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This volume represents the proceedings of the 3rd International Workshop on Augmented Reality in Education (AREdu 2020), held in Kryvyi Rih, Ukraine, in May 13, 2020. It comprises 23 contributed papers that were carefully peer-reviewed and selected from 41 submissions. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

AREdu 2020 – How augmented reality helps during the coronavirus pandemic

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Abstract. This is an introductory text to a collection of papers from the AREdu 2029: The 3rd International Workshop on Augmented Reality in Education, which was held in Kryvyi Rih, Ukraine, on the May 13, 2020. 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 2020 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 since 2018 [20; 21]:

- 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 3rd International Workshop on Augmented Reality in Education (AREdu 2020), held in Kryvyi Rih, Ukraine, in May 13, 2020. It comprises 23 contributed papers that were carefully peer-reviewed and selected from 41 submissions. Each submission was reviewed by at least 3, and on the average 3.2, program committee members. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

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

2 AREdu 2020 program committee

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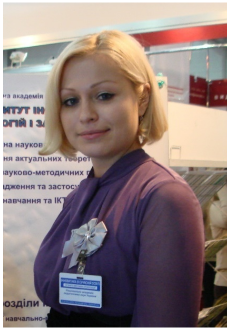

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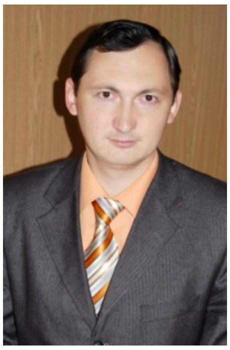

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Oleg Pursky, born in 1967, received a Candidate of Sciences in Physics and Mathematics degree (Dr. phil.) from the Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, in 2001, and a Doctor of Sciences in Physics and Mathematics degree (Dr. habil.) from the Taras Shevchenko National University of Kyiv, Ukraine, in 2010. His research interests include informational systems development, computer simulation and modeling of socio-economic systems. He has published a number of papers in international journals, monographs and volumes in book series, is a member of editorial board of International Journal of Economic Theory and Application, reviewer of scientific journals International Journal of Modern Physics (B) and Heat Transfer and certified Data Science & Machine Learning specialist. He is a member of Scientific Council section of Ukrainian Ministry of Education and Science on the specialty "Informatics and Cybernetics". Currently, he is working as a Head of Department of Computer Science and Information Systems, Kyiv National University of Trade and Economics.

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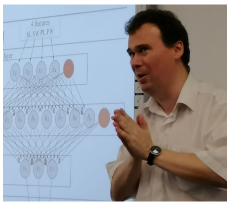
Dr. **Natalya Rashevska**, PhD, Kryvyi Rih National University, Ukraine



Dr. **Serhiy Semerikov**, Professor of Computer Science and Educational technology, Kryvyi Rih State Pedagogical University, Ukraine

Serhiy Semerikov had studied Mathematics and Computer Science at Kryviy Rih State Pedagogical University, Ukraine in 1993-1998. He has obtained an MA Diploma in Mathematics and Computer Science and MS Diploma in Mathematics at Kryviy Rih State Pedagogical University in 1998 (cum laude). In 2001 he was awarded a PhD degree in Computer Science Education at Dragomanov National Pedagogical University, Ukraine. In 2002 he received his habilitation as the Docent (Assoc. Prof.) at the Department of Computer Science and Applied Mathematics of Kryviy Rih State Pedagogical University. In 2009 he was awarded a DrSc degree in Computer Science Education at Dragomanov National Pedagogical University, Ukraine. In 2011 he received his habilitation as the Professor (Full Prof.) at the Department of Fundamental Disciplines of National Metallurgical Academy of Ukraine.

From July till September 1998 Mr. Semerikov worked as a head of Research Laboratory of Department of Computer Science and Applied Mathematics at Kryviy Rih State Pedagogical University. From September 1999 till now he works at Kryviy Rih State Pedagogical University at various positions: Assistant Professor, Associate Professor, Head of Department, Full Professor. In 2010-2016 he was affiliated as a visiting professor at National Metallurgical Academy of Ukraine and Kryviy Rih National University.

Since 1997 he took and is taking part as a researcher, senior researcher, principal researcher in many research and RTD projects funded by Ukrainian Ministry of Education and Science, International Renaissance Foundation, Kryviy Rih National University. Since 2010 he works at the Institute of Information Technologies and Learning Tools of the NAES of Ukraine, Ukraine at the research positions.

Since 1999 Dr. Semerikov teaches undergraduate and graduate courses in Computer Modelling, Operating Systems, Architectures of Computer Systems, System Programming, Econometry, Data Compression Techniques, Programming Theory, Artificial Intelligence, the Machine Learning and Pattern Recognition, Quantum Programming, ICT in Education, Advances in ICT, the Software Engineering and Programming Technologies, Functional Programming. He supervised over 100 successfully accomplished master theses and 11 PhDs. He has also been the member of about 50 PhD Committees.

Dr. Semerikov has published over 300 papers as journal articles, book chapters, refereed conference and workshop contributions. He also co-edited or (co-)authored several proceedings volumes and textbooks. He serves as a member of Editorial Advisory Boards, Editorial Review Boards of international journals, a program committee member of many international conferences and workshops.

Dr. Semerikov is the founder and the co-head of the Joint Laboratory on Cloud Technologies in Education (CTE) at Kryvyi Rih National University.

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Dr. **Yevhenii Shapovalov**, a researcher at Junior Academy of Science of Ukraine, Chief Specialist at Ministry of Digital Transformation of Ukraine

Yevhenii Shapovalov was born in 1992. He defended Ph.D. in 2019 in the field of Biotechnology at the National University of life and environmental sciences of Ukraine. Since 2014 worked in the National Academy of Science of Ukraine where he provided chemical laboratory, work in science in the field of computer sciences. Science 2020 starts working at the Ministry of Digital Transformation of Ukraine. He was a participant of 3 international Jean Monnet projects related to implementing European standards in Educational programs on Environmental Sciences and Sustainable development.

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Dr. **Andrii Striuk**, Ph.D., Head of Simulation and Software Engineering department of Kryvyi Rih National University, Kryvyi Rih, Ukraine

Andrii Striuk, born in 1979. In 2000 he graduated from the Kryvyi Rih Technical University with a degree in Automated Systems Software. In 2001, he received a master's degree in computer science. Has been working at the Department of Modeling and Software of Kryvyi Rih National University since 2000. Combines educational activities with practical, developing and implementing educational software products. In 2011 he defended his Ph.D. thesis. From 2014 to 2017 he is studying at the doctoral program in Institute of Information Technologies and Learning Tools of the NAES of Ukraine (Kyiv, Ukraine). In 2017, he was awarded the Prize of the President of Ukraine for young scientists. Heads the Simulation and Software Engineering department of Kryvyi Rih National University since 2018. Field of scientific interest: professional training of software engineers, mobile learning technologies, the use of augmented reality technologies in education.

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Dr. **Tetiana Vakaliuk**, professor of the department of Software Engineering, Zhytomyr Polytechnic State University, Zhytomyr, Ukraine

Tetiana Vakaliuk, born in 1983, received a Candidate of Pedagogical Sciences degree from the National Pedagogical Dragomanov University, Ukraine, in 2013, and a Doctor of Pedagogical Sciences degree from the Institute of Information Technologies and Learning Tools of the National Academy of Sciences of Ukraine, in 2019. Since 2019, she has been working in the field of information technologies at the Zhytomyr Polytechnic State University. Her research interests include information technologies, ICT in Education, Cloud technologies. She has published a number of papers in international journals, is a member of editorial boards of Information Technologies and Learning Tools, Zhytomyr Ivan Franko State University Journal: Pedagogical Sciences, Collection of Scientific Papers of Uman State Pedagogical University.

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Dr. **Nataliia Valko**, Ph.D. of Physics and Mathematic Sciences, D.Sc. in Education, Department of Informatics, Software Engineering and Economic Cybernetics, Kherson State University, Kherson, Ukraine

Nataliia Valko has extensive experience in teachers' education via modern teaching technologies, blended learning, STEM-education. Her teaching experience in University is over 20 years. She is one of the organizers of the STEM school of KSU. She has management skills in the field of teacher training, planning educational activities, creating distance learning courses on the Moodle platform. She manages students design work to create models of robotic systems. Effectively applies innovative teaching methods for future teachers of natural-mathematical disciplines using robotics and their preparation for using STEM-technologies in teaching. She actively studies innovative teaching methods, methods of project activity. She has published a number of papers of different kinds (including books, articles in scientific international journals, conference proceedings etc.), is a member of editorial boards of Journal of Information Technologies in Education (ITE).

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Dr. **Nataliia Veretennikova**, Ph.D., candidate of social communication, assistant of the Department of Information Systems and Networks, Lviv Polytechnic National University, Lviv, Ukraine

Nataliia Veretennikova, born in 1990, received Ph.D. degree from Vernadsky National Library of Ukraine in 2017. She is a winner of the President's Award for Young Scientists in 2019 and a winner of the Regional Prize for Young Scientists and Researchers for Scientific Achievements that Contribute to Social and Economic Transformation in the Region and Affirm the High Authority of Lviv Region Scholars in Ukraine and in the World. Her scientific research relates to the field of electronic science, linguistic support and social communications.

She is an author of several papers in domestic and international journals as well as volumes. She is a member of editorial boards and joins in Programme and Organizing committees of international conferences or workshops.

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Dr. **Yuliia Yechkalo**, Associate professor, Department of Physics, Kryvyi Rih National University, Ukraine

Yuliia Yechkalo, born in 1981, received a Candidate of Pedagogical Sciences degree from the Kirovograd State Vladimira Vinnichenka Pedagogical University, Ukraine, in 2013. Since 2005, she has been working at the National Metallurgical Academy of Ukraine. She has been working at the Kryvyi Rih National University since 2012. Her research interests include theory and methods of education (physics) and information and communication technologies in education.

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3 Session 1: Augmented reality in science education

Elena V. Komarova and Arnold E. Kiv in the article “Alternatives in biological education as a way to implement an ethical approach to the formation of subject and professional competence of future teachers” [24] (fig. 1) analyzes the experience of using alternative means of teaching biological disciplines, the purpose of which is to partially or completely replace biological objects in educational practice with their visualized copies. The quantitative results obtained make it possible to judge the effect of the applied alternatives on the degree of formation of subject competence of students.

Assessing students' understanding of the ethics of alternative means used, their importance in the formation of elements of teacher's professional competence lies in the area of further development of the topic, begun in [23] and [25].

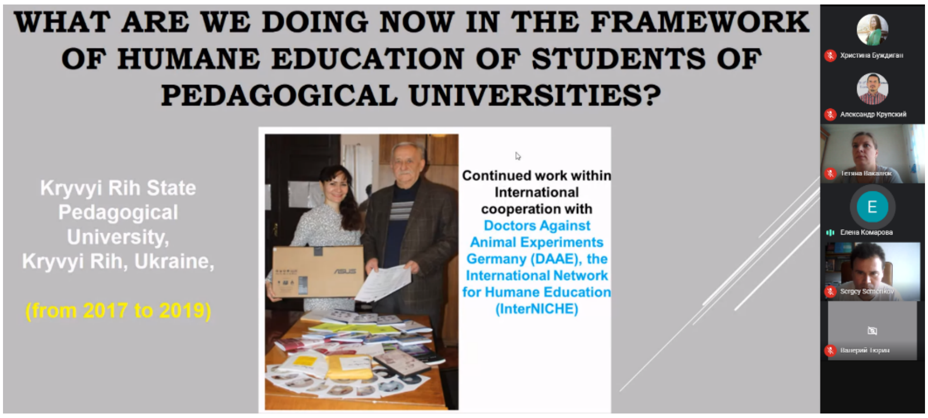

Fig. 1. Presentation of paper [24].

Zhanna I. Bilyk, Yevhenii B. Shapovalov, Viktor B. Shapovalov, Anna P. Megalinska, Fabian Andruszkiewicz and Agnieszka Dołhańczuk-Śródka in the article "Assessment of mobile phone applications feasibility on plant recognition: comparison with Google Lens" [4] (fig. 2) highlights further research, begun in [61], [62] and [63]. The article is devoted to systemizing all mobile applications used during the STEM-classes and can be used to identify plants. There are 10 mobile applications that are plant identifiers worldwide. These applications can be divided into three groups, such as plant identifiers that can analyze photos, plant classification provides the possibility to identify plants manually, plants-care apps that remind water of the plant, or change the soil. In this work, mobile apps such as Flora Incognita, PlantNet, PlantSnap, PictureThis, LeafSnap, Seek, PlantNet were analyzed for usability parameters and accuracy of identification. To provide usability analysis, a survey of experts of digital education on installation simplicity, level of friendliness of the interface, and correctness of picture processing. It is proved that Flora Incognita and PlantNet are the most usable and the most informative interface from plant identification apps. However, they were characterized by significantly lower accuracy compared to Google Lens results. Further comparison of the usability of applications that have been tested in the article with Google Lens, proves that Google Lens characterize by better usability and therefore, Google Lens is the most recommended app to use to provide plant identification during biology classes.

Natalya V. Rashevska, Serhiy O. Semerikov, Natalya O. Zinonos, Viktoriia V. Tkachuk and Mariya P. Shyshkina in the article "Using augmented reality tools in the teaching of two-dimensional plane geometry" [57] (fig. 3) highlights further research, begun in [58], [64], [68], [75], [79] and [81]. This study aimed to analyze mobile tools that can be used to visualize teaching geometry. The use of augmented reality tools in the geometry lessons creates precisely such conditions for positive emotional interaction between the student and the teacher. It also provided support to reduce fear and anxiety attitudes towards geometry classes. The emotional component of learning creates the conditions for better memorization of the educational material, promotes their mathematical interest, realizes their creative potential, creates the conditions for finding different ways of solving geometric problems.

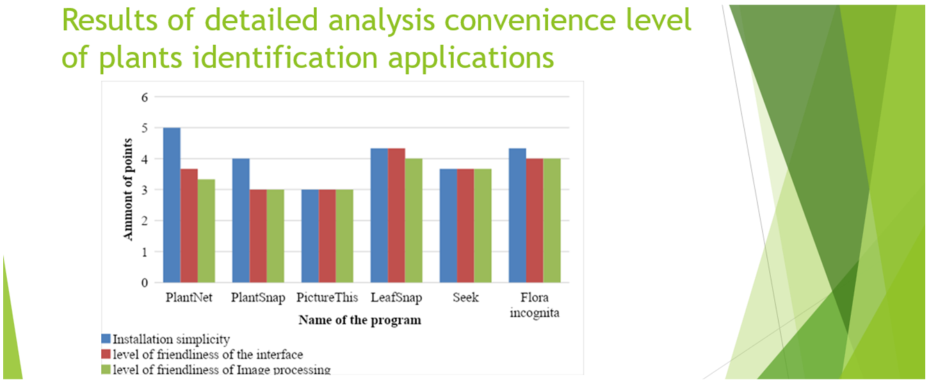

Fig. 2. Presentation of paper [4].

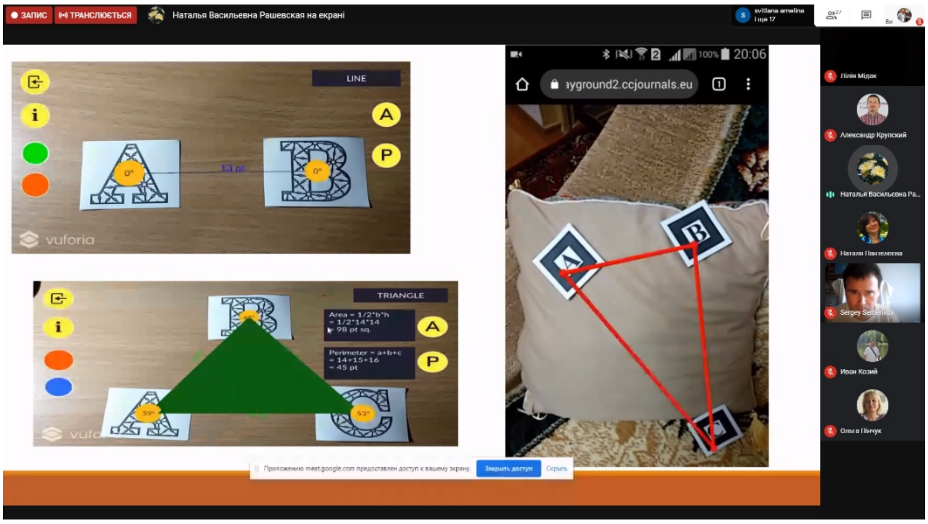

Fig. 3. Presentation of paper [57].

Vasyl P. Oleksiuk and Olesia R. Oleksiuk in the article “Exploring the potential of augmented reality for teaching school computer science” [43] (fig. 4) explored the possibilities of using augmented reality in education. They identified means of augmented reality for teaching computer science at school. Such programs and services allow students to observe the operation of computer systems when changing their parameters. Students can also modify computer hardware for augmented reality objects and visualize algorithms and data processes. The article describes the content of author training for practicing teachers. At this event, some applications for training in AR technology were considered. The possibilities of working with augmented reality objects in computer science training are singled out. It is shown that the use of augmented reality provides an opportunity to increase the realism of research; provides emotional and cognitive experience. This all contributes to engaging students in systematic learning; creates new opportunities for collaborative learning, develops new representations of real objects.

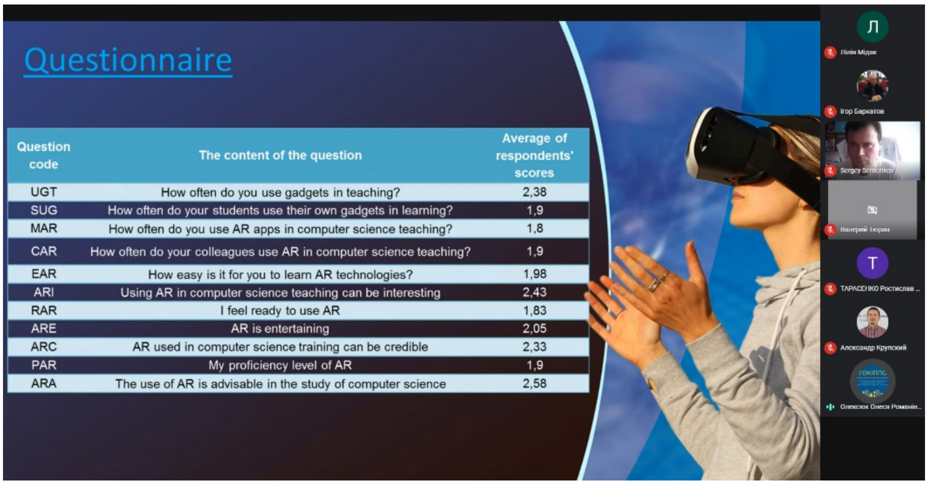

Fig. 4. Presentation of paper [43].

4 Session 2: Augmented reality in professional training and retraining

The article "Methodological aspects of using augmented reality for improvement of the health preserving competence of a Physical Education teacher" [22] (fig. 5) of Oksana V. Klochko, Vasyl M. Fedorets, Aleksandr D. Uchitel and Vitaliy V. Hnatyuk deals with the results of the research aimed at the improvement of methodology of use of augmented reality for the development of health preserving competence of a Physical Education teacher under conditions of post-graduate education. From the point of Umwelt phenomenology, augmented reality is characterized by correspondence to nature, its cognitive, metaphoric, diverse, interactive, anthropomorphic nature. The article analyzes the vectors of using augmented reality in the professional activity of a Physical Education teacher, particularly the one that is aimed at health preservation. The software that may be used with this purpose has been described. The attitude of Physical Education teachers to the use of the augmented reality for preserving their students' health and development of their motion skills, intellect and creativity was determined in the research. The results of the survey show that the majority of teachers positively react to the idea of using augmented reality in their professional activity.

However, in some cases, not a fully formed understanding of this issue was observed. The ways of solving the stated problem could be the inclusion of augmented technologies' techniques into the process of post-graduate education, taking into consideration the anthropological, ethical, cultural contexts as well as teacher involvement in the stated process.

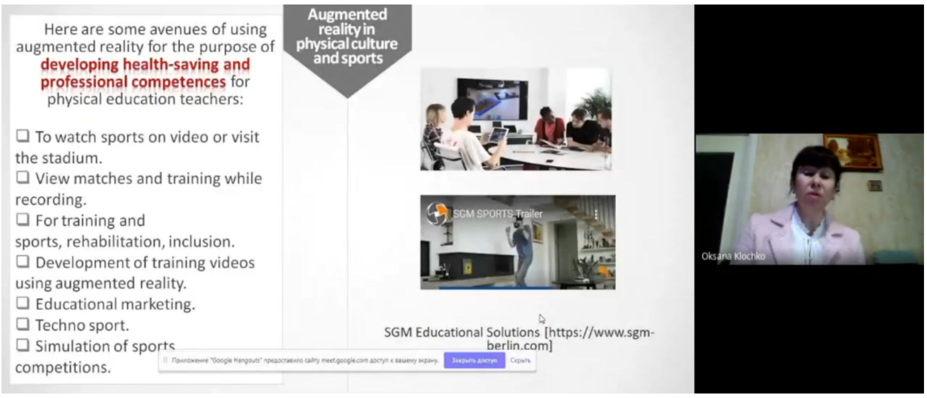

Fig. 5. Presentation of paper [22].

Rostyslav O. Tarasenko, Svitlana M. Amelina, Yuliya M. Kazhan and Olga V. Bondarenko in the article "The use of AR elements in the study of foreign languages at the university" [74] (fig. 6) highlights further research by the authors, begun in [1], [15], [70], [71], [72] and [73]. The article deals with the analysis of the impact of the using AR technology in the study of a foreign language by university students. It is stated out that AR technology can be a good tool for learning a foreign language. The use of elements of AR in the course of studying a foreign language, in particular in the form of virtual excursions, is proposed. Advantages of using AR technology in the study of the German language are identified, namely: the possibility of involvement of different channels of information perception, the integrity of the representation of the studied object, the faster and better memorization of new vocabulary, the development of communicative foreign language skills. The ease and accessibility of using QR codes to obtain information about the object of study from open Internet sources is shown. The results of a survey of students after virtual tours are presented. A reorientation of methodological support for the study of a foreign language at universities is proposed. Attention is drawn to the use of AR elements in order to support students with different learning styles (audio, visual, kinesthetic).

The article "Methodology of using mobile apps with augmented reality in students' vocational preparation process for transport industry" [32] (fig. 7) highlights further research by Olena O. Lavrentieva, Ihor O. Arkhypov, Oleksandr P. Krupskyi, Denys O. Velykodnyi and Sergiy V. Filatov, begun in [14], [33] and [51]. In the article the current state and trends of use AR technologies in transport industry and in a future specialists' vocational training process have been reviewed and analyzed. The essence and content of the AR technologies relevant to transport industry have been clarified. The main directions of the AR introduction for the various spheres of transport industry including design and tuning, mechanical and automotive engineering, marketing and advertising, maintenance and operation, diagnostics and repair of cars have been determined. The AR mobile apps market and the features of the mobile apps with AR have been outlined. The pedagogical terms of effective organizing the students' cognitive activity for transport industry via AR technologies have been determined and researched, namely: to provide each student with the position of an active actor of study and cognitive activity, to switch the study information in a mode of the project activity, the educational content professionalization and to teach students to use the modern ICT purposefully, to manage students' cognitive process by means of ICT. The methodology of using mobile apps with AR in students' vocational preparation process for transport industry has been presented. It covers the system of educational tasks, updated content of lectures, practical and laboratory classes for specialized disciplines.

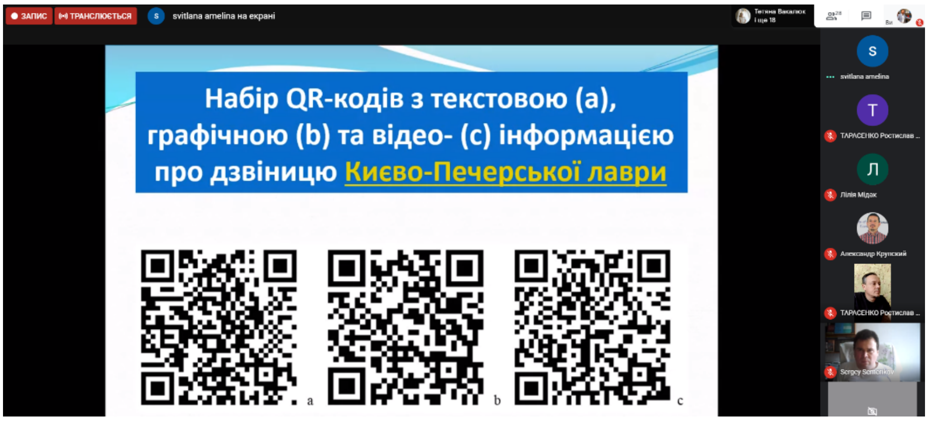

Fig. 6. Presentation of paper [74].

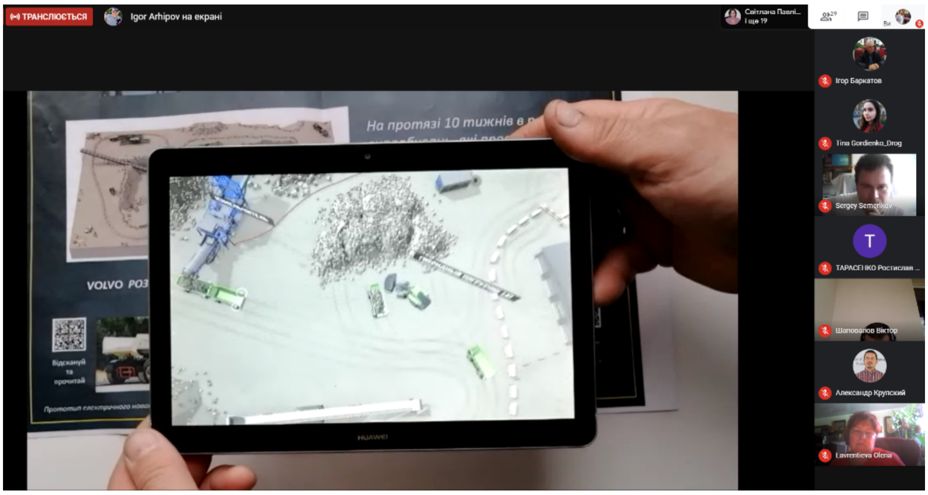

Fig. 7. Presentation of paper [32].

