a sufficiently powerful platform is needed, which can be a modern mobile device [9], due to their widespread and ever-growing capabilities. To draw virtual objects, markers are used that are located in the surrounding space. They are located and analyzed by special software [2; 6; 16].

For the control of the basic technological parameters and mineral beneficiation process control, an important task is to control the parameters of complex heterogeneous mediums, including solid, liquid and gas phases.

In [10; 11; 12; 13; 14; 15] automatic control system of gas bubble size distribution based on the ultrasonic phased array technology, which allows to implement the efficient control of pulp gas phase composition, adjust the aeration degree, increase the flotation speed, increase the concentrate quality and energy efficiency of the entire mineral processing process is proposed. In this research, the ultrasound as the main tool was used.

2 Materials and methods

To facilitate wider adoption of ultrasound technology we use the tools of augmented-reality to visualize the ultrasound propagation in heterogeneous media by providing a specific correspondence between the ultrasound data acquired in real-time and a sufficiently detailed augmented 3D scene. We have established a tablet-based system for visualizing the propagation of high-energy ultrasound in a heterogeneous medium in the process of froth flotation using augmented-reality techniques in conjunction with the streaming data about ultrasound characteristics provided by phased array based on *k*-space method. This system gives the operator visual feedback as to the location of the ultrasonic spot generated by the elements of the phased array, the characteristics of the ultrasound beam, and look inside the flotation tank.

For programming, the AR tools, interactive objects and creating the markers, the method of fiber spaces (*k*-space) for modeling of ultrasonic wave propagation in an inhomogeneous medium using coarse grids, with maintaining the required accuracy was used [1; 11; 19].

We describe the ultrasonic waves propagation depending on the mass conservation equations, momentum conservation law and the equation of state using the first order dual equations, which can be summarized as follows [1; 5]

$$\frac{\partial p(\overline{x},t)}{\partial t}+\rho(\overline{x})c^2(\overline{x})\nabla v(\overline{x},t)=-\alpha(\overline{x})p(\overline{x},t), \quad (1)$$

$$\rho(\overline{x})\frac{\partial v(\overline{x},t)}{\partial t}+\nabla p(\overline{x},t)=0, \quad (2)$$

where $p(\overline{x},t)$ – the time and space dependent ultrasound pressure perturbations (*x* – 3D Cartesian axis (*x, y, z*)); $\rho(\overline{x})$ is the spatially dependent density; $c(\overline{x})$ is the spatial dependent sound speed; $v(\overline{x},t)$ is the velocity of the particle and $\alpha(\overline{x})$ is the absorption coefficient which equivalent to the inverse of the relaxation time.

Let’s represent all absorption effects with one relaxation time. From (2), the simplified equation can be written as follows

$$\frac{\partial v(\overline{x},t)}{\partial t}=\frac{-\nabla p(\overline{x},t)}{\rho(\overline{x})} \quad (3)$$

We differentiate (1) with respect to time and variations in (2), and the final equation can be represented as follows

$$\frac{\partial^2 p(\overline{x},t)}{\partial t^2} + \rho(\overline{x})c^2(\overline{x})\frac{\partial}{\partial t}\nabla\partial v(\overline{x},t) = -\alpha(\overline{x})\frac{\partial p(\overline{x},t)}{\partial t}, \tag{4}$$

$$p(\overline{x},t)\frac{\partial}{\partial t}\nabla v(\overline{x},t) + \frac{\partial v(\overline{x},t)}{\partial t}\nabla\rho(\overline{x}) + \nabla^2 p(\overline{x},t) = 0, \tag{5}$$

Taking into account the permutations (4)

$$\frac{\partial}{\partial t}\nabla v(\overline{x},t) = -\left(\frac{\alpha(\overline{x})}{\rho(\overline{x})c^2(\overline{x})}\frac{\partial p(\overline{x},t)}{\partial t} + \frac{1}{\rho(\overline{x})c^2(\overline{x})} + \frac{\partial^2 p(\overline{x},t)}{\partial t^2}\right) \tag{6}$$

By substituting this equation in (5), we obtain

$$\frac{-\alpha(\overline{x})}{c^2(\overline{x})}\frac{\partial p(\overline{x},t)}{\partial t} - \frac{\partial^2 p(\overline{x},t)}{c^2(\overline{x})\partial t^2} - \frac{1}{\rho(\overline{x})}\nabla p(\overline{x},t)\nabla p(\overline{x}) + \nabla^2 p(\overline{x},t) = 0, \tag{7}$$

The simplification of the pressure deviation to the density gradient can be represented as follows

$$\nabla\left(\frac{\nabla p(\overline{x},t)}{\rho(\overline{x})}\right) = \frac{\nabla^2 p(\overline{x},t)}{\rho(\overline{x})} - \frac{\nabla p(\overline{x},t)\nabla p(\overline{x})}{\rho(\overline{x})^2}, \tag{8}$$

Taking into account (7), eq. (8) can be represented as follows

$$\nabla\left(\frac{1}{\rho(\overline{x})}\nabla p(\overline{x},t)\right) - \frac{1}{\rho(\overline{x})c^2(\overline{x})}\frac{\partial^2 p(\overline{x},t)}{\partial t^2} = \frac{\alpha(\overline{x})}{\rho(\overline{x})c^2(\overline{x})}\frac{\partial p(\overline{x},t)}{\partial t}, \tag{9}$$

This is a linear wave equation of ultrasonic wave propagation in the heterogeneous medium with the absorption parameters.

Let's simplify (9) by separating the parameters of the sound velocity $c(\overline{x})$ and density $\rho(\overline{x})$ from the second derivatives of pressure taking into account the spatial and temporal variables to solve the problem of ultrasound propagation using the fiber space method.

The original equation can be written in the form

$$\nabla\left(\frac{1}{\rho(\overline{x})}\nabla p(\overline{x},t)\right) - \frac{1}{\rho(\overline{x})c^2(\overline{x})}\frac{\partial^2 p(\overline{x},t)}{\partial t^2} = 0, \tag{10}$$

The normalized pressure can be represented as follows

$$\psi\left(\bar{x},t\right)=\frac{p\left(\bar{x},t\right)}{\sqrt{p\left(\bar{x}\right)}}$$

By substituting this equation in (10) we obtain

$$\nabla\left(\frac{1}{\rho\left(\bar{x}\right)}\nabla p^{1/2}\left(\bar{x},t\right)\psi\left(\bar{x},t\right)\right)=\frac{\rho^{1/2}\left(\bar{x}\right)}{\rho\left(\bar{x}\right)c^{2}\left(\bar{x}\right)}\frac{\partial^{2}\psi\left(\bar{x},t\right)}{\partial t^{2}}$$

After simplifying

$$\nabla^{2}\psi\left(\bar{x},t\right)-\rho^{1/2}\left(\bar{x}\right)\psi\left(\bar{x},t\right)\nabla^{2}\rho^{1/2}\left(\bar{x}\right)=\frac{1}{c^{2}\left(\bar{x}\right)}\frac{\partial^{2}\psi\left(\bar{x},t\right)}{\partial t^{2}}$$

Taking into account further simplifications the equation takes the form

$$\nabla^{2}\psi\left(\bar{x},t\right)-\frac{1}{c_{0}^{2}}\frac{\partial^{2}\psi\left(\bar{x},t\right)}{\partial t^{2}}=\frac{1}{c_{0}^{2}}\left[c_{0}^{2}\rho^{1/2}\left(\bar{x}\right)\left(\nabla^{2}\rho^{1/2}\left(\bar{x}\right)\right)\psi\left(\bar{x},t\right)+\left(\frac{c_{0}^{2}}{c^{2}\left(\bar{x}\right)}-1\right)\frac{\partial^{2}\psi\left(\bar{x},t\right)}{\partial t^{2}}\right]$$

Even more, simplification can be obtained by determining the functions $q(r,\ t)$ and $v(r,\ t)$ efficient sources, which can be summarized as follows

$$q\left(\bar{x},t\right)=c_{0}^{2}\rho^{1/2}\left(\bar{x}\right)\psi\left(\bar{x},t\right)\nabla^{2}\rho^{-1/2}\left(\bar{x}\right)$$

$$v\left(\bar{x},t\right)=\left(\frac{c_{0}^{2}}{c^{2}\left(\bar{x},t\right)}-1\right)\psi\left(\bar{x},t\right)$$

By simplifying (11) we obtain

$$\nabla^{2}\psi\left(\bar{x},t\right)-\frac{1}{c_{0}^{2}}\frac{\partial^{2}\psi\left(\bar{x},t\right)}{\partial t^{2}}=\frac{1}{c_{0}^{2}}\left(q\left(\bar{x},t\right)+\frac{\partial^{2}v\left(\bar{x},t\right)}{\partial t^{2}}\right),\qquad(11)$$

This equation can be easily transformed into the frequency domain by using the three-dimensional spatial Fourier transform as follows

$$k^{2}F\left(\mathrm{k,t}\right)-\frac{1}{c_{0}^{2}}\frac{\partial^{2}F\left(\mathrm{k,t}\right)}{\partial \mathrm{t}^{2}}=\frac{1}{c_{0}^{2}}\left(Q\left(\mathrm{k,t}\right)+\frac{\partial^{2}V\left(\mathrm{k,t}\right)}{\partial \mathrm{t}^{2}}\right),\qquad(12)$$

where $F(k,\ t)$, $Q(k,\ t)$ and $V(k,\ t)$ – three-dimensional spatial Fourier transformation of values $\psi\left(\bar{x},t\right)$, $q\left(\bar{x},t\right)$ and $v\left(\bar{x},t\right)$ respectively. Equation (12) satisfies the total wavefield and is defined as the sum of the incident and scattered field $\psi\left(\bar{x},t\right)=\psi_{i}\left(\bar{x},t\right)+\psi_{s}\left(\bar{x},t\right)$, and the scattered wave field.

$$\nabla^2\psi(\bar{x},t)-\frac{1}{c_0^2}\frac{\partial^2\psi(\bar{x},t)}{\partial t^2}=0\ .$$

For the case of an inhomogeneous medium, we introduce an additional source $w(\bar{x},t)=\psi_s(\bar{x},t)+v(\bar{x},t)$ and by substituting it into (13) we obtain the following expression

$$\frac{\partial^2 W(k,t)}{\partial t^2}=k^2c_0^2\left[W(k,t)-V(k,t)\right]-Q(k,t), \qquad (13)$$

where $V(k,t)=F\left[\left(1-\frac{c^2(\bar{x})}{c_0^2}\right)\left(\psi_i(\bar{x},t)+w(\bar{x},t)\right)\right]$;

$$Q(k,t)=c_0^2F\left[\sqrt{\rho(\bar{x})}\nabla^2\rho^{1/2}(\bar{x})=\left[\psi_i(\bar{x},t)+w(\bar{x},t)-v(\bar{x},t)\right]\right]$$

where F is a spatial Fourier transform.

Let's use the substandard finite difference approach to solve this equation [10; 15]. Discretization of the time derivative gives

$$\begin{gathered}W(k,t+\Delta t)-2W(k,t)+W(k,t-\Delta t)=4\sin^2\left(\frac{c_0k\Delta t}{2}\right)\times \\ \times\left[V(k,t)-W(k,t)-\frac{Q(k,t)}{c_0^2k^2}\right]\end{gathered}, \qquad (14)$$

Consider the wave equation on the grayscale for the fiber space method (k-space), which includes the non-linear characteristic of ultrasound, which can be represented as follows [10]:

$$\nabla^2\psi(\bar{x},t)-\sqrt{\rho(\bar{x})}\psi(\bar{x},t)\nabla^2\frac{1}{\sqrt{\rho(\bar{x})}}-\frac{1}{c^2(\bar{x})}\frac{\partial^2\psi(\bar{x},t)}{\partial t^2}=-\frac{\beta(\bar{x})}{\sqrt{\rho_0}c_0^4}\frac{\partial^2\psi^2(\bar{x},t)}{\partial t^2}$$

where $\psi^2(\bar{x},t)$ is the nonlinearity source, $\beta(\bar{x})$ is the nonlinearity coefficient. The harmonic oscillations equation can be represented as follows

$$\frac{\partial^2 W2(\bar{k},t)}{\partial t^2}=\left(c_0^2k^2\right)\left(VNL2(\bar{k},t)-W2(\bar{k},t)\right)-Q(\bar{k},t), \qquad (15)$$

where $w2(\bar{x},t)=\psi_s(\bar{x},t)+v_{NL2}(\bar{x},t)$ – additional source; $W2(\bar{k},t)$ is a spatial Fourier transform.

$$v_{NL2}\left(\bar{x},t\right)=\left(\frac{c_0^2}{c^2\left(\bar{x}\right)}-1\right)\psi\left(\bar{x},t\right)-\frac{\beta\left(\bar{x}\right)}{\sqrt{\rho_0}c_0^2}\left(\psi_s^2\left(\bar{x},t\right)+2\psi_s\left(\bar{x},t\right)\psi_i\left(\bar{x},t\right)\right)$$

After the spatial Fourier transformation, the equation can be expressed as follows

$$VNL2\left(\bar{k},t\right)=\mathsf{F}\left\{\begin{aligned}&\left(\frac{c_0^2}{c^2\left(\bar{x}\right)}-1\right)\left[\psi_i\left(\bar{x},t\right)+w2\left(\bar{x},t\right)-\frac{\beta\left(\bar{x}\right)}{\sqrt{\rho_0}c_0^2}\left(\psi_s^2\left(\bar{x},t\right)-2\psi_s\left(\bar{x},t\right)\psi_i\left(\bar{x},t\right)\right)\right.\\&-\frac{\beta\left(\bar{x}\right)}{\sqrt{\rho_0}c_0^2}\left(\psi_s^2\left(\bar{x},t\right)-2\psi_s\left(\bar{x},t\right)\psi_i\left(\bar{x},t\right)\right)\end{aligned}\right\};$$

$$Q\left(k,t\right)=\mathsf{F}\left[c_0^2\sqrt{\rho\left(\bar{x}\right)}\nabla^2\left(\frac{1}{\sqrt{\rho\left(\bar{x}\right)}}\right)\left[\psi_i\left(\bar{x},t\right)-w2\left(\bar{x},t\right)-v_{NL2}\left(\bar{x},t\right)\right]\right];$$

The introduction of the nonlinearity term in fiber space method makes it easier to calculate the actual relief temperature in heterogeneous large scale models.

Let’s simulate the ultrasonic pressure field propagation in a heterogeneous medium using k-Wave toolbox (Matlab) which is designed for time domain ultrasound simulations in complex media like heterogeneous pulp. The simulation functions of this software are based on the k-space method and are both fast and easy to use [3; 18].

The net pressure of all piezoelectric elements can be obtained by adding the effects of each source and written in the form

$$P_{net}\left(x,y,z\right)=\sum_{i=1}^{n}p_i\left(x,y,z\right). \tag{16}$$

Due to attenuation, the useful power at the point (x, y, z) is given by [18]

$$q\left(x,y,z\right)=\frac{\alpha P_{net}^2\left(x,y,z\right)}{\rho c}, \tag{17}$$

The total energy at a point (x, y, z) is given by

$$I\left(x,y,z\right)=\frac{p^2\left(x,y,z\right)}{2\rho c}, \tag{18}$$

where $I(x, y, z)$ – intensity at the point (x, y, z), W/m^2.

The results of the ultrasonic wave propagation through a heterogeneous medium with density ρ = 1500 g/m^3, for source strength of 1 MPa and tone burst frequency of 1 MHz for 16-element, phased array with a focus distance of 20 mm are shown on Fig. 1. The central slice absorption distribution in grayscale as a background and the square of the pressure distribution on the surface of this background are shown.

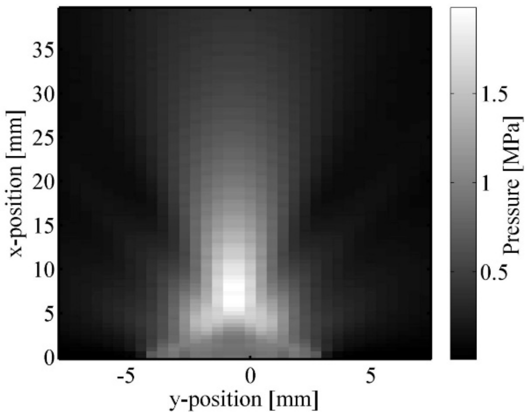

Fig. 1. Total beam pattern using the maximum of recorded pressure

The final pressure field (a), the maximum pressure (b) and standard pressure (c) of the beam are shown in Fig. 2. The transducer focus and sidelobes are visible.

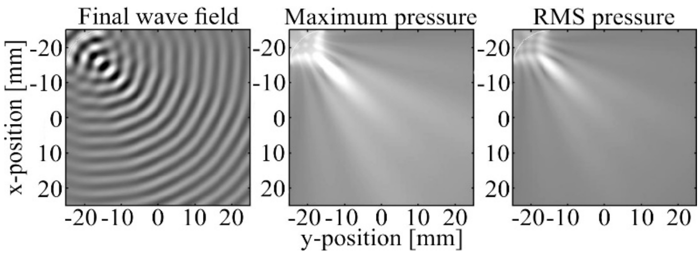

Fig. 2. Ultrasonic wave propagation in a heterogeneous medium: a) the final pressure field, b) the maximum pressure c) the RMS pressure

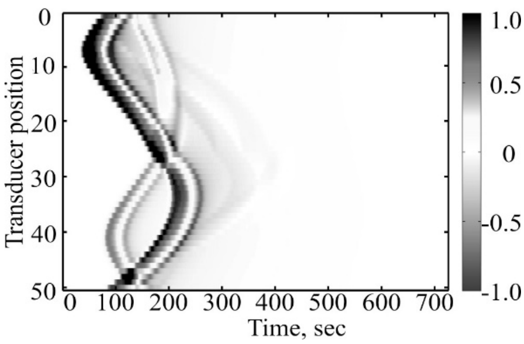

Fig. 3. The shape of the main wavefront

The linear cross-section of the focus in the *x* direction is shown in Fig. 4: 1) for the single source; 2) simulation by a *k*-space method in the water; 3) in a heterogeneous medium.

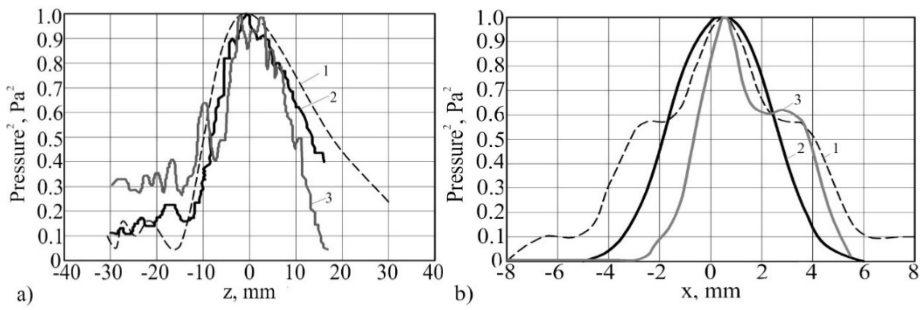

Fig. 4. The simulation results comparison of the normalized square of pressure for: 1) a simple screened source, 2) modeling by the *k*-space method in a homogeneous medium (water) and 3) in the inhomogeneous medium (pulp) along the axis: a) – *z* and b) – *x*.

3 Results

Based on the obtained results, augmented reality tools (interactive objects, markers) (see Figure 5, 6) were developed in the AR Editor, which are implemented based on the following algorithm:

- STEP 1. Image Capture
  - STEP 1.1 Connecting the camera
  - STEP 1.2 Capturing video from the camera
  - STEP 1.3 Reading video frame frames
- STEP 2. Recognition of special points and descriptors
  - STEP 2.1 Finding special points on the image
  - STEP 2.2 Calculation ─ singular points descriptors
- STEP 3. Comparison of descriptors calculated in STEP 2.2 with the database of marker descriptors. Getting id markers, point vector
- STEP 4. Reproduction of relevant content
  - STEP 4.1. If the returned number of points in the vector is greater than the specified value, then go to STEP 4.2. Otherwise, in STEP 4.4.
  - STEP 4.2 Getting the content of the marker from the database
  - STEP 4.3 Display the contents of the marker on the image
  - STEP 4.4 Displaying the image on the screen

The developed algorithm and tools of augmented reality were introduced into the adaptive control system of the pulp gas phase in the iron ore flotation process using a control action on the basis of high-energy ultrasound dynamic effects generated by ultrasonic phased arrays (see Figure 7). The adaptive control system based on the ultrasonic phased array is placed on the wall of the flotation machine. In accordance with the above method and the developed algorithm, the system generates a marker in which the current state of the system is embedded. The tools of augmented reality allow seeing the field of ultrasound propagation, its characteristics, as well as the effect of the dynamic effects of ultrasound on the change in the gas phase during the flotation process.

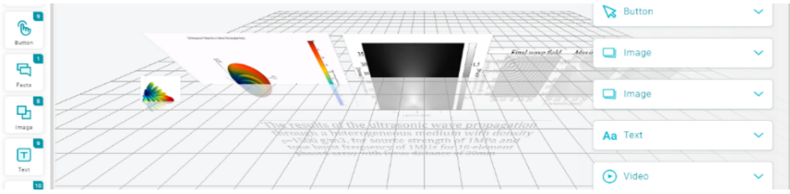

Fig. 5. AR tools (interactive objects, markers) developing in the AR Editor

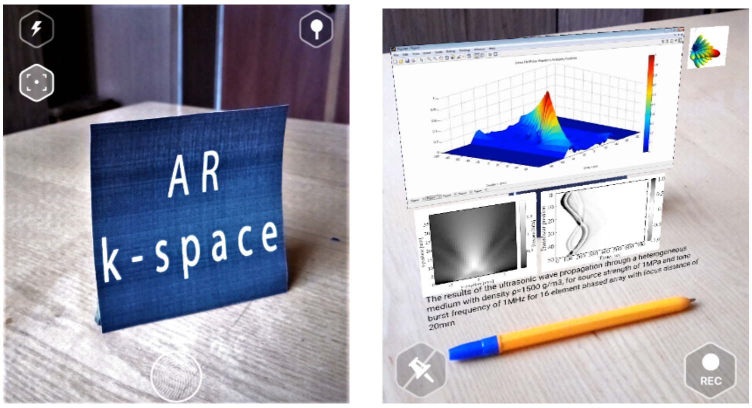

Fig. 6. AR k-space marker and displaying the contents of the marker on the image

Fig. 7. Augmented reality tools in the adaptive control system of the pulp gas phase of the iron ore flotation process

Conclusions

To build a model of the ultrasonic field in a randomly inhomogeneous medium, the fiber spaces method (*k*-space), which increased the accuracy of parameter estimation field is used. The tools of augmented reality based on *k*-space methods were developed, which allow to facilitate wider adoption of ultrasound technology and visualize the ultrasound propagation in heterogeneous media by providing a specific correspondence between the ultrasound data acquired in real-time and a sufficiently detailed augmented 3D scene.

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Possibilities of application of augmented reality in different branches of education

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Abstract. Augmented reality has a great impact on the student in the presentation of educational material: objects of augmented reality affect the development of facial expressions, attention, stimulate thinking, and increase the level of understanding of information. Its implementation in various spheres has indisputable advantages: realism, clarity, application in many industries, information completeness and interactivity. That is why the study presents the possibilities of using augmented reality in the study of mathematics, anatomy, physics, chemistry, architecture, as well as in other fields. The comparison of domestic and foreign proposals for augmented reality is presented. The use of augmented reality in various fields (technology, entertainment, science and medicine, education, games, etc.) should be well thought out and pedagogically appropriate. That is why in the future it is planned to conduct research on the feasibility of using augmented reality and to develop elements of augmented reality accordingly.

Keywords: augmented reality, medicine, education, technology, application.

1 Introduction

The modern world is a very rapid development of technology that contributes to the facilitation of human life. Augmented reality is one of these technologies. It is a combination of computer graphics and the real world. Important benefits of augmented reality are its use of in various fields:

- technology: enrich and improve life experience;
- entertainment: the ability to make the leisure activities of the users more diverse, colorful and fun;
- science and medicine: not only examination or consultation but also serious things, such as remote surgery;
- interactive layouts: visualization of planning of apartments, houses, shopping complexes;

- printing: live flyers, magazines, and newspapers with animation, visualization of advertising products;
- arcade games: flying a plane, driving a car;
- animated technological processes, etc.

Augmented reality (AR) is a technology that aims to complement the real world any elements created graphics or models (and this includes text, audio, and video). This is possible by pointing the smartphone's camera at the special label on which the object is displayed.

The founder of the idea of using AR in the industry is Thomas Preston Caudell. An engineer working at the Boeing Aviation Company in 1990 created an AR helmet that displayed information on the windshield. This invention has become widespread in use [2].

AR has a great impact on the student or student in the presentation of educational material: AR beats influence the development of facial expressions, attention, stimulating thinking, and increase the level of understanding of information.

Many AREdu 2019 authors have addressed various aspects of AR technology, in particular: Ihor O. Arkhypov [8], Volodymyr O. Artemchuk [5], Zhanna I. Bilyk [22; 23; 24], Anzhela P. Boiko [6], Stanislav L. Bondarevskyi [13], Oleksandr Yu. Burov [5], Iryna I. Deinega [5], Andrii V. Iatsyshyn [5], Anna V. Iatsyshyn [5], Valeriia O. Kovach [5], Yaroslav M. Krainyk [6], Tetiana H. Kramarenko [7], Ivan V. Kravets [11], Olexander I. Kuchma [8], Yulii G. Kutsan [5], Olga V. Kuzyshyn [11], Olena O. Lavrentieva [8], Victor M. Lutsyshyn [11], Svitlana H. Lytvynova [5], Maiia V. Marienko [20; 25], Oksana M. Markova [13; 16; 28], Anna P. Megalinska [23], Lilia Ya. Midak [11], Yevhenii O. Modlo [13; 16; 26], Natalia V. Morkun [14], Vladimir S. Morkun [14], Ivan O. Muzyka [18; 23], Pavlo P. Nechypurenko [13; 15; 16], Jurij D. Pahomov [11], Liubov F. Panchenko [18], Andrey V. Pikilnyak [4; 14; 30], Dmytro A. Poltavskyi [6], Oleksandr O. Popov [5], Olha S. Pylypenko [7], Yevhen O. Romanenko [5], Tetiana V. Selivanova [15; 16], Serhiy O. Semerikov [13; 26], Viktor B. Shapovalov [22; 23; 24], Yevhenii B. Shapovalov [22; 23; 24], Ekaterina O. Shmeltser [16], Mariya P. Shyshkina [20; 25], Tetiana V. Starova [15; 16], Viktoriia G. Stoliarenko [16], Stanislav T. Tolmachev [13], Aleksandr D. Uchitel [8; 11; 15; 22; 24], Vladimir I. Zaselskiy [6; 7] etc.

2 Results

To distinguish between AR, one must understand the following: AR is a view of virtual objects and reality, at the same time, where virtual information is added and integrated into the physical world. AR ranges from reality to virtual reality, which is absolute immersion. Figure 1 illustrated a range of mixed reality from the real to the virtual environment.

In virtual reality a man completely immersed in the virtual world, with absolute no does not interact with the real. Special virtual reality glasses are used to fully reflect the virtual environment.

Therefore, understanding the difference, you can present a scheme of AR (Fig. 2).

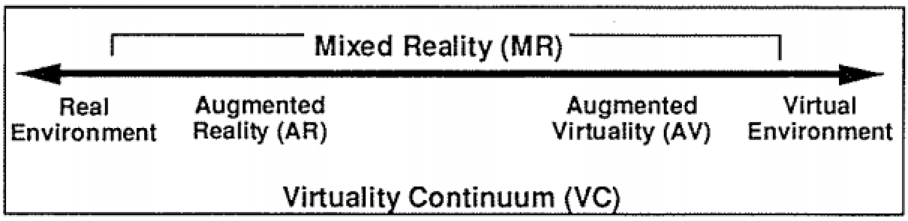

Fig. 1. The range of mixed reality technologies [12]

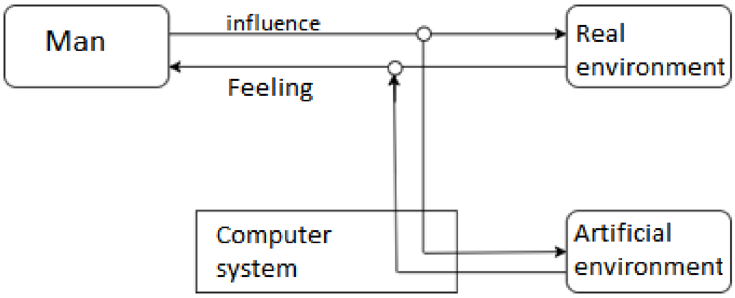

Fig. 2. Schematic of the AR environment

Referring to Ronald Azuma's [1], we can distinguish the main features of AR:

- Combination of the real and virtual world;
- Real-time interaction;
- Represent objects in 3D.

How AR works:

1. The camera finds a real-world marker and then transmits information about it to a computer or smartphone.
2. Computer program replace marker by virtual object (text, music, video, 3D model, etc.) and displays it on the screen.
3. The camera then tracks the movements of the marker, and the program allows you to control the objects.

The possibilities of using AR technologies are almost endless and can be applied in almost every aspect of our lives. They will qualitatively change the ways we communicate, consume information and do business. The following are areas of their use in real life:

— *Education*. The Google Expeditions app can make learning more interactive through special tours where students can view a variety of objects while the teacher talks about them.

- *Medicine*. Viper has proposed a solution that combines telemedicine with AR. With Google Glass and Vipaar, surgeons can assist their colleagues remotely by projecting their hands on the surgeon who performs the surgery.
- *Aviation*. Military pilots have long used AR. Special displays and helmets display information about fighter systems and assist in aiming. AR is also beginning to penetrate civil aviation. For example, Aero Glass has developed special augmented reality goggles that help the pilot navigate space, follow the route, and receive additional information while flying.
- *Marketing*. With AR technology, brands can conduct more creative online advertising campaigns, there by drawing additional attention to their products. For example, to advertise the series “Walking Dead”, at the bus stop installed an AR system that displays the characters both in the real and zombie’ world [27].
- *Tourism*. For new generations, it is inherent to know the world through direct interaction. For example, the Catalan National Museum of Art has begun to actively use AR to better navigate the intricate corridors and interactively view the exhibits [9].
- *Design*. It is much easier to set up an apartment because, instead of imagining whether a particular item will suit you, you can simply put furniture in your interior virtually – using the Furniture Dropping AR application.
- *Shopping*. While you will be in the Supermarket, AR applications will help you navigate a large number of rows and find the shortest route to the right product. It will also be possible to get more information about discounts and great deals.
- *Games*. A prime example is Pokemon Go. However, the most interesting game implementations will come after the official release of iOS 11, which will run ARKit.

Ukrainian AR projects.

Live Animations is an international IT company specializing in the development of innovative AR products for children [10].

At present, there is a mass application of AR in Ukraine. In any supermarket come to life drawings on the floor, when buying ice cream is a bonus viewing the cartoon, and buying a notebook, you can see a realistic animation. The following is a detailed overview of these projects.

1. Mobile application “Wonderland AR” based on the book “Alice’s Adventures in Wonderland”. After recognizing the marker, the camera displays an animation of the characters accompanied by music (Fig. 3-5). With this application, you can interact with fairy-tale characters: shoot videos, take photos and write to social networks.
2. Live Photo mobile application. In 2014, Live Animations, together with Hatber (stationery manufacturer), released the first Live Notebooks in Ukraine. When you point the camera at this stationery, the picture depicted on it comes to life; animation starts (Fig. 6-7).

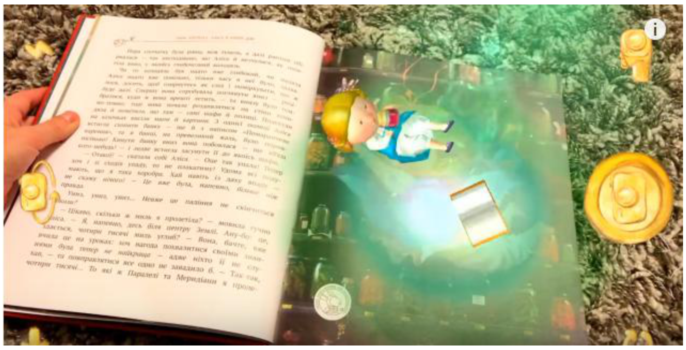

Fig. 3. Wonderland AR example 1

Fig. 4. Wonderland AR example 2

Fig. 5. Wonderland AR example 3

3. Mobile application with AR “My Yeti”. The company developed this project for Gourmet Ice Cream. On 5 types of ice cream were placed 20 different markers (stars), when pointing at them, a cartoon will appear (Fig. 8-9).

Fig. 6. Live Photo example 1

Fig. 7. Live Photo example 2

Trinetix was a company that develops mobile applications, augmented reality and integrated internet solutions [29]. “Architectural monuments of Kiev” is a mobile application that works together with a travel directory “Kyiv is my love”. When you point the camera at a photo of a monument in the catalog, its 3D model is displayed.

Fig. 8. My Yeti example 1

Fig. 9. My Yeti example 2

The main components of the project:

- object markers are photos from the catalog;
- 3D models of Kyiv monuments;
- mobile application with AR module that demonstrates famous architectural monuments.

In Fig. 10 to 11 are photos of augmented reality presentation.

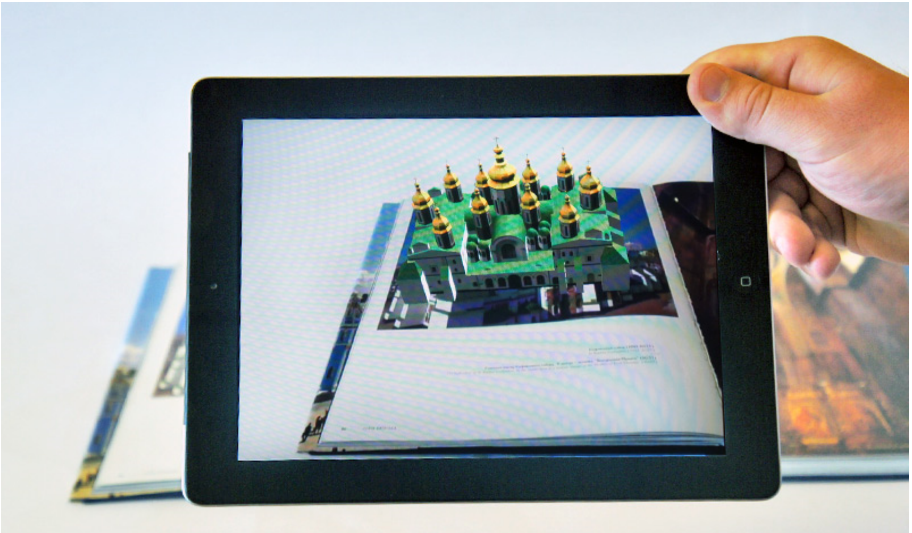

Fig. 10. Mobile application “Architectural monuments of Kyiv” (example 1)

Fig. 11. Mobile application “Architectural monuments of Kyiv” (example 2)

Non-Ukrainian AR projects.

1. Housecraft.

Company Sirvo LLC (USA) has developed a mobile application Housecraft, which runs on iOS 11. The great advantage of this application is that it does not belong to one store, unlike the application IKEA [3]. At Housecraft, you can see a large selection of interior items that can be used in your home with your smartphone or tablet. You can also resize objects and lighting (Fig. 12).

Fig. 12. Housecraft mobile application operation

2. Night Sky.

This mobile application by iCandi Apps run under iOS 11 was developed for those who enjoy astronomy (Fig. 13). Application includes the following features [17]:

- constellations that shine like glass are displayed;
- easy choice of the 8 bright light spectra;
- pollution simulator – it is possible to increase or decrease the star brightness, it simulates different variants of environmental pollution;
- animated planets and the Sun.

Fig. 13. Night Sky

3. Blippar.

A mobile application created by Blippar to recognize any objects in the real world. To get information about the subject, you need to point to your smartphone camera. Works even when pointing the camera at the sky (you can find the weather forecast) (Fig. 14).