5 Session 3: Design and implementation of augmented reality learning environments

The article "New effective aid for teaching technology subjects: 3D spherical panoramas joined with virtual reality" [2] (fig. 8) highlights further research by Igor V. Barkatov, Volodymyr S. Farafonov, Valeriy O. Tiurin, Serhiy S. Honcharuk, Vitaliy I. Barkatov and Hennadiy M. Kravtsov, begun in [13] and [29]. The article raises the problem of extending the range of available teaching aids for vehicle-related subjects. Benefiting from the modern information and visualization technologies, authors present a new teaching aid that constitutes a spherical (360° or 3D) photographic panorama and a Virtual Reality (VR) device. The nature of the aid, its potential applications, limitations and benefits in comparison to the common aids are discussed. The proposed aid is shown to be cost-effective and is proved to increase efficiency of training, according to the results of a teaching experiment that was carried out. A series of panoramas, which are already available, and its planned expansions are presented. The authors conclude that the proposed aid may significantly improve the cost-efficiency balance of teaching a range of technology subjects.

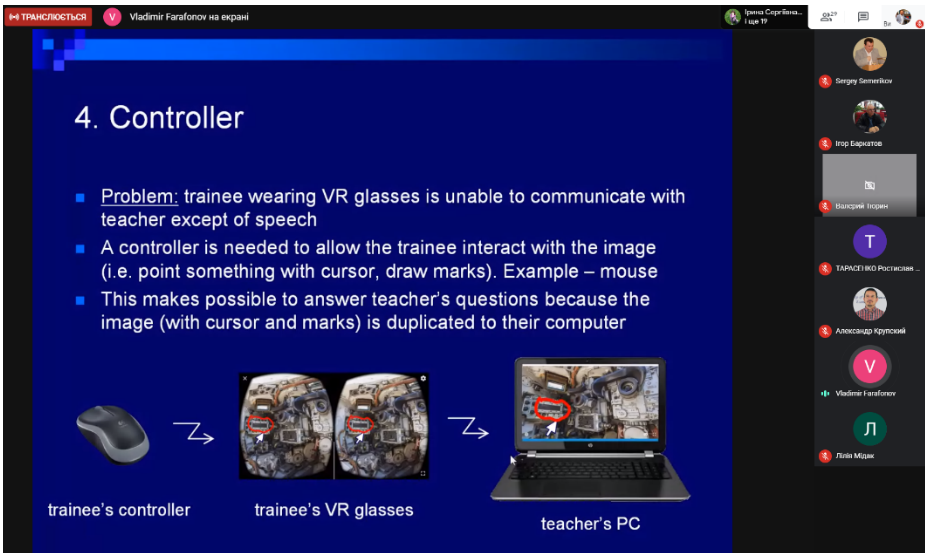

Fig. 8. Presentation of paper [2].

Edgar Iván De la Cruz Vaca, Edgar Roberto Salazar Achig, Jonathan Alexis Romero López, Adriana Estefanía Tigselema Benavides and Jacson Javier Rodriguez Conde in the article "Numerical methods for handling robotic arms using augmented reality" [9] (fig. 9) presents an augmented reality application for mobile devices, as a contribution to education through a technological learning tool that allows the management of industrial robotic arms, implementing advanced control algorithms, which allows the simulation of several selected desired trajectories by the user; and the incorporation of animations that allow to know its operation and to verify the follow-up of the proposed trajectory, as well as the visualization of control errors in each trajectory taken. The application is oriented to the simulation of industrial robotic arms within an intuitive and friendly augmented reality environment, which allows users a great interaction with the robot's structure, providing simulation programs with new immersion technologies, in the educational field. Tests in the augmented reality application demonstrate ease of use and user intuition, providing a better understanding of the operation and structure of programmable manipulators.

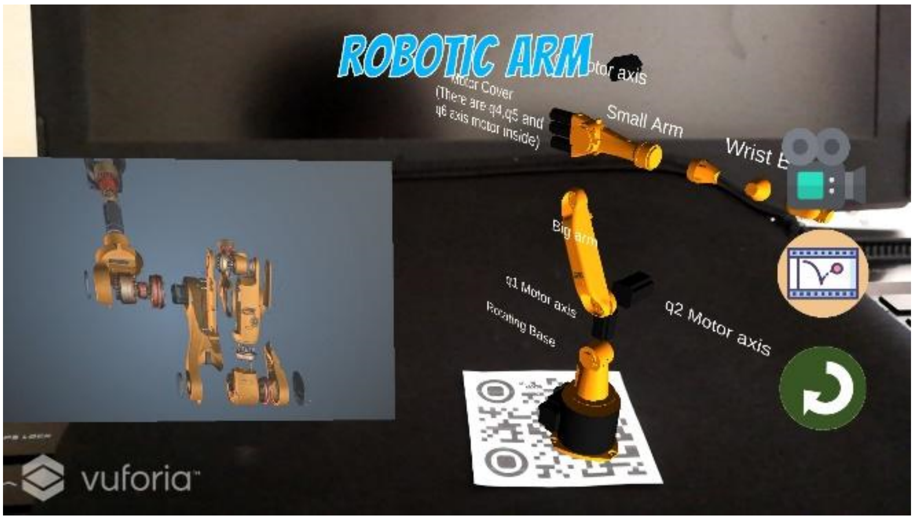

Fig. 9. Presentation of paper [9].

The article "Using a web application to realize the effect of AR in assessing the environmental impact of emissions source" [80] (fig. 10) of Tetyana I. Zhylenko, Ivan S. Koziy, Vladyslav S. Bozhenko and Irina A. Shuda describes a software that helps to show visually how the emissions of a chemical plant are spreading to the surrounding city. The harmfulness to the city of the cloud into which emissions are converted can also be calculated by the program. Authors have implemented a number of functions responsible for emission modeling, taking into account different conditions.

The article "Development of AR-applications as a promising area of research for students" [3] (fig. 11) of Vladyslav V. Bilous, Volodymyr V. Proshkin and Oksana S. Lytvyn substantiates the importance of using augmented reality in the educational process, in particular, in the study of natural and mathematical disciplines. The essence of AR, characteristics of AR hardware and software, directions and advantages of using AR in the educational process are outlined. It has proven that AR is a unique tool that allows educators to teach the new digital generation in a readable, comprehensible, memorable and memorable format, which is the basis for developing a strong interest in learning. Presented the results of the international study on the quality of education PISA (Programme for International Student Assessment) which stimulated the development of the problem of using AR in mathematics teaching. Within the limits of realization of research work of students of the Borys Grinchenko Kyiv University the AR-application on mathematics is developed. To create it used tools: Android Studio, SDK, ARCore, QR Generator, Math pattern. A number of markers of mathematical objects have been developed that correspond to the school mathematics course (topic: “Polyhedra and Functions, their properties and graphs”). The developed AR tools were introduced into the process of teaching students of the specialty “Mathematics”. Prospects of research in development of a technique of training of separate mathematics themes with use of AR have been defined.

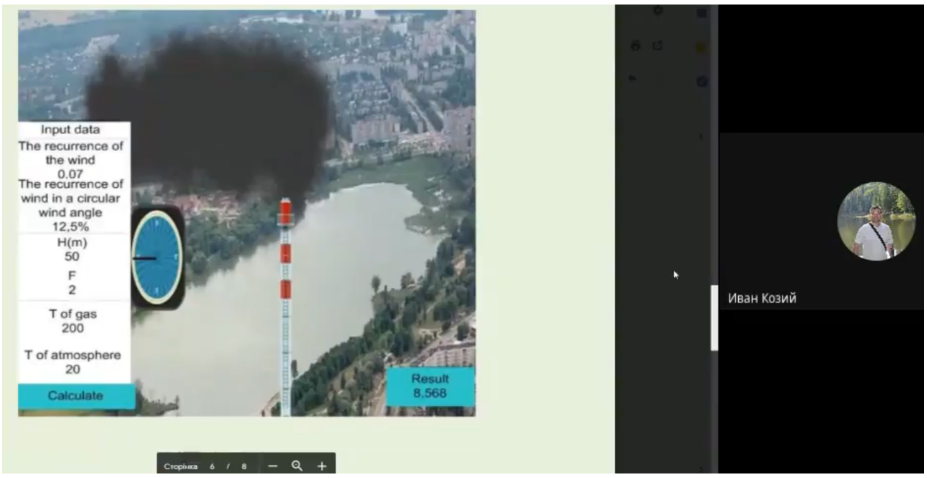

Fig. 10. Presentation of paper [80].

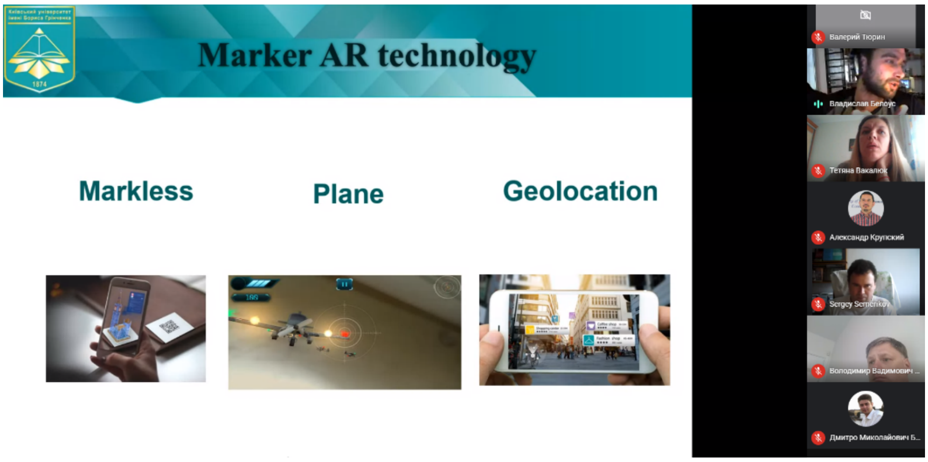

Fig. 11. Presentation of paper [3].

The article “Development of a model of the solar system in AR and 3D” [12] (fig. 12) of Valentyna V. Hordiienko, Galyna V. Marchuk, Tetiana A. Vakaliuk and Andrey V. Pikilnyak highlights further research by the authors, begun in [13], [39], [53] and [81].

In this article, the possibilities of using augmented reality technology are analyzed and the software model of the solar system model is created. The analysis of the available software products modeling the solar system is carried out. The developed software application demonstrates the behavior of solar system objects in detail with augmented reality technology. In addition to the interactive 3D model, you can explore each planet visually as well as informatively – by reading the description of each object, its main characteristics, and interesting facts. The model has two main views: Augmented Reality and 3D. Real-world object parameters were used to create the 3D models, using the basic ones – the correct proportions in the size and velocity of the objects and the shapes and distances between the orbits of the celestial bodies.

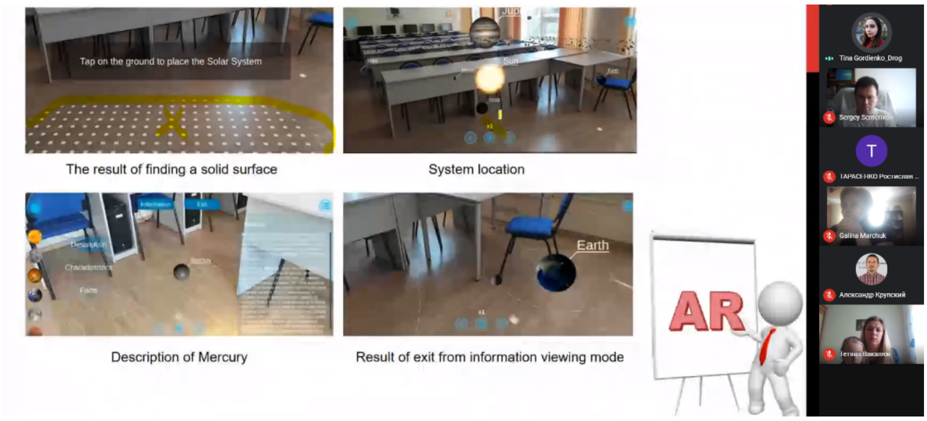

Fig. 12. Presentation of paper [12].

The article "Augmented reality in process of studying astronomic concepts in primary school" [37] of Liliia Ya. Midak, Ivan V. Kravets, Olga V. Kuzyshyn, Khrystyna V. Berladyniuk, Khrystyna V. Buzhdyhan, Liliia V. Baziuk and Aleksandr D. Uchitel (fig. 13) highlights further research by the authors, begun in [38] and [40]. The objective of the research is development a mobile application (on the Android platform) designed for visualization of the Solar System with the AR technology and the alphabet study, applying the astronomic definitions, which can be used by the teacher and the students for an effective training for studying the subjects of the astronomic cycle in primary school. AR cards with the images of the Solar System planets and other celestial bodies were developed, as well as the "Space alphabet" was created. In the developed alphabet every letter of the alphabet becomes a certain celestial body or a different astronomic definition. AR gives the opportunity to visualize images of the Solar System as much as possible, in other words to convert 2D images into 3D, as well as "make them alive". Applying this tool of ICT while studying new data gives the ability to develop and improve the pupils' spatial thinking, "to see" the invisible and to understand the perceived information in a deeper way, which will be beneficial for its better memorizing and development of computer skills. Studying the alphabet in the offered mobile app will definitely help nail the achieved knowledge and get interesting information about celestial bodies that are invisible and superior for kids; to make a journey into the space, prepare a project on “The Space Mysteries” subject; to stimulate the development of curiosity, cognitive motivation and learning activity; the development of imagination, creative initiative, including speaking out.

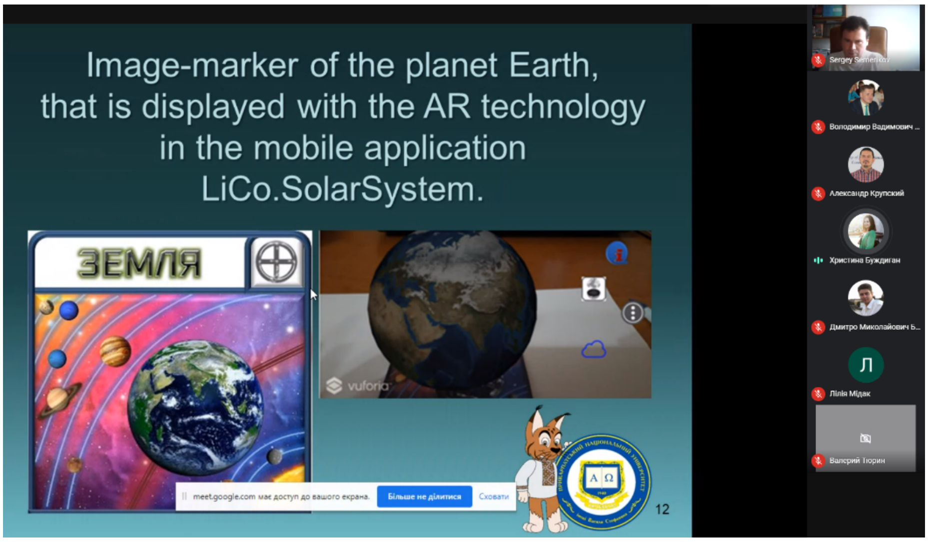

Fig. 13. Presentation of paper [37].

Yulia Yu. Dyulicheva, Yekaterina A. Kosova and Aleksandr D. Uchitel in the article “The augmented reality portal and hints usage for assisting individuals with autism spectrum disorder, anxiety and cognitive disorders” [10] (fig. 14) propose to apply the augmented reality portal as a special tool for the teachers to interact with people at the moment when a panic attack or anxiety happens in education process. It is expected that applying the augmented reality portal in education will help students with ASD, ADHD and anxiety disorder to feel safe at discomfort moment and teachers can interact with them. Authors’ application with the augmented reality portal has three modes: for teachers, parents, and users. It gives the ability to organize personalized content for students with special needs. Authors developed the augmented reality application aimed at people with cognitive disorders to enrich them with communication skills through associations understanding. Applying the augmented reality application and the portal discovers new perspectives for learning children with special needs. The AR portal creates illusion of transition to another environment. It is very important property for children with ADHD because they need in breaks at the learning process to change activity (for example, such children can interact with different 3D models in the augmented reality modes) or environment. The developed AR portal has been tested by a volunteer with ASD (male, 21 years old), who confirmed that the AR portal helps him to reduce anxiety, to feel calm down and relaxed, to switch attention from a problem situation.

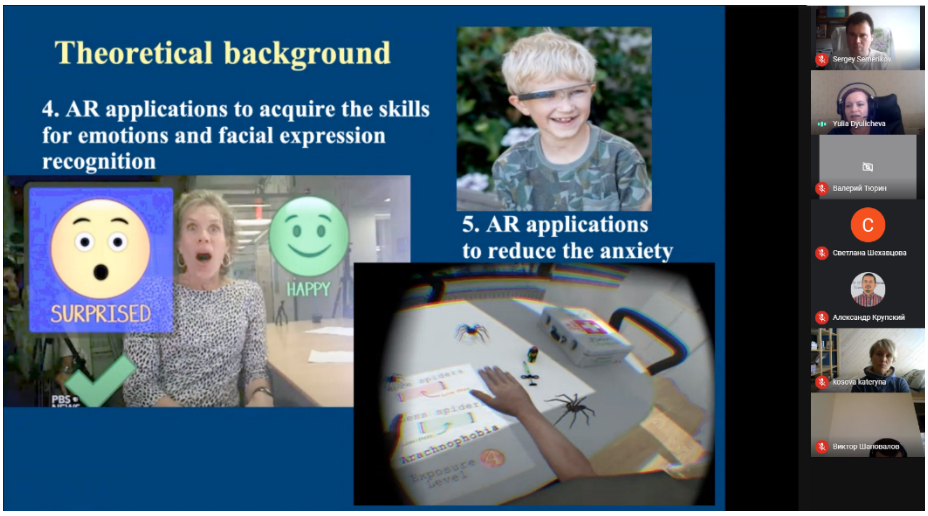

Fig. 14. Presentation of paper [10].

6 Session 4: Augmented gamification

The article "Features of implementation of modern AR technologies in the process of psychological and pedagogical support of children with autism spectrum disorders" [46] (fig. 15) highlights further research by Viacheslav V. Osadchyi, Hanna B. Varina, Kateryna P. Osadcha, Olesia O. Prokofieva, Olha V. Kovalova and Arnold E. Kiv, begun in [67] and [76]. The article deals with the actual issue of the specificity and algorithm of the introduction of innovative AR technologies in the process of psychological and pedagogical support of children with autism spectrum disorders (ASD). An innovative element of theoretical and methodological analysis of the problem and empirical research is the detection of vectors of a constructive combination of traditional psycho-correctional and psycho-diagnostic approaches with modern AR technologies. The analysis of publications on the role and possibilities of using AR technologies in the process of support children with ASD (autism spectrum disorder) and inclusive environment was generally conducted by surfing on the Internet platforms containing the theoretical bases for data publications of scientific journals and patents. The article also analyzes the priorities and potential outcomes of using AR technologies in psycho-correction and educational work with autistic children. According to the results of the analysis of scientific researches, Unified clinical protocol of primary, secondary (specialized), tertiary (highly specialized) medical care and medical rehabilitation "Autism spectrum disorders (disorders of general development)", approaches for correction, development and education of children with ASD, AR technologies were selected for further implementation in a comprehensive program of psychological and pedagogical support for children with ASD. The purpose of the empirical study is the search, analysis and implementation of multifunctional AR technologies in the psycho-correctional construct of psychological and pedagogical support of children with ASD. According to the results of the pilot study, the priorities and effectiveness of using AR technologies in the development of communicative, cognitive, emotional-volitional, mnemonic abilities of children and actualization of adaptive potential and adaptive, socially accepted behaviors are made. The possibilities and perspectives of using AR technologies as an element of inclusive environment, with regard to nosology and phenomenology, need further investigation.

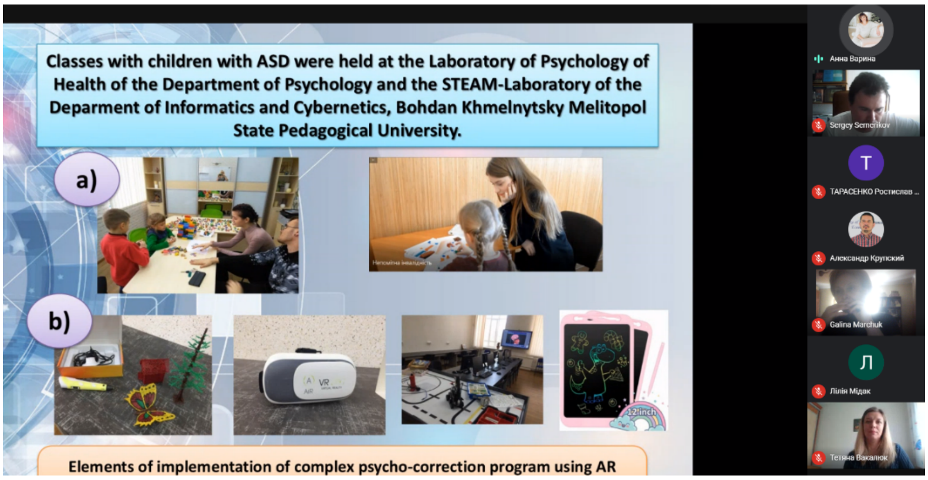

Fig. 15. Presentation of paper [46].

The article "Augmented reality books: concepts, typology, tools" [49] (fig. 16) highlights further research by Liubov F. Panchenko, Tetiana A. Vakaliuk and Kateryna V. Vlasenko, begun in [47] and [48]. In the article the facet classification for augmented books is proposed; the main facets are: reality-virtuality continuum, type of augmented materials, device types, type of interaction, spatial space of book, book's category. Content for a module of a specialty course about augmented reality books for the system of professional training and retraining for educators in postgraduate education is discussed. Some samples of tasks for educators are presented: audio augmented book about world's books monuments; analysis augmented reality examples in the textbook of the New Ukrainian school (subject name, topic, didactic tasks, quality of implementation, directions of expansion etc.), search and analysis augmented books according to the professional interests of the educators; discussion how augmented reality can help to improve student motivation with accent to attention, relevance, confidence and satisfaction; group work about design and creation a fragment of own textbook with augmented reality.

Liudmyla L. Nezhyva, Svitlana P. Palamar and Oksana S. Lytvyn in the article "Perspectives on the use of augmented reality within the linguistic and literary field of primary education" [41] (fig. 17) analyzes the scientific sources on the problem of augmented reality in the educational field. There is a fragmentary rationale for new technology in primary school, to a greater extent the experience of scientists and practitioners relate to the integrated course "I am exploring the world". The peculiarities of Ukrainian and foreign writers’ works with AR applications, which are appropriate to use during the classes of literary reading, are analyzed. The authors substantiated the prospect of augmented reality technology for mastering the artistic image of the world of literary work, the relevance of use of AR to modern educational challenges, and also demonstrated the possibility of immersion into the space of artistic creation and activation of students’ imagination with the help of AR applications. The article demonstrates the possibilities of use AR-technology for the development of emotional intelligence and creative thinking, solving educational tasks by setting up an active dialogue with literary heroes. The basic stages of the application of AR technologies in the literary reading lessons in accordance with the opportunities of the electronic resource are described: involvement; interaction; listening, reading and audition; research; creative work; evaluation. It is confirmed that in the process of using augmented reality technology during the reading lessons, the qualitative changes in the process of formation of the reader’s culture of the students of experimental classes appears, as well as the increase of motivation, development of emotional intelligence and creative thinking.

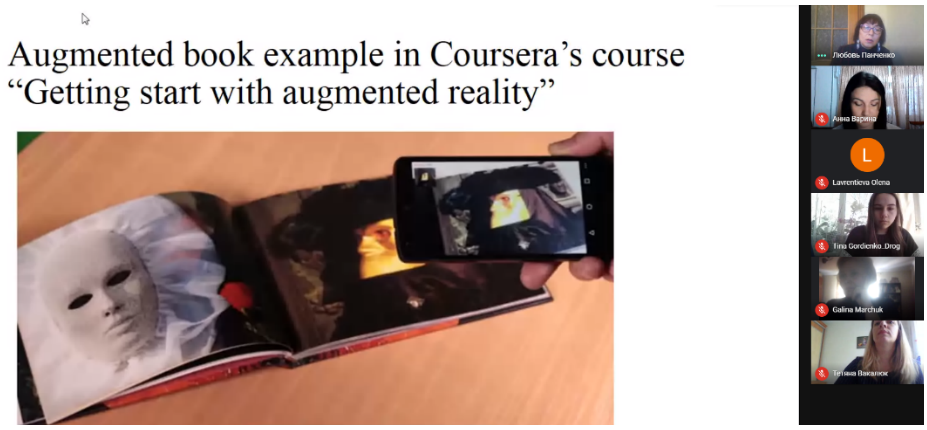

Fig. 16. Presentation of paper [49].

The article “Developing a 3D quest game for career guidance to estimate students’ digital competences” [56] highlights further research by Oleksandr V. Prokhorov, Vladyslav O. Lisovichenko, Mariia S. Mazorchuk and Olena H. Kuzminska, begun in [30], [31], [50] and [55]. This article reveals the process of creating a career guidance 3D quest game for applicants who aim to apply for IT departments. The game bases on 3D model of computer science and information technologies department in the National Aerospace University “Kharkiv Aviation Institute”. The quest challenges aim to assess the digital competency level of the applicants and first-year students. The paper features leveraged software tools, development stages, implementation challenges, and the gaming application scenario. The game scenario provides for a virtual tour around a department of the 3D university. As far as the game replicates the real-life objects, applicants can see the department's equipment and class-rooms. For the gaming application development team utilized C# and C++, Unity 3D, and Source Engine. For object modeling, we leveraged Hammer Editor, Agisoft PhotoScan Pro, and the photogrammetry technology, that allowed for realistic gameplay. Players are offered various formats of assessment of digital competencies: test task, puzzle, assembling a computer and setting up an IT-specialist workplace. The experiment conducted at the open house day proved the 3D quest game efficiency. The results of digital competence evaluation do not depend on the testing format. The applicants mostly preferred to take a 3D quest, as more up-to-date and attractive engagement.

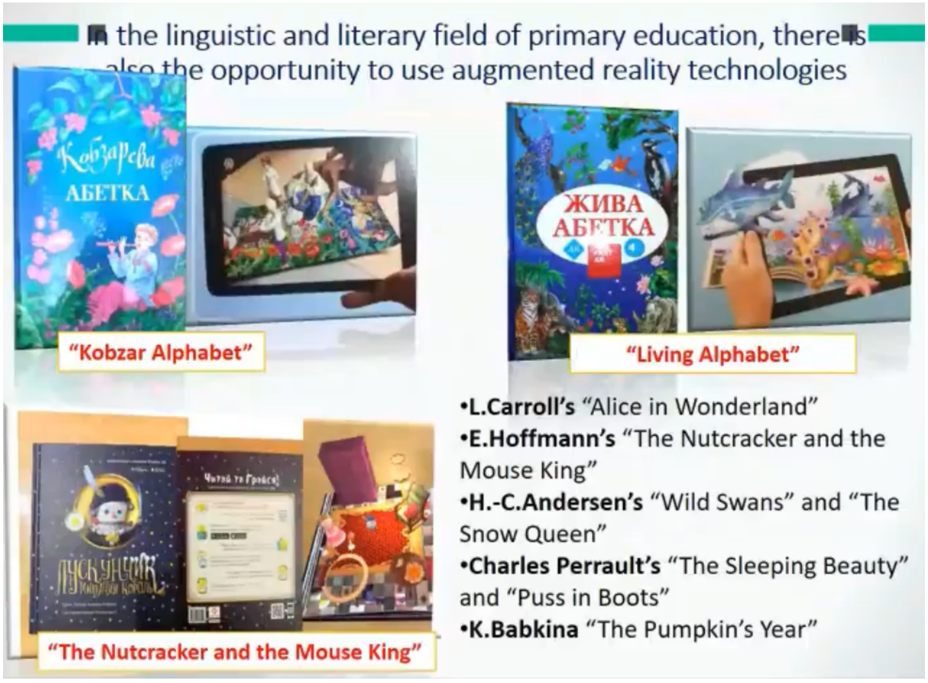

Fig. 17. Presentation of paper [41].