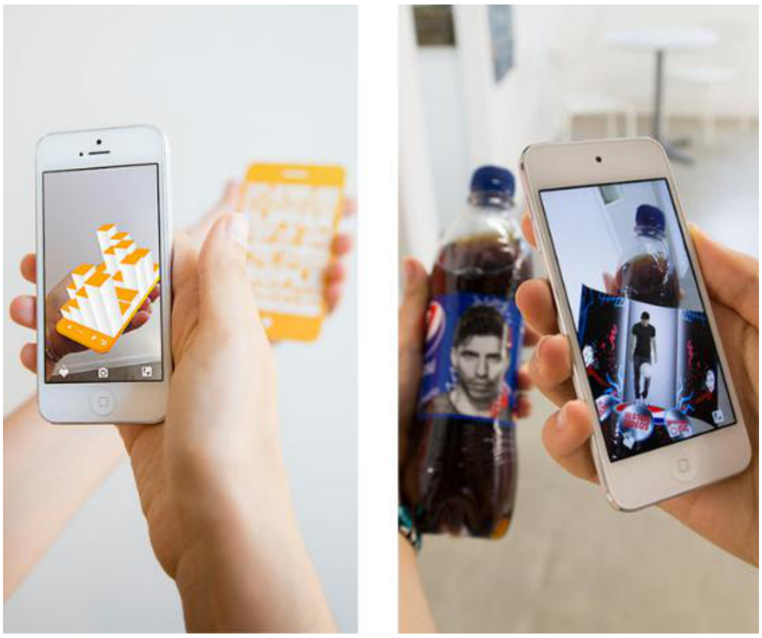

Fig. 14. Blippar

In the field of education augmented reality systems can be widely used in many fields, such as history, mathematics, physics, chemistry, astronomy, etc. You can create books and guidelines on AR technology; simulate the experiments; modeling work with some equipment.

AR widely used in medicine. For example, a laparoscopic operation image on the endoscope complemented the image obtained at the time intraoperative angiography. This information allows the surgeon to locate formation within the body and reduce to a minimum loss of healthy tissue organ of a patient during surgery with removal of formation.

AR can facilitate the study of anatomy by visual effects and information on the organs and bones. You can see the result of the impact of surgical intervention or medicinal preparation as in one body, so also in the group of, not causing harm to a living organism. An educational technology company Visible Body is develop the Human Anatomy Atlas AR application (Fig. 15), which improves the study of the human body. This application provides a detailed 3D model of human anatomy, allowing students to see tissues and organs and virtually dissect the body.

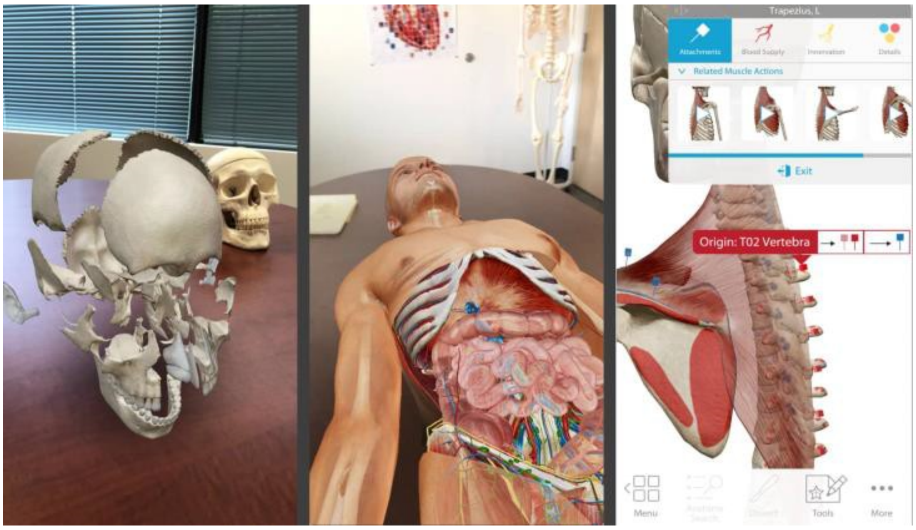

Fig. 15. Human Anatomy Atlas AR Application

Using 3D models with AR in mathematical education can help students to understand math deeply. For example, with Photomath application [19] it is possible to put the camera on the written task and get answer with solving steps (Fig. 16). Features of Photomath: scan textbook (print) and handwritten problems, scientific calculator, step-by-step explanations for every solution, multiple solving methods, no internet connection required to use, 30+ languages supported.

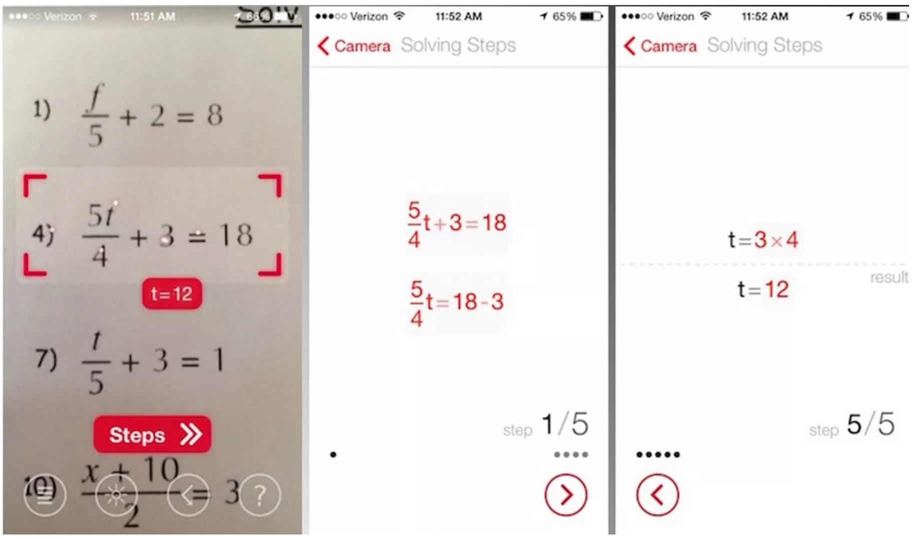

Fig. 16. Photomath

Photomath supports: Basic Math/Pre-Algebra (arithmetic, integers, fractions, decimal numbers, powers, roots, factors), Algebra (linear equations/inequalities, quadratic equations, systems of equations, logarithms, functions, matrices, graphing, polynomials), Trigonometry/Precalculus (identities, conic sections, vectors, matrices, complex numbers, sequences and series, logarithmic functions), Calculus (limits, derivatives, integrals, curve sketching), Statistics (combinations, factorials).

In science education, AR can be used to virtual experimentation. For example, the “Interesting chemistry AR” application (Fig. 17) of SIKE Software allow studying the chemical reactions [21].

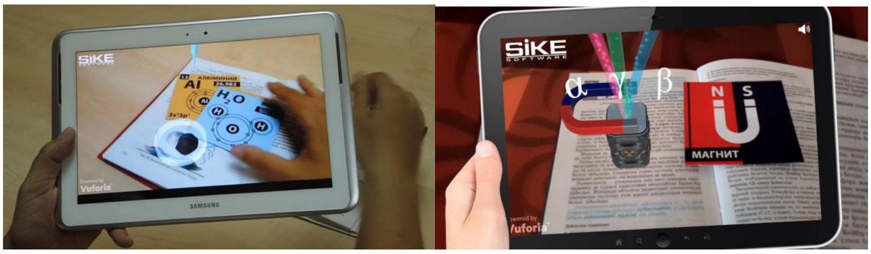

Fig. 17. AR applications “Interesting chemistry AR” and “Interesting physics AR” by SIKE Software

In architectural education, AR can be used, for example, to architectural visualisation. For example, the ARki application (Fig. 18) is a real-time AR visualisation service for architectural models. Darf Design produce each architectural visualisation in-house and provide bespoke AR apps that are unique for each project. By incorporating AR technology within the design process, ARki is able to visualise 3D models for both design and presentation purposes, helping to create an immersive visualisation technique with on-site visualisation and interactivity.

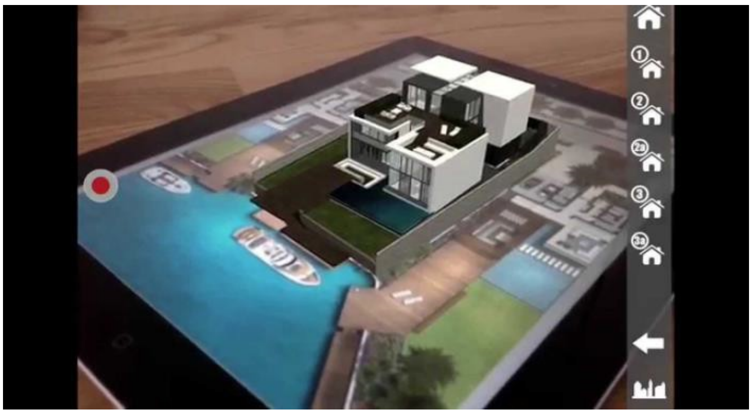

Fig. 18. ARki

3 Conclusions

AR implementation in various spheres has many advantages: realism, clarity, information completeness, interactivity etc. The use of AR in various fields (technology, entertainment, science and medicine, education, games, etc.) should be well thought out and appropriate. In particular, the use of AR in the education involves the development of appropriate applications and methods of their use in the higher educational institutions, which is a prospect for further research.

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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 co-ordination,
- 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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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.

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

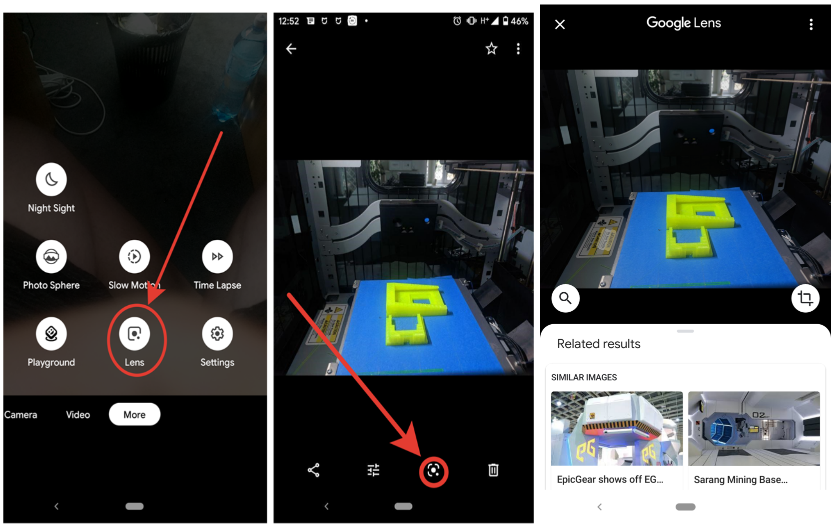
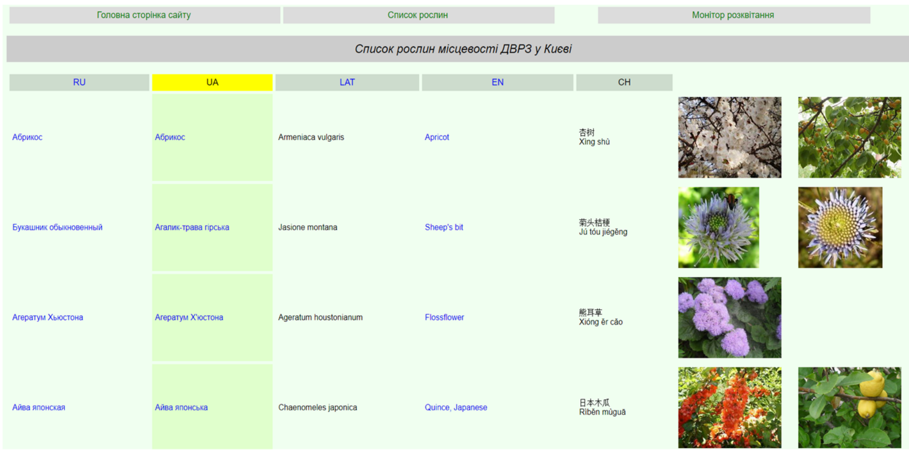


Fig. 1. Google Lens instrument access

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.



Головна сторінка сайту | Список рослин | Монітор розквітання

Список рослин місцевості ДВРЗ у Києві

RU	UA	LAT	EN	CH
Абрикос	Абрикос	Armeniaca vulgaris	Apricot	杏树 Xìng shù
Букашник обыкновенный	Агалик-трава гірська	Jasione montana	Sheep's bit	菊头桔梗 Jú tóu jiégěng
Агератум Хьюстона	Агератум Х'юстона	Ageratum houstonianum	Flossflower	熊耳草 Xióng ěr cǎo
Айва японская	Айва японська	Chaenomeles japonica	Quince, Japanese	日本木瓜 Rìběn mùguā

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.

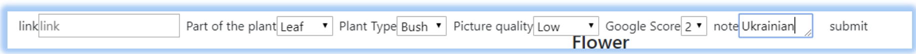


Fig. 3. The input interface

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.

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 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.

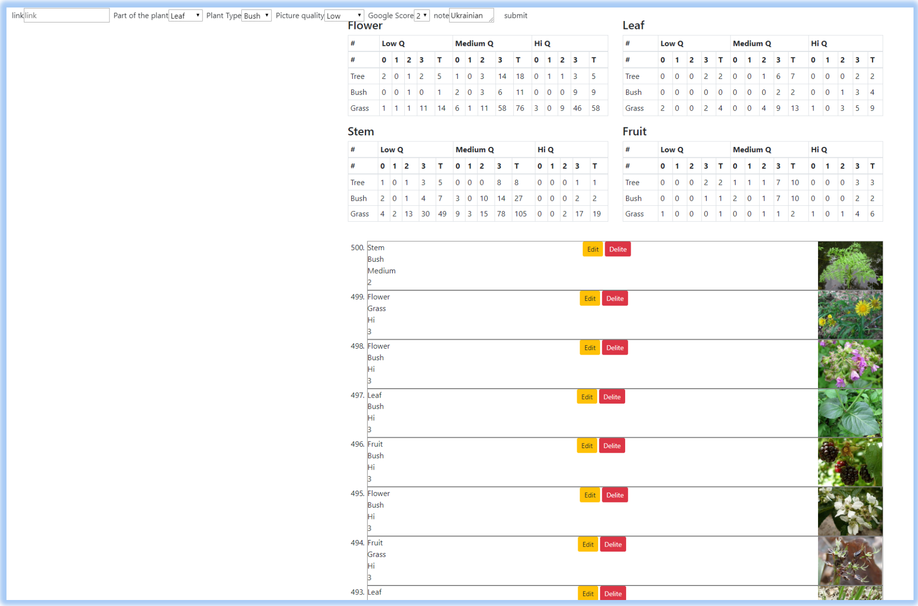


Fig. 4. The output interface

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.

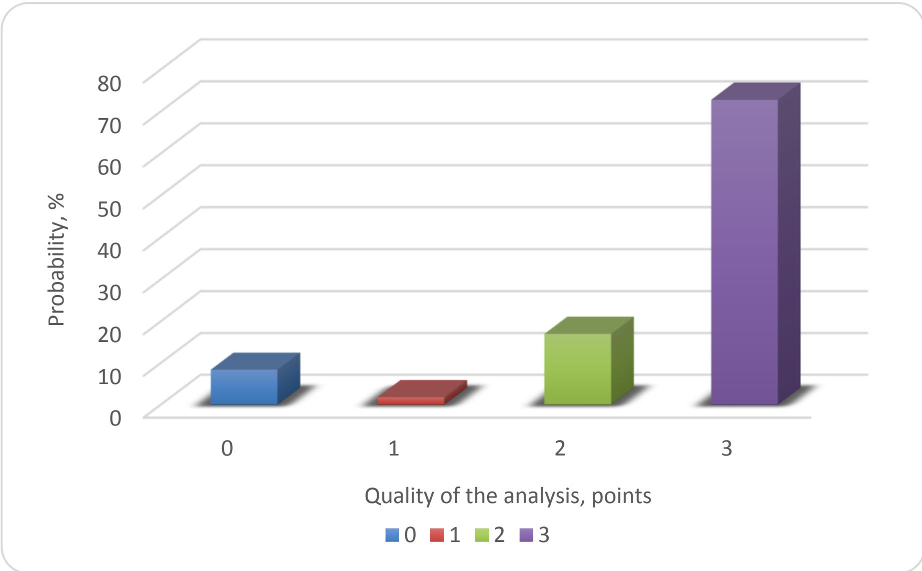


Fig. 5. General Google Lens accuracy

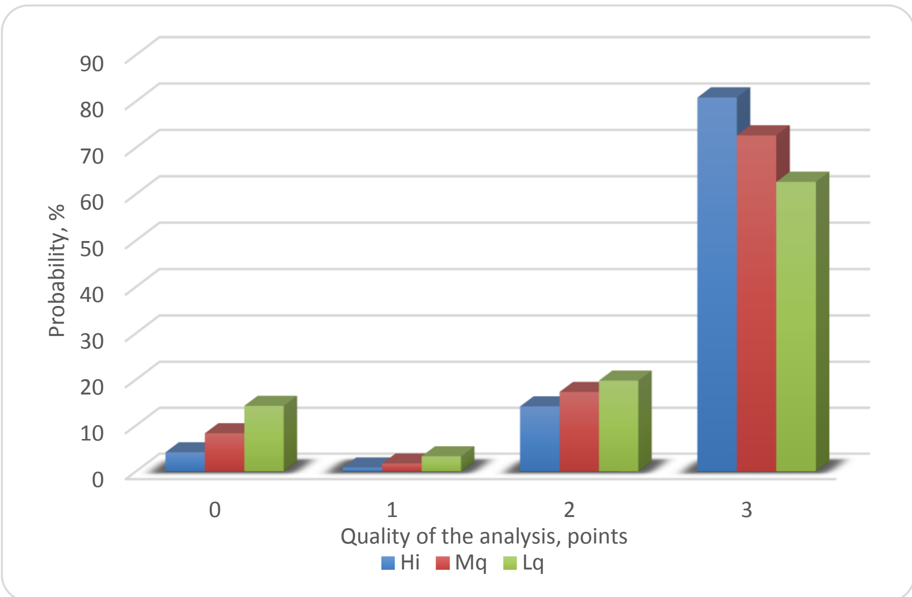


Fig. 6. The dependency of the accuracy of Google Lens analysis quality of photo's quality

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.

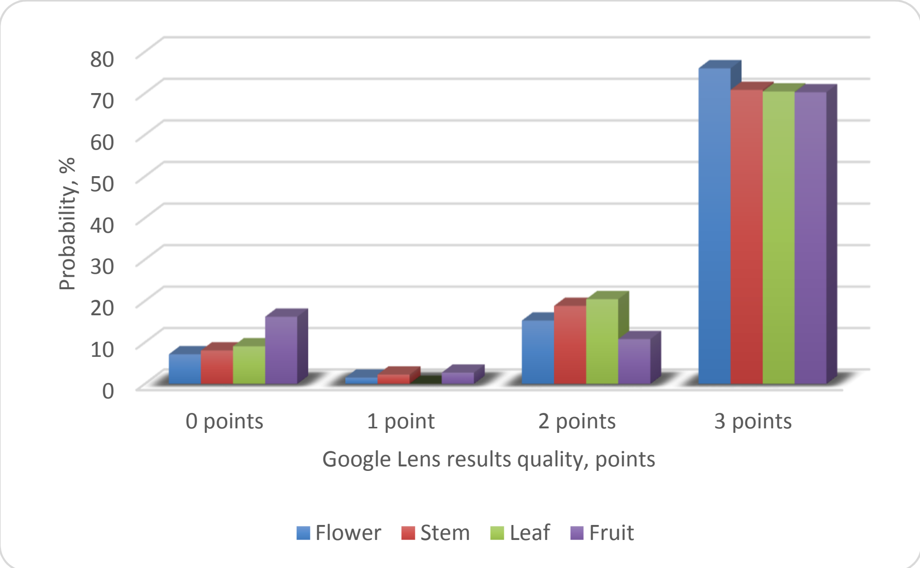


Fig. 7. The dependency of the accuracy of Google Lens analysis quality of analyzing part of the plant

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.

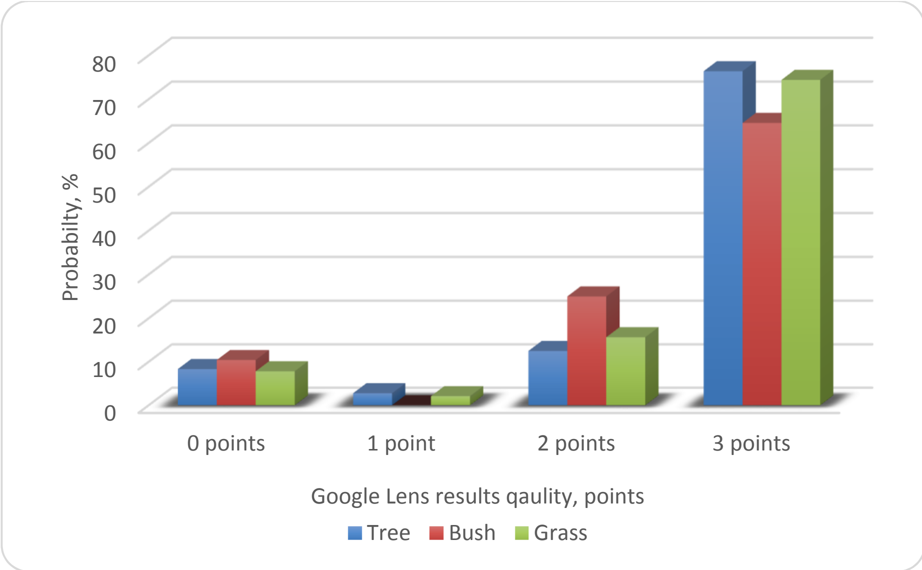


Fig. 8. The dependency of the accuracy of Google Lens analysis quality of analyzing plant type

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. 8.

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.

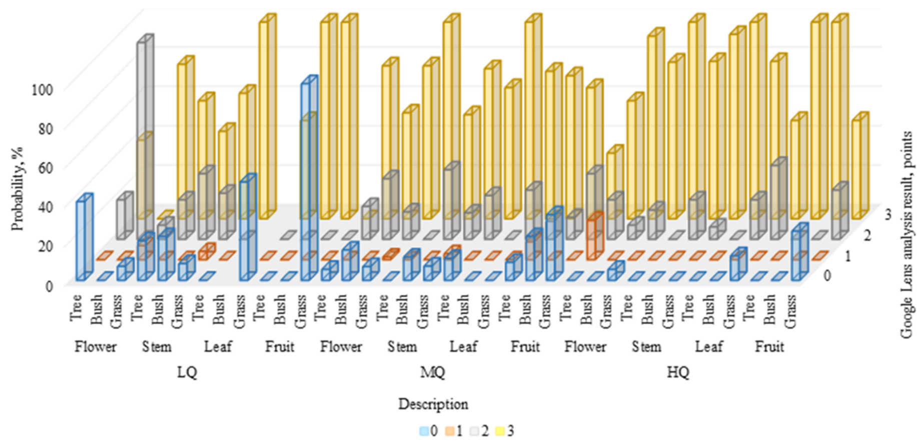


Fig. 9. General results

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; 9; 10; 11; 15].

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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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.

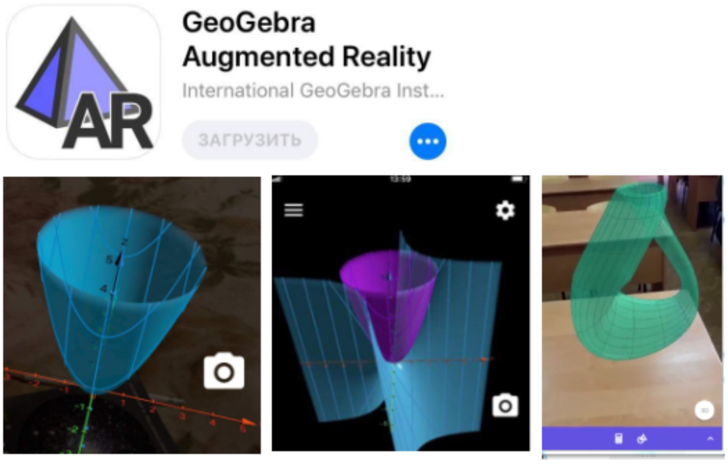


Fig. 1. The surfaces in AR.

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.

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

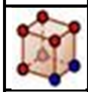
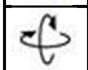
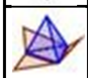
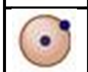
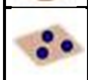
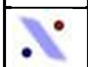
GeoGebra 3D Grapher with AR (iOS) to create dynamic, learner-centered learning environments [2]. In the mathematics teaching it is advisable to use some of his works [1; 3; 4].

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

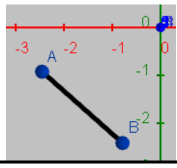
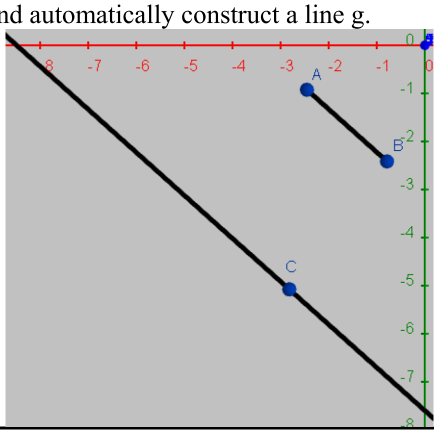
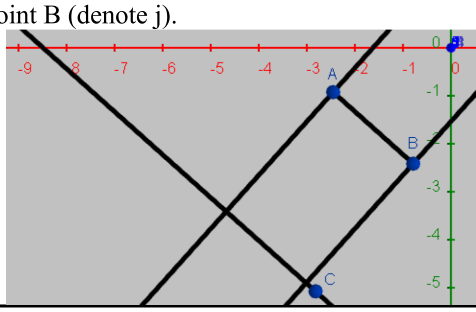
To create a mathematical model in the AR application, first of all, you need to create a model in 3D Graphics using appropriate tools (Table 1), and then using the button “AR” to project into the real world. To place an object in the real world, you must select a location, point it at the camera, and 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.

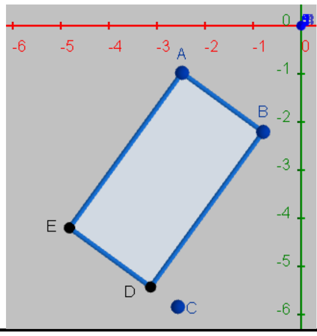
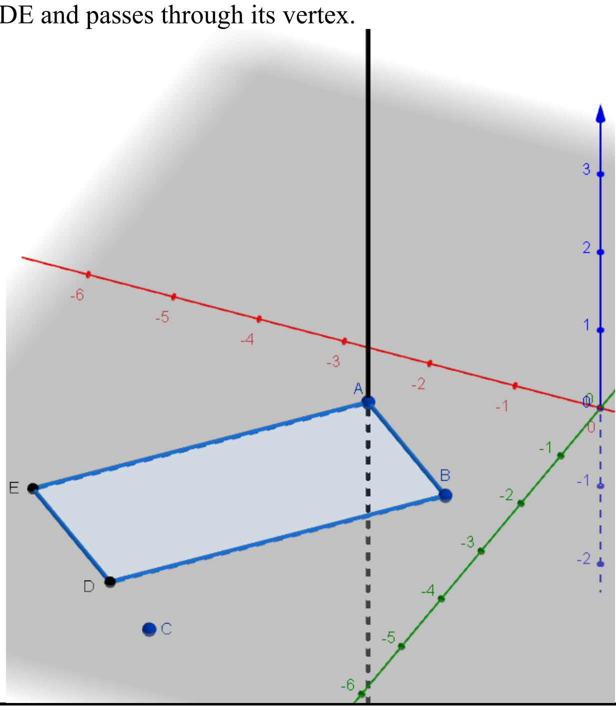
Table 1. Examples of tools for 3D Graphics implementation

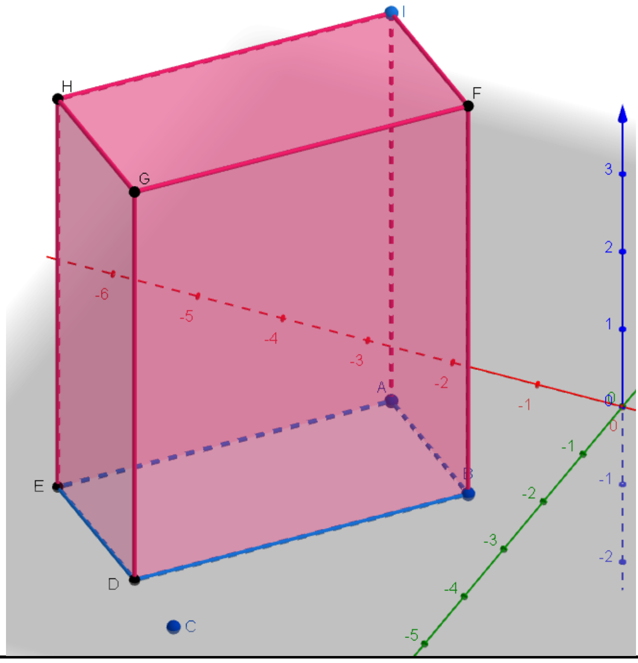
Icon	Tool	Application
	*Cube*	double-click in the 3D view to create points that set the rib of the cube
	*Move*	allows you to move objects, the first click on the point will change its position in the xOy plane, the second click - the coordinate along the z axis
	*Extrude to Pyramid*	allows you to construct 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

No	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. 
3	Construct perpendiculars to the line passing through the ends of the segment	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). 

No	Stage	Instruction and drawing
4	Construct a rectangle	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. 
		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.

No	Stage	Instruction and drawing
		

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; 15; 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).

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.

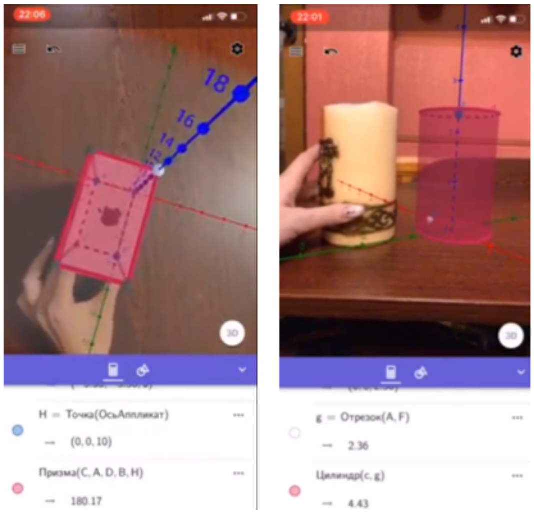


Fig. 2. GeoGebra AR demos

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.

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.

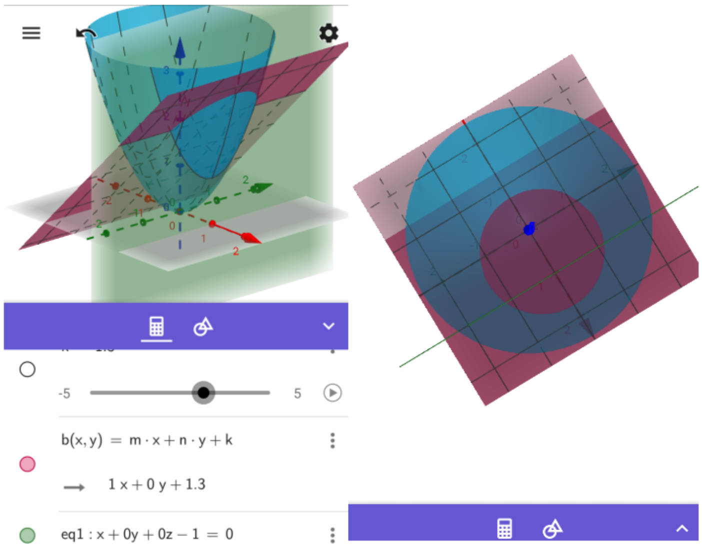


Fig. 3. a) a geometric body constructed in parallel projection, b) a projection on the Ox plane

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).

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.

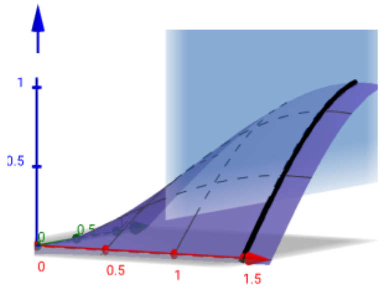


Fig. 4. Graph of the probability distribution function of two-dimensional random variable.

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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Using interactive technologies to study the evolution of stars in astronomy classes

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Abstract. In astrophysics, a significant role is played by observations. During astronomy classes in the absence of surveillance tools interactive programmes such as an interactive programme for space objects simulation can be used as Universe Sandbox². The aim of this work is to implement interactive programmes for effective astronomy teaching, understanding material and increasing cognitive interest. We observe the evolution of stars while using Universe Sandbox² during the study of the topic "Evolution of stars". Using this programme students have an opportunity to get acquainted with the existence of stars with different masses, their differences, to observe changes in the physical characteristics of stars such as: mass, temperature, speed velocity, luminosity, radius and gravity. It will help to develop the ability to analyze, to compare, to form scientific worldview, to develop the attraction for research, to raise the interest for studying astronomy.

Keywords: education, astronomy, computer technology, interactive programmes, Universe Sandbox².

Modern educational technologies are aimed at teaching students to work independently [9; 10; 13; 14], as this quality gives opportunity for them to adapt successfully in the conditions of a rapidly changing society. The ability to learn will allow them to improve experience and knowledge, to analyze and to use the achievements of science and technics in the professional activity. The number of hours to study astronomy is clearly not enough for its quality of teaching and for students to master it at a sufficient level, which also indicates the need to devote the most part of the material for independent study [11; 13]. However, most teachers consider students' independent work only as homework, textbook reproductive study, writing synopses, problem solving and preparing projects. Learning a new material independently is difficult for schoolchildren. Normally they do not do a boring work or they do it mechanically. In the context of the modern new Ukrainian school it is necessary to increase the role of independent work for obtaining sufficient astronomical knowledge but at the same time it is necessary to change the approach to the individual work. It should not be exclusively reproductive homework, it should include interesting tasks for students which they will perform both during and after the classes or at home [12].

Modern technologies are developing enough fast and their use will help to enhance the study of astronomy. For example, such computer and mobile applications as Sky Map, Star Walk 2, etc. and 3-D pens for design 3-D models could be used [2, 5]. It is clear that the use of modern technologies requires additional time, knowledge and skills both of teachers and students.

Nowadays, while teaching astronomy didactic and psychological principles of developmental teaching, individualization and differentiation of teaching, activity and comprehension approaches must be implemented [16]. The transition to the competence approach means reorienting the process to the result of education in the activity, changing the emphasis on the accumulation of normatively defined knowledge, skills and abilities in order to form and to develop individual's ability for practical actions, the use of experience in specific situations [14]. The activity approach to the organization of the educational process in astronomy allows not only to solve the problem of effective mastering the astronomical knowledge successfully, but also to form students' ability to plan their activities independently and competently in different situations.

Today children comprehend the lesson material when information and communication technologies (ICT) are used with greater interest [19]. Such form of organization of various subjects' study becomes more effective and facilitates the new material perception by children. The use of ICT during astronomy lesson develops visual thinking, imagination, visual memory. It becomes possible with the use of star maps, educational pictures, demonstrations, video and audio materials, animated images that are presented in electronic form.

The use of interactive technologies affects the level of student's formation of high internal and external motivation, activity in information and cognitive activity while studying astronomy. And so that it manifests itself in self-determination and self-realization of the personality. Innovative technologies allow to reproduce the high level of visualization of the happening events and processes, the ability of simulation and occurring of their simulation with different values of parameters. Also it allows to reproduce individualization and differentiation of educational material in respect to the student's cognitive abilities as well as the ability to control mastering and understanding teaching material in the classroom for the teacher's management or independent work so that it enables to have an operational feedback for the correcting educational process.

Workshops provide the students with an opportunity to increase theoretical knowledge, to study principles of physical phenomena development, to use fundamentals of scientific experiments, and skills in mathematical analysis of measured results.

Due to the rapid development of computer technologies, it is possible to implement interactive technologies in the work of educational institutions [1; 6]. The implementation of such technologies improves and facilitates astronomy classes. Firstly, visual aids should be used because while learning astronomy it is difficult for pupils or students to understand and to get the idea without realizing how and in what way an astronomical (physical) process passes. Secondly, the use of computer programmes makes easy to implement practical tasks and laboratory work, moreover it allows to extent their quantity. Thirdly, taking into account the fact that it is given not enough time for astronomy study, so the organization of the independent work with the use of interactive technologies will increase the amount of knowledge or even will expand the students' horizons.