7 Session 5: Virtualization of learning: principles, technologies, tools

The article "Conceptual model of learning based on the combined capabilities of augmented and virtual reality technologies with adaptive learning systems" [45] (fig. 19) highlights further research by Viacheslav V. Osadchyi, Hanna Y. Chemerys, Kateryna P. Osadcha, Vladyslav S. Kruhlyk, Serhii L. Koniukhov, Arnold E. Kiv, begun in [26], [27] and [44]. The article is devoted to actual problem of using modern ICT tools to increase the level of efficiency of the educational process. The current state and relevance of the use of AR and VR technologies as an appropriate means of improving the educational process are considered. In particular, attention is paid to the potential of the combined capabilities of AR and VR technologies with adaptive learning systems. Insufficient elaboration of cross-use opportunities for achieving of efficiency of the educational process in state-of-the-art research has been identified. Based on analysis of latest publications and experience of using of augmented and virtual reality technologies, as well as the concept of adaptive learning, conceptual model of learning based on the combined capabilities of AR and VR technologies with adaptive learning systems has been designed. The use of VR and AR technologies as a special information environment is justified, which is applied in accordance with the identified dominant type of students' thinking. The prospects of using the proposed model in training process at educational institutions for the implementation and support of new teaching and learning strategies, as well as improving learning outcomes are determined by the example of such courses as “Algorithms and data structures”, “Computer graphics and three-dimensional modeling”, “Circuit Engineering”, “Computer Architecture”.

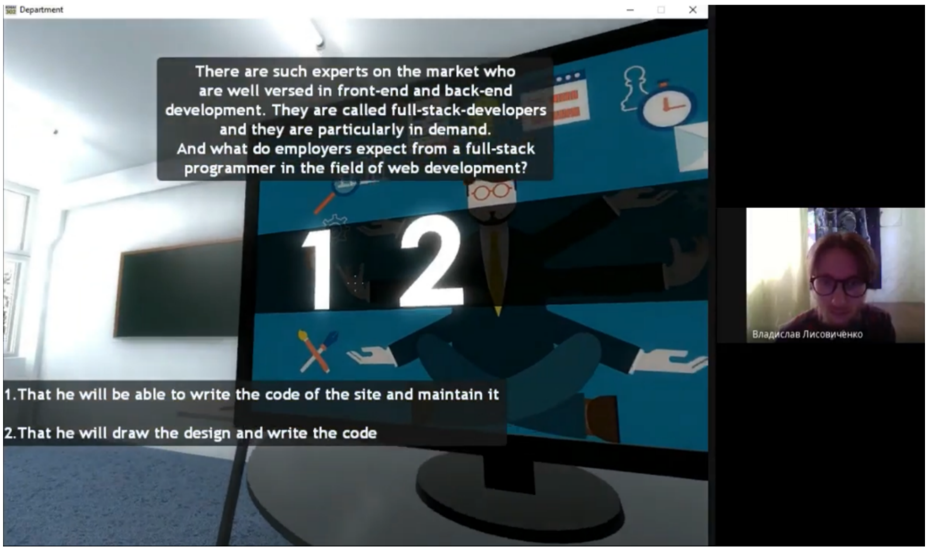

Fig. 18. Presentation of paper [56].

The article “Personalization of learning using adaptive technologies and augmented reality” [35] (fig. 20) highlights further research by Maiia V. Marienko, Yulia H. Nosenko and Mariya P. Shyshkina, begun in [34], [42], [52], [54], [65] and [66]. The research is aimed at developing the recommendations for educators on using adaptive technologies and augmented reality in personalized learning implementation. The latest educational technologies related to learning personalization and the adaptation of its content to the individual needs of students and group work are considered. The current state of research is described, the trends of development are determined. Due to a detailed analysis of scientific works, a retrospective of the development of adaptive and, in particular, cloud-oriented systems is shown. The preconditions of their appearance and development, the main scientific ideas that contributed to this are analyzed. The analysis showed that the scientists point to four possible types of semantic interaction of augmented reality and adaptive technologies. The adaptive cloud-based educational systems design is considered as the promising trend of research. It was determined that adaptability can be manifested in one or a combination of several aspects: content, evaluation and consistency. The cloud technology is taken as a platform for integrating adaptive learning with augmented reality as the effective modern tools to personalize learning. The prospects of the adaptive cloud-based systems design in the context of teachers training are evaluated. The essence and place of assistive technologies in adaptive learning systems design are defined. It is shown that augmented reality can be successfully applied in inclusive education. The ways of combining adaptive systems and augmented reality tools to support the process of teachers training are considered. The recommendations on the use of adaptive cloud-based systems in teacher education are given.

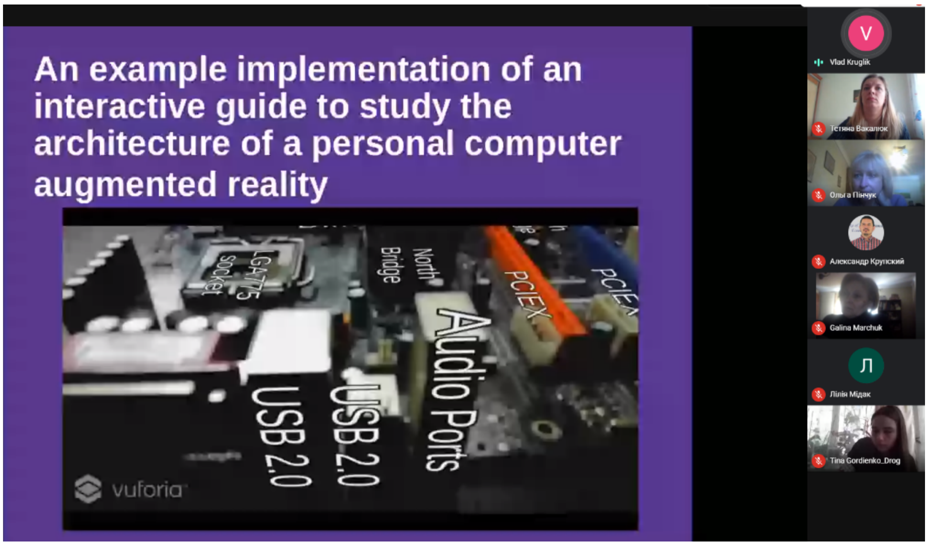

Fig. 19. Presentation of paper [45].

The article “Using a virtual digital board to organize student’s cooperative learning” [5] (fig. 21) highlights further research by Dmytro M. Bodnenko, Halyna A. Kuchakovska, Volodymyr V. Proshkin and Oksana S. Lytvyn, begun in [11] and [60]. The article substantiates the importance of using a virtual digital board to organize student’s cooperative learning in the conditions of distance education, incl. social distance (for the quarantine period 2020). The main advantages of using a virtual digital board are outlined and their functions for the organization of cooperative education are compared. An analysis of the benefits of using virtual digital boards and a survey of experts made it possible to identify the most popular virtual digital boards: Wiki-Wall, Glogster, PadLet, Linoit, Twidla, Trello, Realtimeboard (Miro), Rizzoma. The comparison of the functions of virtual digital boards outlines their ability to organize students’ cooperative learning. The structure of the module E-Learning “Creating education content with tools of virtual digital board Padlet” is presented in the system LMS Moodle. The results of the experiment are presented, which show the effectiveness of the use of instruments of the virtual digital board to organize student’s cooperative learning. Perspectives of researches in developing methods of using a virtual digital board by students of natural-mathematical specialties are determined.

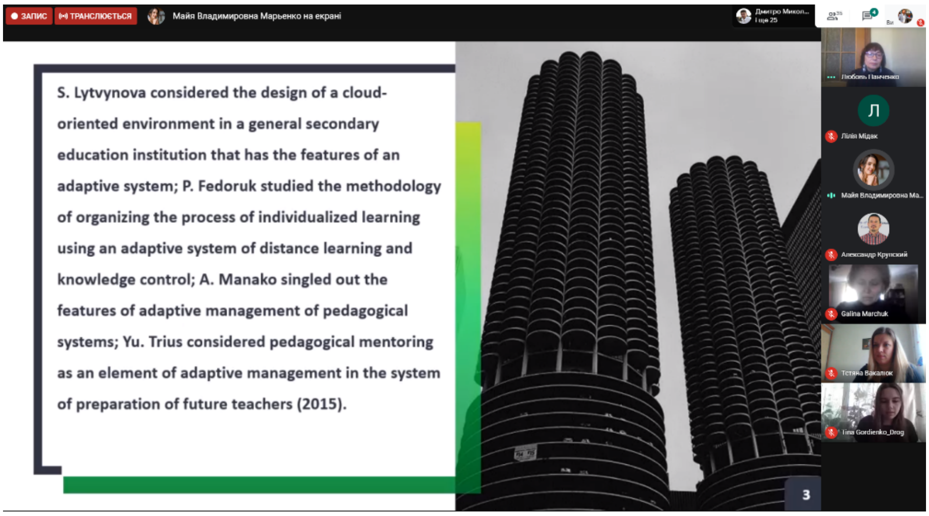

Fig. 20. Presentation of paper [35].

Fig. 21. Presentation of paper [5].

The article “Distance learning as innovation technology of school geographical education” [69] (fig. 22) highlights further research by Myroslav J. Syvyi, Ordenbek B. Mazbayev, Olga M. Varakuta, Natalia B. Panteleeva and Olga V. Bondarenko, begun in [6], [7], [8], [16], [17], [18], [19] and [36]. The article substantiates the necessity of using innovative technologies in the process of studying and teaching geographical disciplines at secondary schools. Particular attention is paid to distance learning as a pedagogical innovation, its theoretical aspects and the ways of its introduction into the educational process. The relevance of using distance learning at the New Ukrainian School is proved. Its advantages and disadvantages are revealed. The examples of some forms of distance learning that will contribute to geographical competence development according to European requirements are provided. The article particularly focuses on the Massive Open Online Courses, modern websites, virtual portals of individual teachers, LearningApps.org portal, and Moodle.

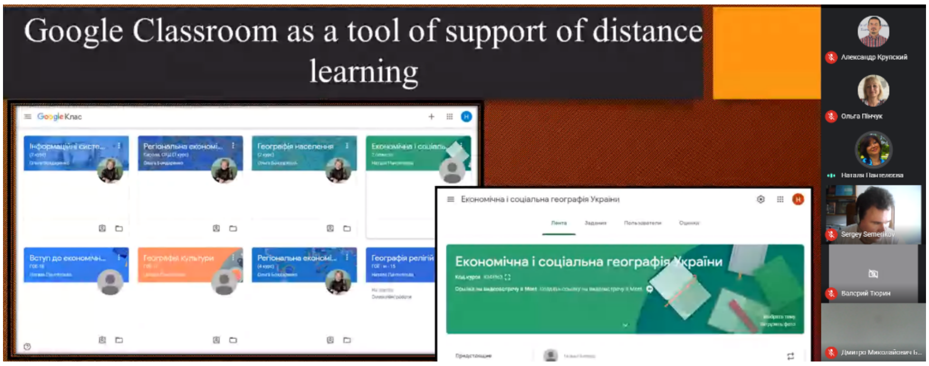

Fig. 22. Presentation of paper [69].

The article “The development of students' critical thinking in the context of information security” [59] (fig. 23) highlights further research by the Sergii V. Savchenko, Svitlana O. Shekhavtsova and Vladimir I. Zaselskiy, begun in [77] and [78]. The purpose of the given research is to introduce theoretical substantiation and experimental approbation of students’ critical thinking development in the context of information security. The skills of critical thinking help students to cope with the bulk of information they daily receive. However, there is still no conventional methodology for critical thinking development in university students. In our study we suggest possible ways to develop critical thinking in university students via introducing some special courses into the curriculum, and consider the results of the experimental study conducted on the basis of two Ukrainian leading universities. In order to improve the students’ skills of critical thinking the author suggested implementing the special course “The specifics of students’ critical thinking in the context of information security”, and an optional distance course on optimization of students’ critical thinking on the background of information and communication technologies. After the implementation of the suggested courses the indicators of students’ critical thinking development showed positive changes and proved the efficiency of the special courses as well as the general hypothesis of the study.

8 Conclusion

The third instalment of AREdu was organised by Kryvyi Rih National University, Ukraine (with support of the rector Prof. Mykola Stupnik), in collaboration with Kryvyi

Rih State Pedagogical University, Ukraine (with support of the rector Prof. Yaroslav Shramko), Institute of Information Technologies and Learning Tools of the NAES of Ukraine (with support of the director Prof. Valeriy Bykov) and Ben-Gurion University of the Negev, Israel (with support of the rector Prof. Chaim Hames).

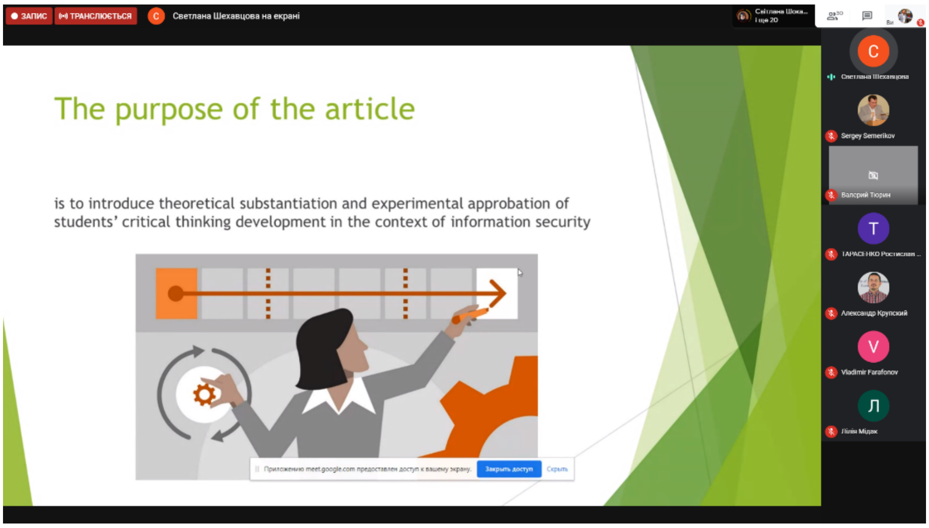

Fig. 23. Presentation of paper [59].

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

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 2021.

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Alternatives in biological education as a way to implement an ethical approach to the formation of subject and professional competence of future teachers

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Abstract. *Research objectives:* the article analyzes the experience of using alternative means of teaching biological disciplines, the purpose of which is to partially or completely replace biological objects in educational practice with their visualized copies. *Object of study*: ethical approach as a leading approach to the teaching of biological disciplines. It is based on the idea of minimizing harm and risk to animals as objects of study when organizing training in biological disciplines. *Subject of study*: the experience of using ready-made alternative teaching aids obtained in the framework of international cooperation and creating their own in teaching biological disciplines to students. *Research results*: tested alternatives obtained in the framework of international cooperation, identified difficulties and limitations of their use in teaching university students, created alternative means of teaching plant physiology – a video sequence of domestic experiments on plant physiology. The quantitative results of the intermediate and final certification of students allow us to state the preservation of the average score in the disciplines "Anatomy and Physiology" and "Methods of Teaching Biology" in comparison with previous years. The quantitative results obtained make it possible to judge the effect of the applied alternatives on the degree of formation of subject competence of students. Assessing students' understanding of the ethics of alternative means used, their importance in the formation of elements of teacher's professional competence lies in the area of further development of the topic.

Keywords: ethical approach, alternatives, subject knowledge, professional competence, ethical thinking, alternative teaching aids.

1 Introduction

1.1 The problem statement

According to the 2030 Agenda for Sustainable Development adopted at the 70th session of the UN General Assembly, 17 new global goals will be included in the subject field of education for sustainable development [17]. It should be noted that according to the Incheon Declaration [9], education is the main driving force in transforming people's lives and achieving sustainable development goals. You need to understand that we are talking about a global revision of value orientations, primarily in the field of education, and, accordingly, changes in the behavioral attitudes of the individual and society as a whole. It is predicted that one of the vectors of such a transformation will be orientation to ethical education at all its levels, to education, where the interests of life as the highest value are paramount.

1.2 The state of the art

The question of the relationship of ethics and science in biological research in different eras was solved differently [16]. So, in the era of antiquity the principle of "watch no touch" prevailed. The principle was dictated by the realities of that time, when the volume of knowledge of mankind about living nature was simultaneously negligible and sufficient for a long-term and even centuries-old contemplative state.

In the Middle Ages, the church imposed a ban on manipulating the human body in the post-vital period. However, the socio-historical processes associated with the opening of new geographical horizons, the rapid development of technology, the transition from manufactory to factory production, led to an increase in the urban population and, accordingly, to increased risks of the spread of diseases of an infectious nature. The current contradiction between the church ban and the objectively low level of development of medicine, based on a small amount of scientific knowledge on anatomy, human physiology, led, on the one hand, to the emergence of the profession of "grave robbers". On the other hand, the objective necessity of "legalizing" the anatomy of the human body, studying the mechanism of physiological processes in it, and the occurrence of responses to ongoing manipulations was revealed.

In the era of modernity and the maximum availability of the necessary tools for conducting complex intraorganic and intracellular manipulations, in conditions where, it would seem, on the contrary, take and examine, we are witnessing a change in the ethical principle of scientific research to "refine, replace, reduce".

The successive change of the prevailing ethical principles in the field of natural science, in particular, biological research, is determined, in our opinion, by two reasons.

The first reason is that a person is gradually approaching such a level of knowledge about nature and himself, when awareness and acceptance of himself as part of living nature, a part that obeys and lives by the same basic laws of life as all its other elements.

Another reason lies in the leading factor, which determines the choice of a strategy for the attitude of a scientist to the studied object of wildlife. Such a factor is the set of cognitive tools available to the scientist. The availability of the latter is determined by scientific and technological progress and the level of development of productive forces. The origins of the question of ethics in natural science research lie precisely at the time when the question of ethics itself was not raised. The reason for this is a poorly developed, practically absent instrumental base for research.

Objectives of the use of animals in educational practice.

The use of animals in the practice of teaching students of biological specialties has as its goal:

1. The study of the internal structure of the animal to familiarize themselves with the topography of organs, their shape, size, color.
2. The formation of subject competencies of students of biological specialties in recognizing internal organs, describing their structure, and performing schematic sketches.
3. Demonstration to students in the process of setting up a physiological experiment through vivisection of the animal of physiological processes, the laws underlying physiological laws.
4. Development of practical skills in catching, determining invertebrates and chordates, compiling collections, and making carcasses.
5. Conducting student training / practice.

As noted by Dimitrii Leporskii, one of the ambassadors of the international organization InterNICHE [4] in Ukraine, as well as colleagues from the Center for the Protection of Animal Rights "Vita", when studying a number of biological disciplines, the university has the practice of using animals as experimental objects. So, on the anatomy, animals are sacrificed for the purpose of subsequent dissection. In the study of biochemistry, physiology, pharmacology, experiments are conducted with drugs obtained from live animals (frog nerve, guinea pig ileum). In the study of physiology and pharmacology - experiments on living animals to study the effect of drugs and hormones on the body. In clinical practice, the skills of capturing and retaining an animal, injecting, and examining internal organs are practiced. In surgery, students of medical and veterinary universities and animal faculties perform an operation on internal organs, perform castration, treat wounds and wounds.

The use of animals in the educational process of a modern school implies a less traumatic practice for representatives of the animal kingdom, without vivisection and postvital incisions.

When teaching biology at school, animals are used to:

1. Familiarization with the peculiarities of the external structure of animals (on macro preparations and living objects).
2. Statement of a biological (physiological, genetic-selection) experiment without vivisection of the animal.
3. Organization of observations of individual and species behavior of animals.

Separately, it is worth mentioning the study of the internal structure of the animal on fixed histological micropreparations. Note that the factory-made drugs themselves are not manufactured in the classroom.

Definition of humane education and alternatives in education and scientific practice.

In the modern world, a movement for humane education is gaining momentum not only in medical [1; 4; 5; 15], but also in pedagogical universities [10; 14]. A humane education is an education that develops compassion, empathy, respect for life in all its manifestations. Humane education refers to education where goals are achieved through humane, alternative teaching methods and the use of alternative teaching aids. Humane education is also considered as one where animals are not subjected to violence and cruelty, and students have freedom of conscience (choice). This is a refusal to study the content of the subject and mastering professional skills by harming the animal. Alternatives are a substitute for natural visibility and working with it. Note that the experience of replacing real animal objects with alternatives in the educational process in biology in high school dates back to the late 90s [2; 3; 6; 11; 12]. Today, the issue of the full transition to alternative training in biological disciplines at school, related methodological features and difficulties, is actively being discussed. Just look at the list of recommended sources on the site http://www.interniche.org/.

Alternatives are learning tools or approaches that replace experimentation with animals that harm them. It should be separately emphasized that the key to understanding the purpose of using alternatives is the elimination of harm to the object of study. What is meant by the term “harm”?

Harm means any intentional or unintentional action that affects the current or future welfare of the animal, denying or restricting any of the following rights:

- the right to live;
- the right to fully exhibit natural behavior;
- the right to be part of a social structure and ecosystem;
- the right not to experience hunger and thirst;
- the right not to feel discomfort;
- the right not to experience pain, damage or illness;
- The right not to experience fear and distress.

At the moment, the main types of alternatives are:

- videos;
- models, mannequins and simulators;
- computer simulation and virtual reality;
- corpses, organs and tissues obtained from ethical sources;
- experimenting a person on himself;
- in vitro studies.

Despite the rather short history of the development of the movement for humane education (late 90s of the XX century), a number of erroneous ideas arose about the effectiveness of using alternatives in educational practice. We characterize them:

Myth 1. Replacing experiments means the absence of the main learning tools - animals.

In fact: “substitution” means “no harm” and may include neutral treatment of animals or work that benefits the animals.

Myth 2. Live animals are an integral part of education and educational practice.

In fact: effective education and training do not always require the involvement of animals.

Myth 3. Experimenting on animals is “real practice”.

In fact: it is important to distinguish between a method and a goal. Experimenting with animals is a method. The goal is to acquire knowledge and skills. All students who will deal with animals in their careers will receive this opportunity after training. It is also important to say about the problem of desensitization, which occurs in hidden messages about the permissibility of using animals in the educational process. Most often, such messages are negative. Learning the “permissibility” of instrumental use of animals contributes to neglect of life and the development of desensitization. We believe that due to the specifics of the professions obtained, the problem of desensitization is extremely relevant not only for students of medical, veterinary, but also pedagogical universities. Lowering the sensitivity and lowering the rate of emotional response is fraught with the education of future doctors, veterinarians, teachers with unacceptably low levels of empathy, empathy and compassion, which we consider not only as personal, but also professional qualities.

The successful introduction of alternatives affects many aspects of not only educational practice, but also social life. So, replacing animal experiments with humane alternatives affects:

- the quality of education in general;
- philosophy of natural science. It is worth recalling the historical way of changing the basic ethical principles of natural scientists;
- emotional and ethical literacy of representatives of professions man - man, man - nature;
- civil rights and freedoms in the choice of educational content.

Replacement of experiments on animals, refusal to cause harm in any form:

- has a practical positive impact on the environment and extends the rights of animals;
- has economic benefits. It is economically viable to invest in the development of high-quality alternative training equipment and facilities, rather than incur costs from maintaining, caring for animals, treating sick animals, and disposing of biomaterial.
- forms a positive reputation of educational and research organizations such as those that adhere to ethical practices in the teaching of biological disciplines and scientific research;
- changes the law [7].

1.3 The purpose of the article

The article analyzes the experience of using alternative means of teaching biology and biological disciplines, which have as their goal the partial or complete replacement of biological objects in educational practice.

2 Results and discussion

2.1 The technological aspect of use

In 2017, a tripartite agreement was signed on cooperation between the Department of Zoology and Biology Teaching Methodology of Kryvyi Rih State Pedagogical University and the Doctors Against Animal Experiments (http://www.aerzte-gegen-tierversuche.de/) and InterNICHE (www.interniche.org) [8].

The leading resources of partner organizations of the pedagogical university were their websites www.interniche.org, www.gumannoe-obrazobanie.org

In general, partner organizations provide support to educational organizations conducting training in undergraduate and graduate programs in biological, medical, and veterinary specialties. Partner organizations provide information support to those who express a conscious protest to harming the animal for educational purposes. In the framework of cooperation, conferences, field events – workshops, educational trainings, individual counseling of teachers implementing work programs are organized. Remote cooperation is organized through the website www.interniche.org (fig. 1). The site is multilingual, interactive, content and functionality are regularly updated.

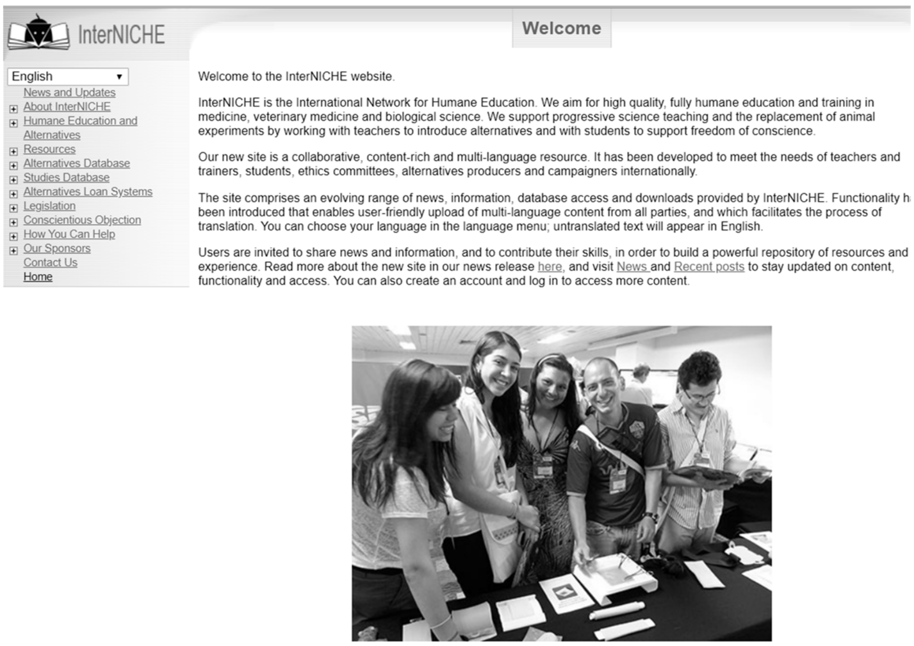

Fig. 1. Site's home page http://www.interniche.org/

Within the framework of the concluded agreement, the provided alternatives were tested.