The aim of this work is to implement interactive computer and mobile programmes for the independent work in effective astronomy teaching as well as understanding material and increasing cognitive interest. An additional aim of this work is the introduction of astronomical practical work for children with educational needs.

Instead of the usual methods of teaching the desire to develop students' ability to work with multiple sources of information has come, and one of the main goals has become not only to provide graduates with specific knowledge but also a need to teach them how to learn. Exactly the mentioned previously will allow to improve experience and knowledge during the whole life, to analyze and to use achievements of science and technology in the professional activity.

The use of modern informational technologies in the process of organization of independent work simplifies teacher's organization of independent work in astronomy and has a number of advantages:

- modern educational products;
- possibility of choice of individual working schedule;
- the use of accents transfers on electronic transmitters;
- variability of tasks taking into account children's potential possibilities and capabilities;
- increase of students' professional motivation;
- an objective checking possibility of the level of mastering educational material.

The use of informational technologies in organization of students' independent work allows not only to intensify their work but also to make base of further permanent self-education.

E-learning environments, that help children to get learning material, include distance learning, interactive exercises, e-testing, mobile applications [15]. New informational technologies such as laptops, smartphones allow children with special educational needs to participate in the educational process without using functional restrictions and residence [4; 5; 17]. Mostly, it is a kind of salvation because due to the sufficient development of technology, they can get education of different levels even without leaving home. Distance learning is used in different countries of the world and that allows, for example, to live in Ukraine and study in Denmark.

Lately the problem of children's "inclusive education" in general educational establishments becomes more essential. And if this issue is studied at primary school, attention is paid not sufficiently to the study of children with the special needs in science and mathematics. ICT implementation allows a teacher to take into account the students' individual educational needs and consequently to involve such children to the astronomy study. Unfortunately, the astronomy study is paid not enough attention in secondary educational establishments and scientific literature. The educational process for children with the special educational needs at senior school lays in personality-centered education. In this case the role of a teacher is to find an approach to every student with individual needs and to involve him to cognition.

To strengthen an effect in the studies of children with the special educational needs, teachers use audio and video materials, pictures, fragments of films, other visual aids, but it is important to make visualization concrete [8]. It is possible and necessary to use a great quantity of illustrative material, atlases, star catalogue, map of the starry sky while teaching astronomy. Students with autistic disorder have unique possibilities for astronomy study. In astrophysics, a considerable role is played by supervisions.

Realistic observations cannot be made in astronomy classes, so virtual computer or mobile applications will help the teacher to increase practical and research components, to bring astronomy study closer to the modern scientific level. By doing their own research students do not only understand the learning material better, but also develop their own research skills, imagine the world's scientific picture better. The use of these applications is possible in the classroom and at home while accomplishing individual work. Learning with the help of computer programmes (applications) makes easier the understanding of the material and contributes raising of cognitive activity.

Interesting graphic arts, pictures, virtual trip are interesting and encourage the effective astronomy self-learning as they are children's visual acquaintance with these programmes. Such programmes can be used in the educational; process for the students with the special educational needs because students can accomplish the majority of the mentioned tasks independently. While working with computer programmes a student can choose complication and speed of work taking into account his own individual features. Thanks to the free access to these programmes all students have an extracurricular time to continue studying, to analyse material independently and to make conclusions.

One of the most interesting question for students and one of the task for an astronomer is star evolution. The theme "Evolution of stars" in the 10-11th grades is devoted about one hour for the study on the standard level. Video, animations, other visualization give an opportunity to understand the physical processes that take place and how physical parameters depend on the evolution process. In this work we also represent interactive computer programmes, for example, *Universe Sandbox*^{2} which is used as an interactive computer programme for space objects simulation.

Universe Sandbox is a physics-based space simulator that allows you to create, to destroy and to interact on an unimaginable scale [3]. Universe Sandbox was introduced in 2008. Moreover, its current version is now available. It includes desktop and virtual reality mode. Universe Sandbox^2 fully supports three of the major VR solutions: HTC Vive, Oculus Rift+Touch and Windows Mixed Reality. With a headset this simulator allows to create one's own virtual reality in order to see and to interact with digital content in the environment. This virtual reality is great for demonstrating scale and distance in a tangible way. Also it can make astrophysical concepts tangible for students like nothing else. With its help the influence of gravity on various objects in the universe can be seen and planetary systems can be simulated.

It is possible through mapping walls and objects, then through superimposing images, that it makes to look like as right objects in front of you. This also allows interactions between the real and digital worlds as, for example, with the use of Universe Sandbox. It means that it is possible to explore the Solar System in a living room and to smash stars against walls.

The laws of physics are performed for planets, stars and other space objects, therefore, this programme may become highly interesting for studying not only astronomy but also physics.

The lesson goal of the topic "Stars. Evolution of the stars" is to understand how, why, where and from what stars are formed. The classes are offered to combine traditional learning tools and the use of modern electronic technologies. After learning new material, the computer programme Universe Sandbox^2 is introduced to the students. It has the ability to:

- consider and modify our Solar System with known planets, starting with Mercury and ending with Neptune;
- change mass of the planets;
- make your own Planetary system;
- observe the collision process of galaxies with further development of this process;
- control the motion of asteroids, meteorites and comets;
- monitor the moment of birth and death of the stars (this process is shown in details);
- monitor the situation in which the Sun goes out and how the Solar system model will look like without the Sun;
- put Black Hole in galaxy or a planetary system and to analyze what could happen.

As a practical exercise, it is suggested that students use the Universe Sandbox^2 to explore the evolution of the Sun and any other stars with larger mass. Students can accomplish this task under the teacher's guidance (if it is possible in the class or after it) or independently at home, at the end of the lesson or at the next lesson. Students make conclusions concerning the time of evolution, the final stage of the evolution of the stars, and the change in the physical parameters of the studied stars.

Task for students: using a computer programme watch the evolution of stars with different masses. Complete the table in order to do the analysis.

	Initial data	Intermediate data	Final data
Mass, M○ Radius, km Surface temperature, K Volume, V○ Time, billion year			

It is the brief instruction to the programme in order to accomplish the task. In order to watch the evolution of the star of the Sun type, a student must launch the Universe Sandbox^2 programme, open the MENU (press the "Home" button, it is on the top left). In the menu press "Open" button, then select the "Explosions" tab, and open the simulation called "Stellar Evolution of our Sun", and for the other stars you need to click on the star itself and informational panel with physical characteristics (mass, radius, density, temperature and speed) will appear on the right side of the monitor. The additional information about the star (title, age, surface temperature, luminosity, rotation speed, gravity attraction) will appear on the informational panel.

Stars with different masses at different stages of evolution are shown in Fig. 1-3.

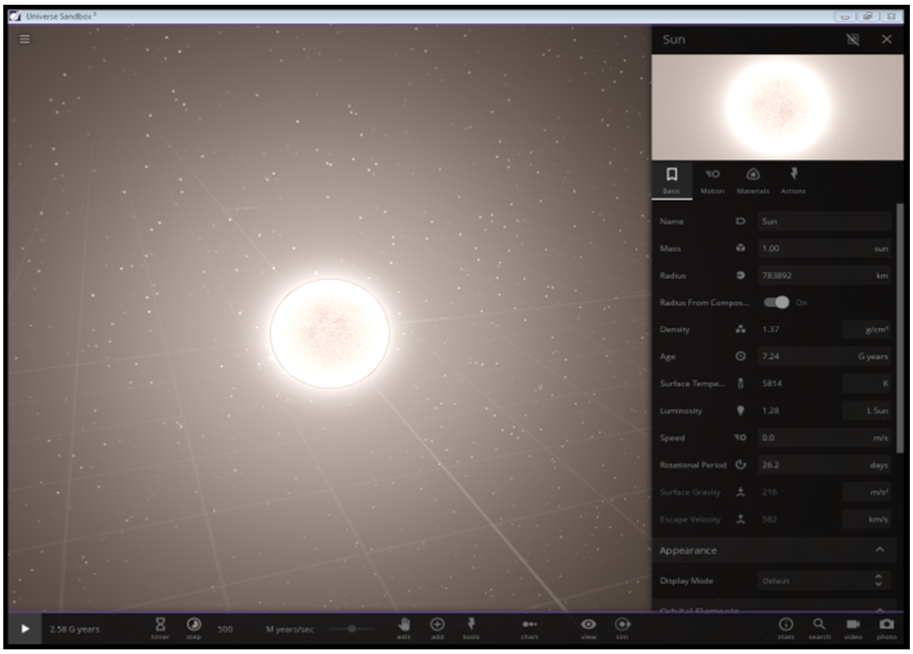

Fig. 1. Star of the Sun type with age of 7 million years

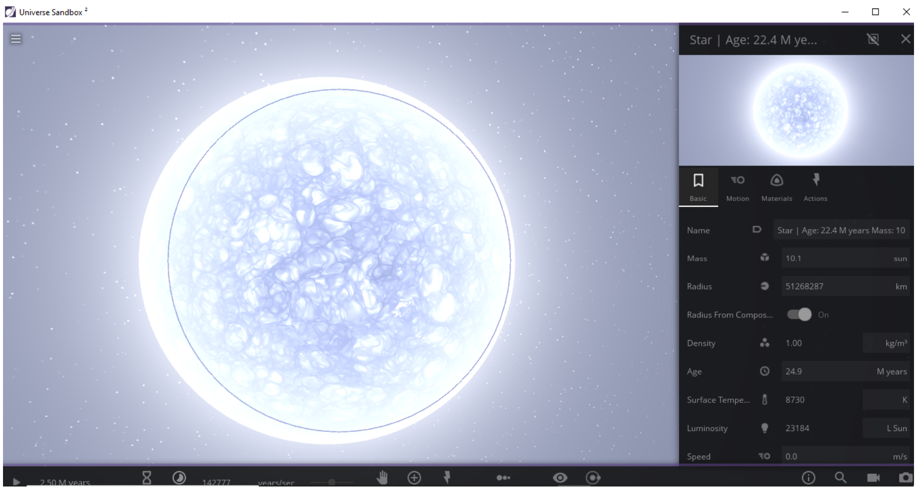

Fig. 2. Star with mass of 10 Sun masses with age of 22.4 million years

Table 1 presents the evolution process of the stars with the Sun mass. The evolution of the star was observed from the stage of the main sequence to the stage of the red giant. From the data in the table all physical characteristics were increasing in the process of stars' development. A red giant was formed with a smaller mass but larger in size in the process of this model development as a result of simulation.

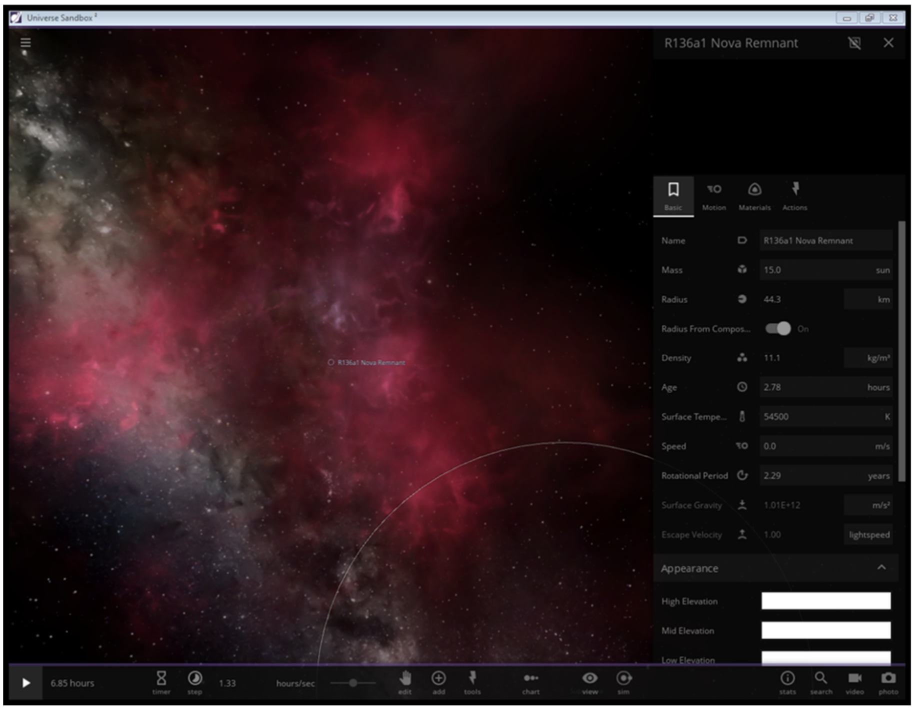

Fig. 3. Star with mass of 15 Sun masses 2,78 hours later after the explosion

Table 1. Star with the Sun mass

	Initial data	Intermediate data	Final data
Mass, M○	1	1,2	0,541
Radius, km	6955000	848960	1219169
Surface temperature, K	5775	5805	5173
Volume, V○	1,03	1,82	6,51
Time, billion year	4,66	8,55	11,2

The star evolution model is standard and is already presented in the programme. During the development of this model the star size enlarges, change of temperature and mass are observed.

The results of observations on the model of a massive star are given in Table 2. As Table 2 shows, the radius, temperature and volume of the star increased. As a result of the evolution, a star of considerable size with the same mass but with a lower temperature was formed. At the final stage of evolution, a clear cloud of gases emerged near the star.

Table 2. Star with 10 Sun masses

	Initial data	Intermediate data	Final data
Mass, M○	10,1	10,1	10,1
Radius, km	7025583	26323386	55057486
Surface temperature, K	19964	13917	8133
Volume, V○	1030	62877	495659
Time, billion year	22,4	23,4	25,1

Table 3 presents the evolution of the star with 260 Sun masses. The evolution was observed from the stage of the main sequence to the stage of supernova. From the data in the table all physical characteristics were increasing in the process of evolution of the stars. A black hole was formed as a result of development simulation of this model.

Table 3. Star with 260 Sun masses

	Initial data	Intermediate data	Final data
Mass, M○	260	265	15
Radius, km	22325550	29243869	44,3
Surface temperature, K	54500	56000	54227
Volume, V○	33048	74274	$25\cdot10^{16}$
Time, billion year	1,70	1,75	–

Students have an opportunity to get acquainted with the existence of stars with different masses, their differences, to observe changes in the physical characteristics of stars such as mass, temperature, speed velocity, luminosity, radius and gravity thanks to practical task accomplishment with the help of this programme. It is also necessary to pay attention to the time of evolution of stars with different masses, it can take a long period of time: from several millions to tens of billions of years.

At the end of this class, students can answer the questions:

1. What is protostars?
2. What is realization of a stellar evolution?
3. What changes during the evolution of the stars?
4. Can we study the stellar evolution when we observe the life of a single star? Why?
5. Are all stars born from collapsing clouds of gas and dust?
6. How different is evolution of stars of different masses?
7. Does the mass of the stars change during their life?
8. How does the size of the stars change during stellar evolution?
9. What is the duration of life of stars?
10. When does the star become a black hole?
11. Which stars have the smallest size?
12. Tell about the evolution of low-mass stars.
13. What is the difference evolution of giant and supergiant in comparison to low-mass stars?
14. What happens after a low-mass star ceases to produce energy through fusion?

Students also can prepare presentation about the life cycle of a Sun-like star, brown dwarfs and sub-stellar objects, red-giant-branch phase, planetary nebula, etc.

The task of modeling the evolution of stars was offered to the students of the 11th grade of Kryvyi Rih Lyceum No 35, who study astronomy at the standard level, and and also this task was offered to the students who study physics at Kryvyi Rih State Pedagogical University as a major subject. Pupils as well as students performed this task after having studied the theme “Stars. The evolution of stars” after classes.

Finally, we can do the following conclusions:

1. Universe Sandbox[2] is a simulation software which allow to explore a star evolution in the virtual reality (using HTC Vive, Oculus Rift+Touch or Windows Mixed Reality). Computer simulation of the stars evolution in astronomy study provides students with knowledge on the peculiarities of stars with different masses (form, size, temperature). Furthermore, it helps to understand the evolution of the stars with different masses, to recognize the physical characteristics and processes taking place into the stars, to consider the conditions of the formation of supernovae, neutron stars and black holes. It will help to develop the ability to analyze, to compare, to form scientific worldview, to attract for a research, to raise the interest to astronomy study.
2. The basic result of implementing practical works in astronomy are the obtained knowledge and abilities which allow students to determine learning tasks; to find the optimum methods of tasks realization; to use different information sources; to estimate the results; to organize one’s own research activity. Therefore, practical tasks in astronomy have an important place in the educational activity, so that the conducting of such tasks is possible even without the special astronomic equipment.
3. Interactive programmes implementation will help students to master the material better, it will allow to visualize educational material, to develop students’ spatial representation, to increase the level of cognitive activity and to provide an effective self-mastering the knowledge in astronomy. Besides the implementation of computer interactive programmes, ICT allows to organize an individual work in astronomy and to involve children with special educational problems into the process of studying astronomy.
4. Experience of using the opportunities of modern computer technologies shows their high efficiency in the course of school astronomy. ICT open new opportunities in order to create virtual space, in which it is possible to observe the processes that are inaccessible in realities due to the classroom conditions.

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Development and implementation of educational resources in chemistry with elements of augmented reality

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Abstract. The purpose of this article is an analysis of opportunities and description of the experience of developing and implementing augmented reality technologies to support the teaching of chemistry in higher education institutions of Ukraine. The article is aimed at solving problems: generalization and analysis of the results of scientific research concerning the advantages of using the augmented reality in the teaching of chemistry, the characteristics of modern means of creating objects of augmented reality; discussion of practical achievements in the development and implementation of teaching materials on chemistry using the technologies of the augmented reality in the educational process. The object of research is augmented reality, and the subject - the use of augmented reality in the teaching of chemistry. As a result of the study, it was found that technologies of augmented reality have enormous potential for increasing the efficiency of independent work of students in the study of chemistry, providing distance and continuous education. Often, the technologies of the augmented reality in chemistry teaching are used for 3D visualization of the structure of atoms, molecules, crystalline lattices, etc., but this range can be expanded considerably when creating its own educational products with the use of AR-technologies. The study provides an opportunity to draw conclusions about the presence of technologies in the added reality of a significant number of benefits, in particular, accessibility through mobile devices; availability of free, accessible and easy-to-use software for creating augmented-reality objects and high efficiency in using them as a means of visibility. The development and implementation of teaching materials with the use of AR-technologies in chemistry teaching at the Kryvyi Rih State Pedagogical University has been started in the following areas: creation of a database of chemical dishes, creation of a virtual chemical laboratory for qualitative chemical analysis, creation of a set of methodical materials for the course “Physical and colloidal chemistry”.

Keywords: augmented reality, chemistry education, technology of the augmented reality (AR-technology), tools for the development of objects of augmented reality.

1 Introduction

The educational process in higher education institutions in Ukraine has recently become aware of serious changes related to both the forms of its organization and its structure. In particular, curricula for training bachelors and masters in most areas of learning are built in such a way that the share of independent work ranges from 50 to 70% of their total volume. In addition, one should take into account the possibility of different force majeure circumstances, both objective and subjective, that can significantly increase the proportion of self-training students within individual disciplines.

Also, the organization of a modern educational process in the institutes of higher education is significantly influenced by the tendencies towards globalization, which are manifested in the needs of students in distance education, continuing education, and so on.

Higher education institutions should address the challenges associated with the above-mentioned changes, with no loss as educational services provided. The most optimal way of modernizing the educational process in these cases is the widespread and methodically balanced use of information and communication technologies (ICT), namely, modern and high-quality ICT tools [13; 14; 16].

For a long time, the most demanded ICT tools in the learning process were multimedia and cloud technologies [6; 10; 15; 21]. Recently, however, one of the most trending tools has become tools of the augmented reality (AR), which to some extent combine the properties of multimedia and cloud technologies, and at the same time have a number of features and benefits [18; 25; 27].

Augmented reality, AR technology has recently expanded rapidly in a wide variety of human activities, from virtual simulation of gaming situations to sports events and virtual online games (ARQuake, Pokemon Go, Silent Streets), to a powerful tool for modeling and visualizing various objects:

- products in online stores [12];
- cultural monuments and geographic landmarks;
- online excursions;
- various natural phenomena and processes [5; 11; 28], etc.

Also, the technologies of the augmented reality have recently become widespread in those industries, for which the development of them was mainly carried out more than 50 years ago – for the creation of training simulators for the training of physicians, military specialists (pilots, sailors, gunners, etc.), specialists in other fields, who have to master complex, expensive or hazardous health devices and equipment.

The tasks described above are solved by developing and implementing more advanced software and devices for its implementation, among which there are various specialized training programs; AR-tutorials, markers on pages which with the camera and the corresponding application on the smartphone launch animated 3D images, videos, etc.; educational games and more [1; 7; 9; 19; 22; 24; 29].

2 Results and discussion

It was shown [2; 3; 8; 20] that the augmented reality has a significant potential for stimulating and motivating students, it has a positive influence on the concentration of attention on the subject of study, and also it creates an active learning environment that positively affects the learning process and the creation of a student knowledge system. However, there is a risk of students being overloaded with a large amount of information and a large number of technological devices that provide AR-support for learning material. Therefore, in order to create a high-quality educational product with elements of the complementary reality, cooperation of specialists from many industries is needed: administrators, engineers, programmers, designers, teachers and students.

The use of any tools of ICT (and AR-technologies too) in the teaching of chemistry should take into account a number of chemistry features as a science.

On the one hand, chemistry operates a huge amount of concepts that are inaccessible to direct sensory perception (atoms, molecules, chemical bonds, etc.), studies processes and mechanisms of their flow, most of which can not be directly perceived (the chemical and biochemical processes, which are too dangerous for students, etc.). Therefore, the simulation and visualization of such concepts and phenomena by the AR tools clearly has a high efficiency.

On the other hand, chemistry as applied science requires specialists in this field to be able to properly handle chemical laboratory ware, facilities and chemical reagents, etc. In this case, the technologies of augmented reality can only partly affect the effectiveness of educational process, since most of the necessary skills student must receive while still working with real materials and utensils.

Nevertheless, the positive moments of the use of augmented reality to support chemistry teaching process prevail, as reflected in a large range of relevant chemistry teaching materials [17].

One more advantage of modern AR-technologies is the technical aspect of the issue of wide introduction them into educational process.

So for the implementation of training using the addition of reality, you need:

1. special software, much of which is freely available;
2. the gadgets on which it will be installed.

As a rule, the introduction of AR-technologies into the educational process does not require significant financial costs.

To date, fully or partially free access has a number of applications for creating Augmented reality products, among which the most popular ARToolKit, HP Reveal (Aurasma), Vuforia, Augment platforms. A brief description of these tools is given in Table 1.

Table 1. Creature and use tools of AR-products characteristics

Platform name	Application access	Simplicity of use	Features
HP Reveal (Aurasma)	Free access	Simple and intuitive interface	HP Reveal works on smartphones and tablets running Android 4.0 and above, and iOS 8.0 and beyond. The program requires a battery charge of at least 15%.
ARToolKit	Free access	Sufficiently complex, requires special programming skills	The ARToolKit Supplementary Reality Library supports Unity, Android (Android build support for Unity), iOS (iOS build support for Unity and Apple Xcode 4.2 and higher)
Vuforia	There are free versions, as well as extended paid apps	Sufficiently complex, requires special skills in working with the application and programming	Vuforia SDK (Software Development Kit) is a software suite that includes an add-on reality platform and an add-on software developer toolkit for using AR on mobile devices: Android tablet, Android smartphone, and U-score glasses (Windows). The Vuforia SDK is integrated with the Unity 3D gaming engine.
Augment	Free access	Simple and intuitive interface	The mobile app allows you to visualize the 3D model in Augmented Reality, with the ability to add your own 3D models and customize trackers. Supports the most popular 3D formats: obj, stl, collada, etc. Works on smartphones and tablets running the iOS and Android operating system.
EasyAR	Free access	Simple and intuitive interface	Platforms: Android, iOS, UWP, Windows, OS X, and Unity. Features of the 3D object recognition application, environmental perception, cloud recognition, smart pointing, cloud deployment of applications

The availability of a sufficiently large number of different complexity and application capabilities enables the use of AR-technologies in the teaching of chemistry to teachers who do not have special knowledge and skills in programming. Yes, HP Reveal and Augment have a fairly simple interface and easy-to-understand working principle that makes it possible to use them without special long-term training [23].

In the case of gadgets for the use of AR-products, in most cases either special glasses, tablets or smartphones with installed AR-software. And if the AR points are not publicly available for students due to their high price (about $ 1500), then almost every student has a smartphone or tablet for today.

Studies conducted on the basis of Kryvyi Rih State Pedagogical University (KSPU) showed that 99% of the students interviewed either have a smartphone or tablet, 62% have both a smartphone and a tablet, 34% have smartphones based on iOS and 58% on Android, 7% do not know, which mobile operating system is installed in their gadget (see Figure 1). Participation in the survey was taken by 100 students of I-IV courses and magistracy majoring in Secondary education (Chemistry) (additional specialty – Secondary education (Informatics)) and Secondary education (Biology) (additional specialty – Secondary education (Chemistry)) [23].

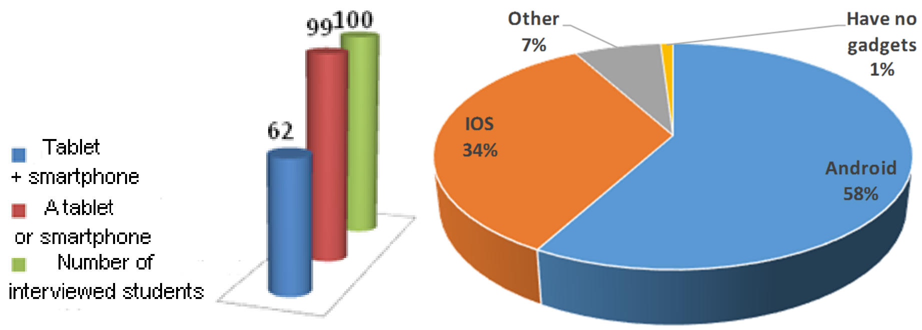

Fig. 1. Analysis of technical capabilities for the implementation of augmented reality technologies in the system of training students of the Natural Sciences Faculty of the KSPU: a) the provision of students with the gadgets necessary for the implementation of training using elements of augmented reality; b) type of mobile operating systems on gadgets.

Thus, in most cases, the problems of technical support for the use of AR-technologies in teaching chemistry students of the corresponding specialties are solved by themselves.

However, there are problems of educational and methodological nature. Most products of the technology of complementary reality, designed to support chemistry training, are oriented on modeling of molecular structures, atom's structure, provision of reference or training information from chemistry individual sections. A certain amount of funds is aimed at familiarizing with chemical devices and the course of chemical reactions. Often these products are of high quality and non-standard approach to the design [17]. In particular, a group of Turkish scientists for the chemical education of students was developed an application designed to study the periodic system of chemical elements structure, their properties, atom's and molecule's structure, which involves the use of special glasses and a high level of interactivity – manipulation of AR-objects occur with the help of hands-on movements, so students play an active role in learning, and not passive observers of the process [26].

A significant disadvantage of the situation for domestic educators in the AR-application market for chemistry training is the fact that the lack of Ukrainian-language products is virtually complete, as well as a limited set of directions for the application of the above-mentioned applications.

Taking into account the advantages and disadvantages of implementation of the augmented reality in the educational process of the institute of Ukrainian higher education, we began to develop and implement our own AR-technologies products.

We use the online resource HP Reveal (former Aurasma) [4] to create the right products, as a simple and easy-to-use, reliable resource. A free HP Reveal application (for Android) must be installed to use the created AR-objects.

HP Reveal Rebuilding Objects is a fairly simple technology and involves several steps:

1. Register on the site of the relevant resource and create a user account.
2. Confirmation of registration by e-mail of the user.
3. Creating a new object - aura:
   (a) load an image that will be a marker for this aura;
   (b) uploading a file that will augmented reality when you hover over an appropriate marker (video, photo and other file types up to 100 MB);
   (c) setting match marker and file, previewing the result;
   (d) creation of the name of the aura, its short description and hashtag;
   (e) preserving the aura, after which the user will have the opportunity to use it, provided that the appropriate application is installed on the gadget.

Separately there is a possibility to make the aura public, with the possibility of viewing by any user.

Creating the appropriate AR-learning resources for chemistry teaching, we carry out our own. At this stage, educational resources are created for teaching to KSPU with the use of AR-technologies in three directions:

1. Creating a database of chemical laboratory ware. When you move the gadget camera to the marker, on its screen appears the image of the representative of the chemical ware with a brief description of its features. Such a database is designed to help solve the problem of familiarizing students with the basics of working with chemical ware and devices. Mostly this is true for students of the specialty Secondary education (Biology), since their laboratory practice is considerably inferior to the volume of the similar practice of chemists-students. Therefore, at least theoretical and visual familiarization with feature of the most necessary chemical ware can be carried out on independent study with the use of technologies of the augmented reality. For students of the specialty Secondary education (Chemistry), this resource should provide familiarization with feature of expensive or rare chemical apparatus, with which they will not work frequently in a real laboratory.

2. Creation of a virtual chemical laboratory for qualitative chemical analysis. The essence of this educational resource is to create a bank of objects of the augmented reality, which are videos, on which there is a course of high-quality chemical reactions of detection of cations and anions. Verbal description of the results of a quality chemical reaction (in particular, the description of the analytical effect) does not always form the idea of the real outcome of such a reaction. In addition, in laboratory classes, only the most important, classical reactions of qualitative detection of substances are usually carried out, and there is not enough time for other qualitative reactions. A certain number of qualitative reactions can not be carried out due to lack of reagents, their high price or significant health hazard. Also, there are cases when students have to master a part of the material from this section of chemistry on their own (for example, because of the state of health), therefore the creation of such a resource will definitely provide an opportunity to better organize independent work of students in the study of analytical chemistry.

The work of this resource is organized in such a way that a student can feel certain autonomy while working in such a virtual laboratory. Aura is a video of a quality reaction performed on a certain cation or anion with the attached text information about it: reaction equation, chemical reaction's conditions, products' feature formed by the reaction, etc. The marker consists of two parts, one of which encodes the corresponding cation and the other anion or other reagent used in qualitative detection (see Figure 2).

The marker triangle plays the role of a landmark for its location - it must be centered on the top, one part of the marker is above the other (cation marker - bottom). Eight circles, which may either have white or black color, make it possible to encrypt such a marker with 28 = 256 variants, that is, 256 different substances (cations, anions, organic reagents), which at present looks more than adequate for full coverage of laboratory workshop on qualitative chemical analysis .

Thus, having a set of appropriate markers, student has opportunity to choose which reaction to see him in the augmented reality by combining markers in a different sequence.

3. Creation of a set of methodical materials for course "Physical chemistry" with the use of AR-technologies. This direction provides an opportunity for a demonstration of complex processes for perception, by transferring educational animations, videos, images in GIF format into AR-objects, access to which is provided by markers placement on pages of relevant educational materials.

Students who study remotely or can not attend practical or laboratory classes can see devices and models of the course of various physical and chemical processes that are not available for real perception. The set created for the course "Physical and colloidal chemistry" can be attributed to educational literature with elements of virtual reality. This kit includes a brief summary of the theoretical material from separate topics of following sections: "Electrochemistry", "Thermodynamics", "Substances aggregate state", "Kinethics", as well as individual laboratory work using AR-technologies.

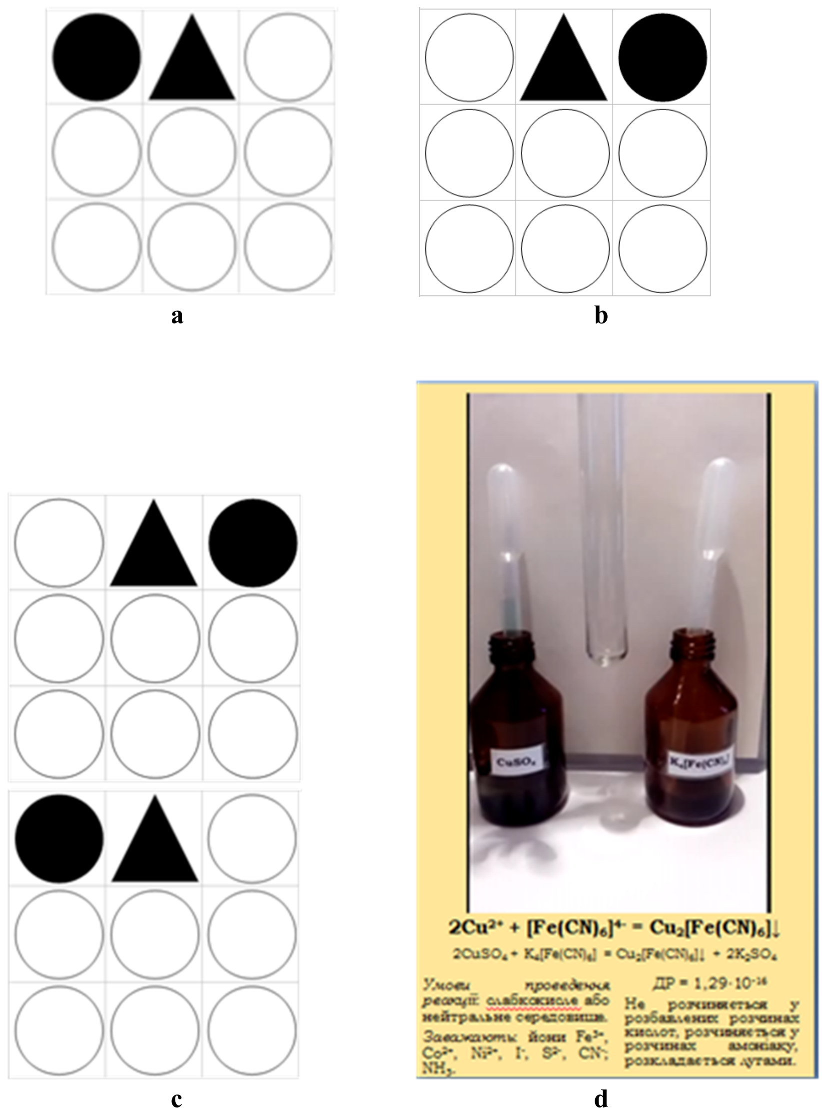

Fig. 2. Markers work scheme of in a virtual chemical laboratory for qualitative chemical analysis: a) is a marker encoded with a Cu^{2+} cation, b) is a marker encoded by an anion $[Fe(CN)_6]^{4-}$, c) is a marker corresponding to the aura showing the course of the reaction between the solutions containing Cu^{2+} and $[Fe (CN)_6]^{4-}$, d) is the aura displayed on the gadget screen.

Access to these educational resources is carried out through the web-page of the Department of Chemistry and its teaching methods at the official website of the Kryvy Rih State Pedagogical University.

3 Conclusions and directions of further research

The application of AR-technologies in chemistry teaching both institutions high and secondary schools, in our opinion, has enormous methodological potential and determines a new level in the creation and use of visibility tools.

Compliance with modern educational standards is important for Ukrainian education system. Therefore, the development of AR-technologies for chemistry training is one of the priority directions of the ICTs introduction in educational process.

When creating training resources with the elements of the augmented reality for study of chemistry, it is necessary to maximize the benefits of AR-technologies: accessibility, visibility, interactivity, ability to provide opportunities for holistic perception of study objects.

Educational and methodological materials on chemistry using the augmented reality developed and implemented at Kryvyi Rih State Pedagogical University are intended primarily to improve the quality and efficiency of independent work of students, to create opportunities for distance and continuous training.

Further areas of work and research are related to the improvement and expansion of the created resources of teaching chemistry with the AR-elements, checking their effectiveness and impact on the quality of student learning, as well as expanding the target audience of these resources at the expense of students from schools engaged in research activities, prepare for chemical competitions and contests, are interested in chemistry and want to study it in depth.

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Analytical review of augmented reality MOOCs

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Abstract. *The aim* of the article is to provide an analytical review of the content of massive open online courses about augmented reality and its use in education with the further intent to create a special course for the professional development system for the research and teaching personnel in postgraduate education. *The object of research* is massive open online courses. The *subject of the study* is the structure and content of augmented reality MOOCs which are offered by acclaimed providers of the world. *The methods of research* are: the analysis of publications on the problem; the analysis of MOOCs' content, including observation; systematization and generalization of research information in order to design a special course about augmented reality for the system of professional training and retraining for educators in postgraduate education. *The results of the research* are the following: the content and program of specialized course "Augmented Reality as a Storytelling Tool" for the professional development of teachers. *The purpose of the specialized course* is to consider and discuss the possibilities of augmented reality as a new direction in the development of educational resources, to identify its benefits and constraints, as well as its components and the most appropriate tools for educators, to discuss the problems of teacher and student co-creation on the basis of the use of augmented reality, and to provide students with personal experience in designing their own stories and methodical tools in the form of augmented books and supplementary training aids with the help of modern digital services.