The use of alternatives took place during classes in the disciplines:

- Methods of Teaching Biology;
- Methods of Teaching Biology in a Specialized School;
- Experimental work in biology.

Taking into account the specifics of the taught disciplines and the implemented forms of classes, the alternatives provided for use were distributed as follows.

In laboratory classes on the “Methods of Teaching Biology” and practical classes on the “Methods of Teaching Biology in a Specialized School”, experimental work on biology, the following were used:

- DVD Anatomy of the Grasshopper;
- DVD Anatomy of the Earthworm;
- DVD Anatomy of the Starfish;
- DVD Anatomy of the Perch;
- DVD Anatomy of the Shark;
- DVD Anatomy of the Freshwater Mussel;
- DVD Anatomy of the Crayfish;
- CD BioLab Invertebrates;
- CD BioLab Frog;
- CD Biolab Fish;
- CD Blood and Circulatory System;
- CD The Human Nervous System;
- Set of 5 DVDs Soviet Life science education films;

In practical classes (seminars) on the “Methods of Teaching Biology” were used:

- book and DVD by A. Naglov, National University of Kharkov;
- book and DVD: “Using alternative methods in studying of cardiovascular and respiratory system physiology”;
- book “Bioethics in Higher Education” by T. Pavlova.

Adjustments were made to the work program for the discipline “Methods of Teaching Biology”, namely, a practical lesson on the topic “Bioethical Aspects of Teaching Biology at School”, a laboratory lesson “Using Information and Computer Technologies and Alternatives in Teaching Biology in 7th Grade” is provided.

Alternatives as demonstration material were used by students of the Faculty of Natural Sciences during their pedagogical practice at school in grades 7-8 when studying zoology and human biology.

A round-table discussion was held with 4th year students of the specialties “Biology and Chemistry”, “Biology and Practical Psychology” on the topic “Bioethical attitude to animals in the legislation of Ukraine and other countries”.

One of the indicators of the effectiveness of using ethical alternative means of visualization, in our opinion, should have been universal indicators of the effectiveness of the educational process – the quality of knowledge and academic performance in the disciplines. To clarify, the active practice of using alternative teaching aids in the discipline “Methods of Teaching Biology” was started in the 2nd semester of the 2017/2018 school year and continued throughout the entire 2018/2019 school year. Upon completion of the study by students of the discipline “Methods of Teaching Biology” (January 2019), an oral exam was conducted, quantitative results were obtained. The results of training students in the discipline “Methods of Teaching Biology” with the used alternative means were compared with the exam results of training in the same discipline without using alternatives in previous years (2017, 2018). A comparison of the results is shown in fig. 2.

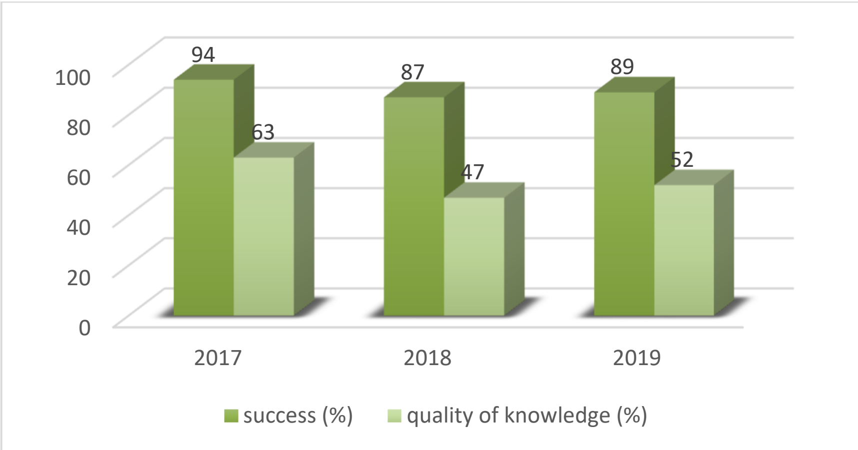

Fig. 2. Quality and performance in the discipline “Methods of teaching biology”.

The quantitative results of mastering the discipline in the first year of using alternative means did not show a drop in such indicators as the quality of knowledge and academic performance. We consider such a result as positive. At the same time, we believe that it is necessary to track these indicators in the future in order to formulate an unambiguous substantiated conclusion.

The practice of using alternatives in the educational process of a pedagogical university when teaching biology students allows us to state the following.

Firstly, alternative teaching aids are uniquely capable of completely replacing the use of live animals in developing the professional skills of future students of biology teachers in their study of the disciplines of methodological content.

Secondly, alternative teaching aids, even if the natural objects are partially replaced, contribute to the formation of a student’s personal conviction as a future biology teacher in the absence of the need to use live animals or their remains to demonstrate the morpho-anatomical structure or physiological characteristics of organisms. The latter can be successfully done using alternatives, while preserving the life of many representatives of the animal kingdom and promoting the idea of ways to preserve biodiversity on the planet.

Thirdly, the use of alternatives as a means of teaching students of a pedagogical university to a large extent prevents the coarsening of the soul and the development of callousness as personal qualities of a future teacher, since the principle of ethics is put at the forefront of working with biomaterial. We understand the principle of ethics as a relation to life in all its manifestations as a basic value.

The difficulties in using alternatives in teaching biology students were caused by the following factors.

- the prevalence of English-language content in the materials presented. This complicated both the process of installing educational content on the computer's hard drive and caused difficulties in understanding the essence of the task for all users of alternatives;
- the effectiveness of the use of alternatives is significantly increased if students work on personal computers. This is how it is possible to carry out laboratory work to study the physiology or anatomy of an animal. In practice, due to the insufficient material security of the laboratory, methods of teaching biology with computers, classes were conducted demo, students acted as passive listeners and observers of actions performed by the teacher.
- the use of alternatives as a replacement for live and euthanized animals will achieve maximum efficiency provided that the educational process of the pedagogical university, faculty or department is maximally involved in the idea of humane education. This requires refusal or the maximum transition to a training format without the use of animals, their preparations in any form.

We consider fundamental the idea that the formation of professional competencies of future biology teachers is quite possible to realize only using alternative teaching aids.

We do not undertake to assert that such an idea is feasible in specialized medical and veterinary higher educational institutions, however, in the system of higher pedagogical education this is one of the promising vectors of future development.

2.2 The ways of implementation

In the 2019/2020 academic years, alternative teaching aids were tested in practical exercises in anatomy and physiology at the Immanuel Kant Baltic Federal University. The course of anatomy and physiology using only alternatives without the use of animals or their parts in any form was developed for 1st year students of specialties "Preschool education. Speech therapy activities", "Mathematics. Informatics", "Primary Education", "Technology. Additional education (technical and artistic-aesthetic creativity)".

As part of the study courses, the following alternatives were used:

- CD Physiology Simulators (Russian);
- CD Blood and Circulatory System;
- DVD Experiments on the isolated rabbit heart in the Langendorff apparatus (Russian);
- DVD Experiments on the physiology of heart and circulation of the rabbit (Russian);
- DVD Anatomy and function of the skeletal muscle (Russian);

- DVD Experiments on the impulse generation and conduction in the frog heart (Russian);
- DVD Circulation Experiments on the rat (Russian);
- DVD Renal microcirculation (Russian).

The materials presented were used at lectures and practical classes in the discipline.

At lectures, content was provided to students in a demonstration way through a multimedia projector. The practical exercises coincided with the active use of distance learning technologies in higher education related to the introduction of a number of measures aimed at preventing the spread of coronavirus infection. Note that the reorientation to conducting practical exercises in a remote format made it possible to maximize the possibilities of the presented alternatives. Firstly, part of the materials presented was posted on a personal YouTube channel with the ability to watch videos by students using the link located in the LMS-3 system.

On the eve of the practical lesson, students had the opportunity to review the proposed material and prepare for the discussion organized at the lesson itself, which was conducted through the Zoom and Webex platform. During the lesson, the teacher showed his screen, including videos of the corresponding alternative, and in the mode of disabled author's sound, commented on the video, using the method of stopping the video or re-viewing it.

The use of alternatives in this case supported the educational process at a level corresponding to the content of full-time study of anatomy and physiology, which required the use of natural objects, living and fixed.

We emphasize once again the idea that in a higher pedagogical educational institution the use of alternatives as the only means of teaching disciplines, the contents of which previously required the use of natural visibility in the form of live or prepared animals, their remains, parts, is entirely justified and realizable.

Experimental training of students in the discipline "Anatomy and Physiology" using only alternative teaching aids on the basis of the Immanuel Kant Federal Baltic University was carried out in the academic year 2019/2020. At the time of writing, the educational process was in an active phase. This explains the lack of relevant quantitative results confirming or disproving the effectiveness of the funds used. However, the received oral feedback from students about the quality of the material presented and the comprehensibility of the studied objects and processes can be regarded as a positive result of the experiment.

An analysis of sources on the research topic showed that the concept of alternative education is used in understanding alternative education using animal models and their parts with virtual models, experiments, real models, interactive atlases, etc. We believe this approach is currently somewhat limited. We are considering the possibility of alternative training in biological disciplines at the university and biology at the school also using alternatives to minimize the use of plant objects for educational purposes. And here we also emphasize the idea of achieving the priority of the educational goal, and not the scientific one.

As part of the study of the possibilities of using alternatives to plant objects, a study was conducted at the Kryvyi Rih Pedagogical University on the topic "Methods of

Using the Botanical Household Experiment as a Means of Forming Subject Biological Competence of Students".

The paper demonstrates the possibilities for expanding the boundaries of the use of alternatives in biological education for both students and schoolchildren when they study plant physiology.

The result of the work was the creation of a video sequence kit on the progress of physiological experiments with plants. In order to popularize the created materials and promote the practice of moving away from the use of plant objects for educational purposes, the YouTube channel (https://www.youtube.com/channel/UCw_aj7KvCFC33uGXc7BlK1A/video) was created on which the created materials are posted (fig. 3, fig. 4, fig. 5).

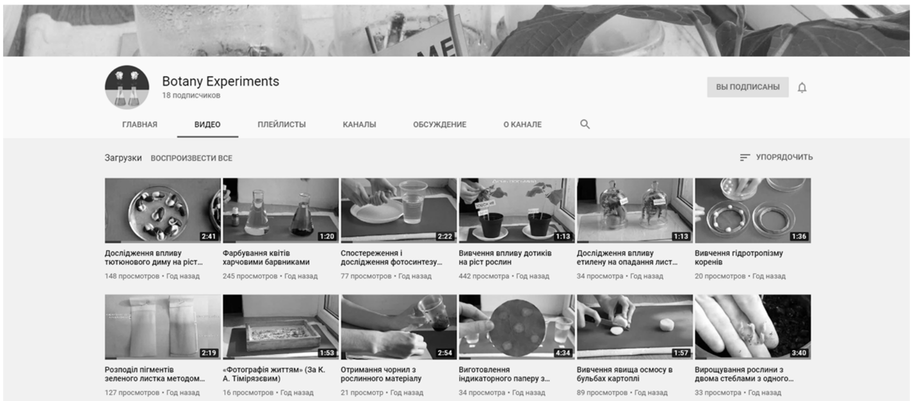

Fig. 3. YouTube channel home page.

Fig. 4. The results of an experiment to study the effect of ethylene on leaf fall (artificial leaf fall).

Fig. 5. The results of an experiment to study the effect of tobacco smoke on plant growth.

Note that this practice of alternative experimentation has several goals:

1. For students – future biology teachers:

- teaches skills in creating elements of an electronic educational environment in biology;
- contributes to the formation of professional competencies in mastering modern teaching technologies;
- forms a conviction of the possibility and necessity of a humane approach to the study of not only animal organisms, but also plant ones;
- positively affects the formation of confidence in the unity of approaches to the study of all manifestations of living things.

2. For students at school:

- contributes to the formation of the belief that animal and plant organisms are different manifestations of one phenomenon – Life;
- forms a conviction that the conservation of biodiversity is possible through humane treatment not only with animals, but also with plants.

To kill a living organism, in this case a plant, to study intraorganism processes for educational purposes, is an optional practical experience. It can very well be replaced with a one-time share of using a small number of objects to create an alternative means of instruction. The latter can be reused, i.e. reproduced.

In the performed work, for an example of creating alternatives, themes were taken for physiological experiments that do not require modern expensive laboratory equipment.

1. The study of the effect of cigarette smoke on plant growth.

2. Dyeing flowers with food colors.
3. Observation and study of photosynthesis using floating leaf discs.
4. The study of the effect of touch on plant growth.
5. The study of the effect of ethylene on leaf fall (artificial leaf fall).
6. The study of hydrotropism of roots.
7. The distribution of green sheet pigments by paper chromatography.
8. "Photography by life" (according to K. A. Timiryazev).
9. Ink production from plant material.
10. Production of indicator paper from solutions of anthocyanins.
11. The study of the phenomenon of osmosis in plant objects.
12. Growing plants with two stems from the same seed.

The paper analyzes the shortcomings and possible difficulties of using the created alternatives, among which: demonstration of mainly qualitative characteristics of a botanical experiment, limited use of quantitative methods, instrumental errors. At the same time, the botanical applied household experiment, including in the form of an alternative learning tool, has several advantages compared to the traditional experiment, namely: accessibility, creating problem situations close to the realities of life, interesting topics, and strengthening students' motivation to study biology. The content component of an alternative physiological experiment allows you to implement the program of the subject in the application of distance learning technologies with virtually no loss in the quality of the result – formed students' ideas about the basic processes of plant life.

3 Conclusions and outlook

We see the prospects for further research, firstly, in the development of the training module "Bioethics in Biological Education" for students of biological specialties at pedagogical universities. The module is designed for students mastering the discipline "Methods of Teaching Biology" or "Pedagogical module". We consider it necessary, within the framework of the module, to familiarize students with the possibilities of using alternatives in the practice of teaching biology at school, when studying both plant and animal objects in school. Secondly, we consider it important to concentrate efforts on expanding the practice of using ready-made alternatives when teaching students of biological specialties of pedagogical universities, taking into account the specifics of the resulting specialty. Thirdly, the study will focus on the methodology of teaching students – future biology teachers – to create author's alternative teaching tools aimed at minimizing the use of animals in the educational process.

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Assessment of mobile phone applications feasibility on plant recognition: comparison with Google Lens AR-app

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Abstract. The paper is devoted to systemizing all mobile applications used during the STEM-classes and can be used to identify plants. There are 10 mobile applications that are plant identifiers worldwide. These applications can be divided into three groups, such as plant identifiers that can analyze photos, plant classification provides the possibility to identify plants manually, plants-care apps that remind water of the plant, or change the soil. In this work, mobile apps such as Flora Incognita, PlantNet, PlantSnap, PictureThis, LeafSnap, Seek, PlantNet were analyzed for usability parameters and accuracy of identification. To provide usability analysis, a survey of experts of digital education on installation simplicity, level of friendliness of the interface, and correctness of picture processing. It is proved that Flora Incognita and PlantNet are the most usable and the most informative interface from plant identification apps. However, they were characterized by significantly lower accuracy compared to Google Lens results. Further comparison of the usability of applications that have been tested in the article with Google Lens, proves that Google Lens characterize by better usability and therefore, Google Lens is the most recommended app to use to provide plant identification during biology classes.

Keywords: mobile application, STEM-classes, augmented reality, plant identification, Google Lens.

1 Introduction

To date, the introduction of a mobile phone into the educational process is a modern instrument to achieve better results. The usage of a mobile phone during classes allows visualization of educational material, involving students in research, which increases students' motivation for learning [20; 26]. Mobile phone applications compared to computer approaches are characterized by the most promising advantages including mobility of usage, possibility to use both internal and external sensors (not commonly used). The modern educational directions include personalization of research process which may be achieved by using mobile phones [25]. However, it was proved that not elements of education led to high efficiency but a general didactic approach during which it was used. The main concept during which the mobile approach relevant to use is STEM/STEAM/STREAM technology. It includes elements of both research and engineering which can be based on the use of computer software or mobile applications.

1.1 Types of educational software

All software that can be used during the learning process in the application of STEM technology can be divided into desktop applications, mobile applications, and web-oriented technologies. There are a lot of scientific papers related to ways of ICT implementation during STEM-based classes. The most interesting of them are providing of augmented reality [2; 21; 26; 27; 29; 30; 33; 37], virtual reality [3; 14; 16; 20; 23; 24; 31; 32; 35; 45], providing of digital environments of education, including computer modeling [7; 19; 34; 36; 40;], providing of centralized educational networks [38; 41; 43], mobile-based education [18; 22; 27; 28; 33], modeling environments [4; 8; 9; 12; 17] providing of education visualization by including YouTube videos [6], 3D modeling [5], and printing [15], etc. Comparisons of the most used in the education process software are presented in table 1.

Table 1. Comparisons of the most used in the education process software.

Type	Web-oriented	Mobile applications	Desktop applications
Instal-lation	Not needed	From official stores or using application file	From official stores or ins-tallation files
General require-ments	Compatible Internet browser for all feathers support	Compatible version of And-roid, iOS or another mobile operating system	Compatible version of Windows / macOS / Linux or another desktop opera-ting system
Faciliti-es	Modeling, calculation, visua-lization, video presenting	Modeling, calculation, vi-sualization, video presen-ting, measuring using both internal and external sen-sors, photo analysis, AR, VR	Modeling, calculation, vi-sualization, video presen-ting, using additional ex-ternal sensors
Main advan-tages	Cross-platforming, no instal-lation required, low device space usage	Huge facilities, mobility of usage	Stability, huge spreading, and variation of applicati-ons
Main disad-vanta-ges	Limited opportunities, may not start correctly depending on the platform and technical characteristics, lack of in-dividualization	Needs technical updates which may be expensive	Lack of individualization, the lesser effect of increa-sing motivation during STEM-education

As shown on the table, one of the most perspective to use in education is the mobile application due to their multi-capabilities, interaction with students in their research and visualization on the educational process. Nowadays a lot of pedagogical researches is related to analyzing approaches mobile phone applications can be used during the educational process. In general, based on the facilities, it is possible to provide a classification of mobile application on those which provides measuring, analyzing, the image recognizing and its classification, providing course education, VR, and AR-based. We offer to structure training applications that can be installed on a student's mobile phone into the following categories, such as:

- training platforms;
- meter applications;
- video analysis apps;
- applications that analyze images and classify them;
- augmented reality (AR) and VR apps.

Comparisons of different mobile apps categories are shown in table 2.

Table 2. Comparisons of different mobile apps categories.

Type of application	Description	Examples
Education platforms	These platforms allow the teacher to create instructional content, communicate with students, give them assignments and check them out automatically	Google Classroom, Prometheus, Coursera, Microsoft Office 365 for Educational
Measuring applications	These sensors and their software are already built into mobile phones	Measure, AR-ruler, Smart Measure, Lux-meter, Accelerometer, Magnet Field Meter
Image analysis apps	It allows you to measure distances, angles, perimeters, areas, and calculate with this data.	ImageMeter
Image recognizing and it’s classification applications	These mobile applications allow you to identify species of plants and animals using photos	Google Lens, Photo Sherlock, Plant Net Identification, Mushroom, Identify, Shazam, Dog Scanner, Identify Anything
VR and AR-based apps	Allow virtual travel, get a spatial image of the training material.	Minecraft Earth, IKEA Place, Ideofit, Lego Hidden Side

We can distinguish some smartphone apps which give the highest potential to increase motivation and integration with providing investigation, especially in biology, which is apps-identifiers. Today, there is a range of mobile applications that identify wildlife. These supplements can identify insects (for example, Insect identifier Photo), animals (Dog Scanner), and plants (Flora Incognita, PlantSnap, Picture This). Some applications identify both plants and animals, for example, Seek. In our opinion, most perspectives are applications that provide analyzing of the static its nature objects (plants) due to the photographic process don't require highly expensive smartphones to obtain sufficient quality photography to provide analysis. Therefore, this approach can be used widely during the educational process, almost in all schools.

1.2 The problem of plants identification

There are about 27,000 species of flora in Ukraine, such biodiversity requires detailed description and study. Also, natural conditions are constantly changing, and this causes changes in the species composition of biocenosis. Both aspects indicate that there is a problem with plant identification. One of the basic principles of pedagogy is the principle of a nature experiment. So, training should be carried out in an environment where the mobile phone should become a full-fledged learning tool.

Some apps can be installed on the student's mobile phone for free to determine the species of plants, their morphology, the range of distribution, and more. In our previous research, it was found that Google Lens characterized by very high accuracy of identification, especially on trees and shrubs [39]. Taking to the account simplicity of the application and its dissemination, there some papers and devoted to describing and researching Google Lens [10; 11; 42]. Google lens can provide analysis of real-life objects in AR and provide additional information neural networks algorithms. However, other applications can be used to provide identification and these applications may be more specialized. Therefore, they can provide more accurate analysis because their database consists only of plants images which can decrease the number of false detections, and apps can provide more correct process of plant identification and inputting the information (requesting from the user to input different parts of plants).

Despite the great specialization of other applications, we hypothesize that Google Lens is the best plant analyzer due to the large selection of plants and the existence of a special application for teaching it to a large number of people – Google Crowdsource (500 000+ installation).

Therefore, the purpose of this article is to analyze existing applications that can be used in teaching biology both in the classroom and in the field.

There are about 10 applications that can be used to identify the plants. Most common of them are LeafSnap, Seek, PlantNet, Flora Incognita, PlantSnap, Picture This, Florist-X (in Russian), What is a flower (in Russian), Manager of houseplants (in Russian).

These applications can be divided into three groups, such as:

- plant identifiers that can analyze photos (Google Lens, for example, PlantNet, Flora Incognita, PlantSnap, Picture This.
- plant classification provides the possibility to identify plants manually. The plant’s classificatory commonly contains pictures and information about plant kind. But the quality of analysis, in this case, will depend on the user's knowledge and skills which may be hard for both teachers and students. Their use in biology lessons within the STEM approach has considerable potential because it allows for interesting and rapid acquisition of plant morphology. However, it works like an interactive book

that can interact with students lesser than apps of the first type (for example, Florist-X and What is a flower).

— plants-care apps that remind water of the plant or change the soil, which by the lower potential compared to other types of application (for example Manager of houseplants).

Taking into account all advantages of plant identifiers, it was used as an object of the research. The analysis of the general view is shown below.

Flora Incognita. According to the developer, the application can identify 4800 species of plants. Before the analysis user chooses plant type (flower, tree, grass). The process of analyzing requests photographs of different plant parts. After determining the species, it links to Wikipedia and the site www.plantarium. A general view of the application interface is presented in figure 1.

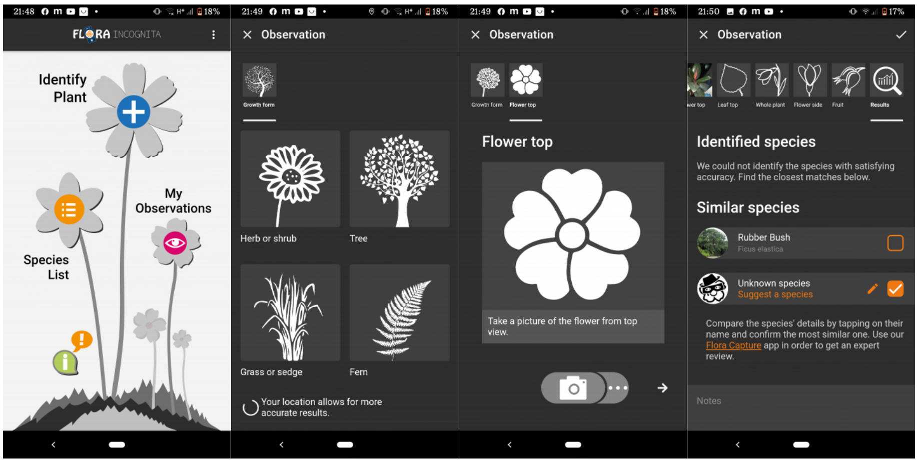


Fig. 1. Flora Incognita interface.

PlantNet. According to the developer, this application can identify 21,920 species of plants. It contains headings: flora of the world (very broad heading Western Europe, USA, Canada, Central America, Caribbean islands, Amazon, French Polynesia), useful plants, invasive plants, weeds. The user can confirm the particular plant, i.e. the program is being trained. When determining the part of the plant (root, shoot) is indicated. There are photos by family and you can determine by family, the principle is the determinant.

There is no connection with other information resources, information about the species is very limited (only photo and Latin name). A general view of the application interface is presented in figure 2.

PlantSnap. According to the developer, this application can identify 585,000 species of plants. Need to create a profile. This can be done using Facebook, almost Gmail Google. Detailed instructions come to the user's mail. It contains instructions with English voice and Russian subtitles. You get a photo and the program offers several options. You can also use images you already have in the gallery. When you define a program, you save, that is, confirm. It contains a ribbon where each corset can post and comment. There are no links to other resources, only the photo and the Latin name of the plant. PlantSnap limits identifications by 25 plants per account per day A general view of the application interface is presented in figure 3.

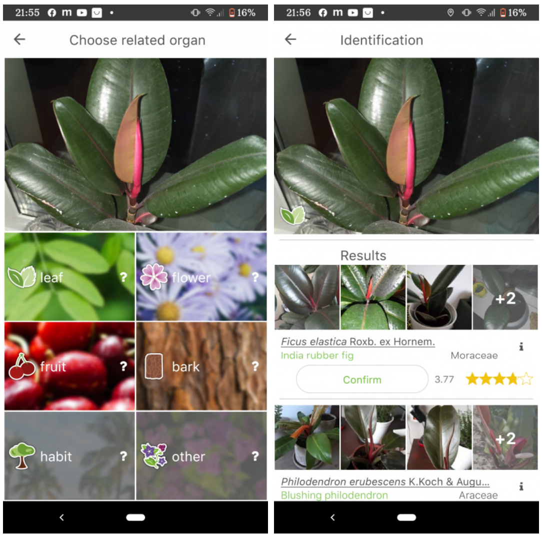


Fig. 2. PlantNet interface.

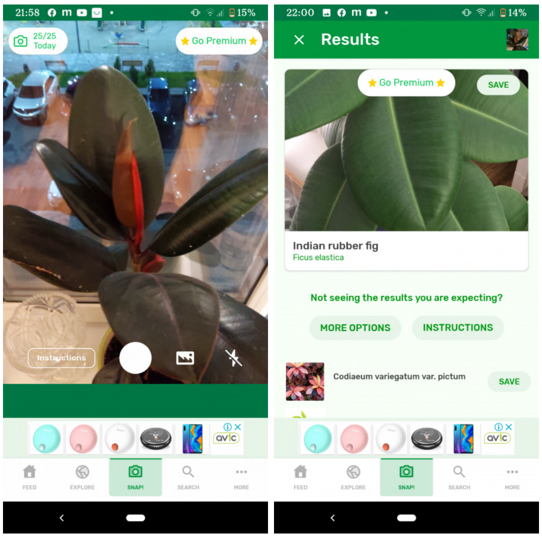


Fig. 3. PlantSnap interface.

PictureThis. According to the developer, this application can identify 10,000 species of plants. During authorization, prompts to enter a bank card immediately, if the user does not, offers a free version. The user points the camera and the program determines the species, under the name of the species is given a botanical description, an interesting fact about the plant. There are plants that you cannot identify yourself, sent by other users, that is how the program learns. A general view of the application interface is presented in figure 4.

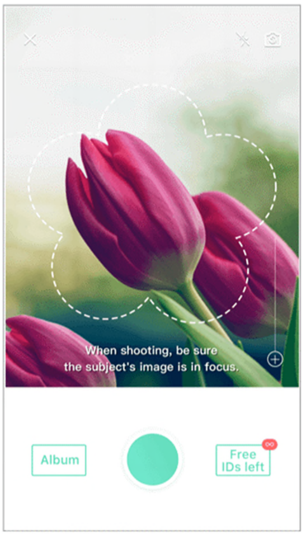


Fig. 4. PictureThis interface.

LeafSnap. The user takes a picture of the plant, indicating which part of the plant it is. And then he chooses the most similar look in the photos. The botanical description of the plant is given under the name of the species. A general view of the application interface is presented in figure 5.

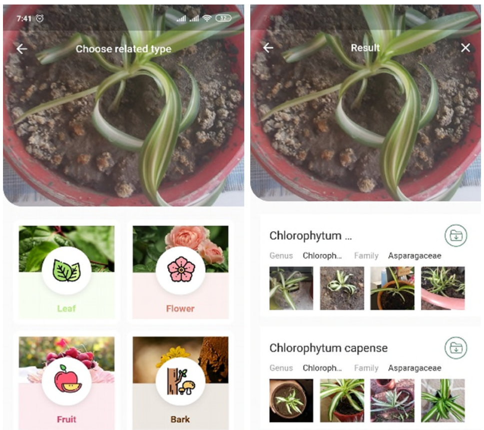


Fig. 5. LeafSnap interface.

Seek. It contains instructions, offers INATURALIST authorization, but can be operated without authorization. Immediately determines the geographical location of the user, sets the rules of safety in the wild. The mobile application provides clear, concise instructions for each stage of the study. For each activity the participant gets achieves that is motivation to learn. The app invites you to participate in nature research projects. A general view of the application interface is presented in figure 6.

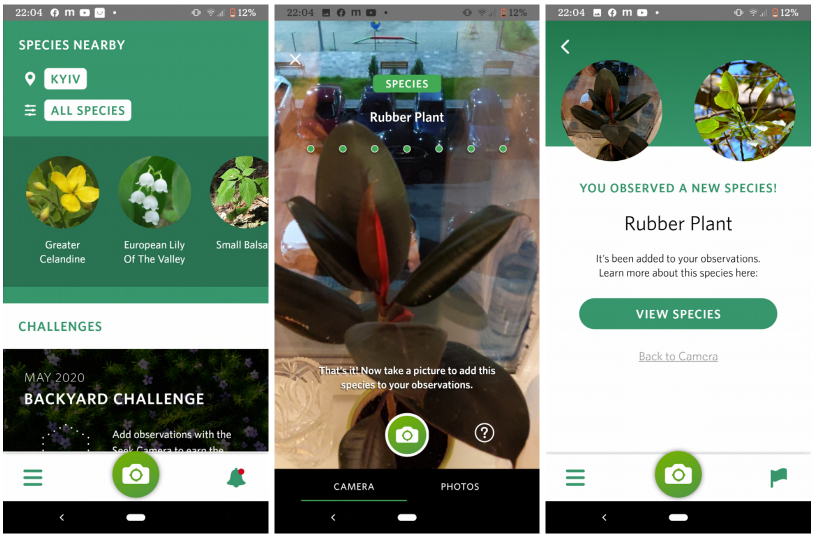


Fig. 6. Seek interface.

2 Methods of analyzing

To provide analysis on the usability of applications related to plant identification, a survey of experts on digital didactics was provided. The main criteria were installation simplicity, level of friendliness of the interface, correctness of picture processing. Each criterion was evaluated from 0 to 5 (as higher than better). Those applications which were characterized by average evaluation more than 4 were used to further analysis on quality of identification due taken to account fact usage of the application during the educational process, where it will be used by students and teachers, both potentially with not the highest level of ICT competence.

Analysis of quality of identification was provided by a simplified method compared to our previous research [34] due aim of this paper to obtain general state on application plant identification accuracy. To provide it, 350 images from the list of plants of the "Dneprovskiy district of Kiev" were taken to provide analysis. The key from the "Dneprovskiy district of Kiev" plant classification was used as control. To provide an evaluation table for each application was used. For each correctly defined type of application received 1 point (see an example in table 3).

Table 3. Example on the table of apps analyzing.

The name of the plant	Flora Incognita	PlantNet
Prunus armeniaca (Apricot)	0	0
Jasione montana	0	1
Ageratum houstonianum	0	1
Chaenomeles japonica	0	0
Amaranthus	1	0
Ambrosia artemisiifolia	0	1
Amorpha fruticosa	0	0
Anemo	1	1
Anemonoides ranunculoides	1	0
Anisanthus tectorum	0	0

Finally, all obtained results, including both, general usability evaluation (survey) and results on identification quality were compared with results on Google Lens to summarize information and achieve a general and final state in this field.

3 Results

3.1 Analysis of application identification accuracy

To compare mobile applications, it is important to explore the algorithm for identifying plants.

According to botanical science, the algorithm for determining a plant includes: establishing the life form of the plant (tree, bush, grass); then studying the vegetative parts of the plant (leaves, stem). Generally speaking, generative organs (flower or fruit) analysis is often required to establish a specific species name. Geographic location is very important to identify many species. For example, Picea omorika and Picea abies are very similar species, but Picea omorika only in Western Siberia and Eastern Bosnia and Herzegovina. If the algorithm for determining the plant in the application includes the definition of life form, photographing the vegetative and generative organs, as well as the geographical location of the object, then we consider such an algorithm completely correct. If the application of plant identification is based on photographs of different organs of the plant, such an algorithm is correct. If the application of the plant is based on the analysis of one image in one click, then this is a simple algorithm. The educational process needs to have links to other sources.

The results of comparing mobile applications that can analyze plant photos are shown in table 4.

PlantNet is the easiest app to install. Also, pretty easy to install are LeafSnap and Flora Incognita. Apps LeafSnap, Flora Incognita, and Seek to have the simplest interface. PlantSnap, PictureThis, and PlantNet are characterized by the most uncomfortable process of identification which can be complicated for teachers. Results of detailed analyses on plant identification applications are presented in figure 7.

Table 4. The results of comparing mobile applications that can analyze plant photos.

	Amount of the plants	Correctly process of analyzing	Communication with other information services
Flora Incognita	4800 (only German)	The analysis algorithm is correct	Contains links to Catalogue of Life, Plants for a Future and Wikipedia. Flora Incognita with Russian interface provides links to the Russian site www.plantarium.ru
PlantNet	21920	The analysis algorithm is completely correct	Only the name of the plant. Includes elements of social networks (by sharing plants student found and subscriptions). It contains links to Wikipedia.
PlantSnap	585000	The analysis algorithm is simple.	Own description. Provides searching on amazon to buy
PictureThis	10000	The analysis algorithm is simple.	Provides very structured information (including type, lifespan, height, flower diameter), care aspects, usage of the plant
LeafSnap	No information available	The analysis algorithm is correct. After determining, the collection of photos of this plant in different conditions (healthy and unhealthy) is possible to use.	Contains links to Wikipedia, Pl@ntUse, Global Biodiversity Information Facility
Seek	No information available	The analysis algorithm is the simplest. For identification users get archives	Has no detailed description, but propose “species nearby in this taxon”

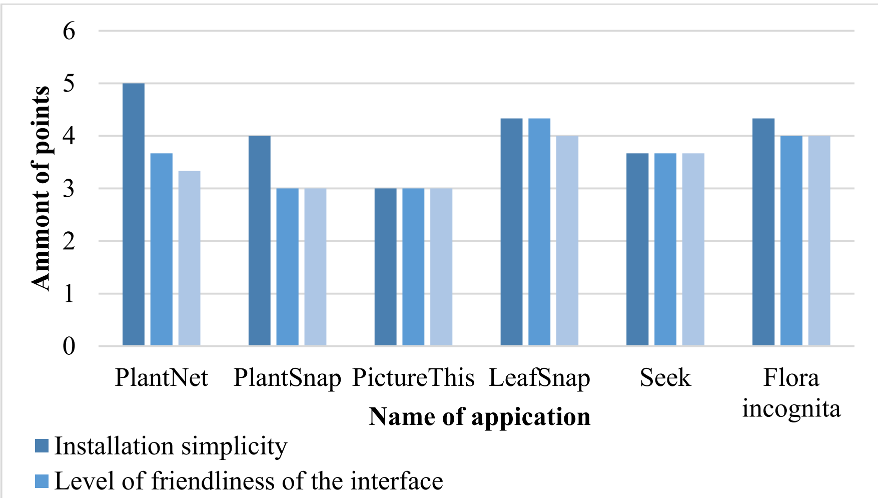


Fig. 7. Results of detailed results on plants identification applications usability analysis.

In general, LeafSnap, Flora Incognita, PlanNet are the most usable. However, the total number of points each of the applications received is presented in figure 8.

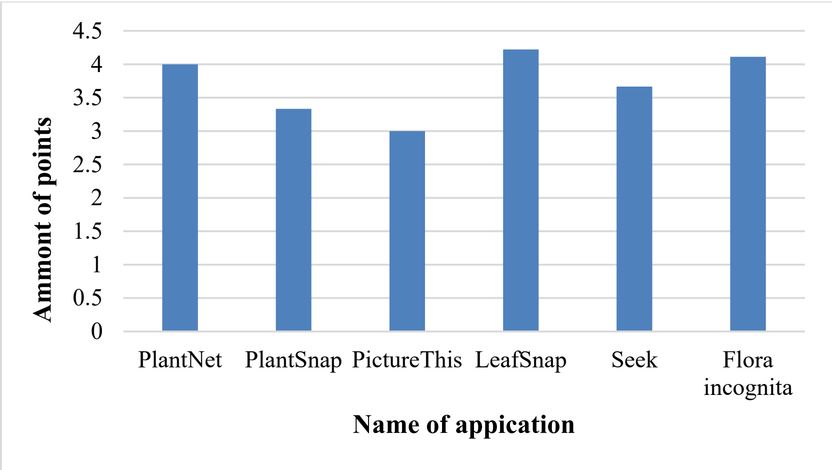


Fig. 8. Integrated results on the usability of plants identification applications.

Flora Incognita provides correct identification of 71% of plants compared to 55% provided by PlantNet. For comparison, this figure for Google Lens is 92.6%. In our previous work, we demonstrated that Google Lens does not differentiate native species from Ukraine. It seems like PlantNet provides the same Google Lens searching only in international resources, unlike Flora Incognita which provides searching at Russian web-site (in case choosing of Ukrainian region). This may explain a higher percent of identification accuracy of Flora Incognita, compared to PlantNet. The comparison of Google Lens with Flora Incognita and PlantNet identification quality is presented in figure 9.

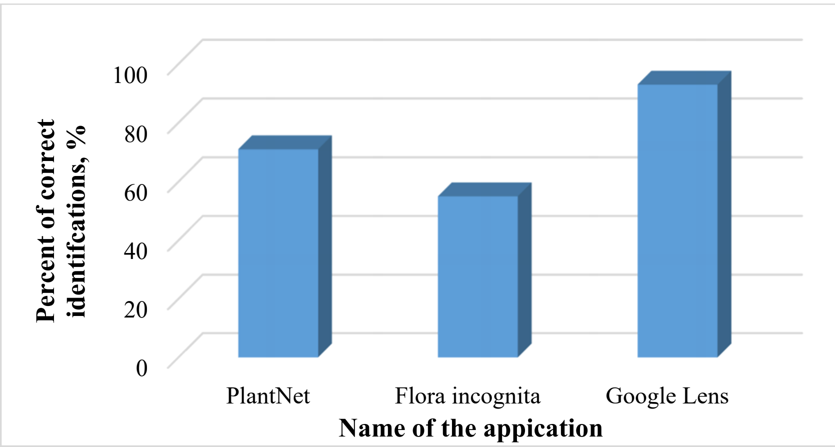


Fig. 9. Results on analysis quality of apps which is identified plant.

So, Google Lens is characterized by the highest quality of analysis which may be due to the better recognition algorithm and the most trained neural network. However, it still may be relevant to use other applications in case it will be characterized by significantly higher parameters of using. To evaluate this, a similar survey as used for other plant identification applications was used for Google Lens. Google Lens has the most intuitive interface, is the most easily loaded, and gives the most accurate definition result and therefore is characterized by the highest general evaluation. A comparison of the total points scored by the experts is presented in figure 10.

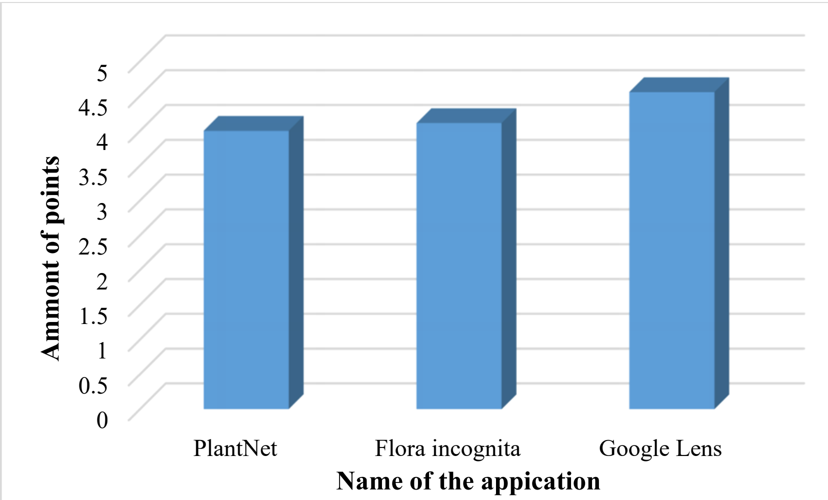


Fig. 10. Integrated results of usability level of PlantNet, Flora Incognita and Google Lens.

Therefore, Google Lens is the most recommended app to use. Talking to account, results of usability analysis, and quality of analysis, for those students and teachers who do not like Google Lens app, it is possible to use Flora Incognita, but PlantNet can't be recommended to use due low accuracy which may provide up to half of incorrect analyzing results.

3.2 Specific features of the applications to use in your own research

Despite the disadvantages, some features of depiction are worth note. Some applications have their own approach to provide complex research of nature. Those features are very useful to increase the motivation of students to research nature. The most interesting approaches to increase motivation provided by PlantNet and Seek. Dispute negative results on Interface (for Seek, only 3,6 points) or for identification (for PlantNet, only 55 % of correct identifications), the approaches used to increase motivation are worth noting.

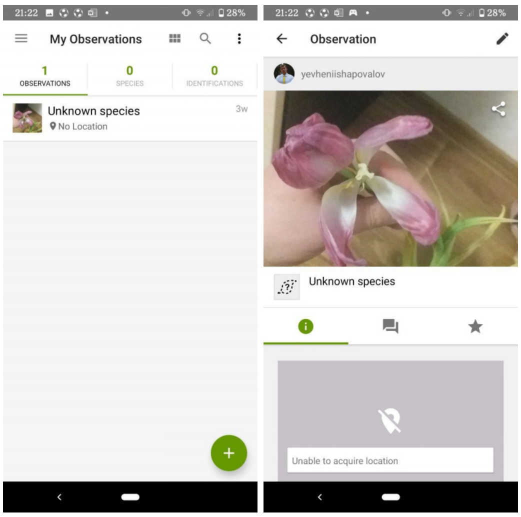
PlantNet approach.

One of the features worth note about on PlantNet is the social network it is based on. It consists of a feed of pictures shared by users of PlanNet. The information in the feed is devoted to classes “identified”, “unidentified”, and there is a function to display all information (by choosing “All”). The items in feed with an “identified” filter will display already identified plants by users and “unidentified” will display not-identified pictures updated by users. The most perspective is using “unidentified” feed which may be useful in a few cases:

- To solve problems with a plant which is hard to identify students have.
- To train own identification skills by providing identification of pictures of others.
- To share thoughts in the field of botanic, communicate with other researchers, and to provide social science networking.

Seek and iNaturalist complex.
The Seek-identification app provides a significantly different approach to increase students' motivation. It provides achieves for each plant students found which motivates students to get new and new researches from time to time. The effect of achievement affects the brain as exaltation and people want it again and again. This is used in games to motivate students to play again [1; 13; 44]. In the case of Seek, some factors will motivate students to research nature.

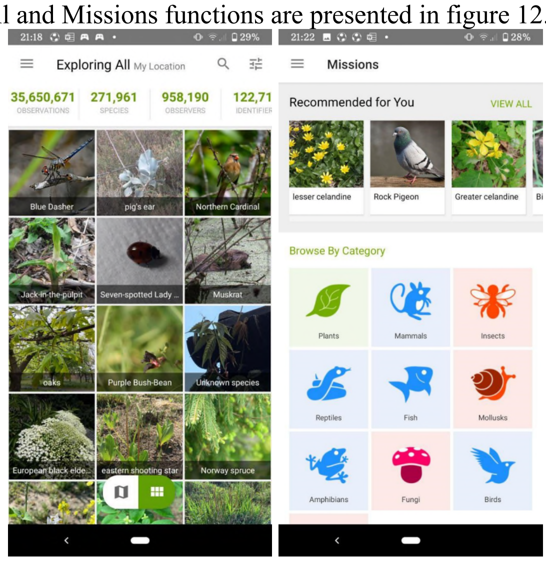
Students who use Seek can integrate it with iNaturalist application (developed by California Academy of Science and National Geographic). Which gives to students and teachers powerful systems of different instruments. The first instrument to motivate is personal journals. This feature gives to student’s possibility to provide own systematical journals. The general view of personal journal and info card on a single plant is shown in figure 11.



a b

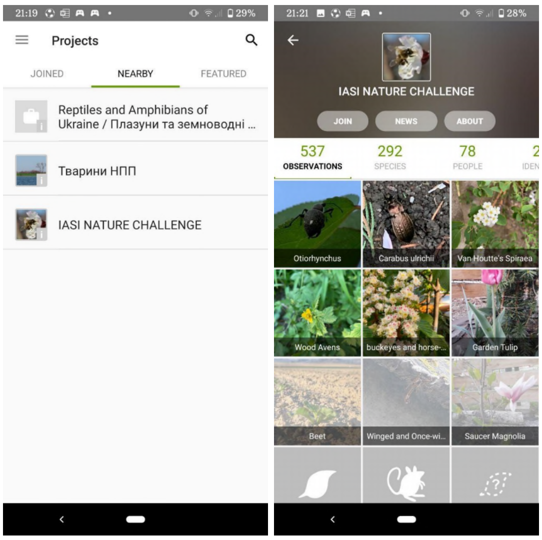
Fig. 11. The general view of a personal journal (a) and info card on a single plant (b).

The iNaturalist propose observing of plants and animals kinds student can find nearby. This feature is activated by the "Exploring All" function and choosing "My location". Also, based on location students can use Missions which provides quests for students to do, for example, to find "Rock Pigeon". So, students can observe nature nearby in general to study it and the program will stimulate students by completing the missions. The Exploring All and Missions functions are presented in figure 12.



a b

Fig. 12. The Exploring All (a) and Missions functions (b).



a b

Fig. 13. The interface of the projects menu (a) and concrete project (b).

The program provides collaboration by providing projects. Users can find and chose projects they like and join be involved in them. It's worth note, that the app is very widespread and there are even projects in Ukraine. The interfaces of project selection and concrete project interface are presented in figure 13.

4 Conclusion

1. Apps related to plant identifications can be devoted to those which can analyze photos, devoted to manual identification and apps devoted to plant care monitoring.
2. It is proved that LeafSnap, Flora Incognita, PlanNet are the most usable plant identifiers apps.
3. It was shown that Flora Incognita correctly identified plant species in 71% case and PlantNet correctly does this in 55 % case which is significantly lesser than the same parameter for Google Lens (92.6 %). Google Lens was characterized by the highest mark of usability compare to PlantNet and Flora Incognita.
4. Therefore, Google Lens is the most recommended app to use during biology classes. However, for those students and teachers who do not like the Google Lens app, it is possible to use Flora Incognita.
5. PlantNet app, which is characterized by an accuracy of 55 % can't be recommended to use during biology classes at all.

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Using augmented reality tools in the teaching of two-dimensional plane geometry

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Abstract. One of the successful components of quality assimilation of educational material and its further use in the learning process is visualization of material in secondary education institutions. Visualizations need the subjects of the school course, which are the most difficult to understand and essentially do not have at the beginning of the study of widespread practical application, mostly mathematical objects. That is why this study aimed to analyze mobile tools that can be used to visualize teaching geometry. The *object of the study* is the process of teaching geometry in the middle classes of secondary schools. The *subject of the study* is the use of augmented reality tools in teaching geometry to students in grades 7-9. The study used such *research methods* as the analysis and justification of the choice of mobile augmented reality for the study of mathematics. Analyses displayed two augmented reality tools: ArloonGeometry and Geometry AR. In order to gain geometry instruction’s academic success for the students, these tools can be used by teachers to visualize training material and create a problematic situation. The use of augmented reality means in the geometry lessons creates precisely such conditions for positive emotional interaction between the student and the teacher. It also provided support to reduce fear and anxiety attitudes towards geometry classes. The emotional component of learning creates the conditions for better memorization of the educational material, promotes their mathematical interest, realizes their creative potential, creates the conditions for finding different ways of solving geometric problems.

Keywords: geometry, augmented reality tools, Arloon Geometry, Geometry – Augmented Reality.

1 Introduction

1.1 The problem statement

Modern rhythm of life and fast-changing information and communication technologies require to the younger generation to adapt quickly to different situations, to acquire knowledge in all conditions and to be able to apply the acquired knowledge in practice.

All the recently innovations of the Ministry of Education and Science of Ukraine are aimed to the fact that the graduate of the educational institution should possess certain competencies and be able to independently acquire the knowledge necessary for solving certain problems.

On the one hand, we have certain requirements for a modern graduate of an institution of secondary or higher education, who in the process of education must develop various competences, acquire knowledge and become competitive not only in the domestic but also in the world labor market.

On the other hand, the situation in the system of secondary and higher education is far from the State standard of education and requires changes, which have been described in the documentation of the Ministry of Education and Science of Ukraine for the last ten years.

1.2 Literature review

Analysis of scientific research has shown that one of the ways to change the situation in the Ukraine education system is a competent and systematic introduction mobile information and communication tools and technologies to the process of learning [2; 8; 10], and also changing the model of learning which means the transition from traditional forms and methods of learning to innovative.

According to Valerii Yu. Bykov [5], informatization of education has become a revolutionary lever that relies on the achievements of classical psychological and pedagogical science. This requires the development of specific tasks for the creation and effective implementation of information and communication technologies in educational practice.

Serhiy O. Semerikov [12] indicated that the introduction of mobile ICT high school education will contribute to the quality of education. It enhances the flexibility of the learning process and meets the requirements of lifelong education and training and this will also help to improve educational opportunities for people with disabilities by offering them more flexibility and choice of time and place of study by delivering training materials to their mobile devices to suit their needs.

Scientists see one of the ways to improve the quality of mathematics education, in particular in geometry, is the introduction into the education system of modern mobile technologies – augmented reality [13].

The work developed by [1], establishes a relationship between problem of development of students' spatial thinking and introducing into the learning process of augmented reality.

It considers that the application Construct 3D, as a tool for constructing three-dimensional geometric structures is a striking example of the use of augmented reality in the study of geometry. This application uses stereoscopic main displays and personal interactive panels. Construct3D allows multiple people to work in the same space and build different geometric models that overlap with the real world.

In [11] propose the possibility of using the SISEULER application in the study of convex polyhedra for the development of spatial imagination in the study of 3D geometry by means of augmented reality. You can use marker cards that show the number of vertices, edges, and faces of a convex polyhedron and see a convex polyhedron with the corresponding Euler characteristic.

Using the AR Math application [7] gives students the opportunity to establish connections between objects from the world around them and geometric shapes, to determine their properties, which creates conditions for the formation of not only spatial thinking, but also the ability to build logical connections. Such learning takes place through virtual manipulation of objects in augmented reality.

The use of AR Math application in the process of studying geometry provides an opportunity to implement the following tasks [6]:

- representation of both virtual and mathematical situation;
- search for specific household items in a real environment and their recognition on the basis of computer vision algorithms;
- solving the problem of determining geometric objects and their classification;
- interactive interaction of students with a virtual person helps the student to solve a problem or write a solution in the form of a mathematical expression based on understanding of semantics (or to compare the found solution to one of the proposed mathematical expressions).

The implementation of AR Math tasks is based on the use of machine learning algorithms, including, for example, the k-mean algorithm for selecting clusters of objects by color or shape. The presence of a virtual assistant that engages students in an augmented reality environment through the “Stories” of interesting history and problem statement contributes to the study of real mathematics.

Another interesting application that allows students to better understand the world of geometry is the program GeoGebra AR [9]. The authors of the article claim that this application will be useful not only for students to develop their spatial thinking, but also for future teachers of mathematics. The systematic use of GeoGebra 3D Calculator with AR can help develop students' research skills, expand their socialization opportunities through the acquisition of ICT, which ensures the development of universal STEM competencies. There is no question that the goal of every STEM teacher should be to motivate and engage students in research activities [15].

That is why the purpose of the article is to review some of the mobile ICTs that can be introduced into the secondary education system of Ukraine in the process of studying mathematics.

2 Research results

2.1 Main definitions and terms

The development of spatial visualization skills is one of the necessary skills required for a graduate. This gives the student a better understanding of the environment and its location. Well-developed spatial thinking makes the study of mathematics more interesting and simple, as it makes it possible to visualize teaching material and make mathematics more comprehensible.

Our own experience in secondary and higher education institutions has made it possible to single out a number of problems of teaching mathematics of high school students and students of the first year of engineering specialties:

- students of humanities subjects classes have no systematic knowledge of mathematics and are not able to integrate into the process of learning a new topic of previously known knowledge;
- students of 10th grade, mostly liberal arts, in the process of studying 3D geometry do not have sufficiently developed spatial thinking and do not understand the location of basic geometric concepts in space;
- according to a study conducted in the first year of full-time students at a technical university and high school students, 25% are unable to find the necessary information on the Internet and require constant monitoring and directed work by the teacher in the search for educational information;
- most of first year students are underdeveloped with independent work skills.