Keywords: massive open online courses, augmented reality, augmented books, professional training and retraining.

1 Introduction

Augmented reality is considered a world trend. Tim Cook, executive director of Apple, says he believes more in the success of augmented reality, rather than the virtual reality, since the former allows people to use new technology and stay in the real world; and he considers the augmented reality to be as "a great idea as smartphones" [26].

Augmented reality allows you to combine the real world with virtual objects and possesses vast and diversified didactic learning opportunities. Use of augmented reality in education has been analyzed by numerous Ukrainian researchers, for instance Yevhenii O. Modlo and others presents using technology of augmented reality in a mobile-based learning environment of the higher educational institution [17; 18; 30]; Tamila H. Kolomoiets and others describe the use the augmented reality in teaching global reading to preschoolers with autism spectrum disorders [13], Pavlo P. Nechypurenko and others analyzed augmented reality in chemistry education [19; 20].

Consequently, we consider it very important tasks to train teachers to use it in the classroom.

UNESCO's motto "Lifelong Learning" suit educators better than anybody else, since, despite their long working hours, sometimes lack funds and opportunities for official retraining, but should always remain at the top of education and research work, constantly updating the content of training programs in accordance with innovative educational processes and changes taking place in the world.

While solving the scientific problem of training educators for using the augmented reality in education, the following main results were obtained in past author works: the potential of the massive open online course (MOOC) phenomenon as an alternative form of teacher training (Coursera, Udacity, edX, etc.) was analyzed [23], the facet classification of the MOOCs was offered [22], the fundamentals of the specialized course "Digital Storytelling in Adult Education" were designed [22; 25], the form of co-creation of teacher and students in the educational environment was described [24].

2 Research objective and methods

Therefore, *the aim* of the article is to provide analytical review of the content of massive open online courses about augmented reality and its use in education with the further intent to create a specialized course for the system of professional training and retraining for educators in postgraduate education.

The methods of research are: the analysis of the publications on the problem; the analysis of the content of MOOCs about augmented reality, including observation; systematization and generalization of research information in order to develop a specialized course about augmented reality for the system of professional training and retraining for educators in postgraduate education.

3 Results and discussion

MOOC (massive open online course) is a kind of online course in which a large number of participants (up to 50,000) can participate, with open access to all materials via the Internet. The most well-known providers of massive online open courses are Coursera [4], Udacity [15], edX [6], FutureLearn [8], the Ukrainian projects are: Prometheus [27] and Ed-Era [5]. Ed-Era focuses precisely on secondary education.

Researchers distinguish two kinds of MOOC, conventionally referred to as xMOOC and cMOOC [14].

The prefix “c” in the cMOOC name refers to “connectivism”, and such courses include George Siemens, Stephen Downes et al. [2; 28]. In connectivism’s courses, knowledge is created and generated as a result of course participants processing large volumes of unstructured information; such courses are a private initiative of individual members of the teaching community, and are usually not funded.

The second category of MOOCS, xMOOC, includes projects such as Coursera, Udacity, edX. Such courses are mostly content-oriented. They contain videos, questionnaires, tests; the educational information is clearly structured, and mandatory student knowledge control and duplication of knowledge is present.

Let us look at the content of some of the most recent MOOCs about the augmented reality (table 1).

Table 1. Augmented Reality MOOC

No	MOOC	Platform	Brief Description	Software of Augmented Reality
1.	Getting Started with Augmented Reality, Institut Mines-Telecom, 2017-2018 [9]	Coursera	Introduction to augmented reality. Augmented Books. Augmented games.	Third partytools http://mymultimediaworld.com, ARAF browser
2.	21st Century Learning, Self-Paced, University of Bath, University of Naples Federico II, Self-Paced [3]	EMMA	Tools and practice of teaching in the 21st century. Evaluation of personal digital literacy, creation of personal learning environment, finding open educational resources, learning about virtual worlds.	–
3.	Emerging Technologies: From Smartphones to IoT to Big Data Specialization, 2017-2018, Yonsei University [7]	Coursera	Fundamental functions, history of virtual and augmented realities, technologies of augmented reality.	–
4.	Zappar Powered STEM Learning Using Augmented Reality, 2016, Self-Paced [32; 33]	Canvas	The creation of augmented poster for scientists in the framework of STEM education	ZapWorks
5	Introduction to Augmented Reality and ARCore, 2018 [11]	Coursera	Fundamentals of augmented reality, and how to build an AR experience using ARCore.	ARCore
6	Introduction to XR: VR, AR, and MR Foundations, 2018 [12]	Coursera	The first course of the “Unity XR” specialization. An introduction to XR (AR, VR, and MR), brief description of each	Unity

No	MOOC	Platform	Brief Description	Software of Augmented Reality
			technology's, history, limitations and future potential for improvement.	

Let us study these courses in more detail.

The first course "Getting Started with Augmented Reality" includes the following 5 modules:

— Introducing Mixed and Augmented Reality
— Augmented Books
— Augment Your City Map
— Augmented Reality with Geolocation
— Customizing an Augmented Reality Game

Module 1. Introduction to mixed and augmented reality. The basics of understanding when working with computers and complementing reality, the basic characteristics of AR systems and the basic components of AR architecture.

Module 2. In this module, the user will create augmented reality application – augmented book with authoring tool (Fig. 1).

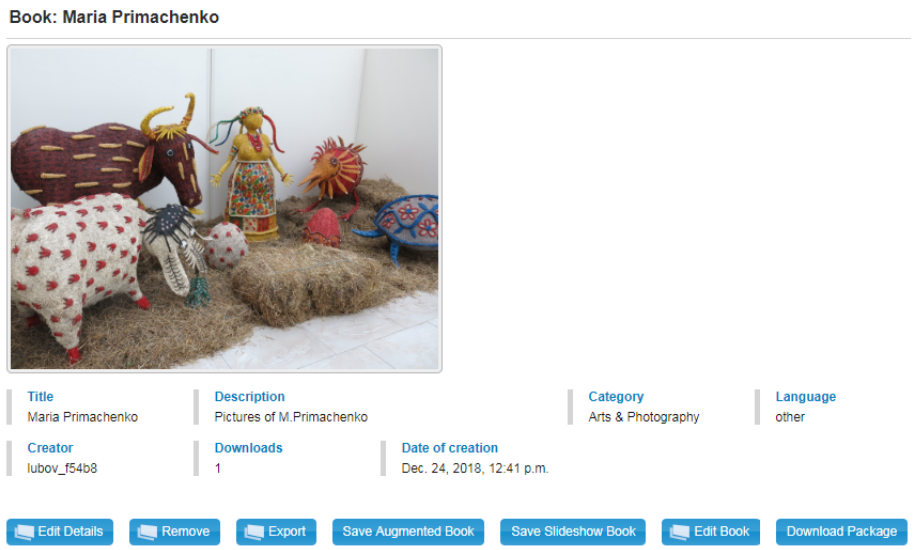


Fig. 1. The augmented book, attached to the story "Invisible" by Maria Primachenko, made during the course

Module 3. In this module the user will build the application, in which a 3D model is added to a city map.

Module 4. This module is about the creation of augmented reality application – geolocalized quiz (Fig. 2).

Module 5. This module is about understanding the ARAF format for quiz and changing the behavior of this application.

The 5th module of the 21st Century Learning course [3] is dedicated to virtual and augmented realities. Students need to learn how to distinguish between games, serious games, gameplay, virtual worlds, and augmented reality. The module demonstrates using games as learning tools and changing people's behavior, as gaming can inspire students; exploring virtual worlds and virtual reality as learning environments; augmented reality as a learning tool for the future. The course uses interesting videos, such as dinosaurs at the mall (from National Geographic [1]).

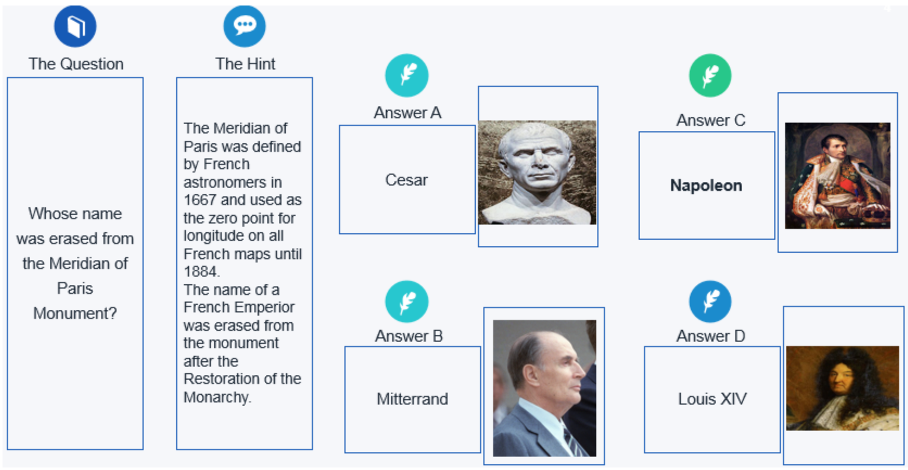


Fig. 2. The augmented reality quiz “Parc Montsouris” [9]

The activity of the students in the course is to participate in the discussion and to describe their personal experience. At the end of each week, one of the developers of the course in the blog summarizes the results of the discussion. In the discussion, students list the applications they worked with, such as Sky Map, as well as zoo burst (http://inform-lider.blogspot.com/2013/10/3d-zooburstcom.html). This course can be categorized as cMOOC.

The second week of the course of the *Internet of Things & Augmented Reality Emerging Technologies* [7] on Coursera platform is dedicated to the augmented reality. Lectures cover the purpose and main functions of the AR. The characteristics and a brief history of virtual and supplemented reality are presented, some definitions of AR; AR technology and directly the process of AR and its stages are given. Tests that check the understanding of the lecture material are offered (Fig. 3).

Thus, the course consists of the following elements: video lectures with built-in questions, tests that help to recall and review the lecture material, a list of further reading, which for the second week of the course consists of only one article, which is indicated as optional [21]. There are no practical tasks in the course.

The Zappar Powered STEM Learning Using Augmented Reality 2016 is based on the use of ZapWorks software. ZapWorks is a complete AR toolkit created by Zappar

[32]. It allows different users to create their own AP experience. ZapWorks includes three tools: widgets, designer and studio. In this online course, a simple "Designer" tool is used (Fig. 4).

The course consists of 9 small simple modules: 1) introduction to the course; 2) what is added to reality; 3) the objectives of the course; 4) introduction to ZapWorks; 5) creation of a ZapWorks account; 6) explanation of the cycle of water circulation (Fig. 5); 7) preparation and planning of the poster; 8) designing a poster; 9) the experience of creating an augmented reality. Each module contains a brief video lecture, its text summary, and tests.

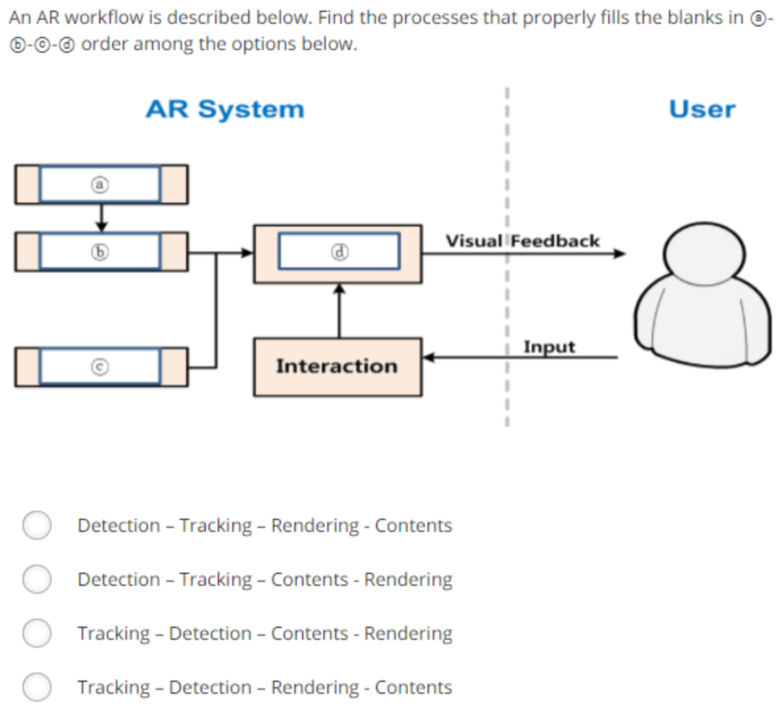


Fig. 3. The test question from "Internet of Things & Augmented Reality Emerging Technologies" course [7]

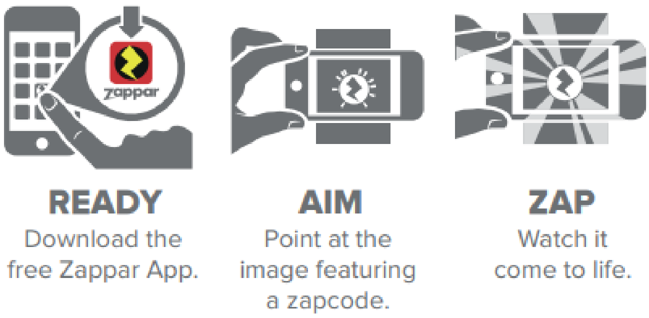


Fig. 4. Augmented reality in the Zappar App [32]

The sequence of creating augmented reality in this course is as follows:

1. choice of own multimedia content and decision on how it will be presented;
2. adding button images, video, links, audio;
3. adding different "scenes" that are similar to slides in PowerPoint;
4. adding conversions so that content is displayed in a variety of ways;
5. adding actions to allow users to interact with the content.

The authors also provided small guidance for 4 lessons on the use of this tool in 5th and 6th grade secondary schools [33].

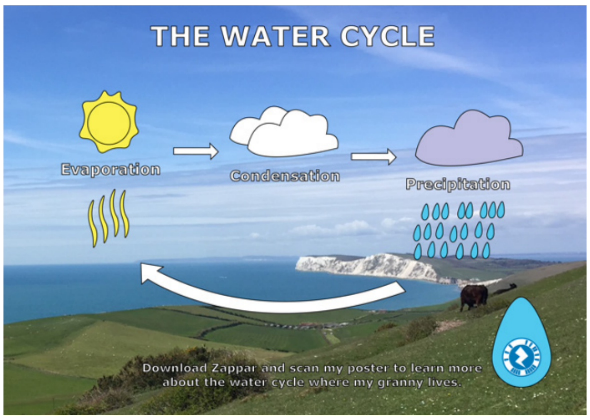


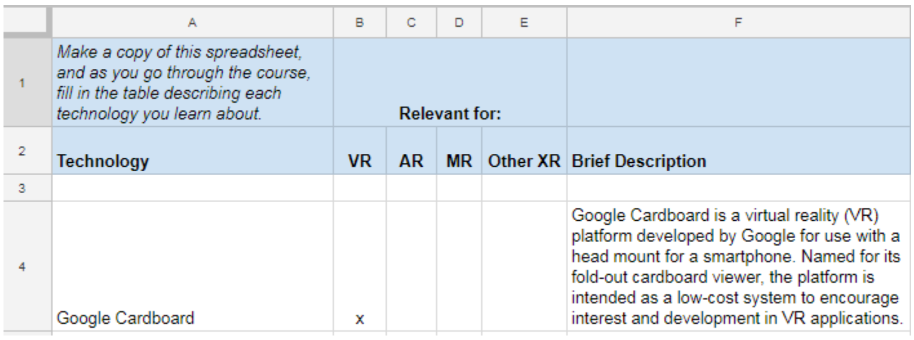
Fig. 5. Module 6 of "Zappar Powered STEM Learning Using Augmented Reality" course [33]

"Introduction to Augmented Reality and ARCore" [11] teach the fundamentals of augmented reality and how to build an AR experience using ARCore. The 4 units of course are: "Introduction to AR", "The basics of AR functionality", "Taking the next steps with ARCore", "Bringing ARCore to life". The course is great for beginners who are just getting started with AR or ARCore. Authors consider advanced 3D design tools like Maya, Zbrush, Blender, and 3ds Max powerful professional tools; and Google's

Poly (repository of 3D assets) can be a good starting resource for building first ARCore experience. In the course next resources proposed: Poly, Tilt Brush, Blocks, Google Development Portal, Unity, Sceneform. The users must fill the spreadsheet and describe the technology they learn about (Fig. 6).

The topics on course discussion forum are: “Looking to the future of augmented reality”, “Understanding AR essentials”, “Thinking about your users”, “Your own AR journey”.

“Introduction to XR: VR, AR, and MR Foundations” [12] is the first of the three planned courses in Unity's XR Specialization. This course is an introduction to XR (AR, VR, and MR), and briefly describes each technology, its history, limitations and future potential for improvement. The users will create two simple applications on their own smartphone: a virtual reality museum and a handheld augmented reality application. The user will brainstorm, define, and visualize their own original concept for an XR application and participate in a peer-reviewed activity. There are peer-graded assignments: brainstorm XR application ideas and XR product brief.



	A	B	C	D	E	F
1	*Make a copy of this spreadsheet, and as you go through the course, fill in the table describing each technology you learn about.*	Relevant for:				
2	**Technology**	**VR**	**AR**	**MR**	**Other XR**	**Brief Description**
3						
4	Google Cardboard	x				Google Cardboard is a virtual reality (VR) platform developed by Google for use with a head mount for a smartphone. Named for its fold-out cardboard viewer, the platform is intended as a low-cost system to encourage interest and development in VR applications.

Fig. 6. The spreadsheet with technology description [11]

In the Table 2 we present some features of Coursera’s MOOCs about augmented reality (as in January, 2019). All of the courses are introduction courses and not oriented towards educators. We think, it’s possible to use the fragments of these courses in the framework of blended education of educators.

Table 2. Course rating

Course	Score	Ratings	Reviews	Year
Introduction to Augmented Reality and ARCore	4,4	495	150	2018
Introduction to XR: VR, AR, and MR Foundations	4,8	6	2	2018
Getting started with Augmented Reality	4,3	133	30	2016-2018

Taking into account the purpose of our article, that is the development of the content of the special course for educators on the use of additional reality in the educational process, we offer the augmented books as a practical component. An augmented book represent a physical or digital copy of a traditional book that contains text and illustrations, and which is connected to additional, non-traditional content through the technology of augmented reality. When the reader accesses the book page for which additional content is specified, the smartphone or other device reads it and displays this additional content on the screen. Additional content may represent a simple image, video file or audio recording, and also be complex, representing animation, play, or interactive activity.

Researches place the augmented books between virtual and mixed reality books on the corresponding reality – virtuality continuum, presented in Fig. 7.

The author module "Augmented reality as a tool for storytelling" consist of next blocks:

- thematic plan of the module (Table 3);
- content of the module by themes;
- lecture plans;
- plans of practical classes;
- independent work of students;
- practical tasks for self-control;
- recommended reading.

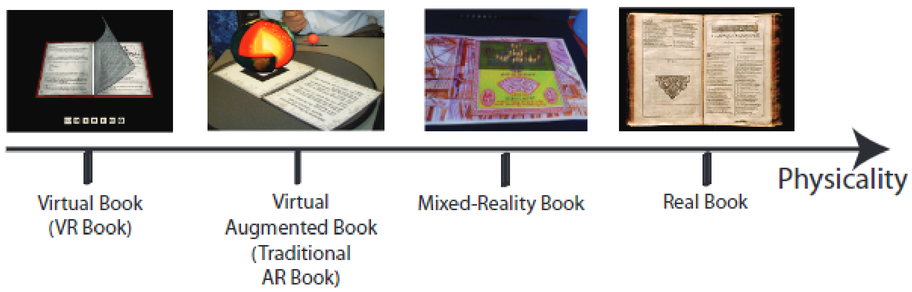


Fig. 7. Virtual book typology [10]

Table 3. Thematic module plan

No	Thematic module	Class format, hours			
		Lections	Practices	Independent work	Total
1	Augmented Reality as a Storytelling Tool	2		2	4
2	Software and Internet Services about Augmented Reality. Augmented books. Augmented books tools.		2	2	4
	Total	2	2	4	8

"Augmented Reality as a Storytelling Tool" lecture plan

Determining reality-virtuality continuum. Virtual reality. Augmented reality. Mixed reality. Examples of application of augmented reality in various industries. Augmented reality in education. Massive open online courses on augmented reality. Tools and platforms used in the augmented reality landscape. Digital storytelling in adult education. Augmented reality as a storytelling tool.

"Software and Internet Services about Augmented Reality" practical training plan.

Motion tracking for augmented reality. Accelerometer. Gyroscope. Phone camera. Location-based augmented reality. Magnetometer. GPS.

Augment Education. Sky Map. Human Anatomy Atlas. HP Reveal (Aurasma). Vuforia, ARToolkit. EasyAR. Wikitude.

Google Poly. Tit Brush. Blocks.

Typology of virtual books. Examples of augmented books. Children's books. Digital stories with augmented reality.

Sample practice tasks for educators:

1. participate in discussion of "Introduction to Augmented Reality and ARCore" course discussion forum in the following topics: "Looking to the future of augmented reality", "Understanding AR essentials", "Thinking about your users", "Your own AR journey";
2. create a sample augmented book about Maria Primachenko's artwork (according to the guidelines of course "Getting started with Augmented Reality");
3. analyze the video about an augmented book from Ukrainian company Live Animations & Little Hippo. The company has released 4 world-famous children's books with Little Hippo: "Little Red Riding Hood", "Three Little Pigs", "Velveteen Rabbit", "Masha and the Three Bears" [16];
4. find and analyze some augmented books according to the professional interests of the student;
5. discuss how augmented reality can help the following: 1) allow student to construct their own understanding or experience in a content area; 2) facilitate collaborative activities in which students work together in small groups; 3) promote in-class discussion; 4) help learn problem-solving and critical thinking skills; 5) help understand complex ideas; 6) introduce student to new content [31];
6. design and create a fragment of their own textbook with augmented reality.

We believe that an augmented textbook is a new educational tool, it can contain fragments of video lectures, electronic pads such as Padlet, augmented quizzes, animated tours in the history of the problem being studied, in-depth exercises, and so on.

We also think that the use of additional reality technology will facilitate the co-creation of students and teachers. We understand co-creation [22] as a joint creative activity of a teacher and a student, aimed at developing the educational environment and ourselves in this environment. Because "the environment begins where their meeting occurs and where they jointly develop or build something" [29].

4 Conclusions

Thus, the augmented reality can provide modern education with new didactic measurements and tools at the teacher and student level, contribute to a better understanding of complex topics, visualize hidden processes, which makes it acceptable for adults and people with disabilities. On the basis of the analysis of the content of the massive open online courses about augmented reality offered by well-known providers of the world, the author's specialized course "Augmented Reality as a Tool for Storytelling in Adult Education" is proposed for the system of professional training and retraining of teachers. The purpose of the special course is to consider and discuss the possibilities of augmented reality as a new direction in the development of educational resources, to identify its benefits and constraints, the components and the most appropriate tools for educators, discuss the problems of teacher and pupil co-creation on the basis of the use of augmented reality, and to provide students with personal experience in designing their own stories and methodical tools in the form of augmented books with the help of modern digital technologies.

The further development of the study is seen in the analysis of the specialty Unity XR on the platform Coursera as well as looking for ways to integrate augmented reality into existing learning management systems.

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Application of augmented reality technologies for preparation of specialists of new technological era

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Abstract. Augmented reality is one of the most modern information visualization technologies. Number of scientific studies on different aspects of augmented reality technology development and application is analyzed in the research. Practical examples of augmented reality technologies for various industries are described. Very often augmented reality technologies are used for: social interaction (communication, entertainment and games); education; tourism; areas of purchase/sale and presentation. There are various scientific and mass events in Ukraine, as well as specialized training to promote augmented reality technologies. There are following results of the research: main benefits that educational institutions would receive from introduction of augmented reality technology are highlighted; it is determined that application of augmented reality technologies in education would contribute to these technologies development and therefore need increase for specialists in the augmented reality; growth of students' professional level due to application of augmented reality technologies is proved; adaptation features of augmented reality technologies in learning disciplines for students of different educational institutions are outlined; it is advisable to apply integrated approach in the process of preparing future professionals of new technological era; application of augmented reality technologies increases motivation to learn, increases level of information assimilation due to the variety and interactivity of its visual representation. Main difficulties of application of augmented reality technologies are financial, professional and methodical. Following factors are necessary for introduction of augmented reality technologies: state support for such projects and state procurement for development of augmented reality technologies; conduction of scientific research and experimental confirmation of effectiveness and pedagogical expediency of augmented reality technologies application for training of specialists of different specialties; systematic conduction of number of national and international events on dissemination and application of augmented reality technology. It is confirmed that application of augmented reality technologies is appropriate for training of future specialists of new technological era.

Keywords: augmented reality, digitalization, professionals training.

1 Introduction

1.1 The problem statement

Current development of digital society is based on improvement of information technologies and their introduction in all industries. In the source [6] term "digitalization" defines process of saturation of the physical world by electronic-digital devices, facilities, systems and establishment of electronic-communication exchange between them, which in fact makes possible to integrate virtual and physical and to create cyber-physical space. Main purpose of digitalization is to achieve digital transformation of existing and creation of new industries, as well as transformation of life spheres into new more efficient and modern ones. Such increase is only possible when ideas, actions, initiatives and programs related to digitization are integrated, in particular, into national, regional, sectoral strategies and development programs [6].

New evolutionary stage of society is called technological era, for which it is important to train specialists who will be competitive and able to quickly master professions of the future. We believe that application of digital technologies, in particular virtual and augmented reality, is important in preparing new technology professionals.

1.2 Literature review

Development of digital tools and introduction of innovation in specialists training in various industries was subject of the following studies: for education [11; 17; 37; 38; 48; 50; 57; 60; 70], for ecology [16; 33; 39; 40; 41; 54], for public administration [13; 46; 47], for energy [4; 12; 24; 66; 67], and others. We emphasize researches aimed at preparation of future PhDs using digital technologies [18; 58; 59].

There are authors who researched and explored various aspects of augmented reality technologies for educational purposes: Juan Acevedo [11], Muteeb Alahmari [1], Faruk Arici [3], Magdalena Brunnhofer [56], Şeyma Caliklar [3], Carlos Delgado-Kloos [19], Dominique Doroszewski [50], Juan Garzón [11], María-Blanca Ibáñez [19], Tomayess Issa [1], Benjamin Knoke [44], S. Zaung Nau [1], Moritz Quandt [44], Dilara Sahin [48], Dominique Scaravetti [50], Sabrina Romina Sorko [56], Pelin Yildirim [3], Rabia M. Yilmaz [3; 48] and others. In Ukrainian educational theory and practice the problems of development and use of augmented reality technologies are researched by: Vladimir N. Soloviev [30; 45], Serhiy O. Semerikov [31], Oleksandr V. Syrovatskyi

[60], Yevhenii O. Modlo [35], Yuliia V. Yechkalo [61; 65], Snizhana O. Zelinska [68], Nataliia Honcharova [14], Iryna S. Mintii [63], Maiia V. Marienko [55], Mariya P. Shyshkina [38] and others. However, there is a need for further in-depth research on application of augmented reality technologies to train professionals in various specialties, and in particular, future PhDs.

1.3 The aim of the research

The aim of the research is to analyze features and best practices of augmented reality technologies to train new technology professionals.

2 Research results

We agree with [6] that digital technologies are both a huge market and an industry, as well as a platform for the efficiency and competitiveness of all other markets and industries. Development of most analog systems becomes impractical in the new technological era with existence of a digital alternative. Principle of “digital default” means digital conversion of those analog systems whose development and support are clearly disadvantageous and inefficient. It is digital state that becomes normal state of functioning and development of many systems, spheres, organizations, industries and economies. High-tech production and modernization of industry through digital technologies, scale and pace of digital transformation must be priority for economic development. Digital economy sectors grow faster, cheaper and better. Life spheres, including education, medicine, transport, which are being upgraded by of digital technologies become much more efficient and create new value and quality [6].

Virtual and augmented reality technologies occupy an important place in the new stage of innovative development of the society, named Industry 4.0. These technologies posses both common and distinctive features, which are reflected in the specifics of their use by companies in process of relevant products creation. Virtual and augmented-reality technologies involve creation of thematic visualized content that can be used by intended audience to meet specific needs through modern electronic devices. Presented technologies are implemented in production processes, in marketing companies, in medical sphere, in educational processes, etc. In Ukraine, virtual reality technology is more common than augmented reality [9].

Humanity has confronted with a problem called cognitive overload with caused by advancement of digital technology and the overall digitalization of social life. Situation in which number of required operations to perform a person’s brain exceeds his capacity. Augmented reality (AR) is technology that can unload human brain, release some of its cognitive effort, and help optimize its use. According to [43] every year business loses up to $ 900 billion through loss of employees’ ability to make decisions, process information, and prioritize tasks [53].

In the work [9] it is emphasized that AR technology has significant potential for implementation, in particular in educational process. Visualization of teaching materials during the classes provides an opportunity to increase level of communication with students, enhance their activity and promotes better learning of material. In these circumstances, there is a need for comprehensive study of opportunities available for introduction of AR technologies in higher education institutions in Ukraine.

AR is a group of technologies that allow you to complement real-world images with different objects in virtual environment. Unlike virtual reality (VR), which involves a completely artificial synthesized world (video series), AR involves integration of virtual objects into natural video scenes [23]. Fig. 1 presents a scheme of AR environment.

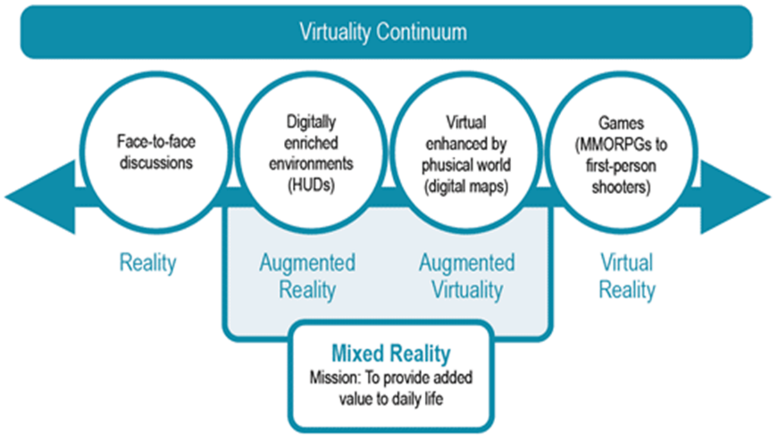

Fig. 1. Scheme of AR environment [29]

The research [20] defines concept of "AR" as "technology that allows to combine layer of virtual reality with physical environment. This technology is necessary for visualization of objects or visual supplement of printed products – newspapers, booklets, magazines, maps, etc. Supplementary information can be in the form of text, images, videos, sound, three-dimensional objects. Labels are scanned using tablets or smartphones for browsing, and then content is added". This technology is already actively used in various fields of human activity (trade, advertising, games, entertainment, military development, tourism, etc. [20].

Implementation of such AR technology is required to improve user-friendly interface of rendering of three-dimensional objects using hardware and software. Computer-aided real-time digital data is added to observable reality to complement our knowledge of our environment. Blurring of terminological boundaries leads to notion that such concepts as "mixed reality", "hybrid reality", "immersive VR", "programmed reality" are often synonymous, which on the one hand states about need for further theoretical study of application of AR technology in transport logistics, and, on the other hand proves practical importance of these technologies, as it is predicted significant increase in revenues from application of AR in various sectors of the economy [10].

Government documents [6] state that it is important now to encourage businesses and citizens to consume and use information and digital technologies, i.e. to make technology accessible in Ukraine. Also digital infrastructures should motivate connection to connect them. Desire to modernize, optimize, scale, accelerate and grow their businesses and livelihoods could be realized and become the backbone of the digital economy. Demand and demand generation implies pursuit of purposeful and innovative policy of creating in various spheres of life conditions (technological environment, digital infrastructures, etc.) that would encourage citizens and businesses to use digital as more efficient, faster instead of the usual analog (traditional) tools and tools cheaper and better.

The rapid development of AR and VR technologies and expansion of their scope led to demand for highly skilled professionals in the field. A number of studies started on development of AR technologies. However, it is important to increase competencies of lecturers and to develop and apply AR technologies in various public sectors. It is also important to share best practices in this field and to prepare educational and methodological materials for higher education institutions based on best practices in the world.

2.1 Experience of AR technologies application in education

Let's consider and analyse researches on approaches to develop and apply AR technologies in educational practice.

The research [60] contains historical and technological analysis of experience application AR tools for development of interactive training materials, software for design of AR educational tools is characterized, and technological requirements for optional discipline "Virtual and augmented software development" are defined, separate components of educational and methodological complex on designing virtual and augmented reality systems for future teachers of informatics are developed.

The article [38] discusses prospects of AR application for cloud environment. It is established that there is an experience of AR tools application in cloud technologies. However, success of such a combination is not proven. Involvement of AR technologies for education requires development of new methodologies, didactic materials, and curriculum updates. Basic principles of AR application in education process are: designing of flexible environment; correction of educational content for assimilation of material stipulated by curriculum; development of research methods that can be used in training with elements of AR; development of adaptive materials, etc.

The publication [30] is devoted to analysis of the current state and prospects of development of AR in Ukraine for business and educational institutions. Experience of AR application in advertising, marketing, education of Ukraine is analyzed; problems in this direction are investigated. Currently, AR is used primarily in the field of advertising and marketing in Ukraine. Problems with implementation of these technologies in education include, first of all, shortage of specialists in preparation of such educational projects and the inconsistent actions of business and education in this area. It is necessary to carry out thematic activities at different levels to disseminate research results.

In the work [52] it is shown that one of conditions for successful scientific and pedagogical work is exchange of methodological materials, including AR application.

It is suggested to classify approaches of placement of methodical materials on closed and open resources. One of the important advantages of closed type is high quality of the methodical material, but it is limited in number of materials and the lack of exchange opportunities. The aim of the research was to analyze approaches to systematizing methodological materials using AR and to recommend using stemua.science for their systematization. It is shown that stemua.science allows lecturers to develop education material and place it on this platform. The platform automatically organizes methodological material in the database. Therefore, the platform meets the methodological needs of Ukrainian lecturers in material using AR in school education. Lecturers and methodologists are encouraged to provide development and methodological materials using AR and to add them to platform database.

Research [15] is aimed at theoretical substantiation of application of AR technology and its features in technical universities. Scientific publications are analyzed and concept of AR is defined. Application of AR objects in laboratory practical work in physics is proposed. The following conclusions are made: introduction of AR technologies in educational process at technical universities increases efficiency of education, promotes education and cognitive activity of students, improves quality of education, provokes interest in subject, promotes development of research skills and competencies of the future specialist.

In the research [14] classification of AR technologies for education is proposed and examples of AR cards, encyclopedias, fiction and educational books, tutorials, textbooks, coloring books that provide for the use of AR technology are described, and AR applications for education are described.

Collective study [3] shows trends of scientific publications in recent years. Content analysis is performed and bibliographic results of descriptions of articles related to the use of AR for educational purposes are analyzed. For the analysis, 147 scientific articles published in printed editions and 79 electronic articles on the Internet published in the period 2013-2018 were found. 62 articles were selected for detailed analysis. The results of the analysis showed that the most common keywords in the articles are mobile learning, e-learning. The most used words in the abstracts of articles were: education, knowledge, scientific education, experiment and efficiency. The most cited journals are Computers & Education, Journal of Science Education & Technology, Educational Technology and Society, Computers in Human Behavior, and British Journal of Educational Technology. These are the most famous magazines on application of different technologies in education. Mobile markers and materials based on paper markers were found to be the most convenient type of materials for AR, since these types of materials are easy to use and can be easily and practically developed.

In the research [48] investigated the impact of educational materials developed using AR technology on the educational achievement of high school students and their relationship to AR technologies. The study describes results of pedagogical experiment where students were divided into experimental and control groups. The experimental group completed Solar System and Beyond module of their training course using AR technology, while the control group completed the same module using traditional methods and textbooks. It was found that students in the experimental group had higher level of achievement and more positive attitude towards the course than in the control group; the students were pleased and wanted to continue using AR applications in the future.