Building a blended learning model is one way to solve these problems [4]. It has proven itself on the positive side and is gaining more and more supporters in the world. This makes the learning process interactive, enables you to learn at your own pace, build a personal learning environment rich with mobile ICT [18].

Blended learning is a deliberate process of acquiring knowledge by learning subjects in the context of integrating classroom and extra-curricular learning. It is rich in information and communication tools and technologies, which facilitates the construction of its own learning trajectory independent of others.

One of the ICT that can be used to visualize learning material in a blended learning model is augmented reality technology. The application of this technology enables the student or student to dive into mathematics and not burden it with its complexity.

The development of students' spatial thinking is one of the pressing problems of mathematical education. Its formation begins in the grades 7-9 course of 2D geometry and deepens in the process of studying 3D geometry at grades 10-11. And if almost all students in grades 7-9 can represent a geometric figure, then upper-class students in the process of studying3D geometry have a problem with this:

- cannot represent the spatial figure depicted in the plane;
- cannot represent a spatial body, especially if there are additional conditions in the task;
- cannot give examples of geometric bodies from the outside world;

— cannot design a geometric body in space on a plane;
— cannot distinguish parts in spatial objects.

One of the ways to solve these problems can be to use mobile tools in geometry lessons or to visualize a geometric figure in the course of homework, namely augmented reality.

Today, there are two basic concepts of augmented reality construction [3]:

— based on a marker [17];
— based on user coordinates [14].

Marker-based technology is a new interactive system for using a special marker. A marker means an object that can be placed in space and which is defined and analyzed by special software to further visualize the object. Based on the data obtained from the token, the program automatically projects a virtual object on it, resulting in the effect of its physical presence in space.

Technologies based on user coordinates are used in mobile devices and rendering in them is due to special sensors.

2.2 Experience of cloud technologies application and their services in educational and scientific space

So, during the studying geometry in grade 7, is advisable to introduce students to the Spanish program Arloon Geometry (http://www.arloon.com/), which will make it easier to understand the process of obtaining knowledge of geometry. The developers recommend using this program, starting at the age of 10, to get acquainted with geometric shapes and bodies (fig. 1).

Fig. 1. The ArloonGeometry application window.

You can download this application from Google Play with minimal requirements to mobile device: Android 4.0.3 or higher, iOS 8.0 or higher.

This program is not affiliated with any textbooks, but is completely autonomous and is freely available but not free of charge, though its price is purely symbolic – $2.99.

Features of this program are:

- student can study geometry both in the plane and in space. Volumetric shapes have a planar sweep, and combinations of flat shapes created by the student on their own can be translated into space;
- if you work with spatial bodies, you can learn to determine the area of the side surface or volume of this body;
- in addition to getting acquainted with the spatial figures, the program can choose the mode of “perform exercises” and study formulas or calculations that work on one or another side face of a spatial polyhedron;
- using of the program will enable students to find and identify polyhedrons or other geometric bodies in the environment;
- independently perform the tasks in the sections “guess”, “right / wrong” and “calculation” and check how much material was learned.

The disadvantages of the program are

- that it is not free;
- today, it is only supported in English and Spanish.

Introducing 7th grade students to this program in geometry lessons will not only create conditions for the development of spatial visualization skills, but will also allow students to see the differences between 2D geometry and 3D geometry. But to determine the applied orientation of geometry; understanding the essence of the geometric task.

In addition to the augmented reality application for geometry, you can also use programs in chemistry, biology, arithmetic, anatomy and astronomy.

It is advisable to use a mobile augmented reality tool such as Geometry – Augmented Reality during the studying geometric shapes in 7th, and especially in 8th grades (fig. 2).

Fig. 2. Geometry –Augmented Reality window.

Provided that Android 4.0 or higher, you can download this app for free on Google Play. This app was first introduced in 2017 and given time is not popular enough. To work with geometric shapes, you also need to download and print the letters that are labeled for this program. The four letters A, B, C, and D are included, but can be repeated to construct polygons.

With this application and mobile device, the student is able to:

— construct segments and determine their length in conventional units;
— build triangles and find their perimeter and area;
— build quadrangles and determine their perimeter and area;
— work with polygons.

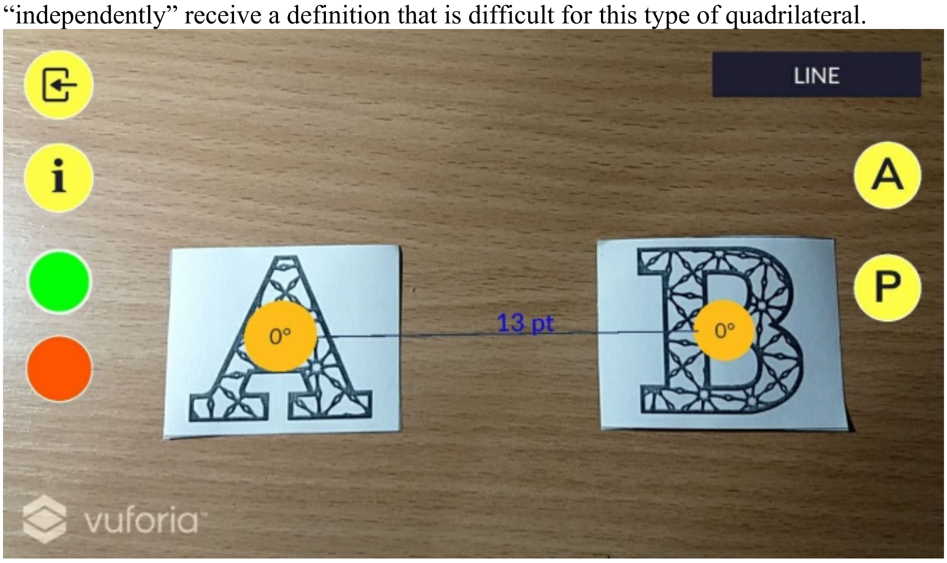
Through this program, students of 8th grade will be able to independently construct and clearly understand the difference between a convex and a non-convex quadrilateral when studying the theme "Quadrilaterals". Determine this type of quadrilateral as a parallelogram by changing angles, and also consider its special cases – rectangle, rhombus, square (fig. 3).

Using this program in geometry lessons in the 7th and 8th grades of secondary schools will allow students to develop of spatial visualization skills as it enables them to visualize geometric constructions, independently work with geometric figures and change them at will.

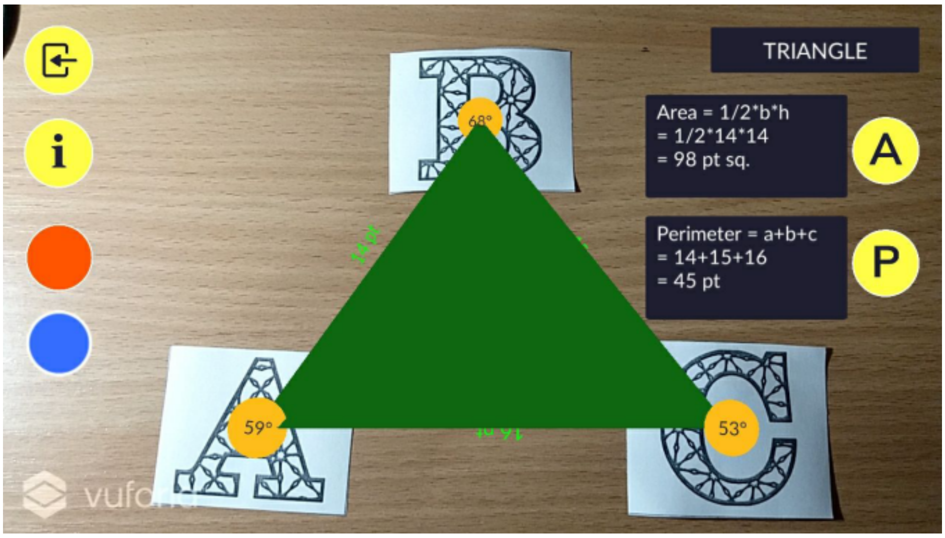
We will describe some possibilities of using Geometry AR when studying the topic "Convex quadrilaterals" in 8th grade.

After the teacher gives the definition of the concept of "quadrilateral", it is advisable to give students the opportunity to independently obtain images of different types of quadrilaterals, so that the meaning of the definition is visualized in their understanding. It is advisable to show them the difference between convex and non-convex quadrilaterals by moving the labels (vertices of the quadrilateral) and changing the lengths of the segments.

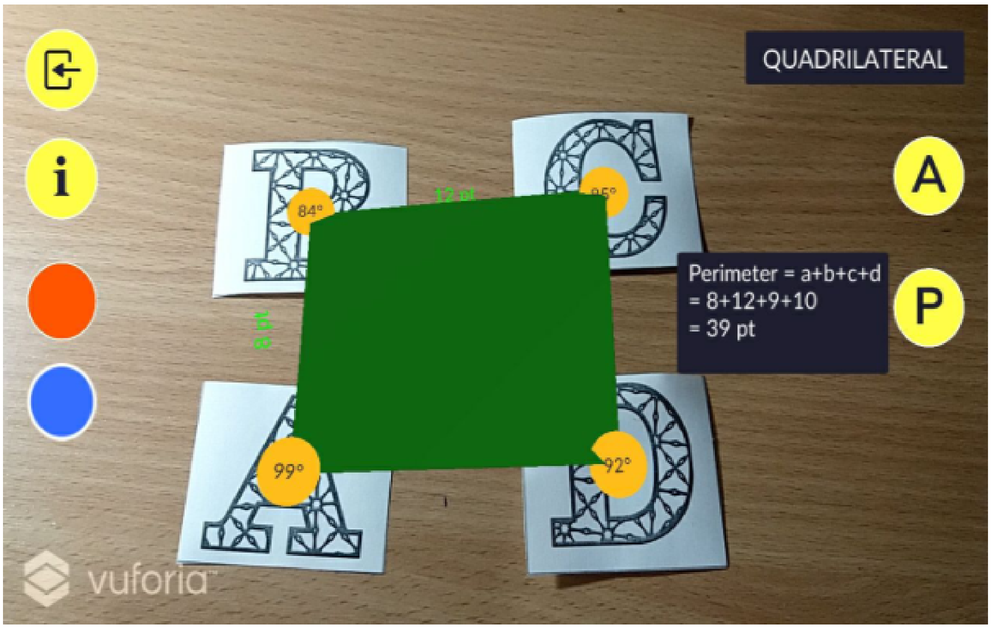
The use of this program will create conditions for the construction of problem-based learning in the study of different types of quadrilaterals. Students independently obtain the properties of the quadrilateral under consideration, formulate its features and "independently" receive a definition that is difficult for this type of quadrilateral.



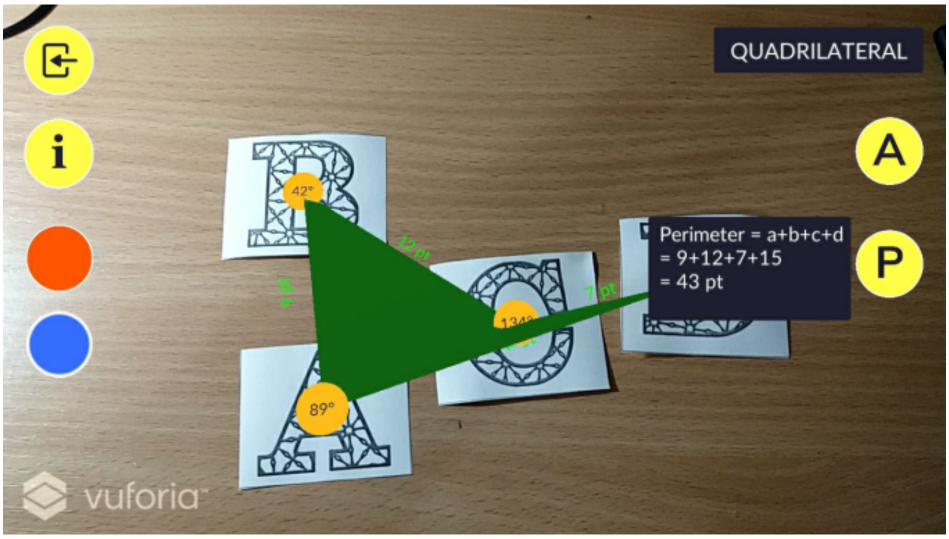
a) construction of a segment



b) construction of a triangle



c) construction of a convex quadrilateral



d) construction of a concave quadrilateral

Fig. 3. Buildings in Geometry – Augmented Reality.

The possibility of self-visualization of quadrilaterals and the separation of their features become even more important in the transition of the school system to the model of blended learning. Therefore, the means of augmented reality become a necessary tool in such a system of education.

The analysis of various technologies and tools of augmented reality showed that at present there are not enough developed and adapted programs for school education, particularly in geometry courses. But at the same time, a sufficient number of platforms have been developed to enable the teacher to create their own applications in AR format, or to provide this opportunity for students.

Consider some platforms for creating applications in AR format that are either freely distributed or require special educational licensing [16]:

- ***ARToolKit*** (http://www.hitl.washington.edu/artoolkit/) is a library of tools designed to create design solutions and augmented reality applications. This platform the most popular among developers.
- ***Vuforia*** (https://developer.vuforia.com/) is a platform that allows you to create applications in AR-format for smartphones on iOS, Android. The ability to create and analyze flat images and simple three-dimensional objects, create geometric shapes makes it usable with the help of virtual controls, the user can rotate the object, zoom it.
- ***HP Reveal*** (until 2018 ***Aurasma***) (can be downloaded from Google Play) is a platform for creating augmented reality projects. Creating educational materials on this platform is very interesting and gives the opportunity to show their creative abilities not only to teachers but also to students.

- ***Metaverse*** (https://studio.gometa.io/landing) is a platform that enables you to create interactive learning tasks without significant programming skills.
- ***EV Toolbox*** (https://nitforyou.com/ev-toolbox/) is a simple and convenient constructor for all programmer users. The student or teacher can create augmented reality on their own. EV Toolbox Designer customizes the ability to visualize textbook material: mathematical abstractions, display a generated object on a smartphone screen: three-dimensional geometric shapes and surfaces. At the same time, the students' drawings on the plane are transformed into interactive 3D objects. Virtual Object Interaction visualizes an action that is practically impossible to perform on a piece of paper.

Therefore, it can be argued that a teacher in his profession can not only be a user of developed augmented reality, but also become the creator of educational products that will develop his creative potential.

3 Conclusions and prospects for further research

An analysis of some augmented reality tools that can be used in geometry teaching at school has made it possible to draw the following conclusions:

1) creation of appropriate conditions for students' self-realization, their intellectual development and the development of their spatial imagination is the main task of the teacher, who is the organizer of the educational process;
2) the teacher in the learning process is the motivator for the construction of personal trajectory of learning. He / she demonstrates the ability to use a variety of information and communication tools and technologies for self-development and self-improvement;
3) the teacher, as an individual, also has a significant influence on the emotional state of the student. It is undeniable that the student's emotional attitude to the teacher reflects his / her attitude towards the subject. If the emotional component of the dialogue between the student and the teacher is some motivational component of their interaction, the learning outcomes are increased, the cognitive activity of the students increases, their creative potential is revealed, the learning process is intensified;
4) in the process of studying geometry, the emotional component has a significant impact on learning outcomes. It is advisable to begin every lesson in geometry precisely with the creation of a teaching dominance, which emotionally sets the students on to acquire knowledge and to apply them in everyday life;
5) the use of augmented reality means in the geometry lessons creates precisely such conditions for positive emotional interaction between the student and the teacher. First, students understand that a mobile device can be used precisely to organize the learning process, to intensify it and to build a personal learning path. Secondly, the emotional component of learning creates the conditions for better memorization of the educational material, promotes their mathematical interest, realizes their creative potential, and creates the conditions for finding different

ways of solving geometric problems. Third, the ability to solve simple geometric problems with augmented reality tools creates a positive disposition for the student to succeed and to solve more complex problems faster and more intensively.

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Exploring the potential of augmented reality for teaching school computer science

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Abstract. The article analyzes the phenomenon of augmented reality (AR) in education. AR is a new technology that complements the real world with the help of computer data. Such content is tied to specific locations or activities. Over the last few years, AR applications have become available on mobile devices. AR becomes available in the media (news, entertainment, sports). It is starting to enter other areas of life (such as e-commerce, travel, marketing). But education has the biggest impact on AR. Based on the analysis of scientific publications, the authors explored the possibilities of using augmented reality in education. They identified means of augmented reality for teaching computer science at school. Such programs and services allow students to observe the operation of computer systems when changing their parameters. Students can also modify computer hardware for augmented reality objects and visualize algorithms and data processes. The article describes the content of author training for practicing teachers. At this event, some applications for training in AR technology were considered. The possibilities of working with augmented reality objects in computer science training are singled out. It is shown that the use of augmented reality provides an opportunity to increase the realism of research; provides emotional and cognitive experience. This all contributes to engaging students in systematic learning; creates new opportunities for collaborative learning, develops new representations of real objects.

Keywords: augmented reality, mobile learning, school computer science, augmented reality applications.

1 Introduction

Today, the topical areas of research for scholars in education are the didactic potential of digital technologies and methods of their application. Modern digital tools create opportunities to complement real space with contextual, dynamic, visual content.

Accordingly, such technologies are increasingly being implemented and explored in education.

Augmented reality (AR) is a technology that enriches human sensations with digital data and thus mixes the real and virtual environment. It uses virtual information as an additional useful tool. As a result, a new, more informative and stimulating environment is created [18].

The principle of the AR program is to use the sensors of the device to read the environment and supplement it with digital, interactive content.

AR applications can be used on different devices such as desktops, laptops, mobile devices. But most AR programs work on smartphones, tablets. Smart glasses, headphones, and other controllers can be further connected to mobile devices. Built-in cameras, GPS sensors, gyroscopes and other sensors are used to recognize objects, images and scenes. After successful recognition, relevant digital content becomes available and is displayed on screen. The purpose of their application is to combine the real environment with digital content. This enables the user to receive more information about the environment than is available to him in the real world. The advantage of AR is not only to increase the available information in the environment, but also to create an attractive representation of the world. For this reason, AR is used in many industries such as marketing, design, medicine, entertainment, tourism, education, etc. [19; 34; 44; 49; 56].

The ability to improve the visualization of objects and processes in the learning environment through interactive digital content has generated interest in the using of AR applications for educational purposes. New possibilities of AR technologies for teaching and learning has been analyzed by Natalya V. Rashevska et al. [43], Dmytro S. Shepiliev et al. [47], Viktoriia V. Tkachuk et al. [52]. Anna V. Iatsyshyn et al. described examples of AR applications in such industries as the entertainment and gaming industries, tourism, sales and presentations, education [19]. Classification of directions of using of augmented reality in education and practice of using AR applications are given in the publications [36; 55]. The analysis of the papers shows that AR is implemented to different disciplines of elementary and secondary school (Nadiia R. Balyk et al. [2], Zhanna I. Bilyk et al. [5], Teresa Coimbra et al. [10], Hennadiy M. Kravtsov et al. [27], Dmytro V. Matsokin et al. [30], Yurii S. Matviienko [31], Liliia Ya. Midak et al. [32], Liudmyla L. Nezhyva et al. [38]) and in the higher education institutions (Igor V. Barkatov et al. [3], Vladyslav V. Bilous et al. [4], Dmytro M. Bodnenko et al. [6], Valentyna V. Hordiienko et al. [17], Oksana V. Klocko et al. [23], Elena V. Komarova et al. [25], Olena O. Lavrentieva et al. [28], Oleksandr V. Syrovatskyi et al. [50], Rostyslav O. Tarasenko et al. [51], Tetyana I. Zhylenko et al. [57], Natalya O. Zinonos et al. [58]). These and many other researchers have found that AR technologies increase the level of success and motivation of pupils and students [15; 21; 29; 41; 42].

Scientists say that learning in the AR can have a positive impact on the development of spatial imagination, the formation of abstract concepts, the transfer of knowledge, the acquisition of digital skills and experience. Yulia Yu. Dyulicheva et al. [13], Tamila H. Kolomoiets et al. [40], Viacheslav V. Osadchyi et al. [40], Viktoriia V. Tkachuk et al. [52] identified AR as an important prerequisite for implementing effective strategies to achieve the goals of inclusive education. Now, AR is not only useful for studying individual subjects or individual students. It can also be applied to the development of new approaches to learning, in particular the concept of STEM [2; 46; 53].

AR technologies can be an effective tool of organizing interaction and collaboration to present learning outcomes. Other studies, such as [10; 18; 19; 30] concluded that AR is particularly suited for teaching subjects that need to form difficult for understanding in the real world concepts [27; 53]. Yurii S. Matviienko described his experience in creating a computer museum. He used augmented reality technology to virtualize objects. The author developed an interdisciplinary study excursion in the museum [31].

The common practice of using AR in education is to create supplementary books. Some didactic aspects of mixed reality books have been studied by Hennadiy M. Kravtsov et al. [27] and Liubov F. Panchenko et al. [41]. When AR is used, books are transformed into dynamic sources of information. Augmented reality technology has made it possible to "revive" its pages [36]. Now this technology is used in cognitive books such as encyclopedias, atlases, books about space, structure of the Earth, dinosaurs, for reproduction of historical events. Gradually, from coloring books and fairy-tales, augmented reality technology is being extended to the production of educational products. That is, they are gradually moving from game technology to learning. For example, students use specialized software for joint study of mathematics, physics, chemistry, geometry [10; 19; 26; 31; 50; 58]. These studies have shown the benefits of using AR books as a tool to increase children's motivation. Books in the AR have also proven to be effective means of concepts formation.

AR technology is developing quite rapidly. As a consequence, research in education does not have time to provide theoretical understanding or develop a systematic methodology for creating appropriate learning tools. We believe that the use of AR technology is a modern trend, and therefore research in this field is relevant and timely.

The **purpose of this study** is to explore the possibilities of using augmented reality technology at school, in particular when teaching computer science.

Objectives of the study are:

1. To analyze the experience of using AR technologies in education;
2. To find out the possibilities of using augmented reality technology in teaching computer science
3. To experimentally test the attitude and readiness of teachers to use AR in teaching of computer science.

Object of study is the process of teaching computer science in secondary school.

Subject of research is augmented reality technology as a mean of teaching computer science in secondary school.

2 Problem statement

In the Ukrainian education system, postgraduate institutes are responsible for implementing innovations in primary and secondary schools. These institutions remain an important component in the process of computer science teacher training. This article will describe the experience of trainings organization at the Ternopil Regional Municipal Institute of Postgraduate Education (TRMIPE). The purpose of these trainings is to develop teachers' skills for augmented reality application. The article will explore the services and their functionality for the computer science lessons. Augmented reality allows the student to visualize complex spatial connections and abstract concepts. Therefore, with their help, the teacher can develop abilities that are difficult to form in a traditional learning environment [39; 48].

Technologies for augmenting reality with digital objects (perhaps not just digital ones) can be conditionally positioned between two polar variants of possible realities: the reality we live in and virtual reality (VR) (see figure 1).

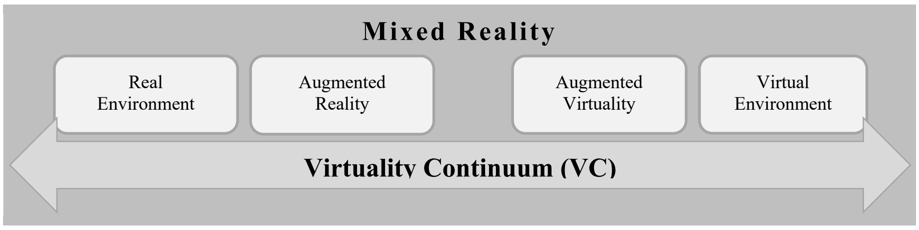

Fig. 1. Reality-virtuality continuum by Paul Milgram and Fumio Kishino [33].

Reality is a philosophical term that means what actually exists in physical space, and physical space itself. Virtual reality is the absolute absence of real objects. It is a technically created world that is transmitted to man through his senses: sight, hearing, touch and others.

Quite often, a combination of these realities is called Mixed Reality (MR). Virtual reality can be filled with people, weather, events, and more. If images of these objects are broadcast from the real world, then the result will be augmented virtual reality (AV) technology. At the current level of development, AV technology is virtually unused, but in the future it can be much more impressive than AR and VR.

Ronald T. Azuma [1] identified augmented reality features such as:

- combining the real and the virtual world;
- interactivity;
- three-dimensional representation of objects.

The augmented reality system is the mediator between man and reality. Therefore, it must generate a signal for one of the human's perception organs. Therefore, according to the type of presentation of information in the AR system, they can be classified such as visuals, audio, and audiovisuals.

By type of sensors for the acquisition of data from the physical space there are AR systems:

- Geo-location. They focus on signals from GPS or GLONASS positioning systems.
- Optical. Such systems process the image obtained from the camera. The camera can move with or without the system.

Augmented reality systems can be classified by user interaction. In some systems, the user has a passive role. He only watches the system react to changes in the environment. Other systems also require active user intervention. There he or she can control the operation of the system and modify its virtual objects. According to this feature, the systems are divided into offline and interactive.

Let's look and analyze the program tools that are most appropriate to use when teaching computer science at school. Based on the analysis of articles and sites, we can say that there are very few such applications and services. Therefore, teachers and scholars are looking for ways to use augmented and virtual reality to improve and support school-based learning. But to make the right choice, they need to know the requirements for existing applications and services and the limitations of using them. As the experience suggests, most Ukrainian schools do not have high-end AR or VR devices.

The benefits of AR are the ability to increase motivation, emotional perception of the students' learning content. The highest level of application of these technologies is the involvement of students in the creation of their own virtual worlds. At the same time, teachers should also be interested in implementing such innovations. They should have as little doubt as possible about the capabilities of AR technologies and their own capabilities.

Among augmented reality applications, there are those that can be used in the study of various subjects, not just computer science.

The Quiver application allows the teacher to create coloring books with augmented reality. With the app, students can interact with objects they create. Painted images are transformed on the gadget screen into augmented reality. There is an opportunity to play with animated characters. The teacher can use the Quiver app in the lesson as a tool for developing creative skills or for pupils' reflection.

WallaMe is a platform that can be implemented to integrate augmented reality into the learning process. WallaMe Ltd launched the application in 2015. Using this app is an easy way for both teachers and students. WallaMe is a free iOS and Android application. It allows users to hide and share messages in the real world using augmented reality. These messages appear as a result of changing the geolocation of the smartphone. In addition, the WallaMe app provides students and teachers with additional tools such as

- a library of stickers;
- advanced drawing tools;
- tools for working with text;
- simple and minimalistic graphics and elements of the interface;
- connection to a smartphone camera;
- comment option;
- accessible to all or private messages.

WallaMe allows a teacher to take a picture on a smartphone and leave a picture or message there. The object created in this way is linked to the image and geographical coordinates. Another app user sees a message icon on the map. He or she will only be able to find out it if he points his camera at this wall.

The application can be used in the study of computer science to create knowledge maps or tests in augmented reality. For example, a teacher creates a geotag on a specific computer hardware device. The learner should identify and add text with the characteristics of this device. In the study of programming, students can perform in augmented reality the task of completing a code snippet, determining the values of variables, finding errors. In the case of a positive experience, the teacher can use the application to create integrated tasks, such as web quests [14].

One of the most popular mobile apps is Google expedition. It is an immersive education application that allows teachers and students to explore the world through over 100 augmented-reality tours. In addition, the app offers more than 1,000 virtual reality tours [8]. They can be used effectively by teachers of various subjects.

Unfortunately, as of now, only 2 expeditions are available for computer science in AR mode:

- Computers. The tour allows students to learn and explore how different components of a computer function.
- Introduction to Computer Graphics. It covers topics such as: History of Computer Graphic, Creating a 3D World, Modeling, Texturing and Shading, Ray Tracing and Light, Rendering.

Google Expedition provides collaborative learning opportunities. The teacher has the opportunity to download the completed tours and invite students to see them in augmented reality. Unfortunately, creating your own AR Tours with Tour Creator is not currently available. For now teachers can use an external tool such as cospaces.io. The service allows them to create or import three-dimensional models. These objects can be offered to students for using on mobile devices.

CoSpaces Edu service provides great programming experience. It enables students to learn by doing, using the various tools available with the VR and AR technologies. All features in CoSpaces Edu can be adapted to fit different class subjects and learning objectives. The platform uses a visual programming language ideal for beginners or gets access to scripting languages for more advanced coding. With its fun Lego-like colored blocks, CoBlocks is the ideal solution for junior pupils. More advanced coders can have fun coding scripts to add interactions and events or even create games [11].

The platform enables the collaboration of the teacher with several students. They can work on individual or collaborative projects. Most of these projects these projects can be saved in AR. Augmented Reality lets students project their own creations onto any plane surface in the real world by looking through the screen of their device.

The advantage of the system is the use of single sign-on technology. It integrates well with cloud services, including G Suite for education.

Michael Drezek of the New York State's Lake Shore Central School District uses the CoSpaces service to perform tasks for students such as creating an animal habitat, creating a game about holiday traditions in virtual and augment reality to share with the schools around the world. Michael says that students in own space can experience what they design and program in virtual and augmented reality [12].

In our opinion, the highest level of implementation of AR in the teaching of computer science is the development of students own elements and scenes in augmented reality. According to research [7; 9; 54] one of the most popular and productive means of achieving this goal is the Unity engine and the Vuforia library. One of the many advantages of Unity is that it is a free game engine that has the possibility to deploy to many different platforms as iOS and Android [16; 20]. This, combined with the Vuforia AR platform, makes it possible to assign a virtual camera in the 3D scene that is linked to an image tracker. This combination can then be deployed to a smart phone or tablet. Finally, it is possible to utilize the camera on the device in order to mix the 3D scene with the camera image [22].

We compared these tools according to the main criteria (type of tool, equipment, interaction with the student, place in training, cost). Table 1 contains a comparative analysis.

Table 1. Augmented reality program tools.

Name	Software	Equipment	Interaction	Place	Cost
Quiver	Application	Mobile device	One user	Reflection	Free/Commercial
WallaMe	Application	Mobile device	Many users	Quests, Learning Projects	Free
Google Expedition	Application	Mobile device	Many users	Demonstration, STEM-projects	Free
CoSpaces Edu	Site, Application	Mobile device, PC	Many users	Programming, development	Free/Commercial
Vuforia AR	Application	PC	One user	Development	Commercial
Unity	Application	PC	Many users	3D-modeling	Free and Commercial
Poly	Library	PC	Many users	3D-modeling	Free
SketchUp	Application, Site	PC	One user	3D-modeling	Free with a state grant/Commercial

In addition to AR services created by IT firms, there are also authoring AR applications to support computer science training. Let's look at some of them.

AR-CPULearn is based application for learning CPU. It was created by scientists of Universiti Kebangsaan (Malaysia). AR-CPULearn was implemented as an exercise activity for computer organization and operating system students in higher education. This applications offer for execution some exercises with overlaid multimedia information. For example, answer a few questions based on a training video; name the main components of the motherboard, explain how the processor and motherboard work [7].

The Mixed Reality Laboratory (Bond University and CQUniversity, Australia) is involved in the development of mixed reality applications for solutions to complex pedagogical problems. In our opinion the “Network and ICT modeling” project is the most exciting startup of this lab. The purpose of this project is to use the augmented reality visualization method to help students understand the theoretical model of open systems interconnection (OSI) and its implementation as a stack of TCP/IP protocols [35].

The application simulates in augmented reality the construction of simple computer networks. This simulation uses a five layer TCP/IP model to visualize how packets are interpreted and distributed. The simulation utilizes augmented reality markers which are detected and tracked in 3D space by smartphones cameras. When students are focusing a camera on the marker then they can see a multiple network devices such as modems, routers, switches, wireless AP etc. These devices can be connected to the network. Visually, this will be shown as lines on the smartphone screen.

The application visualizes packets from devices that generate traffic. This visualization corresponds to the TCP/IP model. The demo shows not only traffic but also individual packages and their headers. Visualization in augmented reality is dynamically transformed as the network topology changes. The application also demonstrates signal conditioning between wireless devices. The student can select any device as the source and as the recipient when transmitting traffic. As a consequence, he or she will see the visualization and model of this process in augmented reality.

3 Results and discussion

We continued our research on augmented reality training. The training was conducted at TRMIPE from September to November 2019. Participants of the trainings were 2 groups of computer science teachers (20 people in each group). They could choose augmented reality topics. We used different techniques to teach different topics (see table 2).

Table 2. Augmented reality training topics.

Topic number	The name of the topic	Training technique
1.	The concept of virtual and augmented reality	Conversation
2.	Types of augmented reality	Mini-lection
3.	Examples of augmented reality	Demonstration
4.	Checking mobile gadgets for support of AR technologies	Work in groups
5.	Prospects for the use of AR technologies in education	Training exercise, brainstorming
6.	Create your own augmented reality effects	Individual work
7.	Develop a list of required AR models for the computer science course	Collaboration

We have conducted a survey to verify attitude and readiness of computer science teachers to use AR in teaching. The participants of the training filled out a questionnaire. They evaluated AR applications by the factors of frequency and usefulness of their use in training. The questionnaire was based on the usability measurement software [45]. The questionnaire contained 12 questions. The answer options were formed according to the 5-point Likert scale. They determined the ratio of the respondents from completely negative (0 points) to completely positive (4 points). This distribution prevented the respondents from making unreasonable choices about the mean of the answer. We avoided questions in the negative form when forming the questionnaire. We also used the Likert scale to determine respondents' age (from 0 points – age over 60 years to 4 points – age 20-30 years). The entire table of respondents' scores can be downloaded from the link https://drive.google.com/file/d/1zIS8c0RForHw8KA49qBQGhynQvAcpzTy

To check the internal consistency of the questionnaire, we calculated the Alpha Cronbach coefficient. Its value (α_{Cr}=0.73) can be considered acceptable. We considered the latent indicator of each question to be the average of all respondents' scores. Table 3 shows the list of questions and their respective mean values.

Table 3. Questionnaire items.

Question code	The content of the question	Average of respondents' scores
UGT	How often do you use gadgets in teaching?	2.38
SUG	How often do your students use their own gadgets in learning?	1.9
MAR	How often do you use AR apps in computer science teaching?	1.8
CAR	How often do your colleagues use AR in computer science teaching?	1.9
EAR	How easy is it for you to learn AR technologies?	1.98
ARI	Using AR in computer science teaching can be interesting	2.43
RAR	I feel ready to use AR	1.83
ARE	AR is entertaining	2.05
ARC	AR used in computer science training can be credible	2.33
PAR	My proficiency level of AR	1.9
ARA	The use of AR is advisable in the study of computer science	2.58

We have selected the following significant average values of respondents' scores:

- less than 1.5 points – the indicator is not almost manifest;
- 1.5-2.0 – the indicator is weak;
- 2.0-2.5 – the indicator is sufficient;
- more than 2.5 – the indicator is strong.

The obtained average values of the indicators are shown in the following diagram (fig. 2). Significant values of indicators are highlighted with colors.

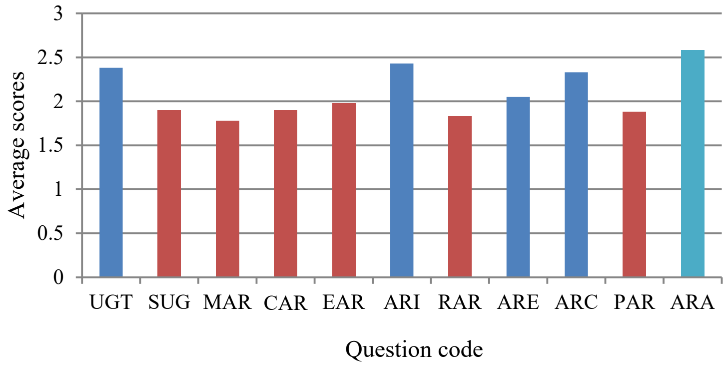

Fig. 2. Distribution of indexes.

As can be seen from the diagram, a weak manifestation is found in indicators related to the readiness and use of AR in the real learning process. However, the study found strong and sufficient manifestations of the indexes regarding the usefulness, motivation for use and pedagogical potential of AR applications. At the trainings we observed the interest of teachers, especially when they saw in AR their own digital world.

Another objective of our study was to determine the dependencies between these indicators. To do this, we used a correlation method. To determine the specific correlation coefficient, we checked the normality of the distribution of each indicator. The results of the statistical study of normality by the One-Sample Kolmogorov-Smirnov Test are presented in table 4.

Table 4. Checking the results for the normality of each indicator.

		UGT	SUG	MAR	CAR	EAR	ARI	RAR	ARE	ARC	PAR	ARA
Normal Parameters	Mean	2.38	1.90	1.78	1.90	1.98	2.40	1.82	2.05	2.33	1.88	2.58
	Std. Deviation	1.25	0.87	0.95	1.17	1.00	0.96	1.13	1.07	0.76	0.85	0.98
Most Extreme Differences	Absolute	0.22	0.22	0.24	0.20	0.20	0.26	0.26	0.21	0.27	0.27	0.22
	Positive	0.14	0.22	0.21	0.20	0.16	0.17	0.21	0.19	0.27	0.27	0.22
	Negative	-0.22	-0.20	-0.24	-0.15	-0.20	-0.26	-0.26	-0.21	-0.21	-0.23	-0.17
Test Statistic		0.22	0.22	0.24	0.20	0.20	0.26	0.26	0.21	0.27	0.27	0.22
Asymp. Sig. (2-tailed)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Since the asymptotic significance is less than 0.05, the distribution is not normal. In this case, the Spearman rank factor should be used. It is a statistical measure of the strength of a monotonic relationship between paired data. Correlation is the size of the effect. The coefficient determines whether the quantitative factor influences the quantitative response. Its absolute value is usually interpreted according to the following ranges:

- 0 – 0.19 – relationship is very weak;

- 0.2 – 0.39 – relationship is weak;
- 0.40 – 0.59 relationship is moderate;
- 0.60 – 0.79 relationship is strong;
- 0.80 – 1.0 relationship is very strong.

Its positive value shows the existence of a direct relationship between factor and response. A negative coefficient indicates the reverse relationship.

We used the Statistica program and calculated the rank correlation coefficients. All correlations are significant at 0.05 level. We considered indicators with a moderate and strong correlation. In table 5, they are highlighted in italics and bold respectively.

Table 5. Spearman rank order correlations.

	Age	UGT	SUG	MAR	CAR	EAR	ARI	RAR	ARE	ARC	PAR	ARA
Age	1.00	*0.49*	*0.46*	**0.80**	0.27	**0.59**	*0.43*	*0.42*	-0.07	*0.41*	**0.79**	**0.80**
UGT	*0.49*	1.00	0.05	0.46	0.19	0.17	0.19	0.34	-0.07	0.25	*0.42*	0.36
SUG	*0.46*	0.05	1.00	0.39	0.02	*0.45*	0.36	-0.06	-0.27	0.18	0.30	*0.48*
MAR	**0.80**	*0.46*	0.39	1.00	0.39	*0.45*	0.26	0.20	-0.10	0.39	**0.63**	**0.68**
CAR	0.27	0.19	0.02	0.39	1.00	0.13	-0.23	0.06	-0.21	0.17	0.03	0.31
EAR	**0.59**	0.17	*0.45*	*0.45*	0.13	1.00	0.20	0.11	-0.26	*0.46*	*0.41*	*0.44*
ARI	*0.43*	0.19	0.36	0.26	-0.23	0.20	1.00	0.29	-0.04	0.17	0.34	0.31
RAR	*0.42*	0.34	-0.06	0.20	0.06	0.11	0.29	1.00	0.10	0.02	0.31	0.16
ARE	-0.07	-0.07	-0.27	-0.10	-0.21	-0.26	-0.04	0.10	1.00	-0.18	0.07	-0.18
ARC	*0.41*	0.25	0.18	0.39	0.17	*0.46*	0.17	0.02	-0.18	1.00	0.20	0.30
PAR	**0.79**	*0.42*	0.30	**0.63**	0.03	*0.41*	0.34	0.31	0.07	0.20	1.00	**0.65**
ARA	**0.80**	0.36	*0.48*	**0.68**	0.31	*0.44*	0.31	0.16	-0.18	0.30	**0.65**	1.00

The first line of the table indicates a strong relationship between teachers' age and their experience with AR use. That is, younger teachers are easier to learn AR applications, they are more confident in their ICT competencies. Therefore, they are more likely to use AR in computer science training.

The study found a strong link between the frequency of use of AR technology in teaching computer science and the beliefs of teachers about the feasibility of its use. A positive strong relationship was also found between teachers' proficiency level and the frequency of AR use.

The use of augmented reality by colleagues has a positive moderate impact on the same activities of the interviewed teachers. The Bring Your Own Device (BYOD) approach also helps to incorporate AR into learning. Teachers who are learning to work with AR applications are more positive about the credible data that this technology displays.

In addition, the survey found several indicators that were poorly explained. First of all, there is no significant positive correlation of ARE (Entertainment of AR) with other survey questions. This may mean that teachers do not pay enough attention to the gaming approach in teaching. A similar situation was found with the RAR indicator. That is, despite some level of AR using, teachers still do not consider themselves ready for it.

We also found no significant correlation between the use of AR and the fact that these technologies are interesting and motivating. Also surprising is the fact that communication with colleagues has no effect on the readiness of a computer science teacher. In our opinion, these paradoxes are a result of the lack of appropriate methodology. In general, we can say that negative research results require rethinking and further exploration.

4 Conclusions

Therefore, innovative ICTs should be used in computer science lessons, as they are necessary and crucial for living in the modern world. Augmented reality is one of the most up-to-date teaching content visualization technologies. Currently, the use of AR in education has been a success. In our opinion, the introduction of this technology will increase the motivation to learn, increase the level of mastering the material. This is also possible due to the variety, interactivity of visual presentation of educational objects, migration of part of students' research work into the virtual environment.

Our analysis of publications on the problem of research has shown that the experience of using augmented reality applications is mostly fragmentarily described in scientific articles and blogs of enthusiasts. Appropriate implementation of AR means in the practice of educational institutions will be done step by step.

It is clear that successful implementation of this technology requires special attention to the system of teacher training and retraining, curriculum development and next-generation textbooks. However, such fragmented use of augmented reality is already facilitating the process of its implementation. Our experience has shown that the developed training courses are in demand in advanced training courses. They are of interest to teachers. The results of this study show that IT teachers have access to computers and mobile devices and have a high level of interest in augmented reality technology.

The study found difficulties in implementing AR such as:

- increasing the time of teacher's preparation for augmented reality classes;
- AR tools are usually application-specific, so learning about different topics requires installing and sometimes integrating multiple applications;
- sometimes AR is perceived by students and teachers as an entertainment game, not as a learning environment;
- development of high-quality AR applications clearly requires the work of professional programmers.

This study has several limitations. The questionnaire was based on self-assessment. Therefore, the level of ICT competence and teacher readiness was not sufficiently objectively determined. Also, the degree of use of AR applications has not been measured in practice. In addition, the number of teachers was limited. As a consequence, it is likely that teachers with advanced digital competence participated in the experiment. There is a need for future research on the technical aspects of augmented reality technologies, in particular in developing a repository of training applications to support computer science education.

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Methodological aspects of using augmented reality for improvement of the health preserving competence of a Physical Education teacher

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Abstract. The article deals with the results of the research aimed at the improvement of methodology of use of augmented reality for the development of health preserving competence of a Physical Education teacher under conditions of post-graduate education. From the point of Umwelt phenomenology, augmented reality is characterized by correspondence to nature, its cognitive, metaphoric, diverse, interactive, anthropomorphic nature. The article analyzes the vectors of using augmented reality in the professional activity of a Physical Education teacher, particularly the one that is aimed at health preservation. The software that may be used with this purpose has been described. The attitude of Physical Education teachers to the use of the augmented reality for preserving their students' health and development of their motion skills, intellect and creativity was determined in the research. The results of the survey show that the majority of teachers positively react to the idea of using augmented reality in their professional activity. However, in some cases, not a fully formed understanding of this issue was observed. The ways of solving the stated problem could be the inclusion of augmented technologies' techniques into the process of post-graduate education, taking into consideration the anthropological, ethical, cultural contexts as well as teacher involvement in the stated process.

Keywords: health preserving competence, a Physical Education teacher, post-graduate education, augmented reality, Umwelt, pedagogy of health, methodology, digital technologies.

1 Introduction

The need to use augmented reality in education [29; 31; 34; 41; 43; 49; 57; 62; 63] and, first and foremost, in practices and technologies of Physical Education is caused by its "congruence" to the "human reality", particularly its correspondence to the peculiarities of a pupil's motor activity and the multi-dimensional, adaptable and diverse spectrum of tools that can be used within it. The use of augmented reality in the educational process correlated with the disclosure of the value of human existence and the anthropological-value reflection of Lebenswelt [17] of a person may form synergic, developing and intellectual effects, which are the manifestation of digital transformation of education and its shift to a new quality level. At the same time, the issue of using augmented reality in the professional work of a Physical Education teacher, namely, for health preservation, is an actively developed topic. We view the problem of development of a methodology for using augmented reality for the development of a health preserving competence of a Physical Education teacher in conditions of post-graduate education and on the basis of anthropological [3; 12; 23; 30], ontological and value paradigms, which includes the need to consider the phenomenology of a person, his/her multidimensionality and the peculiarities of this field of education (of physical culture and sport), creativity and potential of a personality.

Considering the introduction of the augmented reality in an educational process, the necessity of use of ontology-oriented comprehension of a person and his/her motion activity is actualized. In the semantic framework of ontological understanding of a person, he/she is represented as a multidimensional and polyontological creature. Experimental data received by N. Nosov and then used by him as the foundation for the development of the virtual psychology, prove the polyontological nature of a person, view the person as place for integration of many realities [44; 45]. Therefore, it is necessary to examine the augmented reality not only traditionally from the "instrumental and technological" point of view but also from ontological positions. In such a case, the augmented reality is considered as a relevant component of person's ontology.

Accordingly, the methodological perception of the possibilities of using augmented reality is carried out with the application of relevant from the point of biosemiotics Umwelt ("the surrounding world") concept [28; 56; 59]. This concept provides a holistically oriented reflection of a special world or a specific reality of a living organism. The stated reality (Germ. Umwelt), according to Jakob von Uexküll (his work "Umwelt und Innenwelt der Tiere" [59], 1909) is manifested through integration of the world of perception (Germ. Merkwelt) and the world of action (Germ. Wirkwelt) [59]. Thus, in the course of its existence, the body forms a "relevant zone", which is that very fragment of reality, which seems to be vitally significant for its perception and activity.

The application of Umwelt conception for the improvement of the use of the augmented reality is a methodologically determined way of ontologization of Homo Educandus (A Person who studies) and humanization of an educational process. Accordingly, the use of an Umwelt idea can extend methodological and technological possibilities of application of the augmented reality by the selection of the special "transitional reality" between a person's reality and the world. Therefore, we suggest to perfect the methodology of use of the augmented reality in professional activity of a Physical Education teacher in the ontology oriented direction, which considerably extends and anthropologizes traditional methodologies and technologies in particular.

In addition, in order to broaden the possibilities of implementation of the existing potentials of the motor and mental fields of a person, an integrated "external" reality is needed. In this respect, there occurs a need to integrate "corporal", "motor" and "intellectual" realities and "ontologies" (in the sense of reality) of health through the use of an external integrating factor (a "special" reality), which a priori must itself be intelligent. Such an "external reality" within the framework of methodological comprehension presents itself as Umwelt and as the augmented reality.

Accordingly, such an "external" reality must form an intellectualized, dialogic, activity based and intentional (in the sense of targeted) anthropo-technical medium, capable of self-development. A natural pre-condition of the indicated "corporal and intellectual" integration is the phenomenon of Umwelt, and an artificial one is the augmented reality. Nowadays, such a "new" and "integrating" reality may be formed using digital technologies [25; 26; 42; 48], namely, in the form of augmented reality. The example of the indicated "corporal and intellectual" integration is the use of the augmented reality for the development of emotional intellect of children with disorders of autism spectrum [7]. In the work of C.-H. Chen, I.-J. Lee, L.-Y. Lin, the augmented reality was used to teach to recognize mimic patterns [7]. Accordingly, in the indicated cases [7], while forming mimic characters there will be present integration of corporal, emotional, intellectual components and an "external" component as the augmented reality.

Thus, we determine the need to use augmented reality in the course of training a Physical Education teacher, particularly, for improving his health preserving competence [12], as a nature-corresponding way of a person's development, which correlates with a person's transcendent and polyontological essence. Augmented reality is a way of integrating the realities already existing in a person (mental, corporal, motor) as well as a way of their improvement. Thus, the application of augmented reality is an end-to-end anthropological project [1; 51], which corresponds to human nature and his/her motor being, and not a "local improvement". Accordingly, in this aspect, the concept of Umwelt can be applied.

Despite a considerable number of studies dedicated to the use of digital technologies and, first of all, of augmented reality in the educational physical culture practices and technologies, the problem of using augmented reality for the development of the health preserving competence of a Physical Education teacher in conditions of post-graduate education has not been sufficiently studied yet. Particularly, the methodological, pedagogical, anthropological, prognostic and psychological aspects of the stated problem haven't been thoroughly studied. In the methodology of use of the augmented reality, the presence of a "transitional zone" between a person and the world (Umwelt) is not sufficiently taken into account.

Taking into consideration the digital trend of education development and perceiving the practical demand for raising the effectiveness of pupils' health preservation during motor activity, as well as actualizing the issue of education professionalization, pedagogization, digitalization and technologization, the stated research is defined as relevant.

Purpose of the research: improving the methodology of use of the augmented reality for the development of a health preserving competence of a Physical Education teacher under conditions of post-graduate education.

2 Related works

As of today, augmented reality has become an effective digital learning technology based on the achievements in the field of artificial intelligence [15; 36; 52; 53; 58]; a way of "broadening" the living world (Germ. Lebenswelt, by Edmund Husserl – the world of everyday life, which is the basis of cognition) [17] of a person; a way of reflection and effective innovative methodology of actualizing emotional intelligence [7], intellect, storytelling activities [1], creativity [47; 61], 21st-century skills [50], interaction of parents with children [22] and potential of a personality.

The issue of using augmented reality in physical culture and sports has been studied by many researchers [2; 6; 11; 16; 21; 33; 35; 39; 46]. A. Casey and B. Jones used digital video technologies to raise the level of interest and motivation to motor activity in pupils of general secondary schools of Australia [6]. The authors note the efficiency of this technology in terms of improving coordination skills of the pupils and raising their learning interest [6].

P. Legrain, N. Gillet, C. Gernigon, M.-A. Lafreniere used ICT at Physical Education lessons in combination with the increase of the autonomy and independence of pupils proportionally to the decrease of the teacher's active interference [35]. Such approach increased the efficiency of forming motor and cognitive skills, raised independence and motivation to doing sports activities as well as actualized progress [35].

K.-F. Hsiao in Taiwan used augmented reality (AR) integrated with the educational process [16]. This included the use of the developed AR-Fitness system. At the same time, he actualized the development of knowledge in such fields as "cardiac-lung stamina", "muscle conditioning", "explosiveness", "flexibility" [16].

M. M. H. Alhamdi, S. B. Salih and M. A. A. Abd used digital technologies to increase the efficiency of forming motor skills in the deaf and dumb children [2]. The authors note the efficiency of the development of motor skills while using the stated approach included computer movement analysis [2]. Computer movement models can be represented as components of augmented reality.

In order to increase the efficiency of forming motor skills in pre-school children, E. E. Lauer, S. B. Martin and R. A. Zakrajsek created a virtual interactive study environment with the help of ASUS Xtion PRO [33]. According to the data given by researchers, the stated methodology is effective.

Using digital video for teaching 9-10-year-old children, J. O'Loughlin, D. Chróinín and D. O'Grady raised the motivation and self-esteem with regard to Physical Educational lessons as well as showed better results in mastering motor skills [46].

B. Melton, H. Bland, B. Harris, D. Kelly and K. Chandler successfully used mixed technologies to increase the efficiency of dance teaching as well as to raise the motivation and self-sufficiency [39].

Such authors as E. Enright, J. Robinson, A. Hogan, M. Stylianou, J. Hay, F. Smith and A. Ball analyze the need to use digital technologies in physical culture on the basis of democratic values and innovative, critical and praxeological methodological orientations [11].

While studying the use of augmented reality, we develop the methodological constructs based on the idea of unconditional value of intellect development, creativity and motor activity, which are being implemented due to physical culture. It is based on the fact that it helps the pupil to unveil his/her corporality as well as the mental sphere in the form of a special motor being, as well as through actualization of vitality, life-creativity and sense-creation. Thus, physical culture is a particular motor reality, which corresponds with human nature. Movement and motor being are interrelated with health, which is viewed as an authentic and anthropologically specific way of human existence.

Corporal and motion reality are also the basis of the psychic and mental fields of a person. According to L. S. Vygotski (the cultural-historical psychic concept), consciousness is the result of interiorization (in the sense of shifting to the center, into the psychic reality) of the "history" of a person's interaction with the environment [24; 60]. Motor activity occupies the central role in this interaction. At the same time, motor activity lies at the basis of the intellect, both during its formation in ontogenesis (individual development) and during a person's mental activity, as it is in fact a specific motor reality and existence of a human being.

From methodological positions, following the ontological approach, accordingly, we present health, motion and corporealness of a person as special realities. Therefore, they can be purposefully perfected by cooperation with the augmented reality. Meaningful in this aspect is sense-forming and intellectual dimensions of such cooperation. The use of the augmented reality in health preserving practices of physical culture is the way of opening of motion activity in the formats of intellectual existence.