The study by [50] focused on the application of AR technologies in higher education. It is noted that virtual representations are quite widely used in higher education to visualize design or simulation model. However, many students have difficulty understanding mechanical systems, starting with a two-dimensional design plan. That is why real system manipulations related to different ideas was implemented, especially for students who do not have technological skills. AR can answer difficulty of establishing a connection between the imagination and the real system. Since AR technology is still not fully used in the pedagogy of mechanical design an assessment was made and relevance of AR technologies application was determined to facilitate understanding of creation of different mechanisms. The AR script is implemented on electromechanical mechanism. It makes possible to identify components and their location, to study mechanism, and thus to make it easier to identify, for example, a kinematic circuit or a flow of transmit power. Two different interfaces were used by students (tablet and HoloLens glasses), each with its own advantages. The experiment was conducted by students of technical specialties. The results of experiment showed that students who used AR technology had better learning outcomes.

Existing scientific literature reflects the multiple benefits of integrating AR technologies into educational programs. [11] stated that most publications do not measure the impact of this technology on education. Therefore, an analysis of 64 scientific papers published in the period from 2010-2018 in well-known journals was carried out. The purpose of the study was to analyze the impact of AR on students' knowledge acquisition. The study analyzed the impact of AR technologies on the learning environment and the results of student assessment.

Traditional higher education methods, such as lectures, seminars, homework form required basic set of competencies, but they should be complemented by new interactive forms of education. These technologies allow student to be more immersed in educational process and motivate to self-education and contribute not only to obtaining necessary knowledge in subjects, but also to improve communication and organizational skills. Methods for joint solution of certain problems ("brainstorming", role-playing and didactic games, discussions, etc.) should be highlighted among methods of engaging students in interaction with lecturers and with groupmates [36]. Degree of students' involvement in educational process and efficiency of this process largely depends on availability and convenience of technical devices used by students. Interactive technologies that can be used in the educational process include: computers, mobile devices (smartphones, tablets), electronic devices (smart watches, fitness bracelets, etc.), virtual and augmented reality devices (glasses, helmets). Application of mobile devices and AR/VR devices has both advantages and disadvantages. Their use in educational process can improve academic performance [36].

The team of authors [60] emphasized that it is advisable to use integrated approach during professional training of future informatics teachers to develop interactive teaching materials. In this approach, design is performed using standard objects. It is performed in visual design environment with provision of standard objects with new properties and creation new ones. At the current stage of digital development, it is advisable to share the Unity environment for visual design [21], Visual Studio or similar programming environments, as well as virtual (Google VR or similar) and augmented (Vuforia or similar) platforms. Integrated approach is implemented within optional course "Development of virtual and augmented reality software" for future computer science teachers, which consists of two content modules: "Development of virtual reality tools" and "Development of augmented reality tools".

The study [19] presents review of literature on the use of AR technology to support education, science, technology, engineering and mathematics. 28 publications for the period 2010-2017 are reviewed. Results of the analysis: Most AR applications for STEM training offer research simulation activities; programs under consideration offered number of similar features based on digital knowledge discovery mechanisms for consumption of information through interaction digital elements; most studies evaluated effect of AR technology on student learning outcomes; little research with recommendations to assist students in learning activities. Researchers should develop guidelines and features that will allow students to acquire basic competencies related to the STEM disciplines. It would be useful to explore how learning with AR technology can be part of blended learning strategies such as "upside-down learning".

Technological advancement through digitalization provides basis for new format of human life. Orientation to future of work, automation and digitization of many technological processes led to modernization of jobs, especially in the industry. It changes requirements for employees (acquisition of new digital competences). Different technologies, in particular, AR can be used to support employees in developing the required competencies. Potential of AR technologies to address identified issues was analyzed. Potential of AR as innovative learning environment that can be applied to different cases is revealed. It is defined what teaching and learning goals can be achieved through application of AR technology in learning [56].

Rapid development of AR technologies and expansion of their scope led to demand for highly skilled professionals in field. The research [22] provides an overview of current AR teaching practices. This review is aimed at teachers, academics and policy makers to inform them about teaching methods, learning goals, assessment criteria, and required knowledge, skills and competencies in AR.

AR applications are used in industry. Applications are often seen as standalone solutions, applicable only under defined and static operating conditions. This contribution meets general requirements for AR applications with two examples from industrial context: developed assistance system for AR-based wind energy maintenance and an AR-based welding simulator for training purposes. Possibility of applying these general requirements in the context of case studies is critically described. Specific requirements can be specified for AR applications that are caused by product and process differences, operating conditions, data connectivity issues, and media literacy and technology adoption. Approaches to meeting requirements for successful application of AR solutions in industrial scenarios were identified [44].

2.2 Examples of AR technologies application in various fields

AR technology has great potential for many applications. AR applications have been used for many years for medicine and military purposes. We describe various practical examples of the AR technologies application for different industries.

In the article [26] algorithm of work of AR technology is presented. It is shown in Fig. 2. Its essence is following: camera of mobile device reads image containing tags (markers) and transmits video signal to computer (smartphone, tablet). Special program processes received signal (recognizes markers) and overlays virtual object on screen of real object. Texts, sitelinks, photos, three-dimensional elements, sounds, videos, and more can be used as virtual objects. The most common ARs are QR codes, augmented reality browsers, auras. All these technologies have following characteristics: they complement real world with virtual elements; add-on happens in real time; addition must take place in three-dimensional space.

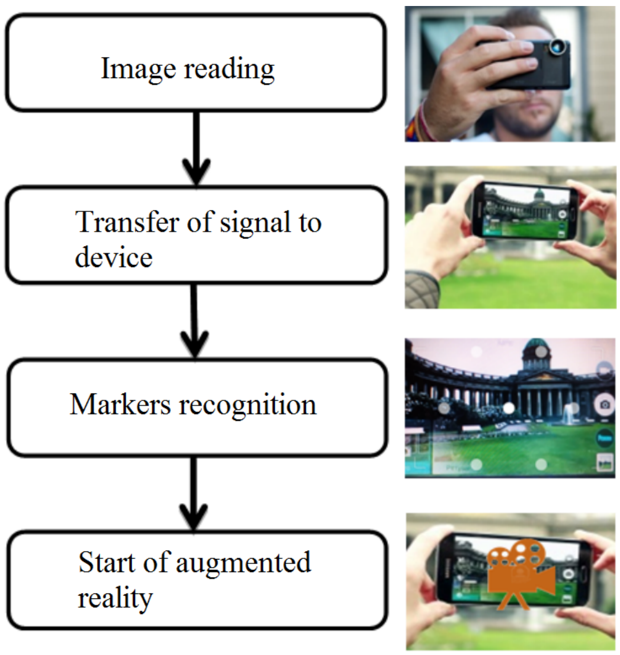

Fig. 2. Application algorithm of augmented reality technologies [26]

It is possible to project digital information (images, videos, text, graphics) beyond screens of devices and integrate virtual objects with the real world with AR technology. Pokemon GO is a prime example of AR technology. AR technology can be used for leisure, games and professional activity. It helps to navigate in unfamiliar places and sometimes unknowingly change our appearance. Device processor, screen and its camera will be used to combine virtual objects and elements with real objects. Device must have a GPS sensor and an accelerometer. It's easy to use AR. You just have to point camera at the right place and result will appear on the screen. It could be text, animation, a 3D object, or something else [53].

In today's context, smart technologies should be one of the main topics of research. It is important to meet needs of society through means that do not harm environment and do not deplete natural resources [7; 16; 32]. AR technologies can be useful tools to help modernize higher education [69]. The study [1] analyzed potential benefits of AR technologies application at Saudi universities in terms of its economic and environmental component. For this study, quantitative data were collected using a questionnaire. The study involved 228 Saudi students. Factors related to awareness of benefits of AR application in education were identified (Fig. 3). Two factors were identified, namely environmental and economic factors. Results of study indicated that Saudi staff believes that AR application in higher education has positive environmental and economic benefits.

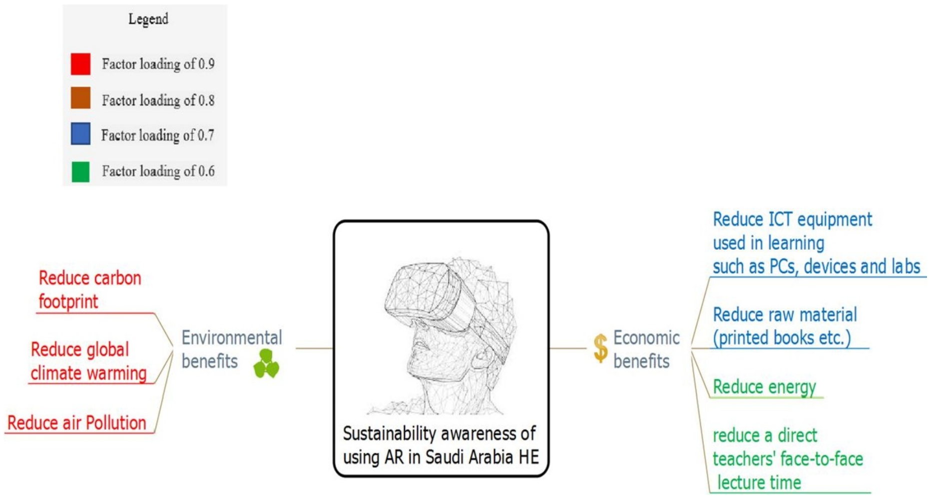

Fig. 3. Factors related to sustainability awareness of using AR in Saudi Arabian HE [1]

The work [49] states that the US Navy tests use of Magic Leap One AR glasses for personnel training. A system called is TRACER. It was specifically designed to decipher tactically reconfigurable artificial combat enhanced reality. This system includes directly Magic Leap goggles attached to processor in a backpack behind the back, a mock-up of a weapon designed by Haptech (formerly known as StrikerVR) that supports firing recoil, a hand tracking system, and special software which provides different simulation scenarios. Big plus of virtual training – it becomes less predictable for participants, and it allows you to create scenarios for learning much faster and cheaper than learning in the real world [25; 27; 34].

NASA contractors use Microsoft AR HoloLens augmented reality goggles for quick and correct assemble of Orion spacecraft items. Lockheed Martin (an aerospace engineer) uses the Microsoft HoloLens AR glasses to assist in assembly of cockpit capsule. It saves considerable time, since there is no need to read thousands of pages of paperwork for preparation and production. Engineering personnel began using AR equipment daily to perform their current job responsibilities. Experts can see holographic models of spacecraft layout that are designed for engineering design with the help of special Scope AR software. Virtual parts models and marking schemes visually overlap with already assembled parts of the design [64].

Augmented Reality APP – Chornobyl NPP ARCH AR was officially launched in 2018. According to the State Agency of Ukraine on Exclusion Zone Management, this application allows you to visit new safe confinement on your smartphone and take a closer look at the arch and shelter design. With this tool you can view all details up to size of exhibition stand. It is possible to get a real picture of little things of the Shelter without risking human health [8]. Figure 4 shows an example of how this app works. In the future, applications of this type may be used to increase efficiency of emergency preparedness and response system and emergency situations on potentially hazardous sites. New methods, approaches and information systems need to be developed to meet the challenges of emergency prevention. These systems should be based on adequate mathematical models for development of different emergencies and meet current requirements in the field of civil protection. The authors of this publication started work in this area, and main results are shown in [16; 39; 40; 41; 54].

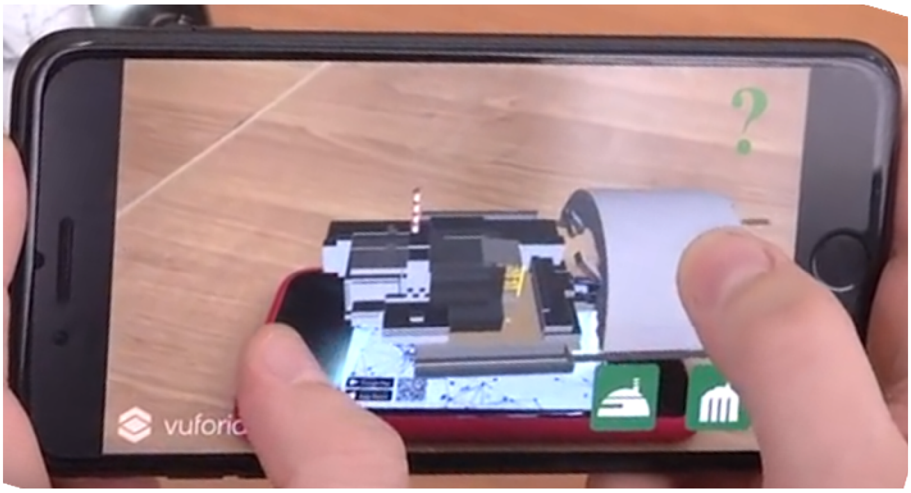

Fig. 4. Example of the application (Chornobyl NPP ARCH AR) operation on smartphone

After analysis of the scientific literature [1; 14; 38; 60] and publications on the Internet [8; 53] it is determined following areas of AR application:

1. *Social interaction: communication, entertainment and games*. AR technology is actively used for entertainment because it is possible to bring and interact with fun objects in our day to day life. Many developers are actively working on mobile games using AR. Use of electronic social networks for communication is now very important attribute of social life. AR technology is an aid. It uses variety of animated

characters that replicate our looks and can convey our emotions incredibly accurately.

2. *Education*. AR technologies application can significantly revitalize educational process and make it more interesting.
3. *Tourism*. If you do not know language and do not understand signs or pointers in the street, you can use AR technology. You need to point camera at pointer with unfamiliar text. Then the text is converted and translated into the desired language. This will greatly improve comfort of being in different countries.
4. *Buying/selling and presentation spheres*. AR technologies can be applied to visualize materials. For example, designer shows to customer how apartment will look with particular collection of furniture. Advertising agent demonstrates all benefits of product to customer. At the same time AR allows creation of presentations in 360° mode. It is possible to get acquainted with the project from all sides. To buy goods online, AR technology gives us the opportunity, from all sides, to consider what we want to buy, to get acquainted with the design and all the nuances [53].

2.3 Promotion measures for AR technologies

Currently, there are various scientific and mass events conducted in Ukraine. They include specialized training to promote AR technologies, in particular:

1. “Augmented Reality in Education” is an international peer-reviewed workshop on computer science that looks at results of augmented reality research in education. Scientific areas of the seminar: augmented reality gamification; design and implementation of augmented reality learning environments; mobile technology of augmented reality; aspects of environmental augmented reality security and ethics; augmented reality in science education; augmented reality in professional training and retraining; augmented reality social and technical issues [2].
2. “Sensorama Academy” was founded in 2018 by the Sensorama team with support of Lenovo Ukraine and UNIT.City. The purpose of the Academy is to develop a community of augmented and virtual reality developers. Lectures, workshops and courses are held with involvement of local and international specialists. Education at Sensorama Academy is free of charge after competitive selection of students. Successful selection requires prior development experience, as well as motivation and interest in immersive technology (VR/AR) [51].
3. Sumy State University actively introduces AR technologies in the courses “Descriptive Geometry”, “Engineering Graphics”, “Computer Graphics in Mechanical Engineering” [**Ошибка! Источник ссылки не найден.**].
4. “Distance Academy” offers number of paid courses: “Learning of Natural Sciences Using Augmented Reality Technologies” and “Gender Sensitive STEM - A Lesson Using Augmented Reality Technologies”.
5. “IT future school” is an online school of programming for children from 8 years. Course “Unity 3D Programming” includes AR unit. As result students: will understand basics of programming and creating algorithms in C# programming

language; will be able to create 3D models of game characters and true 3D worlds; will understand principles of computer software development and the key elements of the game; will master stages of computer game development: genre, engine choice, game design, production, testing, release; will be able to use professional platform to create Unity 3D games [42].
6. There was a master class on programming of augmented reality of football training of students in format of “Meet and Code” initiative of the EU Code Week at the Institute of Computer Systems of the Odessa National Polytechnic University in Odessa in October 2018 [28].
7. In 2018 the Google launched a free course on Coursera. In this course you can acquire basic knowledge of AR technologies. Coursera is technological company operating in the field of education; founded by Stanford University professors Andrew Ng and Daphne Koller in April 2012.

However, it is important to carry out series of national and international events on the dissemination of AR technology.

3 Conclusions and prospects for further research

1. Experience in AR technologies application. Scientific literature describes some experience in AR technologies application in various fields, in particular for educational purposes:

- it highlights main benefits that educational institutions will receive from introduction of AR technology;
- it determines that AR technologies application in education will promote development of these technologies, and therefore demand of specialists in AR field;
- it proved professional growth of students due to AR technologies application;
- features of adaptation of AR technologies in teaching discipline for students of different educational institutions are outlined;
- application of integrated approach in process of future specialists preparation of new technological era is advisable;
- AR technologies application increases motivation to learn, increases level of assimilation of information due to variety and interactivity of its visual presentation.

2. Difficulties in AR technologies application:

- financial: expensive equipment and lack of high quality programs;
- professional: small experience of this technology application by lecturers/teachers and the need to increase competencies in this field;
- methodical: lack of literature, including textbooks/manuals with AR technology, and lack of developed techniques for developing and implementing AR technologies in various fields.

3. Prospects for AR technologies application. AR is one of the most up-to-date information visualization technologies. State support for such projects and

government procurement are urgently needed because creation of small AR application requires several specialists. There is a need for number of scientific studies and experiments to confirm efficiency and pedagogical feasibility of AR technologies application for use in training of future professionals of new technological era. Use of this technology has positive effect on competitiveness of the national workforce and contributes to the country's position in global economic space. It is important to carry out series of national and international events on dissemination and application of AR technology.

Areas of further research should focus on exploring of AR technologies application in advanced training, preparation of students and future PhDs.

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Use of simulators together with virtual and augmented reality in the system of welders' vocational training: past, present, and future

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Abstract. The article discusses the theory and methods of simulation training, its significance in the context of training specialists for areas where the lack of primary qualification is critical. The most widespread hardware and software solutions for the organization welders' simulation training that use VR- and AR-technologies have been analyzed. A review of the technological infrastructure and software tools for the virtual teaching-and-production laboratory of electric welding has been made on the example of the achievements of Fronius, MIMBUS, Seabery.

The features of creating a virtual simulation of the welding process using modern equipment based on studies of the behavioral reactions of the welder have been shown. It is found the simulators allow not only training, but also one can build neuro-fuzzy logic and design automated and robotized welding systems.

The functioning peculiarities of welding's simulators with AR have been revealed. It is shown they make it possible to ensure the forming basic qualities of a future specialist, such as concentration, accuracy and agility.

The psychological and technical aspects of the coaching programs for the training and retraining of qualified welders have been illustrated.

The conclusions about the significant advantages of VR- and AR-technologies in comparison with traditional ones have been made. Possible directions of the development of simulation training for welders have been revealed. Among them the AR-technologies have been presented as such that gaining wide popularity as allow to realize the idea of mass training in basic professional skills.

Keywords: simulation training, couching programs for welders training, hardware and software for simulation training.

1 Introduction

In order to make professional preparation more attractive and engage in a new generation of skilled workers, computer-centric technologies, such as computer training devices and simulators, are increasingly used. These are computer applications imitating the behavior of real objects, processes, systems and their interfaces in a variety of conditions. Having gone a long way in their evolution, now training devices and simulators build on the technologies of virtual reality (VR) and augmented reality (AR). They are generally recognized to organize professional training in line with principles of visualization, gamification, task centered and activity approaches.

In the system of training and retraining of qualified welders, thanks to the rapid development and cheapening of computer technology and progress in the field of AR- and VR-technology, machine vision, artificial intelligence systems and whatever, the training simulators are widely used. This makes it possible to increase the efficiency of vocation training by several orders of magnitude in compare with the traditional form of welders training. According to the estimates of flagships this market segment, in particular Fronius, Seabery and others, this allows to prepare certified welders more, then 34%, to reduce the training period by 56%, decrease the cost of laboratory work by 68%, to diminish CO_2 emissions to the environment, to save considerable resources and materials, to avoid physical risks for students in 84% of cases [31].

The programs of welding training that based on simulators are being created and implemented everywhere. Such programs are also patronized by the Ministry of Education and Science of Ukraine, which started 50 modern training centers for qualified welders' preparation. During 2017-2018, they received government assistance on a tender basis for the modernization of the material-and-technical and training resources. By means of this program three vocational education institutions have purchased modern virtual welding devices [41].

Although the problem under investigation couldn't call current, a lot of teachers and masters of vocation training are not well-versed in this field; they insufficiently master of the simulation training with use AR- and VR-technologies.

The ***purpose*** of the publication is to review the most common hardware and software solutions for the simulation training of welders, as well as analysis of the advantages and disadvantages of such training using AR- and VR-technologies.

2 Materials and methods

Should take into account, the performance and quality of welding depend on the used welding equipment, the materials, the welding modes, and last but not least – from the welders' qualification, the level their theoretical knowledge and practical skills, as well as the degree their readiness to be make quick and reasonable decisions. Such qualities are possible to obtain only due to the long-term training. However, this process can significantly accelerate if ones use of the simulators and training devices.

The issues the methodology on working with emulator programs and simulator ones are investigated by Albert A. Azayan [15], Ihor S. Chernetskiy [6], Muhammet Demirbilek [7], Roman M. Horbatiuk [8], Arnold E. Kiv [14], Oleksandr H. Kolgatin [3], Maiia V. Marienko [19], Yevhenii O. Modlo [25], Vitalii Ya. Pazdrii [27], Halyna V. Popova [18], Irina A. Slipukhina [33], Vladimir N. Soloviev [32], Illia O. Teplytskyi [38] and others.

General aspects of the application of AR- and VR-technologies in the simulation studies organization are being disclosed by Victor V. Aulin [1], Platt Beltz [2], Yevhenii O. Modlo [23], Serhiy O. Semerikov [24], Viktoria V. Tkachuk [39], Denis O. Velykodnyi [1], Yuliia V. Yechkalo [36] and others.

The state-of-the-art successes in the design of the ideology of simulation training together with use AR-and VR-technologies have contributed to the development of the theory and methodology of vocational training, which is being developed by Christian Dominic Fehling [9], Mario Heinz [13], Dieter Mueller [26], F. David Rose [28], Lina M. Rubalko [29], Kai Schmudlach [30], Huiying Zhao [43] and others [16].

Well-grounded approaches to the use of AR-and VR-technologies for the design of training simulators in the welding industry are being elaborated by such well-known companies as Amatrol [42], Fronius [11], Miller Electric [21], MIMBUS [22], Seabery [31], Tech-Labs [37], Virtual Logic Systems [40], etc. The developments that have been started by these companies are being widely used for simulation training in a lot of countries around the world. Researches in the area of engineering psychology concerning formation of the most important competencies in qualified welders while the use of these firms' simulators are being carried out by Ryan G. Anderson [4], Alex P. Byrd [4], Siu-Ju Chen [5], Yukang K. Liu [5], Richard T. Stone [4], Yan-Ming Zhang [5] and others. It's determined the prototype and analogue of modern training technologies for welders is the methodology of the simulation training for medical staffs [35].

3 Results and discussion

3.1 Features of the virtual teaching-and-production laboratory of electric welding

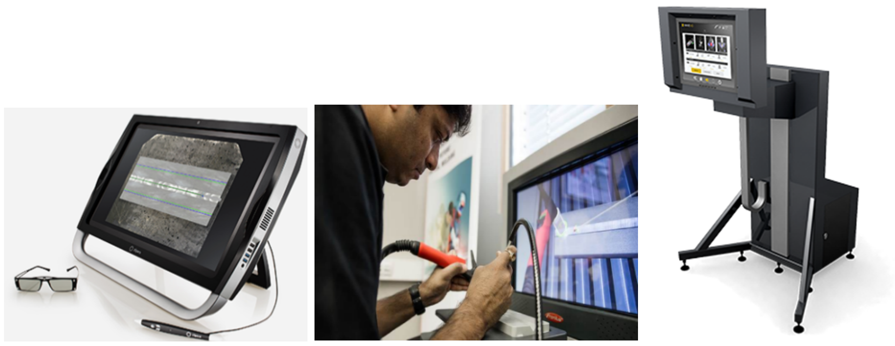
It should make a point that the ***simulation*** is a reproduction of a system or process purely virtually. Typically, imitation refers only to certain properties, capabilities or functions, and in the extent that is necessary within the framework of set tasks. As to the participant of the simulation process, the work is being done by him/her like in actual fact; at the same time the simulator's functional part is virtual either completely or almost completely.

In the medical education system the simulation training signifies an important role as one enables a future specialists to develop their skills and abilities without risk for the patient. Simulation is treated as a technique (but not a technology) allowing either to replace or to enrich intern's the practical experience by means of an artificially created situation. Simulation reflects and reproduces the problems taking place in the real world in a fully interactive manner [12].

Simulation training is a compulsory component of vocational education that uses a model of professional activity. It enables future specialists to carry out their professional activity or its element in line with professional standards and / or rules with the help of "immersing into a particular environment" [35, p. 36].

The equipment kit of the virtual training laboratory allows accelerating the learning process of welding technology (and therefore reducing costs), improving the quality of the specialists' training. These are the computer based systems imitating the welding equipment and tools, as well as typical welder scenarios. The simulators usually build in accordance to the recommendations of the International Program of Welders IWS, the Programs Sense AWS, the German DVS Media, CESOL, etc., and based on American ASME and European ISO standards [22].

On the whole, the wide variety of equipment offering for the virtual educational and production laboratory can be divided into three categories. One is an educational solution (Fig. 1a), another is a transportable industrial solution (Fig. 1b), yet another is a heavy industrial solution (Fig. 1c).



a) b) c)

Fig. 1. Main types of equipment for welding training laboratory on the example of products of companies MIMBUS (a, c) [22] and Fronius (b) [11]

Both the additional means of VR and AR (3D glasses, welder's gloves and helmet) and equipment (torches, rack, table, workstation, coupons, holders and whatever) use in various combinations for realize the assigned tasks of vocational preparation. This allows for virtual welding of various details unrestricted that the protective devices or missing welding equipment can give at the time of work in a real environment.

Fig. 1a demonstrates the capabilities of Z-Space technology. For its implementation, it is necessary to have only a monitor with a touch screen, stylus, 3D-glasses. The software includes a wide range of training exercises by means of a stylus with a view to learning the processes that most commonly use in welding production. There are simulations of Manual Metal Arc (MMA) welding and Metal Inert / Active Gas (MIG / MAG) one in this set. The goal of such a training device is mastering by trainees the theoretical knowledge and development their welder's important qualities, such as concentration, accuracy and agility [22].

Fig. 1b presents an industrial solution with a full set of tools including the capability to Tungsten Inert Gas (TIG) welding and simulating short arc, spray and pulse. There are a touch screen monitor, a welding burner, a surveillance device and a work surface. Most of the known simulators of this type are equipped sound devices for imitation the tones that arising while welding, as well as for the generation of warning signals in the case of improper actions by the trainee. All of this can be located in a lightweight and portable case. Work with the simulator takes place in real time with a burner that completely simulates the welding process. To determine the quality of the welding and the shape of the weld, monitor the position of the burner and the speed of its movement the sensitive sensors are used. Furthermore the system can analyze the dependence of the shape and the quality of the made seam from the input initial parameters of welding [22; 37].

Fig. 1c shows an industrial solution for a virtual training laboratory for welding including all of the options that described above. It is an integrated robot weighing about 200 kg with a computer controlled mobile display; a set of burners and equipment for different types of welding and various positions whiles the work. The system is protected by locks, an emergency stop and an inverter, that enables the trainee to perform a significant amount of exercises autonomously and with significant level of safety [22].

3.2 The simulation of welding with AR-technologies

Prima facie, VR-technology is rather as promising for welders' preparation then AR one. However, AR, using elements of the real production environment and imposing on it a certain proportion of virtual information, can significantly improve the efficiency of simulation training process.

The equipment's kit offering for the implementation of this idea, almost fully simulate the real welding machine. Fig. 2 presents the main elements of this technological solution developed by Soldamatic and Lincoln Electric. As can be seen it includes:

- the real torches with in adapted tip with markers for AR detecting;
- the consumable electrode sticks and torches with grip that have a mechanism imitating electrode's burning out;
- the simulator based on real sources of welding current that made in either mobile or industrial versions; it supports all four manual arc welding process (TIG, MIG, MAG, MMA);
- the AR helmet, it is an analogue of a real welding mask that can reflect the surroundings of your welding space as well as simulate the future result;
- the PVC coupons to simulate work with different welding surfaces;
- the torches to perform high-quality welds of the type Gas Metal Automatic Welding (GMAW), Gas Tungsten Automatic Welding (GTAW) and Submerged Metal Automatic Welding (SMAW).

The system can also include volumetric models for simulating welded joints and welding positions, a display, a torch tracking system, an audio device for simulating sound, and whatever. Thanks to ergonomic welding torches and typical details of the simulator's kit, one can safely learn welding while use different parameters. The four functional packages that supply with kit allow one to work through four process options – TIG, MIG, MAG, and MMA [11].

The control center is provided access to several functions, such as: a welding track; distance between sheet steel and nozzle; the speed of the welding, the orientation and the welding angle, the time of the exercise. During operation by means of the electromagnetic field and sensors the device transmits the direction of the torch, the distance to the product and even weak hand movements. An additional sensor on the AR Helmet makes it possible to see the product in all angles on the touch screen or 3D-glasses. In the end, one can analyze the result obtained by evaluating the length of the welding arc, the speed of the welding passage, the angle of inclination during the welding passage, the angle of the torch, the distance to the workspace, the pores into the welded joint, the burrs during welding, the cuts, the etching, the welding of the root and whatever [37].

a) b)

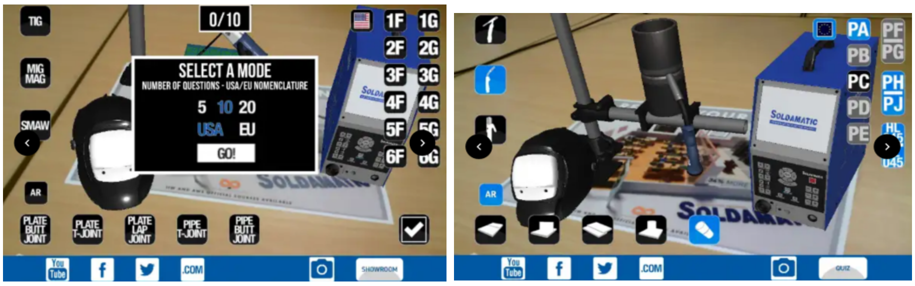
Fig. 2. A set for the organization of Augmented Training by Seabery (a) and Lincoln Electric (b), [31; 37]

At the moment, AR-technology in the training of welders are widespread to mobile applications, and, take note, in most cases, they are either free or conditionally free. The apps can run on an ordinary smartphone, a tablet PC, and so on, it is enough so that this gadget has a reader device and a touch screen.

Soldamatic AR is a freeware app to test the theoretical knowledge of welders offering by the Play Market (show Fig. 3). To attach an AR to the surface as a marker one can use whatever, even a business card.

As you can see, it almost simulates the equipment that was given on Fig. 2a. Thanks to AR-technologies it is possible to see on the gadget's screen the various types of welding equipment, to consider it from different sides, to simulate the work fully with a real welding machine, as well as to check the theoretical knowledge of three topics (types of welding, types of welding joints, spatial position of the welding unity).

In the upper left angle of the Fig. 3a you can see symbols of welding types: TIG, MIG / MAG, MMA. Below them AR cursor is presented, if you are touching it, the markers are added to the product. The following one can see the types of welding joints, such us: butt, T-shaped, lapped, pipe-plate, pipe-pipe ones. In the upper right angle in Fig. 3a there are marks of the standards of the spatial position of the welding.



a) b)

Fig. 3. Soldamatic AR Dialog Box

Welducation basic is a free game virtual welding simulator developed by Fronius. It can help arranging work on training and controlling knowledge of welders.

The simulator offers like variants for work the AR- or 3D-technologes. In any case the Fronius logo is a marker for fixing the augmented reality.

As you can see from Fig. 4, the menu on the choice of welding connection is offered on the right side. App's menu proposes: bead on a plate, fillet and single weld. As soon as user has chosen a type of welding connection in the next window a burner simulator will appear and one will be able to start simulating the welding process. Over and above the app offers 50 questions with four variants of answers that to be solved for a certain period of time.

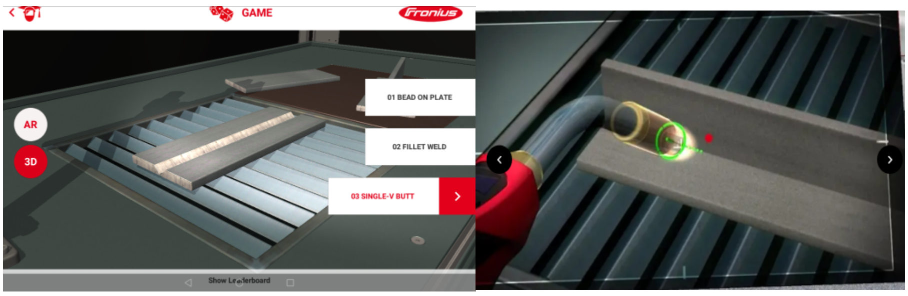


Fig. 4. Work in Welducation basic in simulator mode

Unfortunately, within the publication it is impossible to disclose all the existing proposals from producers for the organization of welders' simulation training based on AR-technologies.

Far-reaching prospects in this area are discovered in using SMART-glasses technologies. These glasses are equipped with technical features that provided by the processor. Ones can be manage in several ways, including buttons, sensors, voice or gestures, or using a connected smartphone and others devises. They are also able to perform various manipulations with the incoming information, as well as record and transmit information through the Wi-Fi system. As you understand, this is only the beginning their development way [20].

The device weighs about 400 grams and it is fully compatible with the existing analogues in its own technical and software characteristics. The glasses are completed with several 120 degree cameras, screens, microphones and speakers that facilitate the transfer of the enhanced image AR and create a natural sound effect from the object [20].

According to experts mean these devices or their analogs may be about to squeeze smartphones out of the market and make significant changes to the ideology of simulation training. What's more, we understand that technologies AR that implemented by virtue of mobile devices and smart-glasses have become a serious alternative to Z-Space technology in the welders' preparation process.

However, it should be noted the simulation training to be carried out according to a certain methodic and its structure must not depend on the type of used equipment.

3.3 Augmented training as a comprehensive educational and technological solution

The creation of welder simulators and building on their basis training programs using AR- and VR-technologies has become the answer to the issues naturally occurring in the vocational training process. As it is known, welding is a harmful high-temperature procedure which with the formation of molten metal spray, with ultraviolet radiation and with the evolving of welding smoke and aerosols. During a training process a lot of samples are being processed that need to be further disposed of, furthermore the materials and energy are being consumed. At the same time there is a lack of qualified instructors for training and retraining of welders [11].

The ***welding's simulator*** is a device imitating of movements of a welder during welding that shows the welding process and the obtained outcomes [37].

As soon as the AR-and VR-based welding simulation launch, a lot of steps have been taken to improve hardware and software solutions for simulation training. The main achievements in this direction are the creation of the most realistic three-dimensional weld pool and human welder response models that were built by observing the actual work of the welder. Researches in this area of expertize have been realizing around study of the reactions of welders and the work of automated welding systems, which are able to change the parameters, whiles the process, depending on the type of the weld pool [4].

Investigators of this problem have discovered and originated a neuro-fuzzy logic of the human welder behavior, and compared reaction an experienced welder with it reproduction by automated welder machines. Due to this fact the machine algorithms were created that can manage a simulation training through feedback systems. Initially, the visual feedback devices were made for VR trainers, but they were not as effective for vocational training as a systems basing on vibration sensors on the welding helmet. It is these devices that have made it possible for trainees to immerse themselves in a VR environment and organize simulation exercises [4; 5].

All companies offering hardware and software for simulation welding training formulate their proposals on a modular basis. This approach allows, first of all, to consider carefully all the pros and cons, to selection the most necessary equipment and software, to save money, to create a long-term plan for further equipping the training virtual laboratory, and, at the end of the day, to choose the most appropriate training programs.

Soldamatic's ideologues and managers have been given a definition of Augmented Training as a comprehensive educational and technological solution that are implemented a new paradigm of professional, technical and production training, using innovative technology, resources and techniques based on simulations with VR and AR, and exploring their management (Fig. 5) [31].

Fig. 5. Soldamatic Augmented Lab [31]

The simulator is built on the implementation of a task-oriented approach in training and contained a powerful library of exercises that designed for any equipment, welding systems or their subsystems. It is a reliable tool for analyzing and evaluating performance of typical exercises, which enables monitoring of the effectiveness of the trainee's work [31].

The simulator cover a wide range of tasks, such as: forming of effective welding skills for beginners and either improvement or acquisition of new skills in certified staffs; adaptation to the specific production of new welding technologies; receiving qualification requiring for the operation and programming of automated and robotized welding systems [37].

In general the technology of simulation training consist five consecutive stages [35, p. 38-40]:

1. It is entrance testing. According to its results, a program and a training route for the welder are formed.
2. It is briefing that conducted with the analysis of theoretical material and fixing the "key" provisions.
3. Work with computer training devices and simulators.

Supposedly the choice of simulation technique is mediated by the trainee's previous practical experience as well as a set of procedures that welder would like shaping. In welders' vocation training it can be used the following leading systems, such as: objective, operational, motor-training, subject-operational (complex) and design-technological ones.

The work takes place in *two stages*. The *first stage* is a theoretical training mode consisting of 3 sections. The so-called “Ghost”, a virtual teacher, gives a piece of advices to trainee. In this manner the best technique for performing the exercise is indicated. The Ghost presets the optimum welding speed, the distance to the workspace and the angle of inclination of the welding torch. The colored signals on the screen, similar to the signal of the traffic light, and the realistic welding sounds show to trainee the current status of the process, fixed the errors and / or correctly performed actions. The visualization of the welding process and trainee’s hands can be traced on the built-in touch screen as well as to broadcast in a larger format through a projector or a TV screen. In this mode the corrections in welder’s actions can be made [11].

The *second stage* is a simulation that includes 2 sections. Initially, the beginner trains to perform welding in the real situation – unassisted of so-called Ghost, a virtual coach. Then the trainee himself may be about to set the necessary parameters (Fig. 6). This well-designed learning structure always provides the high results [11].

Fig. 6. Fronius simulator menu [11]

Depending on the composition of the procedure that forming, the simulator can provide a consistent execution of exemplary action at a slowed pace; then to fulfilment it at a natural pace with a demonstration of speed and correct execution. Finally, one arranges a series of exercises for working out simple abilities and their automation. After skills’ shaping in, usually tasks are offered; they based on the most probable professional situations and made in order to include a new skills in the spectrum of already formed competences and their transfer to new non-standard situations [17; 10].

4. It is Debriefing. On this stage the welding quality and fixedly attached of levels process can be analyzed and verified. The simulator can detect the welding defects

and establish their causes, to reproduce the movements of the torch during simulation and to save data. The training process can be printed, if necessary, for evaluation by an instructor or whoever (Fig. 7). The system evaluates the welder’s skills basing on five welding parameters; these are position, arc length, work angle, travel angle, and travel speed [34].

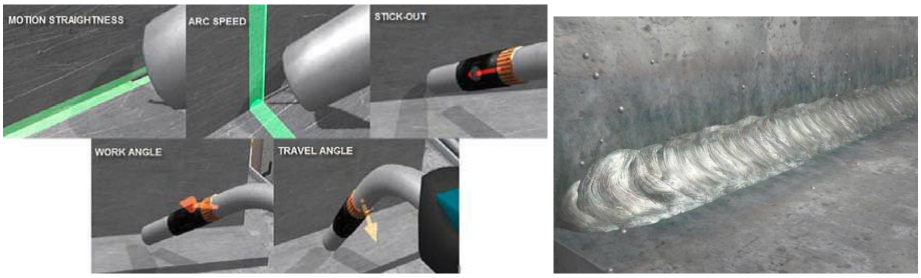


Fig. 7. Possible results of debriefing [34]

5. It is summing up of work and the test control. As has been shown in a lot of investigations the objective system of estimation of welding within the limits of simulators is developed allowing estimating actions of the trainee under certain parameters. The program automatically generates a score sheet including an assessment of each trainee’s individual performance. It allows getting information about that must to be repeated and that to be focused on [34].

This system also enables to compare trainees’ grades and track their skills upgrades.

4 Conclusions

Simulation is a technique that allows either replace or to enrich the trainee’s practical experience with the help of an artificially created situation reflecting and reproducing problems that take place in the real world in a completely interactive manner [12].

Simulation training is a compulsory component of vocational training that uses the professional model to enable everyone to perform actions effectively and productively and in accordance with professional standards by means of immersing in a specific environment [35, p. 36].

For one’s turn simulation training founding on AR- and VR-technologies has a number of advantages. It allows improve the educational process, to accelerate the transfer of knowledge and experience, and also to take up to new qualitative level the vocation preparation and retraining of welders, to facilitate one the process of transition to other types of equipment and technologies.

Simulation training technology in generally consists of five consecutive steps [35, p. 38-40], such as: Initial testing → Briefing → Work with simulators and simulators → Debriefing → Summary of work, test control.

In this time welding simulators are complex systems of visualization, imitation and simulation including both computer programs and physical models, based on special methodology. The simulator trainings and the coaching programs are oriented both on the development of trainee's practical skills with their theoretical study. They are designed to prepare the trainee for making quality and fast decisions in the future professional area. Visualization of educational material and practical actions facilitate its perception and assimilation, built-in gamification enables to push up the motivation and emotional adjustment of students on several orders. Such programs are able to progress along together with as well as those taught and trainees [2].

Simulators allow not only training, but also ones to investigate the responses of the human welder's during the simulator's work, build neuro-fuzzy logic and design automated and robotized welding systems.

The only disadvantage of such simulators is too much high their cost. One way to look at this issue is a choose alternative from the standpoint of simulators' cost and also its benefits and advantage. In fact, if the simulation is closer to the actual operation of the welding equipment, then cost and potential benefits are higher. However, on a case-by-case basis it should to be guided by specific teaching and production tasks. In any case, during the first year using the simulators they will be able to pay for themselves fully.

Significant prospects are observed in the widespread introduction of mobile educational AR apps and SMART-technologies in general. These devices or their analogs is seems may soon squeeze smartphones out of the market and make significant changes to the ideology of simulation training for welders.

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Methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects

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Abstract. An analysis of the experience of professional training bachelors of electromechanics in Ukraine and abroad made it possible to determine that one of the leading trends in its modernization is the synergistic integration of various engineering branches (mechanical, electrical, electronic engineering and automation) in mechatronics for the purpose of design, manufacture, operation and maintenance electromechanical equipment. Teaching mechatronics provides for the meaningful integration of various disciplines of professional and practical training bachelors of electromechanics based on the concept of modeling and technological integration of various organizational forms and teaching methods based on the concept of mobility. Within this approach, the leading learning tools of bachelors of electromechanics are mobile Internet devices (MID) – a multimedia mobile devices that provide wireless access to information and communication Internet services for collecting, organizing, storing, processing, transmitting, presenting all kinds of messages and data. The authors reveals the main possibilities of using MID in learning to ensure equal access to education, personalized learning, instant feedback and evaluating learning outcomes, mobile learning, productive use of time spent in classrooms, creating mobile learning communities, support situated learning, development of continuous seamless learning, ensuring the gap between formal and informal learning, minimize educational disruption in conflict and disaster areas, assist learners with disabilities, improve the quality of the communication and the management of institution, and maximize the cost-efficiency.

Bachelor of electromechanics competency in modeling of technical objects is a personal and vocational ability, which includes a system of knowledge, skills, experience in learning and research activities on modeling mechatronic systems and a positive value attitude towards it; bachelor of electromechanics should be ready and able to use methods and software/hardware modeling tools for processes analyzes, systems synthesis, evaluating their reliability and effectiveness for solving practical problems in professional field.

The competency structure of the bachelor of electromechanics in the modeling of technical objects is reflected in three groups of competencies: general scientific, general professional and specialized professional. The implementation of the technique of using MID in learning bachelors of electromechanics in modeling of technical objects is the appropriate methodic of using, the component of which is partial methods for using MID in the formation of the general scientific component of the bachelor of electromechanics competency in modeling of technical objects, are disclosed by example academic disciplines "Higher mathematics", "Computers and programming", "Engineering mechanics", "Electrical machines".

The leading tools of formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects are augmented reality mobile tools (to visualize the objects' structure and modeling results), mobile computer mathematical systems (universal tools used at all stages of modeling learning), cloud based spreadsheets (as modeling tools) and text editors (to make the program description of model), mobile computer-aided design systems (to create and view the physical properties of models of technical objects) and mobile communication tools (to organize a joint activity in modeling).

Keywords: mobile Internet devices, bachelor of electromechanics competency in modeling of technical objects, a technique of using mobile Internet devices in learning bachelors of electromechanics.

1 Introduction

In previous work [13] it has been established that despite the fact that mobile Internet devices (MID) are actively used by electrical engineers, the methods of using them in the process of bachelor in electromechanics training [4] is considered only in some domestic scientific studies. The article [13] highlights the components of the methods of using MID in the formation of the ICT component of the competence of the bachelor in electromechanics in modeling of technical objects [7; 8], providing for students to acquire basic knowledge in the field of Computer Science and modern ICT and skills to use programming systems, math packages, subroutine libraries, and the like. For processing tabular data, it was proposed to use various freely distributed tools that do not significantly differ in functionality, such as Google Sheets, Microsoft Excel, for processing text data – QuickEdit Text Editor, Google Docs, Microsoft Word. For 3D-modeling and viewing the design and technological documentation, the proposed comprehensive use of Autodesk tools in the training process.

According to the model of the use of mobile Internet devices in the formation of the competence of the bachelor in electromechanics in the modeling of technical objects [6], it is need to develop the methods of using mobile Internet devices in the formation of the general scientific component of the competence of the bachelor in electromechanics in the modeling of technical objects.

To achieve this goal, the following *tasks* must be solved:

1. Identify the leading mobile software tools for the development of competence in applied mathematics and illustrate their use in the academic disciplines “Higher Mathematics” and “Computing Engineering and Programming”.
2. Identify the leading mobile software tools for the development of competences in fundamental sciences and illustrate their use in academic disciplines “Higher Mathematics”, “Theoretical Mechanics and Electrical Machines”.

2 Results of the research

2.1 Use of mobile Internet devices in the formation of competence in applied mathematics

The formation of such a general scientific component of the competence of the bachelor in electromechanics in the modeling of technical objects, as the competence in applied mathematics, involves understanding students of the basic facts, concepts, principles of applied mathematics; mastering the methods of system analysis, construction and research of models of applied problems using the modern ICT tools, establishing their adequacy to real processes and phenomena; knowledge of numerical methods and algorithms for their implementation; determination of the correctness of the applied mathematics methods, the conditionality of the problems and the stability of the algorithms to the errors of the input data; selection and rational use of ready-made software (including computer mathematics systems) for computational experiments to verify hypothetical statements, etc.

Formation of competence in applied mathematics occurs primarily in the study of such disciplines as “Higher Mathematics” and “Computer Science and Programming”. Thus, among the content modules of the “Higher Mathematics” one of the most important for the formation of competence in applied mathematics is module 1 “Elements of linear algebra”, which, in particular, considers the concepts of matrix, matrix types, actions on matrices and their properties, the notion and solution of a system of linear algebraic equations by the Gaussian and the matrix methods.

In order to establish the interdisciplinary connections of the “Higher Mathematics” and “Computer Science and Programming”, it is expedient to consider similar models that are investigated by various means. Thus, before implementing the polynomial model of the approximation of the function of one variable by means of Visual Basic for Application in the third content module of the “Computer Engineering and Programming” it is expedient to consider it in practical lesson on the academic discipline “Higher Mathematics” in the matrix form, which students mastered in module 1 “Elements of linear algebra”.

Output data for constructing a model is a value from the table of the form:

x_{exp}	y_{exp}
x_1	y_1
x_2	y_2
…	…
x_i	y_i
…	…
x_n	y_n

The polynomial expression should be written in the form

$$y = a_p x^p + a_{p-1} x^{p-1} + \dots + a_2 x^2 + a_1 x + a_0$$

Here *n* – is the number of pairs of values of the form (*x*; *y*) in the table, and *p* – is the order of the polynomial ($p << n$).

After substituting each value from a table into a polynomial, we obtain a system of *n* linear algebraic equations with $p+1$ unknown:

$$\begin{cases} y_1 = a_p x_1^p + a_{p-1} x_1^{p-1} + \dots + a_2 x_1^2 + a_1 x_1 + a_0 \\ y_2 = a_p x_2^p + a_{p-1} x_2^{p-1} + \dots + a_2 x_2^2 + a_1 x_2 + a_0 \\ \dots \\ y_i = a_p x_i^p + a_{p-1} x_i^{p-1} + \dots + a_2 x_i^2 + a_1 x_i + a_0 \\ \dots \\ y_n = a_p x_n^p + a_{p-1} x_n^{p-1} + \dots + a_2 x_n^2 + a_1 x_n + a_0 \end{cases}$$

The main matrices that characterize the system are:

A – is a matrix column of unknown coefficients of the polynomial:

$$\mathbf{A} = \begin{bmatrix} a_p \\ a_{p-1} \\ \dots \\ a_2 \\ a_1 \\ a_0 \end{bmatrix}$$

X – the main matrix of the system:

$$\mathbf{X} = \begin{bmatrix} x_1^p & x_1^{p-1} & \cdots & x_1^2 & x_1 & 1 \\ x_2^p & x_2^{p-1} & \cdots & x_2^2 & x_2 & 1 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_i^p & x_i^{p-1} & \cdots & x_i^2 & x_i & 1 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_n^p & x_n^{p-1} & \cdots & x_n^2 & x_n & 1 \end{bmatrix}$$

Y – is a matrix column of values:

$$\mathbf{Y} = \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_i \\ \cdots \\ y_n \end{bmatrix}$$

A shortened system can be written as a matrix equation:

$$\mathbf{Y} = \mathbf{XA}$$

The direct solution of such system by methods considered in the first module is impossible due to the fact that the number of equations is greater than the number of unknowns. The same can be said about solving the matrix equation: finding a matrix inverse to the matrix **X**, is impossible because matrix **X** is not square. To get out of this dead end, we suggest students apply the property of a transposed matrix, namely: the product of a transposed matrix on the output is a square matrix, so we apply this property to both parts of the matrix equation:

$$\mathbf{X^TY} = \mathbf{X^TXA}$$

The resulting equation contains a new matrix – $\mathbf{X^T}$, which is a transposed matrix **X**. Using the associativity properties of multiplication of matrices, we obtain the following equivalent equation:

$$\mathbf{(X^TX)A} = \mathbf{X^TY}$$

It corresponds to the normal system of linear algebraic equations, for solving which one can use any of the mastered methods – Cramer's rule, Gaussian elimination or matrix inversion. To use the latter, we make a left multiplication of both parts of the matrix equation on the matrix inversed to the product $\mathbf{X^TX}$:

$$\mathbf{(X^TX)^{-1}(X^TX)A} = \mathbf{(X^TX)^{-1}X^TY}$$

Get the next equivalent equation:

$$\mathbf{IA} = \mathbf{(X^TX)^{-1}X^TY},$$

where **I** – is an identity matrix of dimension (p+1, p+1):

$$\mathbf{A} = \mathbf{(X^TX)^{-1}X^TY}$$

To find the solution, we first suggest using the traditional methods of "manual" solution in order to make sure that the time spent on such work is incommensurate with the time spent on the mathematical description of the model. It pushes for the use of ICT. For matrix models we are propose an electronic spreadsheets. Google Sheets provides to students and teachers the opportunity to put together experimental data and corresponding formulas.

To do this, make a spreadsheet accessible to all students in the academic group and invite each of them to fill in a line corresponding to the student number in the group's journal with a pair "weight – height".

To select a polynomial order, we visualize the entered values and suggest justification of the choice. As a result of the discussion, we agree with the assumption that the line to be held at the smallest distance from all points can be a parabola, so our model will have the quadratic form $y = a_2x^2 + a_1x + a_0$. Accordingly, it is necessary to construct the matrix **X** from the elements of the column x_{exp} in the second, first and zero degrees, and the matrix **Y** – from the elements of the column y_{exp}. The $\mathbf{X}^\mathbf{T}$ matrix is constructed using the transpose function, giving it the parameter range of the values of the matrix **X** (E3:G32), and the products of $\mathbf{X}^\mathbf{T}\mathbf{X}$ and $\mathbf{X}^\mathbf{T}\mathbf{Y}$ – by calling mmult(M3:AP5;E3:G32) and mmult(M3:AP5;I3:I32) respectively. We find the inverse to the $\mathbf{X}^\mathbf{T}\mathbf{X}$ matrix with a minverse(M8:O10) call and make the left multiplication of it to the $\mathbf{X}^\mathbf{T}\mathbf{Y}$ matrix by calling mmult(M13:O15;Q8:Q10). As a result we obtain **A**, the matrix of polynomial coefficients (fig. 1).

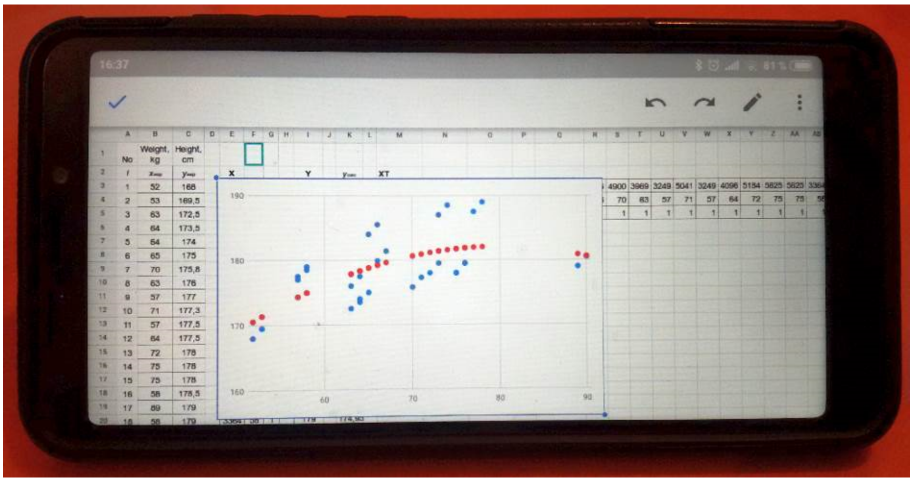


Fig. 1. Mobile Internet device while working with the model on higher mathematics classes

In fig. 1 shows an updated graph of the ratio of weight and height of students, where the approximated growth values were added to the experimental points, calculated using the formula $y_{\text{calc}} = -0{,}0148x^2 + 2{,}3669x + 87{,}4835$. The simulation results make it possible to draw an important conclusion that this model can be simplified to linear without losing adequacy. Since the factor of the second power x does not make a significant contribution to the calculated value of growth; therefore, the ratio of weight and height of students can be described not parabolic, but linear dependence. Such task can be offered for self-study.

The considered algorithm of approximation can be illustrated also on the material of other modules. As shown in [12], the course of higher mathematics in technical universities traditionally ends with the Fourier transform and Fourier series as its partial case. Considering the high practical significance of this topic for the further professional activity of future engineers-electromechanics, when studying the module 16 “Trigonometric series and their applications”, it is expedient for students to propose solution of the approximation problem by a fragment of a trigonometric series of sequence of points corresponding to the financial series. As a data source, we use the Google Finance online service, which provides the ability to export data to Google Sheets using the function =googlefinance("currency:usduah"; "close"; date(2013;1;9); date(2018;9;9)), the first parameter of which is the currency pair, “US dollar – Ukrainian hryvnia”, the second is the closing price of exchange rates of given currency pair, the third is start date and fourth is end date of the time interval *l*.

The mathematical model of the renewal dependence is a cosine decomposition of an unknown function $f(x)$ on an interval [0; l):

$$f(x) = \sum_{n=0}^{N} a_n cos\frac{\pi nx}{l},$$

where n – is the harmonic number, $N+1$ – is the number of harmonics, a_n – is the Fourier coefficients.

We put the measurement vector (value of the price) in the column matrix **Y** of the $l\times1$ dimension. Due to find the column matrix **A** of the Fourier coefficients of by dimension $(N+1)\times1$ we perform calculation $\mathbf{A}=(\mathbf{X}^{\mathrm{T}}\mathbf{X})^{-1}\mathbf{X}^{\mathrm{T}}\mathbf{Y}$, where **X** – is the matrix of the plan of the dimension $l\times(N+1)$, containing the cosine Fourier coefficients: $\mathbf{X}_{xn} = cos\frac{\pi nx}{l}$. As the value of the independent variable, apply the measurement number $x = 0...l-1$, and the harmonic number $n = 0...N$.

The call of the googlefinance function in cell A1 will provide two columns of values, the first of which will contain a date, and the second is the price. To determine the value of *l* we use the function of counting the number of column elements: count(A:A). We assign the number of harmonics manually: $N = 30$. To the first cell of the plan matrix **X** (N2) we enter the cos(pi()*N$1*$G2/$E$1) formula, which will be copied to all other cells of the **X**. The matrix column **A** are described by the formula – mmult(mmult(minverse(mmult(transpose(N2:AR1693);N2:AR1693));transpose(N2:AR1693));H2:H1693). To calculate the predicted values y_{calc} we use the scalar product of the line matrix to the column matrix **A**: mmult($N2:$AR2;$S$1696:$S$1726) to the J2 cell and distribute it to the entire range.

To analyze the results we draw plots of currency values y obtained from Google Finance and approximated data y_{calc} (fig. 2). The function plot indicates that 30 harmonics in the general case is quite a satisfactory amount for the function estimation, but such amount is not enough to simulation of fast processes with a large amplitude of fluctuations. An example of such phenomena in the electromechanics are the modes of starting the engine, sharp loading of the load and short circuit.

Discussion of this model in several classes provides an opportunity to evaluate its adequacy by forecasting future values of the currency pairs. So, it is advisable to compare the currency values for the dates that were not used when constructing the plan matrix, with the predicted values. To do this, we propose calculating at least three future values of the currency and compare them with the real ones. In fig. 3, the last three values (1692-1694) were not used in constructing the plan matrix, but they reflect the tendency of the currency change.

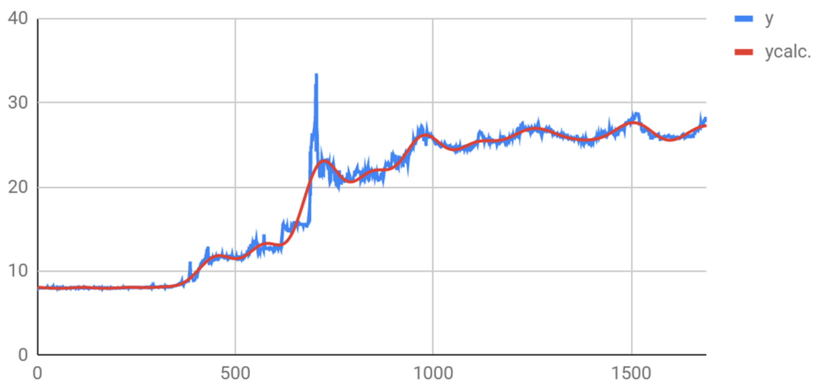


Fig. 2. Dynamics of currency pair "US dollar – Ukrainian hryvnia" and its approximation by Fourier series

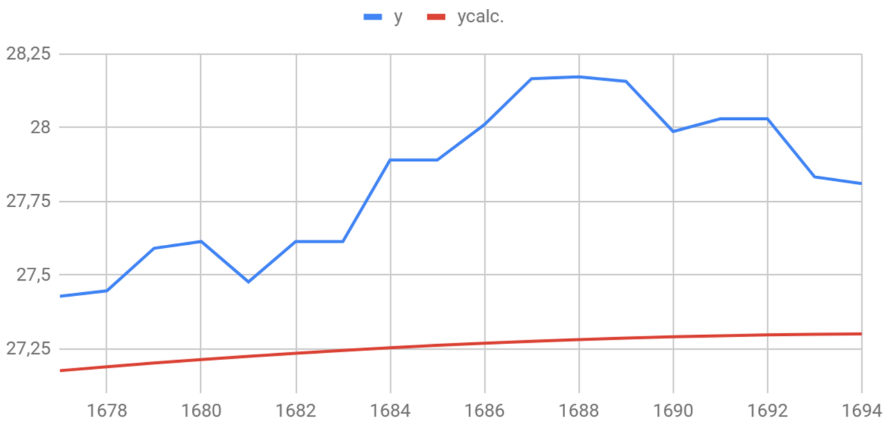


Fig. 3. Forecast of dynamics of currency pair "US dollar – Ukrainian hryvnia" for the period from September 10 till September 12, 2018

In studying the module 7 "Differential calculation of the function of several variables" it is expedient to consider the problem of finding the extremum of a convex function by a gradient descent method. To do this, you can return to the ratio of the two measured values *x* and *y*, considered in the first module of the model, but write down its solution using partial derivatives.

The function of communication of these values (hypothesis) is written in the form $h(x) = \theta_0 + \theta_1 x$, or

$$h(x) = \vec{\theta}^T \vec{x} = [\theta_0 \quad \theta_1] \begin{bmatrix} 1 \\ x \end{bmatrix},$$

where $\vec{\theta} = \begin{bmatrix}\theta_0 \\ \theta_1\end{bmatrix}$ – column matrix (vector-column) of unknown coefficients $\vec{\theta}$, and $\vec{x} = \begin{bmatrix}1 \\ x\end{bmatrix}$ – non-transposed element of the plan matrix.

Let us construct a function of value, which depends on the parameters of the hypothesis:

$$J(\theta_0, \theta_1) = \frac{1}{2m}\sum_{i=1}^{m}(h(x_i) - y_i)^2.$$

The function plot has a single extremum (fig. 4). The gradient descent method is based on the fact that starting from a certain initial value of the vector $\vec{\theta}_0$, we will take steps on the surface of the paraboloid in the direction of minimizing the function value, that is, the direction opposite to the gradient vector of the function: $\nabla J(\theta_0, \theta_1) = \left(\frac{\partial J}{\partial \theta_0}, \frac{\partial J}{\partial \theta_1}\right)$.

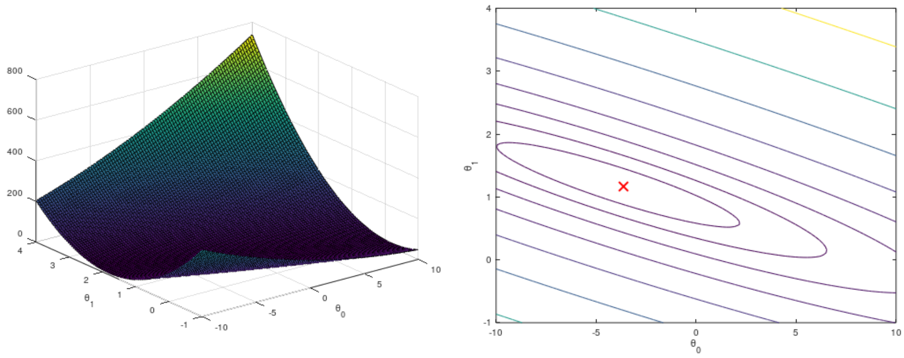


Fig. 4. Function plot (left) and its contour plot (right); the cross indicates the global minimum

The partial derivatives of the function with the respect to the θ_0 and θ_1 are equal:

$$\frac{\partial J}{\partial \theta_0} = \frac{1}{m}\sum_{i=1}^{m}(h(x_i) - y_i),$$

$$\frac{\partial J}{\partial \theta_1} = \frac{1}{m}\sum_{i=1}^{m}(h(x_i) - y_i)x_i,$$

The algorithm of the gradient descent method will look:

$$\vec{\theta}_{\text{next}} = \vec{\theta}_{\text{prev}} - \alpha \nabla J(\theta_0, \theta_1),$$

where α – descent speed.

The software implementation of this numerical method can be performed in mobile versions of Scilab [5], MATLAB or Octave. Thus, the function of the value of *J* can be realized through the scalar product of the defined vectors:

```
function J = computeCostMulti(X, y, theta)
  m = length(y);
  J=1/(2*m)*(X*theta-y)'*(X*theta-y);
end
```

The number of iterations `num_iters` an additional parameter used when implementing the method:

```
function [theta] = gradientDescentMulti(X, y, theta, alpha,
num_iters)
  m = length(y);

  for iter = 1:num_iters
    temp=theta;
    n=size(X,2);
    s=zeros(n,1);
    for j=1:n
      for i =1:m
         s(j,1)=s(j,1)+(X(i,:)*theta-y(i))*X(i,j);
      end;
    end;

    temp=theta-alpha*(1/m)*s;
    theta=temp;
  end
end
```

As a result, we obtain the vector of the parameters $\vec{\theta}$, and can visualize the results of the simulation (fig. 5).

In the content module 9 “Definite and improper integrals” the competence in applied mathematics can be developed on example of the problem of building plot of electrical load. The corresponding code with teacher’s explanations can be offer in SageCell:

```
#Output data
data=[[1,6],[2,7],[3,7.5],[4,7.5],[5,7.5],[6,8],[7,8],[8,10],[9,
13],[10,15],[11,13.5],[12,13.5],[13,11],[14,12],[15,14],[16,11],
[17,10], [18,12],[19,14],[20,14],[21,15],[22,13],[23,12],[24,7]]
p=point((0,0))
S=vector([0,0,0]) # sums by the method of left and right
rectangles, and the trapezoid method
for i in range(len(data)-1):
    p += line([data[i], data[i+1]], color='red')
```

```
    p += polygon([data[i], [data[i+1][0], data[i][1]],
[data[i+1][0], 0], [data[i][0], 0], data[i]], color='lightblue')
    dt = data[i+1][0]-data[i][0] # integration step
    S += vector([data[i][1]*dt, data[i+1][1]*dt,
(1/2)*(data[i][1]+data[i+1][1])*dt])
show(p, figsize=[4,5])
html("Daily electricity consumption calculated:<br><ul><li> left
rectangular method - %s,</li>"
     "<li>right rectangular method - %s,</li>"
     "<li>trapezoidal rule - %s</li></ul>"%(S[0],S[1],S[2]))
```

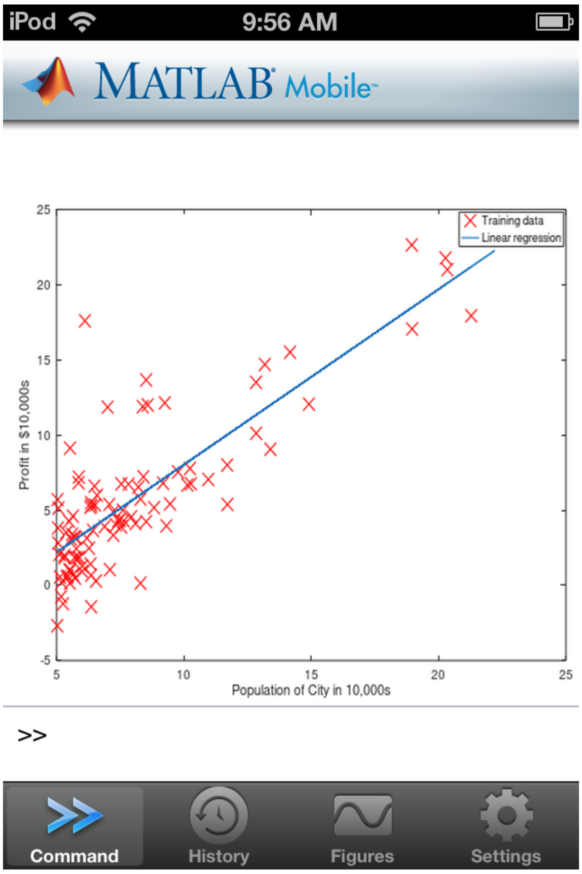


Fig. 5. Visualization of cloud points and regression lines in MATLAB Mobile

To enable students to conduct their own experiments, the teacher can generate a SageCell QR code (fig. 6a), which is processed by a mobile Internet device (fig. 6b).

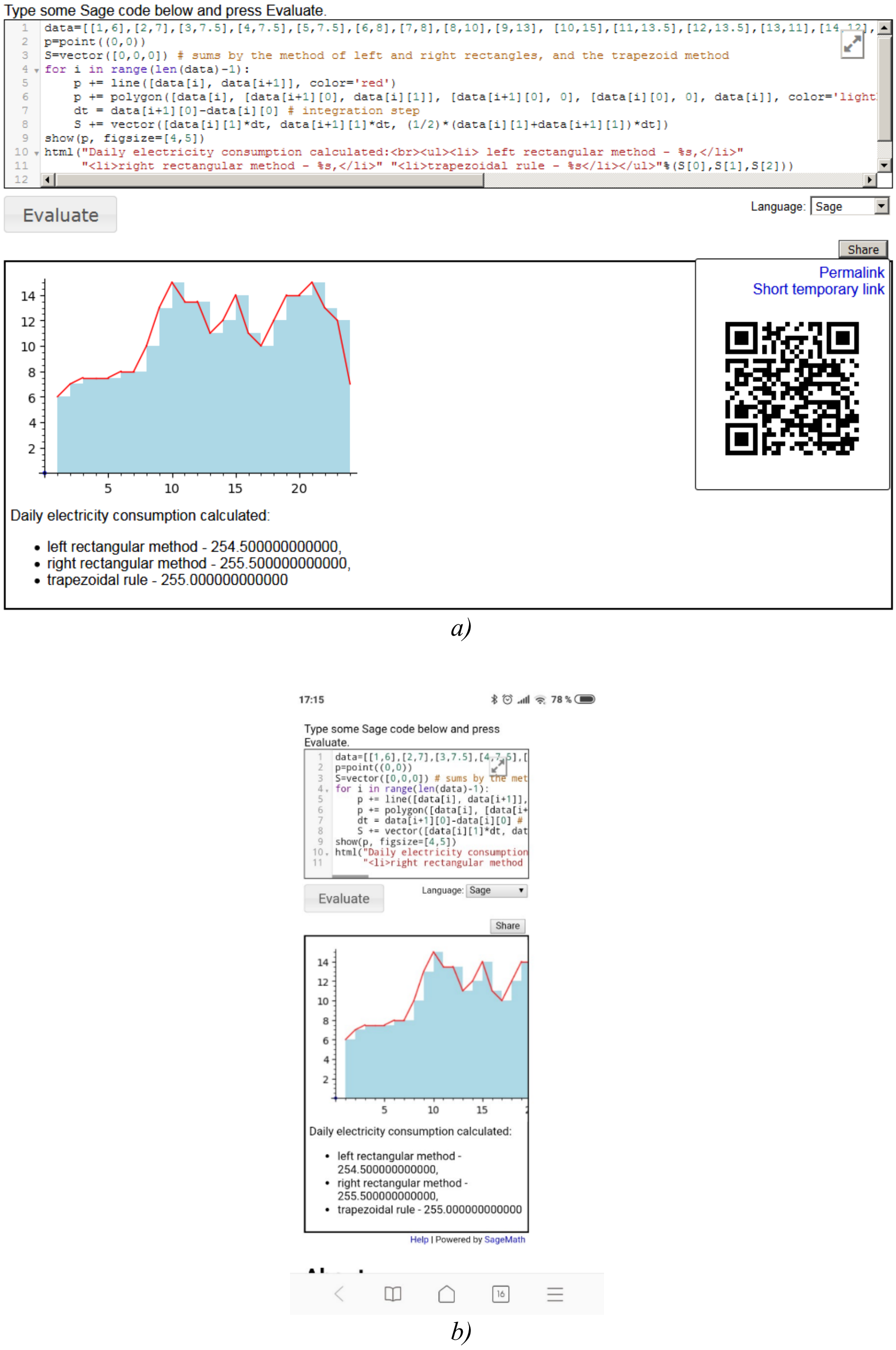


Fig. 6. The use of SageCell on the teacher (a) and student (b) devices in the process of learning numerical integration of table-set values

In content module 14 “Linear differential equations of higher orders with constant coefficients” we can illustrate the use of another mobile mathematical system – SMath Studio [9], which allows both analytic and numerical solution of differential equations (fig. 7).

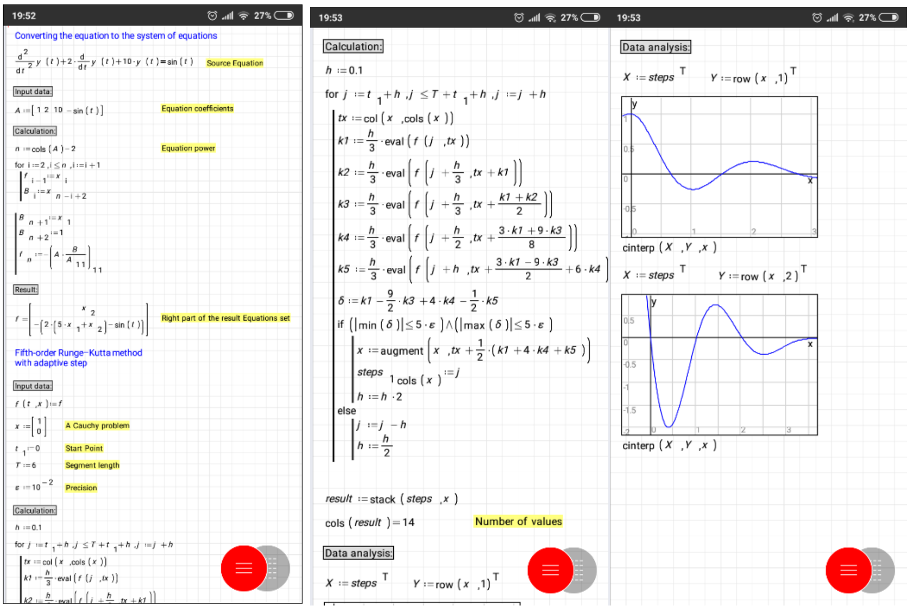


Fig. 7. Using SMath Studio to analyze dynamic systems

2.2 The use of mobile Internet devices in the formation of competence in the fundamental sciences

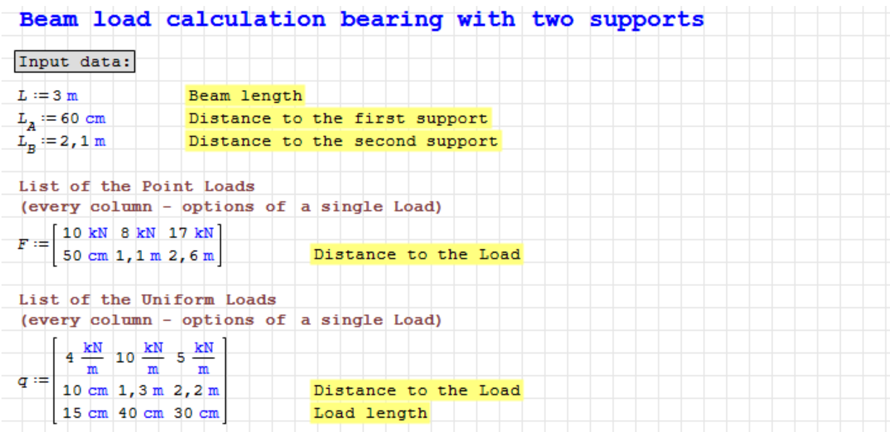
The formation of a general scientific component of the competence of the bachelor in electromechanics in the modeling of technical objects, such as competencies in fundamental sciences, provides for the acquisition of basic knowledge of the fundamental branches of the natural sciences and mathematics to the extent necessary to obtain the mathematical methods of the electromechanical branch of knowledge; ability to use mathematical methods and methods of natural sciences in research and applied professional activities.

In addition to the content of the “Higher Mathematics”, for the formation of competence in the fundamental sciences, it is necessary to implement the substantive component of the disciplines “Theoretical Mechanics” and “Electrical Machines”.

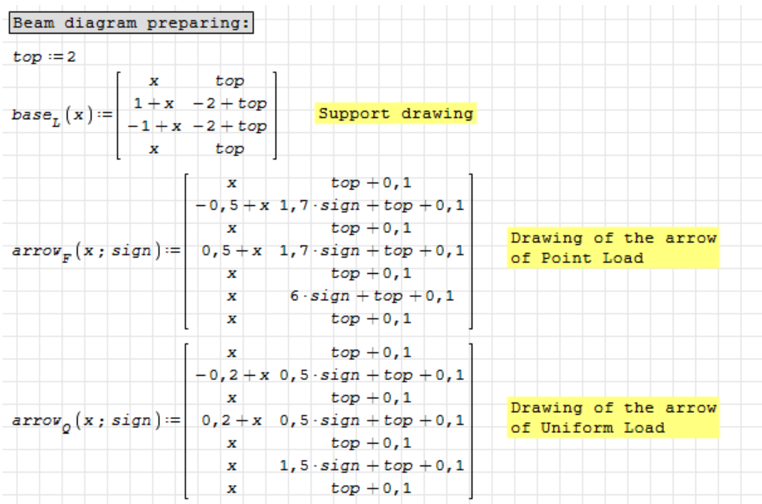
The purpose of studying the “Theoretical Mechanics” is the getting of knowledge and the acquisition of skills necessary to study the general laws of mechanical movement, the interaction of material bodies based on the laws of classical mechanics, the acquisition of skills to perform calculations for strength, rigidity of structural elements, machine parts, research and design of modern heavy machines, development of textual and graphical design documentation.

As a result of studying the discipline, the student, should be able to: make up mathematical models of material objects, solve problems related to the study of the movement and equilibrium of certain material bodies under the action of forces applied to them using ICT; analyze kinematic schemes of machines.

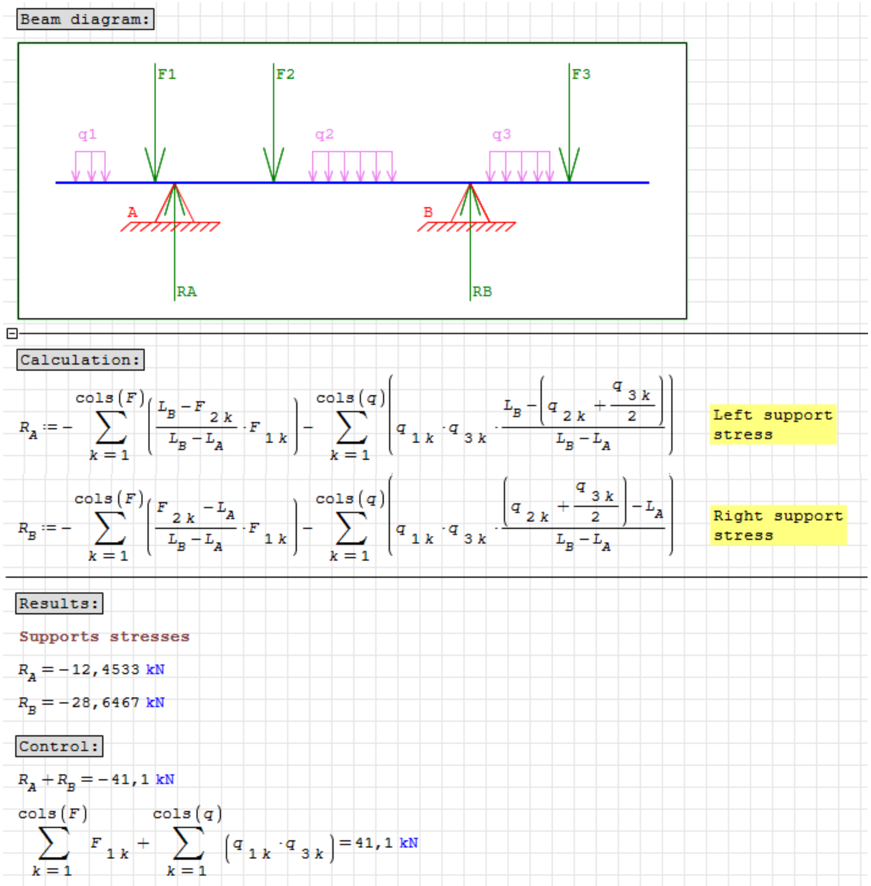
For the implementation of the first task, as in teaching higher mathematics, we suggest using SMath Studio as a free and mobile equivalent of the Mathcad system. In fig. 8 shows the sequence of screen copies of the implementation of the calculation model for a beam with two supports.



a) problem statement



b) example of the calculation of displayed objects



c) simulation results

Fig. 8. The model for calculating beams on two supports in SMath Studio

To solve the problem of analysis of kinematic schemes of machines, we use the augmented reality (AR) solutions for intuitive analysis and material design [10].

Dieter Weidlich, Sandra Scherer and Markus Wabner in [11] describe the experience of improving the process of developing machine parts using the virtual and augmented reality systems of Chemnitz Technical University, which developed new methods visualization to study the result of modeling by the finite elements method. The main purpose of software development was the visualization of the direction and stress gradient by 3D glyphs. The finite element method is a numerical method of engineering analysis, used for many types of tasks, such as determining loads and shifts in mechanical objects, or heat transfer and flow dynamics.

Calculating mechanical stresses is fundamental to the analysis of strength behavior in mechanical engineering. Glyphs are a way of graphically coding numeric information. A glyph is a graphic unit that can communicate various data attributes by its appearance (shape, color, orientation, position, and so on). A special characteristic of glyphs, as compared to simpler concepts, is the number of data attributes that can be communicated. Glyphs are primarily used for representing multidimensional data. Glyph-based methods represent a multitude of tensor values by reflecting tensor eigenvectors and values in terms of shape, size, orientation, and surface characteristics of geometrical primitives such as cubes and ellipses (fig. 9).

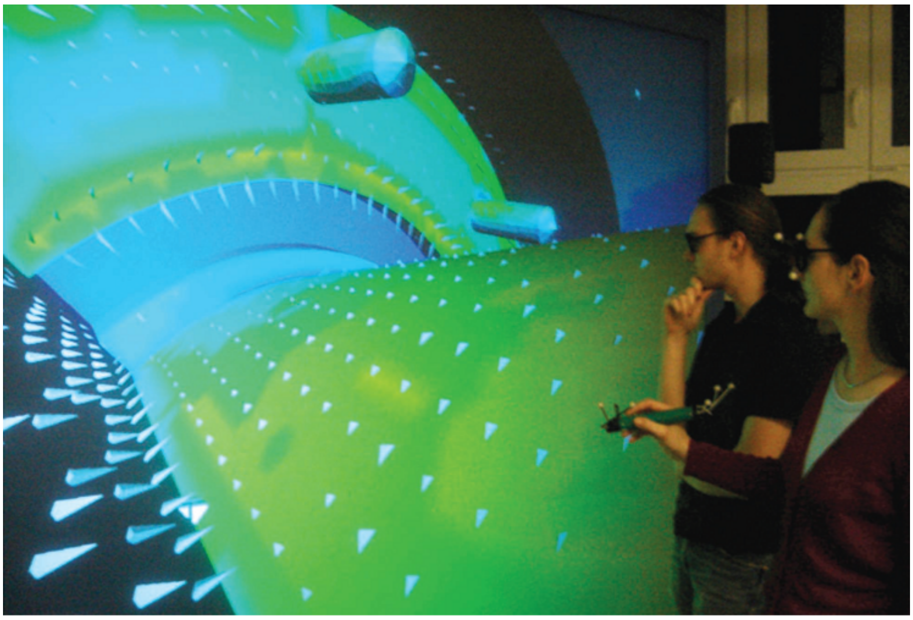


Fig. 9. Visualization of the results of the finite element analysis: the outward glyph vertices reflect tensile loads, and the inward glyphs represent the compression load

Various geometric primitives such as cuboids, tetraeders, spheres, and lines can be used to represent multidimensional data. However, this requires a preliminary study into which shape of glyph is suitable for the data to be represented. Tests have shown that the tetraeder is well-suited for visualizing stress direction and gradient because the tip of the tetraeder indicates an exact direction. In addition to stress direction, the 3D glyphs can also reveal whether the stress is tensile or compressive.

The software developed by the authors of [11] allows switching between the results of structural and thermal analysis and comparing them with a real physical object. In fig. 10 shows the imposition of a finite element model on a real system: the more "hot" the color is, the greater the load. A black and white marker in the user's hand is necessary for positioning the analysis results.

Michele Fiorentino, Giuseppe Monno and Antonio E. Uva in article [3] identify 6 main ways of using augmented reality in engineering, for each of which are defined aspects like hardware configuration, add-on method, TUI/GUI interactivity level (TUI – Tangible User Interface, material user interface; GUI – Graphical User Interface, graphical user interface), viewpoint, physical collaboration support and remote collaboration.

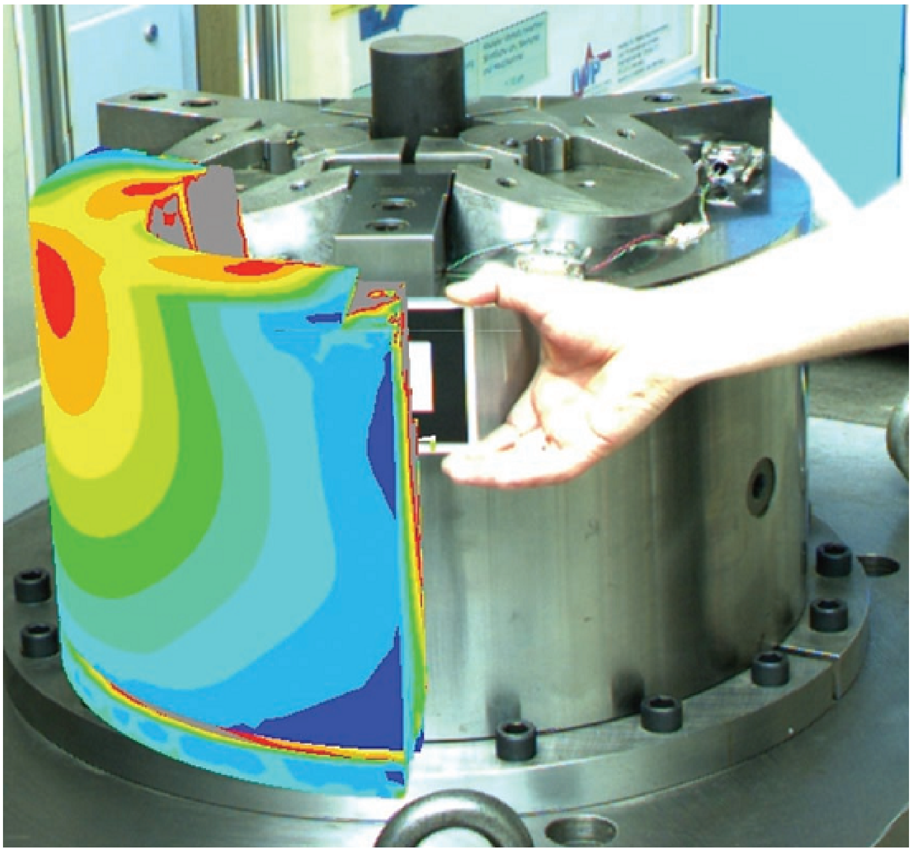


Fig. 10. Display of simulation results on a real object

1. Augmented user

The user wears see-through AR glasses connected to a wearable PC. See-through displays allow the user to be aware of the real industrial environment. This configuration allows maximum mobility for the user letting him work in a large workspace with free hands. The interaction is achieved mostly by TUI with none or limited GUI. Suggested applications for this setup are: inspection, training, etc. Disadvantages may include the display resolution, the limited field of view and the optical tracking robustness in hostile manufacturing environments. In another setup the user holds a handheld (flashlight-like) camera and a wearable PC connected to the network. The user is free to move in the industrial environment and to teleconference with other users remotely logged. The difference compared to previous setup is the viewpoint mobility. The user can move the camera in the industrial environment, reaching potentially every location under wireless coverage. Local tracking is provided by markers and broadcasted to the system. This scenario is particularly important in maintenance, where remote experts can guide and assist the user. The user loads his customized visualization of the model and broadcasts it remotely. The main advantage of this configuration is the maximum mobility for point of view. This may also lead to an unsteady point of view due to the fact that the user must hold the camera. TUI and GUI interaction is also rather limited.

2. Mobile window

The user holds a tablet PC with a camera on the back side. Tablet displays allow the user to be fully aware of the real industrial environment. This configuration allows a good mobility for the user letting him work in a large workspace but it requires that at least one hand holds the tablet. The interaction is achieved mostly by GUI with the tablet pen. Suggested applications for this setup are: design review, inspection, etc. Disadvantages may include the weight of the tablet and the single-handed interaction limitation.

3. Augmented desktop

The user works on a desktop workstation with a camera pointing on a free area on the desk, which will be the augmented workspace. The AR workspace is limited to the user's desktop and the model interaction is achieved by moving the TUI (augmented technical drawings) and by the traditional desktop GUI with a mouse and a keyboard. In normal use, the TUI is just a support to the ordinary GUI. For this reason, this scenario is suggested for all tasks which involve an heavy use of keyboard entry of numerical or text data: e.g. detailed design, engineering, numerical analysis, etc. The main advantage of this setup is the similarity with the traditional working environment, allowing an easy access even for a non technical user. Users, in fact, find much easier and intuitive the navigation of 3D models using a tangible metaphor. A limiting factor is that it must be implemented in an office-like environment.

4. Augmented workshop

This scenario is similar to the augmented desktop as regards the hardware setup, but it is designed for a production stage environment instead of a clean office desk. The user is on a workbench on the production line where no keyboard or mouse is present. The user can interact by touch screen on industrial monitor and by tangible augmented drawings. An industrial buttonbox can also be used. The main advantages are: both hands free for the user, possibility to display high resolution rendering of the 3D model, comfortable working environment, similar to a non augmented one. Ideal applications may be quality check or guided assembly.

5. Augmented collaborative table

This scenario supports collaborative workspace at best. It consists of a meeting table with the function of shared augmented area and of a large screen. The screen can be vertical or horizontal and eventually have stereographic or holographic display. All users can access to the augmented shared area with their tokens and they can annotate the model using their own PC laptop for precise GUI input. Remotely located users can join the group and participate with virtual meeting tools. The system will take care of the synchronization of the digital master data including annotations, chat and history. The main applications of this scenario are marketing and design review: the shared workspace can contain virtual CAD models, real pre-production mock ups, on-line technical content and simulation results for collaborative discussion. The main advantages of this scenario are the high collaboration support, the coexistence of real and virtual products and the social contact of real meetings.

6. Augmented presentation

This scenario considers a speaker who wants to present a solution to a large audience. A large screen is the main visualization device. The data management is achieved mainly by TUI in form of digital drawing or mock-up placed on the speaker's stand. The audience can access to the same digital data with personal visualization devices and can add annotations, which are updated in real time for all the members of the discussion.

The characteristics of each method proposed by the authors of [3] are summarized in Table 1.

Table 1. The main ways of using augmented reality in engineering

Scenario	Viewpoint	TUI level	GUI level	Collaboration level	Remote coworking
Augmented user	mobile	high	high	low	medium
Mobile window	mobile	low	high	medium	medium
Augmented desktop	fixed	medium	high	low	high
Augmented workshop	fixed	medium	low	low	low
Augmented collaboration table	fixed	high	medium	high	medium
Augmented presentation	fixed	high	low	medium	medium

The purpose of learning the "Electrical Machines" is the formation of students' theoretical knowledge of the design, principle of operation, the field of use electrical machines and transformers, as well as the acquisition of practical skills related to connecting, operating and determining the parameters of electric machines and micromachines. As a result, a student should be able to draw up electrical circuits and calculate the parameters of the circuit elements, to turn on electrical machines and micromachines, provide experiments to determine the parameters of electrical machines, and perform calculations of the structural elements during the design and repair of electrical machines.

In the process of acquiring theoretical knowledge of the design of electric machines, it is advisable to use mobile augmented reality tools developed by SIKE Software. Training simulator system with augmented reality technology makes it possible to form a complex of knowledge about the structure of electric motors of various types and acquire skills in identifying the component parts of electric motors and the safe, correct and fast order of assembly and disassembly of electric motors (fig. 11). The system can be applied in practical training, laboratory and independent work, examinations, etc., and in the process of industrial training – for theoretical interactive training of workers involved in the installation and dismantling of industrial electrical equipment. The program provides access to 3D models with a high degree of accuracy, repeating the structure of real equipment.

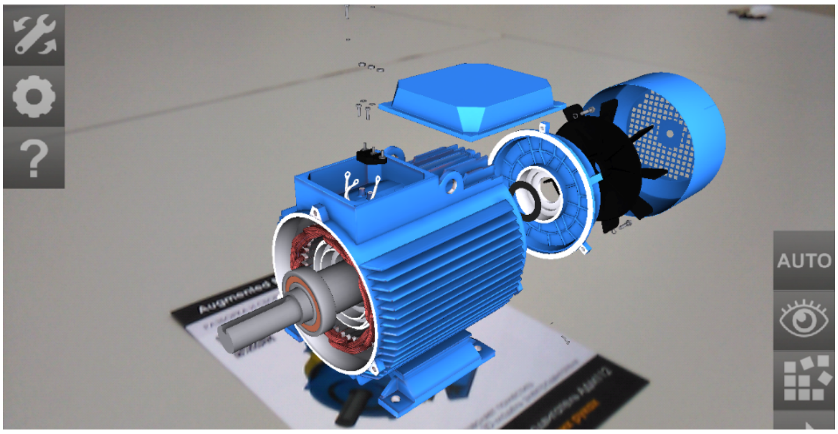


Fig. 11. Training system-simulator SIKE Software

Each detail of the design has name, description, and the order of technological operations corresponds to the actual process and is developed in conjunction with the experts of leading industrial enterprises.

This system uses the QR code as a marker on a special card. Another approach is to use a universal marker (fig. 12) or a scene marker containing a real object (fig. 13).

Fig. 12. The model of the Rossi motor reductor in the Augment system is tied to a universal marker

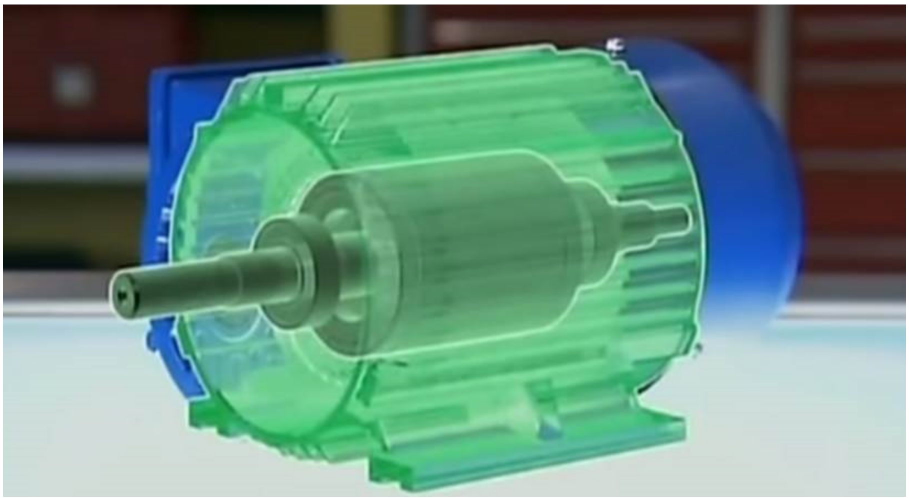


Fig. 13. The asynchronous motor model, which tied to the scene containing the real object in the HP Reveal system

When performing the calculation of a three-phase asynchronous motor after repair and restoration works (module 7 “Three-phase asynchronous machines”) it is advisable to use SMath Studio. Fig. 14 shows the beginning of the calculation of the natural electromechanical and mechanical characteristics of the engine, and fig. 15 shows the calculated mechanical characteristics diagram.

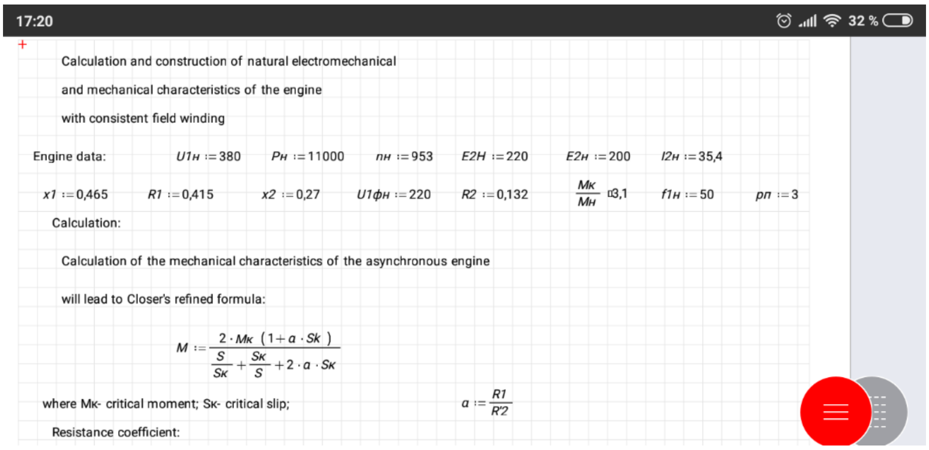


Fig. 14. Setting model parameters and starting the calculation

Models for all content modules of the “Electric Machines” course include Scilab on cloud (https://cloud.scilab.in/). To select a model, you must select the main category Electrical Engineering / Electronics & Telecommunication Engineering / Instrumentation & Control Engineering, subcategory Electrical Devices / Machines and the corresponding course manual (for example book [2] and its corresponding manual [1]). An example of calculating the synchronous speed of a polyphase asynchronous machine in Scilab on cloud:

```
// Example 1.60
clc;clear;close;
// Given data
PA=4;//no. of poles
PB=4;//no. of poles
f=50;//in Hz
V=440;//in volt
//calculations
//Independently with A
Ns=120*f/PA;//in rpm
disp(Ns,"Independently with A, Synchronous speed Ns in rpm is :
");
//Independently with B
Ns=120*f/PB;//in rpm
disp(Ns,"Independently with B, Synchronous speed Ns in rpm is :
");
//Running as cumulative cascaded
Ns=120*f/(PA+PB);//in rpm
disp(Ns,"Running as cumulative cascaded, Synchronous speed Ns in
rpm is : ");
```

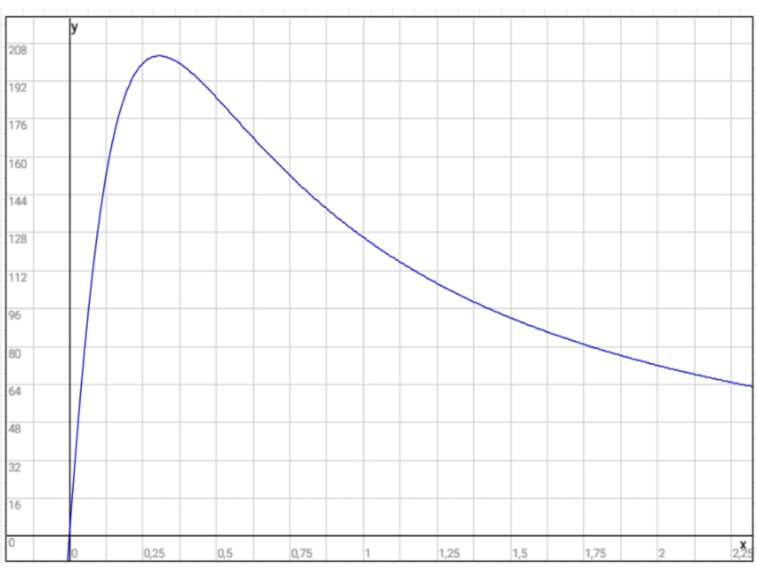


Fig. 15. Diagram of the mechanical characteristics of the engine

The result of calculation according to example 1.60:

```
Independently with A, Synchronous speed Ns in rpm is : 1500.
Independently with B, Synchronous speed Ns in rpm is : 1500.
Running as cumulative cascaded, Synchronous speed Ns in rpm is :
750.
```

3 Conclusions

Thus, in the process of forming the general scientific component of the competence of the bachelor in electromechanics in the simulation of technical objects, it is expedient to use the following software of mobile Internet devices:

- mobile augmented reality tools used to visualize the structure of objects and simulation results;
- mobile computer mathematical systems with object (SMath Studio) and character input type (Scilab, Octave, MATLAB, SageCell), which is used at all stages of modeling;
- cloud-oriented tabular processors as modeling tools;
- mobile communication tools for organizing joint modeling activities.

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Augmented Reality-based historical guide for classes and tourists

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Abstract. In this paper, development of historical guide based on Augmented Reality (AR) technology is considered. The developed guide application it targeted to be used in different scenarios, in particular, during history learning classes, for guidance of the tourists to exhibits both indoor and outdoor. Common features of all these scenarios are generalized and according to them main information and objects model for forming scene are identified. This part is followed by detailed description of objects and scene representation, markers usage, employment of additional services, etc. Finally, the developed historical guide application has been introduced. It harnesses A-Frame library for processing of models and their representation. The application is able to work with different markers so that it can be extended easily. In addition, one of the main benefits of the developed application is support of multiple platforms because it works from web-browser and does not require installation of additional software. The developed application can be effectively used for all provided scenarios and has potential for further extension.

Keywords: augmented reality, historical guide, class, model, application, information.

1 Introduction

Augmented Reality (AR) technology has managed to become mainstream technology in a short period. Many of new devices on the market are powerful enough to support the technology. There are also huge demands and expectations from this technology at the customers' side. One of the most promising fields of use for AR is educational technology. Possibilities to enrich learning experience with AR seem to be almost unlimited. It relates to all age categories and all fields of knowledge. The major attractive point of AR is high level of interactivity that allows communicating with AR-objects.

The great advantage of AR is a huge visual experience for users. It is especially effective for the subjects with massive amount of visual data for presentation. From the student's point of view, visual data is much more involving and comprehensible than other types of information. Moreover, AR allows student to participate actively in the educational process.

One of the good candidates for application of AR is historical content and all historical-related activities. It can be learning history at university, automated guide over historical places, interactive application for museums, etc.

2 Overview of scientific sources and AR-tools

It can be alleged that AR has a huge potential in educational sphere [20]. Modern researches emphasize development of complex learning environment based on AR [10]. However, another approach supposes that each learning subject has its own peculiarities and they should be treated in context of the subject. This is the reason why specialized tools appear for learning chemistry [12; 13], physics [8] etc. In fact, they are easier from the design point of view because they do not require to cover multiple learning scenarios and can limit student to usage of only a few tools within educational framework [6; 9; 11; 14; 15; 16; 17; 19; 22]. It has advantage for both students and lectures as clearly identifies activities that include AR. Hence, in the proposed work we design AR-application for historical education with precise cases for its usage.

Many new libraries for AR-development has appeared in the recent time. Let us analyze most popular among them.

ARKit [2] is an AR-platform designed specifically for Apple devices. It procures great user experience for AR-applications. ARKit support various objects for tracking (posters, images, etc.) which means that requirements for the marker view is much softer. However, the obvious drawback is that ARKit available only on vendor's devices and cannot be used on other platforms.

At the other side, ARCore [5] and Vuforia [23] software development kits (SDKs) are much more flexible and support deployment on most popular mobile platforms. They are a great choice for developers who are going to implement application for multiple platforms. In terms of services, Vuforia is advanced SDK as it has integration with cloud. However, Vuforia inserts watermarks in the content if you use it for free and has limitation on performed requests, while ARCore is an open-source and provides free license.

All previously mentioned libraries have one feature in common. Their work is based on some native application programming interface (API). Therefore, application for one platform cannot be installed directly on the other one. More universal approach leverages capabilities of web-browsers installed in all platforms. Code executed in the browser is instantly available to any device. Developer needs to guarantee correct deployment on the server and qualitative implementation of client-side functions.

A-Frame [1] is an open-source library for Virtual Reality (VR) and AR (by including side-project library). This is a JavaScript library and it works out of the browser. Thus, A-Frame is not bound to the specific platform and can be launched on almost any device that has necessary computational ability. Because A-Frame is open-source and requires no fee payment from developers, it is a perfect choice for educational projects that leverage AR in their functionality.

So, originally, A-Frame is supposed to work with VR-facilities. To map functionality of the library to AR, it is necessary to include one additional library available from [4]. It enables markers, processing image from camera, and other basic features of AR.

One more library works behind the curtain of A-Frame. three.js [21] library serves as a basic software for A-Frame. three.js is fully-featured library in terms of VR-operations. However, it heavily relies on scripting and requires that all functions have to be declared and implemented in code. That detail can make code developed with three.js cumbersome and demands more time to implement all tasks from specification. In comparison with three.js, A-Frame provides many new components (in form of html-tags) that greatly simplify development process and allow organizing all elements on the scene in a structural way. Therefore, A-Frame can be considered as a wrapper around basic library but it greatly extends initial version in various terms. It clearly decouples declaration of element from implementation of its actions. Additionally, it binds default functionality set to the object even when developer wrote no script code for actions.

In this work, we develop AR-application that can be used as a tool in learning history and as a tourist guide. We identify differences for these cases in context of application usage and AR-involvement. A-Frame library has been chosen as a base platform for application implementation due to its free license, automatic support of multiple platforms, and rich set of components and functions that speed up and simplify development process.

3 Results and discussion

It can be assumed that application under development has three categories of users:

1. Students of historical classes.
2. Tourists who visit indoor exhibitions (e.g. in museums).
3. Tourists who visit outdoor locations and exhibits possibly located on a notable distance from each other.

All these groups should be treated differently by application in terms of content presentation, location tracking, and selection of models to form the scene, etc. Students are going to work in group while tourist will use application individually in most cases. Estimated time that student spends with application is bigger than tourist does. Consequently, we suggest that for classes' purposes scene should contain more activities and provide more factual information.

In general, models of objects should be close to the outer view of the original objects. However, approaches for content presentation are quite different. For the historical classes, historical facts must be emphasized and established for learning. Two remaining options may contain some entertaining content to seize attention of the user to the current item or maybe to the other items from the list. But it does not prohibit entertaining entities (e.g. animated character) to be present in the educational content as long as they support it and enrich user experience.

For the first group, they always stay within the same classroom. In the second case, application users move from one room to another. Thus, indoor navigation will be sufficient for this task. The last group of users can be tracked via the means of Global Positioning System (GPS).

AR-based historical guide performs the following functions:

1. Provides visual representation of historical object, dynamic scenes, etc.
2. Reaction to user input actions and provides dynamic behavior of the object.
3. Facilitates additional information about the presented entity to the user.
4. Switching between different objects in catalogue.
5. Location of the object in the museum, park, etc. on a map or by other means (optional).
6. Animation of the object in context of one or several scenes (optional).
7. Guides user to the object in interactive manner (optional).

The function list implies permanent presence or temporarily appearance of the following object types in the scene:

- historical object itself;
- textual description of the object;
- graphical information about object location.

As A-Frame library requires markers for its work, it is necessary to provide markers and bring them into the scene. Historical guide is able to display different objects; therefore, two options can be used. The first one is to provide multiple markers and switch among them manually. Booklet with set of markers seems a feasible solution for this case because it is compact but still provides information to the application. The second option is to implement switching directly in the application. It implies presence of additional object in the application, menu. The user can select object he or she is interested in and processing engine will treat marker as a starting point for different object.

For the development of complex scenes, presence of multiple markers is required. They must be captured and tracked simultaneously to provide better user experience. Hence, placement of the markers on the surface and scenario for user actions should be worked through carefully. Multiple objects on the scene make it more dynamic. However, in context of learning history, those objects have to relate to each other, have some comparable feature to analyze, so the overall scene will have sense and represent part of historical knowledge.

Textual information that accompanies the object on the scene has an aim to provide brief description about object shown. Its location on the screen depends on the current point of view selected by the user. It should stay readable regardless of user actions specifically connected with object rotation. From the implementation perspective, such textual model can be represented as text object in the A-Frame library. It is also a good practice to give user choice to turn off visibility of the description object.

Location information in the AR-historical guide depends on what institution actually uses it. If it is application for tourists, it shows path to attractions via card service (e.g. Google Maps). On the other side, application for museum does not need such functionality and in-building navigation is preferable in this case. User can select exhibit he/she interested in and make use of markers placed inside the museum. Depending on the selected item, arrows that show direction or next step on the route will be shown. Thus, route to the exhibit is constructed dynamically and guides user to the necessary location inside the building. Finally, for the history classes at school or university, routing to the object is not necessary and brief static information about object location is enough. The location block should be placed beside the main object on the scene. However, we can employ different approach to represent place of the object by using interchangeable surrounding assets. For instance, if object is located in snow region, the object itself is surrounded by snow. In opposite, if object relates to the warm region, it might be demonstrated in the scene with desert environment and appropriate landscape.

One of the most indispensable features of AR-application is active participation of the user and ability to respond to user actions. In general, we can suppose that device with deployed program contains touch screen and sensors to react on user's movements and gestures. By default, the user observes front side of the object. The user is able to change perspective in two ways:

1. By gestures sensed by inertial sensors (accelerometer, gyroscope).
2. By gestures received from touch screen.

Both of them can be considered as primary actions to control the scene.

A-Frame supports several formats of object models. glTF format is recommended by A-Frame documentation as format for WebVR. Nonetheless, during development of historical guide application, it is possible to convert format of the file to the required one using modeling environments such as Blender. The main issue concerned with models is to obtain models of historical objects. Complex models may contain as much as several hundred thousand vertices and go with multiple textures. Design of precise copies of objects is very time-consuming task that will take much more time than application development. Therefore, it would be a better choice to find freely available models on services like Sketchfab [18] or order models from designer. Downloading models from the specialized websites puts additional constraints because you may not find the object you are looking for and will include some similar object or have to refuse from the demonstration of the object.

In general, A-Frame proposes traditional web-site architecture for the purposes of AR-application. User sends request to retrieve corresponding resource from server and works with it. It is preferably to direct user to single page and do not switch from this page as it requires more time. It is obligatory for the user to grant access for camera usage for the page. When page receives this access level, it can act. The next step to do for the user is to provide marker(s) into the scene and direct camera at the marker(s). After that moment, all previously mentioned scenarios and tools take place to demonstrate scene.

The following part of the page markup is used in description of the scene:

```
<a-scene embedded arjs="sourceType: webcam; ">
      <a-assets>
        <a-asset-item
          id="scene-1"
          src="/models/scene-1/scene.gltf"
        ></a-asset-item>
        ...
      </a-assets>
      <a-marker
        type="pattern"
        url="./chnu-marker.patt"
        emitevents="true"
        registerevents>
        <a-entity> </a-entity>
      </a-marker>
      <a-entity camera></a-entity>
</a-scene>
```

The outer element defines the scene and sets support for AR-capabilities via web-camera-support. Inner elements of the scene are list of assets (only the first one is shown while the rest are omitted), marker, and camera. The models are stored in the models directory and for performance reasons models in glTF-format are applied for demonstration application.

Let us provide demonstration of software developed according to the proposed model background and functional requirements for history learning AR-environment. For demonstration purposes, the application has been deployed on the local machine. In Fig. 1, starting scene with no selected model is shown.

The menu appears over top of the image captured from camera and is always available to change the model. As one of the option from the list is selected, corresponding model appears at the marker place. In this case, the first model corresponds to pearl monument as well as second model is represented by castle object as demonstrated in Fig. 2.

Besides presence of the model, textual description for the model is provided (in this case, text does not contain information about the model, it just performs placeholder function).

Once again, this fictional model does not correspond to any known architectural form. However, it proves that even such large-scale buildings like castles are suitable for demonstration in AR-guide even on mobile device.

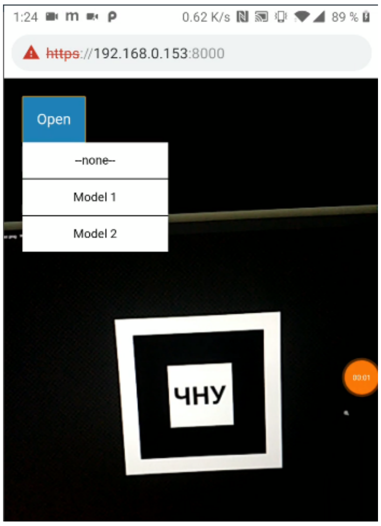

Fig. 1. Screen with open option menu and camera directed to the marker

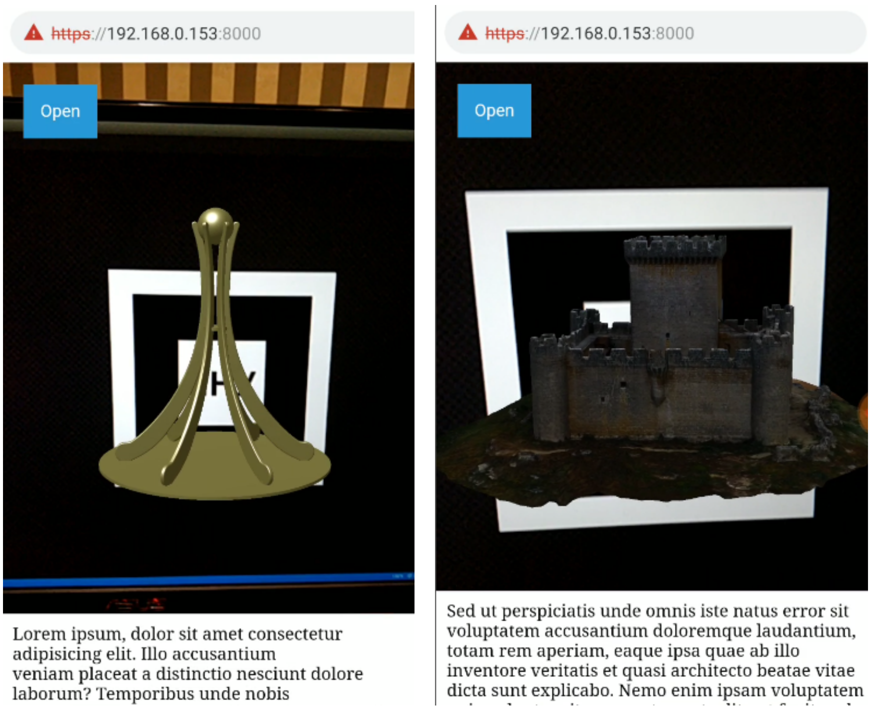

Fig. 2. Demonstration of the first model

Despite demonstration figures have been retrieved in the local infrastructure, the application code is available from Github repository [7]. It is also deployed at the github.io [3] for fast acquaintance with site and can be launched from every mobile device with camera that provides resolution sufficient for marker recognition and has internet access. We also make available for use and immediate testing marker for the application that is a Fig. 3.

Fig. 3. Marker for application

During the testing stage, several artifacts have been observed in the application work. First, it is required for the camera image provide distinguishable image of the marker. Otherwise, the model disappears. Secondly, the speed of processing for browser application even in the local network is lower than for native ones. We also experienced problems with launching site directly from the deployed location. Hence, possible solution for this problem is to pull source code from repository and run it from local environment.

The further development of the project is concerned with addition of new model into the application and improvements from the interactivity point of view.

4 Conclusions

In the presented paper, we established AR-based application that can be used in context of effective presentation of historical materials and history-related content. The application is meant to be used for historical classes and as a mobile tourist guide. We have provided detailed description of the system and all of its components. The entities used in application have been thoroughly inspected and functionality of each of them is identified. The developed application is based on the A-Frame JavaScript library that works from the browser. Hence, application is available to almost all device types that have web-browser installed and support capturing image from camera.

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Augmented reality technology within studying natural subjects in primary school

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Abstract. The purpose of the research is creation of mobile app (supported by Android) for visualization of chemical structure of water and to display video-data of laboratory experiments that can be used by the teacher and pupils for an effective background for learning natural cycle subjects and performance of laboratory experiments in the elementary school using lapbook.

As a result of work, aimed at visualizing the education material, a free mobile app LiCo.STEM was developed; it can be downloaded from the overall-available resource Google Play Market. Representation of the developed video materials on the mobile gadgets is conducted by “binding” them to individual images-“markers” for every laboratory experiment.

Applying such technologies gives an opportunity to establish educational activity, based on interference of adults with children, oriented on interests and abilities of each kid, development of curiosity, cognitive motivation and educational energy; development of imagination, creative initiative, including the speech, ability to chose the materials, types of work, participants of the common activity, promotion of conditions for parents participate in the common study activity.

Keywords: information and communication technologies, Augmented Reality technology, mobile education, 3D-visualisation, Vuforia, Unity 3D.

1 Introduction

1.1 The problem statement

Nowadays, the development of information and communicational technologies allows to modernize the education process in general schools, utilizing various trends of the contemporary education. New methods of teaching natural and mathematical sciences, as well as chemistry, have to deal with up-to-date demands for using informational technologies [4; 8; 9; 10; 11; 12]. Applying information and communicational technologies (ICT) within chemistry training allows to intensify the educational process, accelerate the knowledge and experience transfer, as well as upgrade the quality of study and education [4; 5]. Utilization of multimedia presentations, Internet-resources during the lessons gives teacher an opportunity to explain the theory understandable, increase the pupils' interest for study, keep their attention in a better way.

At the same time, natural sciences are mostly experimental ones. An effective pupils' knowledge perception in natural science, and later on in physics, chemistry, biology and astronomy depends not only on the way of presenting the theory, but also on accomplishment of the experimental part in practical works and laboratory experiments, which demands decent theoretical background both from the teacher and the pupils.

Besides, the nowadays condition of material support of the majority of schools demands an update and does not allow a proper performance of practical works and laboratory experiments by the pupils. Within the primary school another appearing problem is professional training of the primary school teacher, not enough to perform laboratory experiments in natural sciences (physics, chemistry, biology etc.). Because these subjects are not their specialization, performance of such an experimental part in class requires extra training.

1.2 The objective of the research

The objective of the research is creation of mobile app (supported by Android) for visualization of chemical structure of water and to display video-data of laboratory experiments that can be used by the teacher and pupils for an effective background for learning natural cycle subjects and performance of laboratory experiments in the elementary school using lapbook.

2 Discussion and results

In the modern era, there are a lot of views about the definition of mobile learning [6; 15; 16; 17; 18; 19; 21]. The European eLearning Guild defines it [22] as any activity, allowing people to be more productive in consumption, interference or creating information by compact digital gadgets, if they do these actions on a regular basis, has a reliable connection and the gadget can be stored in a pocket or a little bag. In this case, using present day mobile gadgets (smartphones, tablets etc.), which are an inevitable attribute of a general school pupil, they can prepare him for performance of a practical work in chemistry, physics, biology, introduce the safety regulations and demonstrate the performance technique [7].

Visualization of the study process makes its perception and digestion easier. The demonstration material, chosen in the right way enables better understanding of different processes and phenomena, the structure of chemical compounds and mechanisms of their interference. Usual 2D images of the traditional handbooks and textbooks does not give the full image about the basic ideas of the natural disciplines: the spatial structure of molecules, physical processes, mechanisms of the courses of chemical reactions etc. In this way, for an effective study of natural sciences, at the present day, it is practical to use numerous demonstrations, which are impossible without utilization of applications-implementors of augmented reality.

Augmented reality (AR) gives the ability to visualize an object (atoms and molecules, their interference, circuits of the devices, technological processes, etc.) as much as possible, meaning to convert a 2D image to 3D, as well as "make it alive". AR allowing to visualize information, show 3D-models, the pupils can receive it ready to be precepted and they will not waste time and cognitive efforts on its interpretation.

Thomas P. Caudell and David W. Mizell [1], characterizing the augmented reality, emphasize the simplicity of representation of virtual objects, comparing with virtual reality.

Any augmented reality tool can be an educational object [20], if it is controlled and supports interference of the user with real objects for the purpose of learning their characteristics during experimental research.

Applying augmented reality tools [14; 20]:

- gives ability to increase the realism of the research;
- provides the emotional and cognitive experience which enables engagement of students into systematic study;
- gives correct data about settings within the experimental process;
- creates new methods of presentation of real object within the education process.

Educational AR-technologies modify visual and contextual education, boosting the meaningfulness of the information as much, as up to 80% remains in short-term memory comparing with 25% while aural perception (traditional lectures) or reading text [5].

Nowadays, the system of primary education is being fundamentally changed [13]. An important aspect of education is the development of a pupil's skill "to learn by themselves". A contemporary child does not need to know as much, as think consistently and argumentative, demonstrate mind activity [13]. The context and methods of education in the primary school are aimed at the development of concentration, memory, creative thinking, for training the ability to compare, emphasize special characteristics of objects, classify them for a certain feature, get satisfaction from a solution found. When a kid interferes with object personally, it discovers the world around it in a better way, that is why, working with children, the priority must be given to practical methods of education [13]. Especially effective are these methods while learning the integrated course “I discover the world”.

Due to this the pedagogues have a task to find new unusual forms of interference with our pupils. Traditional education is being changed by productive one, which is aimed at the development of creative abilities, growth of pupils’ interest for creative activity. One of the promising methods, supporting the solution of this problem, is a lapbook [13].

Combined with augmented reality, lapbook gives opportunity to improve understanding of the theory, specify and illustrate it, which promotes increasing of perceptional activity and development of creative thinking. The goal of using such technologies is establishment of learning activity based on interference of adults with kids, oriented at interests and abilities of every child, development of curiosity, perceptional motivation and educational activity, development of imagination, creative initiative, including the speech, the possibility of selecting the materials, types of work, participants of the common activity, arranging conditions for participation of parents in the common education activity.

Advantages of lapbook applying [13]:

1. Helps organizing the information, received from the subject learned, voluntarily.
2. Promotes better understanding and remembering the data.
3. A convenient method of repeating and generalizing the learned.
4. The pupil learns to analyze and make conclusions by himself.
5. Lapbook can be created on any topic.
6. Creation of a lapbook is one of the types of common activities of adults and kids. It can also be a form of representing some project conclusions or a topic-based week.
7. The child learns to chose and sort the information, added to the lapbook.
8. The child is more interested in learning, when it is “alive”, and can be touched.
9. A lapbook can be created individually or within a group, depending on the reasonable goals for any child.
10. Lapbook can be a meaningful element of the depending environment of a group.

The only “minus”: to create a lapbook they need time, imagination, efforts and absence of laziness.

This research is dedicated to learning of the subject “Water” in the first form (week 12) on “I discover the world” lessons. According to the requirements, learning this subject includes the next questions and tasks:

Research / problematic questions

Where does the water “live”? How does it travel?

Why do we need to drink water? Why is needed for human and nature?

What can water be?

What happens, if water disappears?

How to safe water?

In the developed lapbook the objects, represented by the AR technology, have the relevant mark ; there is a mark about this on the back side of the lapbook.

As a result of work, aimed at visualizing the education material, a free mobile app LiCo.STEM was developed; it can be downloaded from the overall-available resource Google Play Market.

On the first stage, 3D-images of water molecules and ice structure (crystal grating), water and water vapor.

Augmented reality gives an opportunity to visualize the water molecule maximally, meaning convert 2D image into 3D, as well as make it "alive" [4]. Applying such a tool of ICT while learning new material allows to develop and boost spatial imagination of pupils, "to see" the invisible (molecule, crystal grating) and to understand the heard material deeper, which promotes its better understanding and development of certain practical skills [4]. This method has its advantages over applying computer programs, because it gives the opportunity to visualize the lapbook images with a phone or tablet no matter where the pupil is located (in class, on a walking-tour, home, etc.) and does not require being in front of a computer or laptop.

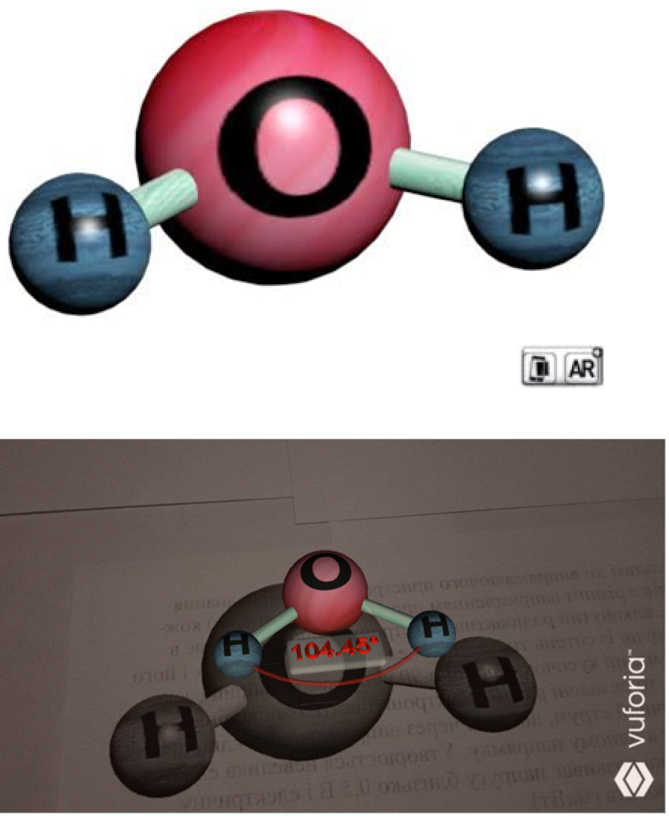

Fig. 1. 2D-image ofwater molecule, located on the lapbook, which can be represented with AR-technology in LiCo.STEM mobile app.

For applying AR-technology, augmented reality markers were developed [1] on the Vuforia platform; 3-D objects (water molecule and ice, water, vapor structures) were modeled [4] in 3ds Max program, augmented reality objects were realized using multiplatform instrument for development of two- and three-dimensional mobile apps Unity 3D [2; 3].

If they point a mobile phone or tablet at a marker (Fig. 1), the image "becomes alive", its 3D model appears on the screen and it can be manipulated in some way (inversion, expansion, view from different angles) for a better understanding of its structure, operating principle etc.

On the second stage, video-data of laboratory experiments, researching surface tension, capillary effect and water filtration methods.

For development of practical skills while studying this subject the next experiments can be performed:

1. **Surface tension:** Surface tension research; Damage of the surface tension.
2. **Capillary effect:** Capillary effect analysis; Plant nutrition.
3. **Methods of filtration:** Selecting the appropriate filter; Water filtration with a table napkin.

Fig. 2. Marker for representing laboratory experiments, researching capillary effect, located on the lapbook (displayed by AR-technology on the LiCo.STEM application).

Fig. 3. Marker for representing laboratory experiments, researching surface tension, located on the lapbook (displayed by AR-technology on the LiCo.STEM application).

The video materials developed demonstrate the laboratory experiments, performed by an experienced lab scientist keeping up all the safety regulations. The experiment performance is subtitled with text explanation. Applying the developed video information gives pupil an opportunity (guided by the teacher or parents), to repeat such experiments in class or home, makes the perception of this material easier and demonstrates sometimes hard understandable experimental part in a perceptible form.

Fig. 4. Marker for representinglaboratory experiments, researchingwater filtration methods, located on the lapbook (displayed byAR-technologyon theLiCo.STEM application).

Representation of the developed video materials on the mobile gadgets is conducted by "binding" them to individual images-"markers" for every laboratory experiment (see Fig. 2-4).

Vector images were selected for markers"; they can show the context of the experiment, are established as objects of augmented reality by multiplatform instrument for two- and three-dimensional applications Unity 3D.

Fig. 2-4 show examples of the developed markers for recommended laboratory experiments on the subject "Water", located on the lapbook for teachers and primary school pupils.

3 Conclusions

A mobile application (supported by Android) was developed for visualization of chemical structure of water and representation of video materials of laboratory experiments, which can be used by the teacher and the pupils for an effective preparing to learn natural cycle subjects of the integrated course "I discover the world" and performance of laboratory experiments in the primary school using the lapbook.

In a combination with augmented reality technology, lapbook gives an opportunity to improve understanding of the theory, specify and illustrate it, which boosts perceptional activity and development of creative thinking.

Applying such technologies gives an opportunity to establish educational activity, based on interference of adults with children, oriented on interests and abilities of each kid, development of curiosity, cognitive motivation and educational energy; development of imagination, creative initiative, including the speech, ability to chose the materials, types of work, participants of the common activity, promotion of conditions for parents participate in the common study activity.

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Development of mobile applications of augmented reality for projects with projection drawings

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Abstract. We conducted an analysis of the learning aids used in the study of general technical disciplines. This allowed us to draw an analogy between physical and virtual models and justify the development of a mobile application to perform tasks on a projection drawing. They showed a technique for creating mobile applications for augmented reality. The main stages of the development of an augmented reality application are shown: the development of virtual models, the establishment of the Unity3D game engine, the development of a mobile application, testing and demonstration of work. Particular attention is paid to the use of scripts to rotate and move virtual models. The in-house development of the augmented reality mobile application for accomplishing tasks on a projection drawing is presented. The created mobile application reads, recognizes marker drawings and displays the virtual model of the product on the screen of the mobile device. It has been established that the augmented reality program developed by the team of authors as a mobile pedagogical software can be used to perform tasks both with independent work of students and with the organization of classroom activities in higher education institutions.

Keywords: virtual model, augmented reality, mobile application, Unity3D, Vuforia, testing, resource-based learning, mobile learning.

1 Introduction

1.1 The problem statement

Now the tendency of the rapid development of computer tools and digital technologies, their widespread adoption in all spheres of public life, the desire of students to widely apply them in everyday life and professional activities, actualize the need for their use in the educational process [2; 4; 10]. In recent years, digital technology has made a huge leap in the development and expansion of areas of use. Augmented Reality (AR) is an environment which combine the physical world objects with digital data in real time using mobile Internet devices (MID), as well as software for them. If earlier this technology was used mainly in the military industry and computer games, now AR penetrates almost all spheres of human social activity: economics, medicine, education, architecture, advertising, etc. [30].

Thoroughly studying the problem of organizing mobile learning (m-learning), domestic and foreign scientists Luke Bennett [5], Valerii Yu. Bykov [4; 3], Baiyun Chen [5], Abdel Rahman Ibrahim Suleiman [13], Oksana M. Markova [17], Natalia V. Moiseienko [26], Pavlo P. Nechypurenko [18], Olena O. Pavlenko [19], Kristine Peters [20], Oleksandr P. Polishchuk [31], Maryna V. Rassovytska [22], Serhiy O. Semerikov [24; 25], Ryan Seylhamer [5], Andrii M. Striuk [29], Illia O. Teplytskyi [27], Viktoriia V. Tkachuk [32] note that the introduction of mobile learning with MID is an effective way for students to gain knowledge, develop information skills, as well as a unique form of vocational training and maintaining the productivity of the learning process while a student it is independent of time, place and space.

The main task in the vocational training of first-year students of technical specialties is the development of spatial thinking for quality reading of drawings, drawing skills, memorization and systematization. To do this, use various learning aids, such as diagrams, photographs and technical drawings. Basically, it is quite difficult to teach students to read drawings, which is associated with the need to develop orientation skills in 3D space and spatial imagination. This requires additional efforts from students to visualize objects in different projections and orientations (axonometric perspective geometry), as well as to manipulate imaginary 3D models to create two or three flat views. Thus, in educational institutions it is customary to use 3D physical objects or other models as additional learning tools.

3D physical models (Fig. 1) are used in the learning of Engineering Graphics and Descriptive Geometry, Engineering and Computer Graphics et al.

A typical example is the use of 3D physical models to solve metric and positional problems in descriptive geometry, which help students look at solutions from different perspectives and improve the understanding of the relationship between a real object and a two-dimensional image [6].

The use of physical models also has several disadvantages, such as: high cost, which leads to the purchase of models only from the basic topics of the discipline. In the process, models wear out and break their parts, and sometimes, due to inadvertence and difficulty in moving, entire models are destroyed. Usually, physical models belong to educational institutions and require special storage, which in turn makes it impossible for a student to constantly have free access to objects. These and other factors limit the possibility of the full use of models in the educational process.

To solve these problems, it is advisable to use virtual models of products. They are easily using on MID with AR. But some scientists [1; 7] emphasize the importance of using physical models in the educational process, justifying this by lowering the prices of digital manufacturing technologies, such as 3D printers.

Fig. 1. 3D physical models in teaching projection drawing

1.2 Theoretical background

AR attracts a lot of attention in education. In our study, mobile learning is understood as a form of resource-based learning and is considered as a system of organizational and didactic activities based on the use of mobile ICT. Undoubtedly, the problem of developing such mobile pedagogical software tools that will improve the quality of professional training of specialists, in particular, technical specialties, is also becoming relevant now [16].

A number of scientists [1; 7; 9; 23] provide comparative data on the use of physical and virtual models. After analyzing the possibility of replacing the physical (material) model with a 3D virtual one when studying the drawing course, the scientists recorded that the students did not feel any discomfort when working with electronic models.

The use of 3D virtual models makes it possible to level out some negative factors that have real physical models, such as breakdowns or damage, since a mobile application that demonstrates virtual models can be effectively used with MID. The problems of transportation, storage and exchange of learning equipment outside the laboratory are also solved, in connection with the possibility of their placement on cloud media or virtual training classes on the Internet.

The display of digital models on MIS, as a rule, is based on the capabilities of AR, which attracts more and more attention of the educational community. Unlike multimedia and virtual reality (VR), AR reflects virtual objects as holograms superimposed on the real world [28]. Most of the published studies in the field of AR are presented on promising technologies (imaging, passive visualization), there are also applications on experimental prototypes with an active interface [12].

1.3 The objective of the article

Consider the methodology for creating mobile applications using AR technology and present your own development to perform tasks on a projection drawing.

2 Results and discussion

We performed the development of AR mobile application on a laptop with the following characteristics: processor Intel Core i7-3520M, RAM 12 GB, video card Intel HD 4000, web camera and network card with Windows 7 Ultimate (64-bit version).

At the beginning of development, it is necessary to design all models. While the mobile application is running, virtual models that are better developed in a CAD program are displayed on the phone screen.

This mobile application is being developed to study the Engineering Graphics or Descriptive Geometry, Engineering and Computer Graphics using Compass 3D, AutoCAD, Inventor, Solidwork, 3ds Max, Cinema4d or Maya.

The above software product is paid and for their use it is necessary to have the appropriate knowledge and skills. Therefore, in the project we used an open source program – Blender [23].

The next stage of development is the installation and configuration of Unity3D. Download the free version 2017.3.1f1 (64-bit) for Windows of the Unity3D game engine from the official site [33]. During the installation, in addition to the Unity3D and MonoDevelop, we also note the Android Build Support and Vuforia Augmented Reality [21] support, which are necessary for developing and compiling augmented reality programs in the Android system.

We are developing an AR application using the Vuforia AR platform. To use it, you must register for free on the official website. This makes it possible to download the software and get an access key. In the account in the target manager, create a new database. Upload target images to the new database. Each target image is processed by means of computer vision and a rating is set (Fig. 2).

Fig. 2. Vuforia Target Image Recognition System

The best images have five stars. They will be quickly and efficiently allocated by the application. The minimum recommended value is three stars. A fully formed database of target images is loaded into Unity3D.

Unity starts with a dialog box for creating and storing a new 3D project. The user dialogue with the Unity3D game engine is possible using the Visual editor and C# programming language.

The Visual editor consists of a Scene, a window in which all the models used in the program are displayed; Inspector – a panel for setting properties of Project commands – an analogue of Explorer in Windows; hierarchy window – a window with a list of all project objects.

Since we are developing the AR program for the Android platform, we therefore additionally install and configure the Android SDK [8] and JDK [14]. These are free products from Google and Oracle, the latest versions of which can be downloaded from official sites.

We begin the development of a mobile application with video tutorials on building a cam. We took the video from the lessons of Anna Veselova [34]. In the hierarchy window, replace the standard camera with AR. On the scene we add the target image of the cam, which is a child of the AR camera. Using the Component – Video – Video Player command, we create funds for playing a video resource, which already has a start and pause button (Fig. 3).

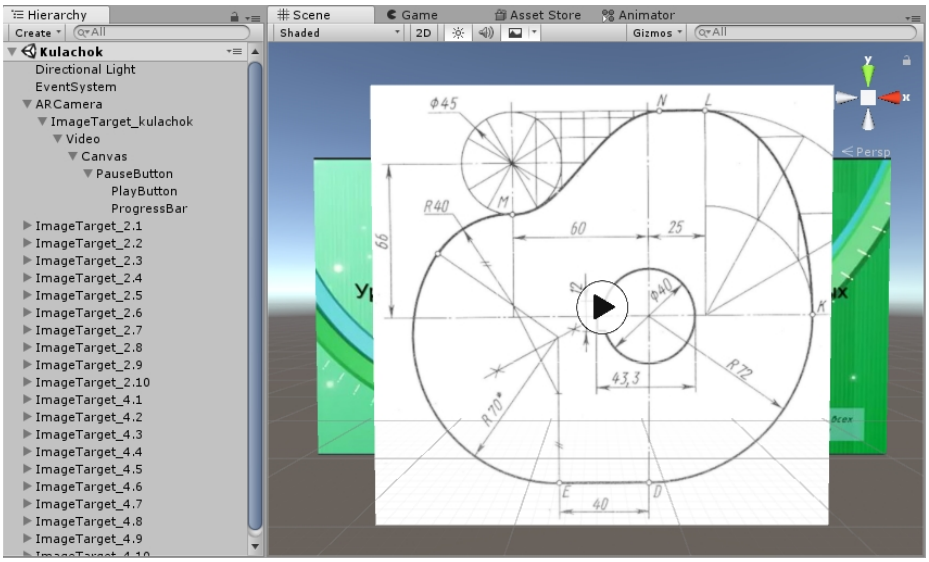

Fig. 3. Video resource development

We begin the development of the main part of the program by downloading ImageTarget and the most virtual models (Fig. 4). Thus, the program through the phone's camera, having scanned the correct figure, will show the correct model on its screen.

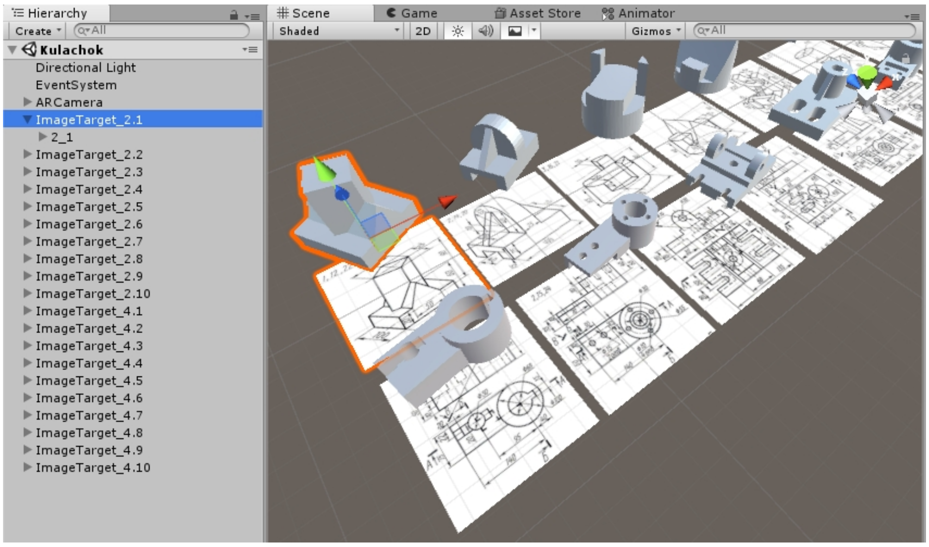

Fig. 4. Download ImageTarget and its model

The model is controlled using the fingers of a user who can move and rotate it. Such work is ensured thanks to new components – scripts that will indicate the action to perform when they are activated. In our project, we used open source scripts provided by Carlos Wilkes in the free Lean Touch project [35]. For example, the scenario for moving the model on the phone screen is as follows:

```
using UnityEngine;

namespace Lean.Touch
{
  /// <summary>This script allows you to translate the current
  /// GameObject relative to the camera.</summary>
  [HelpURL(LeanTouch.HelpUrlPrefix + "LeanTranslate")]
  public class LeanTranslate : MonoBehaviour {
    [Tooltip("Ignore fingers with StartedOverGui?")]
    public bool IgnoreStartedOverGui = true;
    [Tooltip("Ignore fingers with IsOverGui?")]
    public bool IgnoreIsOverGui;
    [Tooltip("Ignore fingers if the finger count doesn't match?
(0 = any)")]
    public int RequiredFingerCount;
    [Tooltip("Does translation require an object to be
selected?")]
    public LeanSelectable RequiredSelectable;
    [Tooltip("The camera the translation will be calculated
using (None = MainCamera)")]
```

```
    public Camera Camera;
#if UNITY_EDITOR
    protected virtual void Reset()    {      Start();    }
#endif
    protected virtual void Start()    {
      if (RequiredSelectable == null)
        RequiredSelectable = GetComponent<LeanSelectable>();
    }
    protected virtual void Update()    {
      // Get the fingers we want to use
      var fingers =
LeanSelectable.GetFingers(IgnoreStartedOverGui, IgnoreIsOverGui,
RequiredFingerCount, RequiredSelectable);
      // Calculate the screenDelta value based on these fingers
      var screenDelta = LeanGesture.GetScreenDelta(fingers);
      if (screenDelta != Vector2.zero)      {
        // Perform the translation
        if (transform is RectTransform)
          TranslateUI(screenDelta);
        else
          Translate(screenDelta);
      }
    }
    protected virtual void TranslateUI(Vector2 screenDelta)    {
      // Screen position of the transform
      var screenPoint =
RectTransformUtility.WorldToScreenPoint(Camera,
transform.position);
      screenPoint += screenDelta; // Add the deltaPosition
      // Convert back to world space
      var worldPoint = default(Vector3);
      if
(RectTransformUtility.ScreenPointToWorldPointInRectangle(
transform.parent as RectTransform, screenPoint, Camera, out
worldPoint) == true)
        transform.position = worldPoint;
    }
    protected virtual void Translate(Vector2 screenDelta)    {
      // Make sure the camera exists
      var camera = LeanTouch.GetCamera(Camera, gameObject);
      if (camera != null)      {
        // Screen position of the transform
        var screenPoint =
camera.WorldToScreenPoint(transform.position);
        // Add the deltaPosition
```

```
        screenPoint += (Vector3)screenDelta;
        // Convert back to world space
        transform.position =
camera.ScreenToWorldPoint(screenPoint);
      }
      else
        Debug.LogError("Failed to find camera. Either tag your
cameras MainCamera, or set one in this component.", this);
    }
  }
}
```

According to the method described above, we add all the models and scripts to the program, as well as compile the installation file for the Android system. The work and the main features of the mobile application can be seen on the demonstration video [15].

The next stage in the development of any program is testing. The developed mobile application was tested on the following Android-based mobile devices:

1. Samsung Galaxy A5 A520F – Android 8.0.0; 5,2"; 1920x1080; Exynos 7880 Octa; 16 MPx camera; RAM 3 GB;
2. Xiaomi Redmi Note 4x – Android 7.0; 5,5"; 1920x1080; Qualcomm Snapdragon 625; 13 MPx camera; RAM 2 GB;
3. Xiaomi Redmi 4x – Android 7.1.2; 5,0"; 1280x720; Qualcomm Snapdragon 435; 13 MPx camera; RAM 2 GB;
4. Lenovo S8 A7600 – Android 5.0; 5,3"; 1280x720; MT6592M; 13 MPx camera; RAM 2 GB;
5. Lenovo A6010 Pro – Android 5.0; 5,0"; 1280x720; Cortex-A53; 13 MPx camera; RAM 2 GB.

It is necessary to check the display of models, the operability of their movement and rotation with the touch of a finger on the screen, playing the training video and the sound. According to testing results, we can conclude that the program works correctly on phones with Android 5.0 system and on newer systems, regardless of processor type, screen matrix and RAM size.

Thus, we have developed a mobile application, which reads, recognizes the image marker and displays an model of a product on the MID screen that can be moved or rotated with the touch of a finger. After receiving the input information and its processing, the program inserts the corresponding 3D model into the real image displayed on the screen of the MID.

Moreover, the 3D virtual object is correctly located relative to the marker and interacts with it according to the given rules: for example, it is tilted along with the marker printed on the textbook or manual page. At the same time, moving the textbook, you can consider the model of the product in different angles and scales.

The designed AR app allows to implement a number of important tasks of the modern educational process: thanks to the capabilities of 3D modeling, visualize solutions to key problems (teach students how to read and execute working drawings and sketches, assembly drawings, schematic images, build virtual models) when students majoring in engineering study the Engineering graphics, Descriptive geometry, Engineering and Computer graphics, Mathematics, Physics, Theoretical Mechanics, Resistance of Materials, Theory of Mechanisms and Machines [11], within the framework of which 3D physical models are used; help students better understand complex structures and complete tasks that require spatial imagination and developed spatial thinking, which are the basis for the successful implementation of future professional activities of students majoring in engineering; provide students with the opportunity to master practical skills, research experience using their own MID; increase the motivation for learning and the effectiveness of independent work of students, making learning a bright and interesting process; create a new generation of mobile learning tools in the context of the implementation of the concept of resource-oriented education of students in higher education.

3 Conclusion

Thus, in the statement of the problem, we substantiated that a person equally perceives both physical and virtual models, but virtual models have some advantages over physical ones, thereby proving the desirability of describing the methodology and creating applications for MID using AR technologies.

The analysis of programs for 3D modeling made it possible to substantiate the choice of open source software. The main points of installing the game engine Unity3D and additional components, including the AR platform Vuforia, are shown. The stages of the development of the scenes were given. Particular attention is paid to writing detaily commented scripts. The finished program was tested by students on mobile phones with various technical characteristics when performing tasks on independent work and preparing for classroom studies in Engineering Graphics and Descriptive Geometry, Engineering and Computer Graphics. And also a demo video was created showing the operation and main features of the program. Demonstrated experience in the development of AR programs with engineering graphics will be useful to the pedagogical community for writing their own applications.

This article describes a methodology of application developing for MID using AR technology on one topic of an engineering graphics course. In the future, we plan to create full-fledged electronic systems (handbooks), including tests and tasks for self-testing, from the most difficult topics, such as the formation of projection images, simple and complex cuts, types and formations of threads, detachable and integral connections, and others.

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