For the anthropological-value perception of the phenomenon of an intellect as an anthropologically specific reality and ontology (being) it is important to understand that its beginnings and currently relative components lie in the body, corporality and motor activity. This is described by G. Lakoff in his classical work "Metaphors We Live By" [28]. In his embodied cognitive science, G. Lakoff [28] points out that the notion and metaphors, as system-organizing "elements" of the intellect are primarily formed as corporal phenomena. Currently, embodied cognitive science is developed on the basis of the idea about a close and interdependent connection between the mind, the body and the environment [56].

Schematically, the stated above ideas can be depicted as a sequence of a mutually determined and mutually dependent phenomena, namely: "body, motor activity and interaction with the environment – intellect – adaptation, creativity, development". Thus, a person may be viewed as a human being that consists of various ontologies (beings) and realities [44; 45]. And the "way" they are organized into a unity makes the very phenomenon of a person. The stated unity is first and foremost carried out "from within" as this is determined by human nature. According to C. Jung, such unity is perceived by a person as Self, which predominantly is perceived by a personality as the highest harmony of the "internal" God [7]. The idea of a polyontological character of a person is the basis of virtual psychology worked out by N. Nosov [44; 45]. Relevant in this aspect is the conception of Umwelt [28; 56; 59]. Umwelt is a special "perception and activity reality" of a living organism.

Thus, the reality is being "fragmented" and "channeled" into a countless number of "parallel" Umwelts "in" which certain biological species live and which they "carry around" with them. This means that the existing reality is multi-dimensional and multi-aspect due to the formation of specific individualized "perception-activity" worlds – Umwelts.

Thus, every biological species generates, masters, sees and somehow understands and interprets the specific and significant for him/her personally spectrum of phenomena, which together form Umwelts. According to E. Husserl, we comprehend being through perception of relevant phenomena [17], which together reflect the reality in one's consciousness. That's why, in the context relevant to our problematics, we may speak about the peculiarities of the living world (Germ. Lebenswelt) [17], which is formed through a person's unveiling, perceiving and using the significant for him/her phenomena. In comparison we should note that apart from Human, other biological species have quite a limited number of phenomena that form their worlds and are presented and "narrowly" specific. These are the worlds of perception, action, being, which primarily define the mode of existence. Quite strictly determined combinations of specific phenomena form the Umwelts of biological species. Thus, all the biological species except for humans are maximally adapted to "their" Umwelts.

Limitation in space and time of animals' Umwelt is pointed out by M. Stella and K. Kleisner [28, p. 69; 56, p. 39]. At the same time, when an animal is transferred to a different environment the stated adaptation possibilities drastically decrease and it is not always possible to for "new" Umwelts, even when resources are available. In essence, living organisms form, support and "carry around" a certain fragment of the reality, which is desired and to a considerable extent set for them. Thanks to the use of the Umwelt concept, subjectivity and personalized differences are actualized alongside with the significance of species peculiarities [28, pp. 68–70]. Every or person has their own Umwelt.

Analyzing the Umwelt concept, O. Knyazeva singles out some aspects that are significant for our methodology: active influence on the environment; feedback between the environment and the creature; selectivity of perception and action; sense making; existence of a dynamic boundary between a creature and the environment; interactive unity of the environment and the organism [28, p. 69].

3 Selection of methods and diagnostics

In the course of the research, the following system of methods and approaches was used: analysis, synthesis, statistical, empirical (survey, questionnaire); competence, health preserving [12], ontological, hermeneutical, axiological, phenomenological [17], epistemiological, transdisciplinary, systemic, holistic, biosemiotic [40], semiotic, humanistic, psychological [20; 24; 44; 60], anthropological [3; 12; 23; 30], cultural, innovative, futuristic, problematic, targeted.

We used the concepts of anthropologization [3; 12; 23; 30]; knowledge transfer; sustainable development, anthropological practices and "technologies of self" (M. Foucault) [13]; Umwelt (J. von Uexküll) [28; 56; 59]; living world (Germ. Lebenswelt) of E. Husserl [17]; of contact boundary developed in gestalt psychology; of sense making (C. Lorenz) [28]; autopoiesis (U. Maturana, F. Varela) [37]; of embodied mind (J. Lakoff) [32]; of cultural-historical theory of psychic development (L. S. Vygotski) [24; 60]; of C. Jung's Self (Germ. Selbst) [20]. We also used visions and methodological approaches developed in the system of embodied cognitive science [55], enactivism [27] and virtual psychology and virtual science [44; 45].

For the methodological perception, the following Ancient Greek concepts were used: "human nature" (Ancient Greek *φύσις του άνθρωπου*) [19, p. 15; 24; 32; 33; 55]; "harmony' or 'mixing" (Ancient Greek *κρασις*) [19, p. 15]; "self-perception" (the Delphian principle "Perceive yourself" – gnothi sautou) and "care of self" (epimelēsthai sautou) described by M. Foucault [13].

Proceeding from the methodological understanding of peculiarities of the augmented reality as well as Umwelt, we can point out that they are the phenomena that contribute to the formation of meanings, semantic contexts, values, patterns of action, images of health, and semantic images. Therefore, for the expansion of the education-oriented understanding of the augmented reality, we determine the attitude of teachers to the necessity of using the augmented reality for preserving health, development of creativity, intelligence, etc.

In order to determine the attitude of Physical Education teachers towards the idea of using augmented reality in the educational process with the purpose of preserving pupils' health and development of their motor skills, intellect and creativity, we developed a questionnaire that consisted of 6 questions. The respondents were asked to choose one of the three possible answers – "Yes", "No", "Cannot decide". The survey contained 6 questions:

1. Does the use of augmented reality facilitate the development of critical thinking and forecasting (anticipation) skills in pupils aimed at trauma prevention during lessons? ("Yes", "No", "Cannot decide")
2. Can the use of augmented reality facilitate the development of corporality, aesthetic and ethic orientation of a pupil as well as of the competence of self-health preservation? ("Yes", "No", "Cannot decide")
3. Can the use of augmented reality facilitate the formation of ergonomic lessons and the creation of a comfortable, safe and health preserving environment? ("Yes", "No", "Cannot decide")
4. Can the use of augmented reality facilitate the development of harmonious relations with the environment, eco-consciousness, implementation of the sustainable development concept and health preservation? ("Yes", "No", "Cannot decide")
5. Can the use of augmented reality facilitate the development of motor skills, creativity, existence and reflection in pupils? ("Yes", "No", "Cannot decide")

6. Can the use of augmented reality facilitate the development of digital and learning competences and intellect (motor intellect, in particular) in pupils? (“Yes”, “No”, “Cannot decide”)

4 Results and discussion

The methodological search was carried out based on the ideas and intentions of integrity, anthropologization [3; 12; 23; 30] and humanization. Thus, the peculiarities of using augmented reality with the aim of improving and implementing the health preserving competence of the Physical Education teacher in conditions of post-graduate education were studied using the anthropological and biosemiotics approaches [40].

Within the framework of the indicated approaches, as well as following the idea of integrity of an organism and the environment and their dynamic cooperation we actualize the question of the use of the conception of Umwelt [28; 56; 59] for the improvement of the methodology of use of the augmented reality for the development of health preserving competence of a physical culture teacher.

Clarifying the importance of the formative specificity of the Umwelt [28, p. 69] as a manifestation of life that is related to the semantic potential of augmented reality. Umwelt as well as augmented reality can thus be regarded as environments (or worlds) of forming meanings and ways of using them.

Concerning Umwelt, this is analyzed by the ethologist Conrad Lorenz [28, p. 69]. That is, through the mind-body, the living organism acquires meaning (living is sense making) [28, p. 69], which can be modified and enhanced or weakened by the use of augmented reality. The semantic sphere of man, in turn, is connected with life, existence, images and symbolic and symbolic reality. Therefore, the Umwelt is the living condition or “transient” fragment of reality that contextually integrates or correlates (according to the concept of autopoiesis by V. Maturana and F. Varela) [27; 37] life is represented as existence, as a given and semiotic-symbolic systems. On the other hand, semiotic systems are formed and exist precisely because of the specific formation of the Umwelt, which is a transition zone or a contact boundary between man and environment. These effects can to some extent be achieved through the use of augmented reality, which we consider as a component of the mind of the modern man or as a way to compensate for disturbed natural connections with the environment and by forming new ones. Similar understandings of the significance of boundary phenomena exist in Gestalt psychology in a system that is considered by the psyche as the contact line between a person and a significant problem. Therefore, one can say, metaphorically, “Whoever controls the Umwelt shapes meaning and influences life.” To a large extent, such an impact can be realized through the use of augmented reality.

Human Umwelts are qualitatively different from other living beings. Man, in the course of its development has created a special environment that at this stage of its existence and development becomes cognitive and cognitive-semantic. The Umwelt created by man actively interacts with it, forming communicative-semantic and cognitive contexts and essentially “communicates” with it. No wonder some creative people point out that the environment “speaks” to them and they take ideas and forces from it. As a specific feature of a person, we distinguish his ability to form "cognitively oriented" Umwelts. In this context it can be stated that by means of professionally made advertising it is possible to form a "digistic Umwelt" through which it is possible to "easily" gain 10 kg of body weight. Accordingly, through the use of physical culture and augmented reality, which will form the "Umwelt of movement", this process can be reversed.

Let us present the methodologically and technologically significant characteristics of the human mind: historicism; cognitive, that is, it is an environment in which data is partially processed and information and knowledge are contained; aesthetism (even the presence of anti-aesthetic tendencies is the antithesis of illuminating aesthetism); ethics (or anti-ethics); value character (in animals we can mostly talk about the hierarchy of needs and importance); dynamism; anthropomorphism; ergonomics; comfort; interpretability; speech characteristic; antitrusting (predictive) nature and predictability; ecology (nowadays); promoting sustainable development (at this stage of humanity's existence); harmony; educational; semiotic; digital (currently); health-saving; humorous (only human inherent humor); existential – as open, independent and self-sufficient being; multidimensionality; developmental and creative character; polyontological character; psychologically significant; technological and technical; characterization of relative autonomy. Our understanding of the human mind is close to the concept of the world of life (Germ. Lebenswelt) by E. Husserl [17]. That is, we do not reduce a person's mind to a perceptual-activity phenomenon, but understand it a little more broadly – based on the allocation of relatively autonomous other components or spheres. For example, training, technology, creativity and more. This understanding of the human mind is also based on an understanding of the as yet undiscovered potential of using augmented reality and digital technologies in general. Based on a methodologically and technologically oriented understanding of the phenomenology of the human mind, we interpret it as a significant multidimensional cognitive and meaningful human reality that has a degree of autonomy and significant contextual impact on humans. Based on the selected characteristics of the human mind, a questionnaire was developed for physical education teachers.

We consider it expedient to use purposefully or at least take into account the phenomenology of human mind when designing and implementing augmented reality technologies. That is, the construction of augmented reality can be carried out not only on the basis of effective target, needy, technological methodological installations, but also taking into account the "transition zone" between man and the world – mind. Digital technologies and approaches that take into account the phenomenology of Umwelt, we call Umwelt oriented. Accordingly, augmented reality can be shaped as mind-oriented. The peculiarity of such technologies will be primarily the use of non-direct influences, cognitive, metaphorical, contextual, spatial, temporal, variability, interactivity, anthropomorphism, individual orientation and other characteristics that reflect the specificity of a person and his mind. This approach is contextually existent and is still being implemented mostly intuitively. In order to maintain health and improve motor activity, the importance of this Umwelt oriented approach is relevant because movement and health are, in so far as they are, contextual values. Movement and health are completely shifted to the actual area of consciousness when a person has certain problems, risks and threats.

Augmented reality allows you to "delicately" create "mental health", "mental movement", "mental health and comfort" and more.

Thanks to the use of the augmented reality, we can create "tactfully" the "Umwelt of health", "Umwelt of motion", "Umwelt of safety and comfort", etc.

The indicated Umwelts are a special-purpose transformation or one of possible variants of a person's Umwelt. The purposeful Umwelt formation with desired qualities is a human specific that, first of all, can be exposed due to the use of the augmented reality.

Considering the "multichannel" of human perception, it can be noted that the actual component of "human Umwelts" that can be formed on the basis of augmented reality is their "ability" to synthesize different sensory modalities, namely, sound, visual, tactile, motor. We represent this as a "cognitive-environment synthesis" that facilitates the discovery of humans as beings of "cognitive-motor", intellectual, creative and polypotent. Similar synthesis occurs in associative areas of the cerebral cortex. Artists dreamed of such a synthesis, namely of union, music, light, visual images, movement, movements, odors, touches [14; 22, pp. 269–362]. This is partly embodied in contemporary art. Thus, augmented reality opens up new and special possibilities for a "new cognitive synthesis." For physical culture, the use of augmented reality, considered in relation to the preservation of health, opens up innovative perspectives, which are first and foremost related to the intellectualization of motor activity and to the ergonomic and natural disclosure of the potentials of man, in particular motor, physical, cognitive, creative.

The actual contemporary direction that gives the opportunity to consider augmented reality and Umwelt as an "active" "cognitive-activity" reality is the concept of autopoiesis by V. Maturana and F. Varela [28, pp. 70–72; 37]. Within the semantic sense of this concept, the phenomenon of life, including the interaction of the organism with the environment, is presented as an active autopoiesis and cognitive process. Also significant is the trend of enactivism [27], in which the mind-body problem [27; 28, p. 70]. The body and consciousness in this system of ideas are understood in a holistic way. Defining in this aspect are also the ideas of Embodied Cognitive Science [55]. In the system of this direction, cognitive is represented as a phenomenon that is formed by the interaction of consciousness, body and environment. The notion of cognition as a physical and environmental phenomenon is significant for the professional activity of a physical education teacher, because it works primarily with interdependent phenomena – movement, body, health, which exist in a particular reality and form it. The above ideas about Umwelt and the concepts of autopoiesis, enactivism and embodied cognitivism are considered as aspects that contribute to the introduction of augmented reality, defining the latest understanding of physical culture and sports as "body-cognitive-environmental" and "health-protective" only as a traditional development of strength, endurance, or other qualities. The key in these cognitively oriented interpretations of motor activity is the phenomenon of augmented reality as one of the "paths" of the autopoiesis of a person. Similar notions of bodily, motor, and mental perfection existed in the system of the Hellenistic tradition of the paidae (Greek

Παιδεία) [18; 19] and were realized through "taking care of themselves" [13] and "self-knowledge" [13]. Thus, through the use of augmented reality, we actualize the development of physical culture as a "body-cognitive" and health-saving anthropopractic and promote intellectual activity of motor activity.

Here are some avenues of using augmented reality for the purpose of developing health-saving and professional competences for physical education teachers:

1. To watch sports on video or visit the stadium. For example, overlaying content with real-time commentary or recording of a given sport or team player, in particular using face recognition technology and more (see fig. 1).

Fig. 1. Organizing specialized online training using SGM SPORTS [54].

2. View matches and training while recording. Here, it is possible to overlay video comments, discussions, graphics, graphic analysis on video; such as displaying trajectories, etc.
3. For training and sports, rehabilitation, inclusion. For example, analysis of data on individual stages of training, displaying the strengths and weaknesses of students in this process, overlay training videos, graphics, comments, realistic 3D simulations, organizing discussions in real time, evaluation of the training session, etc. (see fig. 2).
4. Development of training videos using augmented reality: commenting on individual stages of training, monitoring the functioning of individual body systems during appropriate physical activities, graphical analysis, discussions, displaying trajectories, etc.
5. Educational marketing. For example, advertising an educational institution, developing links to your own training courses and training sessions, site pages, programs, and links to other pages of academics, coaches, athletes, clubs, and more.
6. Techno sport. The combination of augmented reality and the physical movement of a player, such as competing with a virtual sport tool (this use is less traumatic than real competition).

Fig. 2. Organization of individual training using SGM SPORTS [4].

7. Simulation of sports competitions: conducting competitions and trainings, graphical analysis, discussions, help, comments, etc.

The use of augmented reality increases the motivation of physical culture teachers to master the complex of professional knowledge, promotes the humanization of the educational process, develops intellectual, emotional and volitional spheres, improves critical thinking, promotes professional reflection of practical experience. It is also aimed at the development of professional subjectivity, the discovery of sports talents, the improvement of sports equipment, the regulation of the volume and intensity of physical activity according to the state of health, etc. Considering all the advantages of this technology, it should be noted that it cannot completely replace the traditional technologies of organization of the educational process and will be the most effective in combination with them.

Consider software that implements augmented reality technologies that can be used in physical education. That software contributes to the formation of “human Umwelt”. The specificity of “human Umwelt” is the preservation of health, in particular, through physical activity. Opportunities for augmented reality make it possible to build a trajectory of learning according to individual requirements and needs, and immersion in the audiovisual space makes the theoretical learning experience interesting, engaging and motivating students.

SGM SPORTS by SGM Solutions & Global Media GmbH is designed to organize specialized online training [54] (see fig. 1, 2). The basic idea behind this product is learning to generate sports strategies through augmented reality experiences. One of the company’s products is a prototype ARVolley volleyball strategy that can be downloaded for free and used on Android and iOS platforms. The program demonstrates and explains the attack numbering system. With it, you can place a virtual interactive playground on the table. These tools are implemented using virtual and augmented environments .experience from brainshuttle™.experience [4]. Immersing students in the augmented reality environment of brainshuttle™.experience with realistic simulations, activates them in the learning process, exploring their own opportunities at an individual pace. Depending on the actions, students’ situations and outcomes change dynamically, supporting the student to actively engage and achieve learning outcomes. With realistic simulation, the student perceives and performs the task at any level. Playing situations of realistic simulations can teach students some maneuvers, understanding of complex games, which can also help prevent injury.

brainshuttle™.experience augmented reality environments are created using 3D video, 360 degree video, Combined 3D and 360 degree video, 3D animation, Virtual environments, Game environments, Augmented environments (3D video, 360 degree video, Combined 3D and 360 Degree Video, 3D Animation, Virtual Environments, Game Environments, Enhanced Environments) [4].

DribbleUp offers software based on Augmented Reality Basketball (Smart Basketball), Soccer (Smart Soccer Ball), Health Gymnastics with a Ball (Smart Medicine Ball) [8; 9; 10; 38] (see fig. 3, 4, 5): DribbleUp add-ons are designed for both phone and tablet. DribbleUp products provide the ability to work with a virtual trainer, track the accuracy of the exercises performed, train muscle memory, track workouts over time. DribbleUp Smart Ball allows you to combine different cardio-strength exercises.

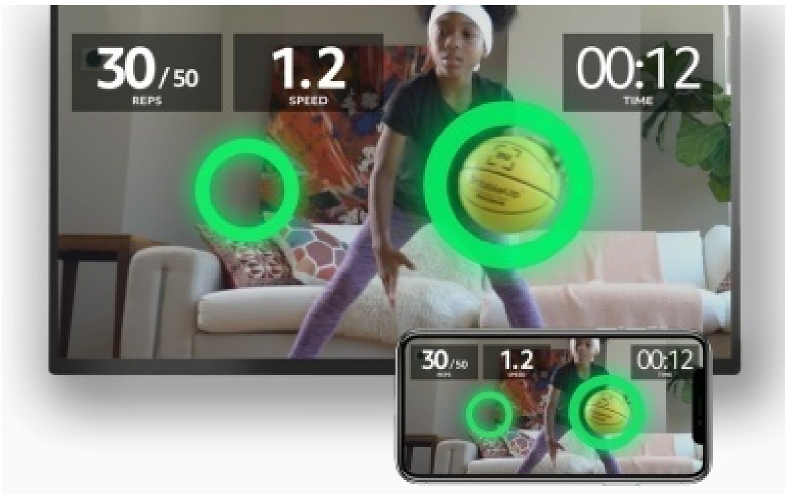


Fig. 3. DribbleUp: Smart Basketball [8].

For techno sports (a new HADO sport format that combines augmented reality with players' physical movement) from Japanese company Meleap Inc. developed hardware and software based on augmented reality [4] (see fig. 6.). To play the game, players must also wear a motion sensor and specially designed HMD to track virtual balls and other players. This integration of augmented reality into sports adds magical effects in a normal game, is health-friendly and prevents injury.

In order to determine the attitude of physical culture teachers to the use of augmented reality in the educational process, a survey was conducted by 36 Physical Education teachers. The research was conducted in 2017-2018 at Drohobych Ivan Franko Pedagogical University, Sumy Institute of Postgraduate Pedagogical Education, Mykolayiv Institute of Postgraduate Pedagogical Education. The results obtained are presented in fig. 7 and fig. 8.

Fig. 4. DribbleUp: Smart Soccer Ball [10].

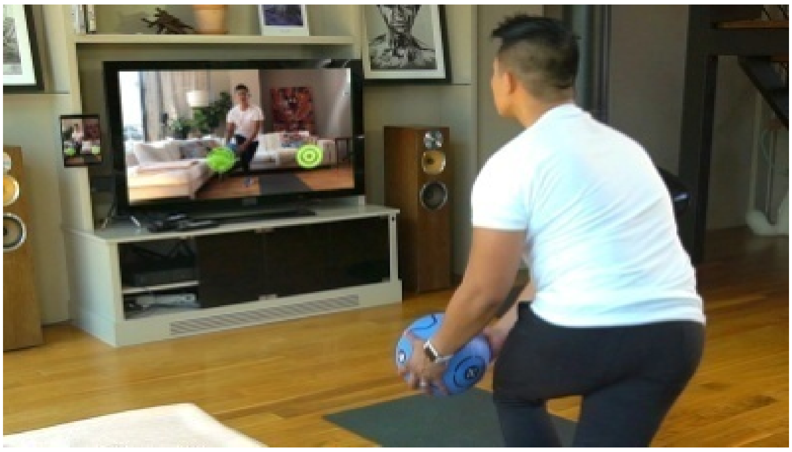


Fig. 5. DribbleUp: Smart Medicine Ball [9].

Having analyzed the results of the survey we can note that the majority of teachers (57%) have a positive attitude towards this issue, 18% of the teachers demonstrate negative perception of the idea and 25% were not able to provide a definite answer. Such response distribution within the survey may be caused by the fact that the teachers are not sufficiently informed about the potential possibilities, opened by the use of augmented reality in the educational process.

Fig. 6. HADO Game Using Means by Meleap Inc. [38].

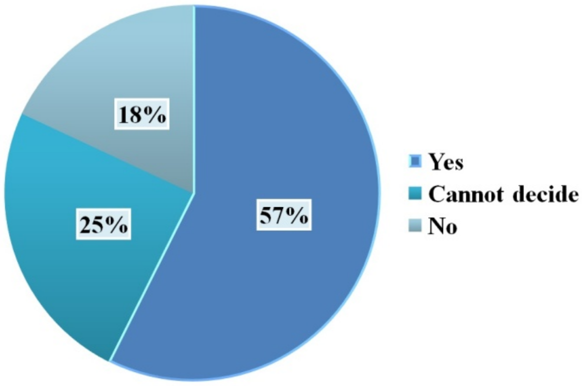
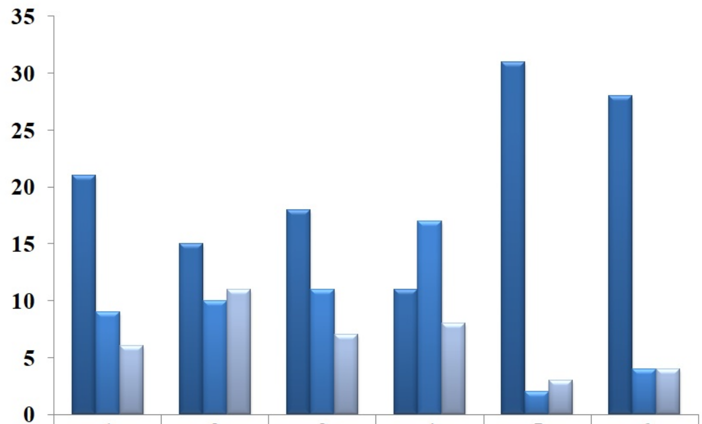


Fig. 7. Percentage distribution of responses of physical education teachers by the criterion of their attitude to the use of augmented reality in the educational process to preserve the health of students and develop their motor skills, intelligence and creativity.

The analysis of the structure of the answers, provided by Physical Education teachers in the questionnaires shows that so far, the teachers do not fully understand the possibilities of augmented reality in forming ethical attitudes of the health preserving environment, eco-consciousness, comfort. This means that Physical Education teachers do not fully understand the sense-forming, contextual and environmental influences of augmented reality.

The ways of solving the stated problem may include the inclusion of augmented reality technologies into the process of post-graduate education taking into consideration the anthropological, ethical, cultural contexts and using the competence based and personally-oriented paradigms; the involvement of Physical Education teachers to the development of educational software applications using augmented reality technologies in the role of consultants, coaches, experts etc.; improving the knowledge and skills of Physical Education teachers on concrete issues and phenomena related to health preservation; involvement of Physical Education teachers into the project work on introduction of the software that includes augmented reality.



	1	2	3	4	5	6
Yes	21	15	18	11	31	28
Cannot decide	9	10	11	17	2	4
No	6	11	7	8	3	4

Fig. 8. Visualization of the structure of physical education teachers ‘responses to the questionnaire aimed at determining attitudes toward the use of augmented reality in the educational process to preserve students’ health and develop their motor skills, intelligence and creativity (see questionnaire in “Selection of methods and diagnostics”).

5 Conclusions

The use of augmented reality is an effective innovative technology of development of a health preserving competence of a Physical Education teacher under conditions of post-graduate education. Improving the methodology of use of the augmented reality for the development of health preserving competence of a Physical Education teacher under conditions of post-graduate education was carried out on the basis of the anthropological paradigm and the concept of Umwelt. Umwelt represents a “perceptive-acting” world of a person. A person’s Umwelt has a sense-forming potential. Such features as correspondence to nature, indirect and contextual influences, cognitive, metaphoric, diverse, interactive, anthropomorphic, image-based and personalized nature as well as other characteristics, which take into consideration the anthropological and personalized peculiarities should be characteristic of Umwelt oriented technologies of augmented reality.

The relevant forms of augmented reality representation with the purpose of improving the health preserving competence of a Physical Education teacher include the combination of the content with real time or recorded comments, graphic images, graphic analysis; realistic 3-D simulations, assessment of the training session, etc. the important vectors of using augmented reality with this purpose is the development of study videos, techno sport, simulation and watching sports competitions and workout sessions, educational marketing etc. As for a Physical Education teacher the application of augmented reality in the educational process facilitates professionalization, technologization, axiologization and humanization of his/her professional activity, including its health preserving component, technologies into the educational process in order to conduct Physical Education lessons, workout sessions, sports competitions, rehabilitation activities etc.

Based on the analysis of the currently available areas of use of the augmented reality, as well as through its methodological understanding, we point to the significant innovative, educational potential of this digital technology. From a methodological point of view, the use of the augmented reality correlates with the application of the concept of Umwelt, contributes to the formation of meanings, semantic contexts, values, patterns of action, images, semantic images, motor images, and images of health. This determines possibilities for extended and innovative use of the augmented reality for the development of a health-preserving competence of a Physical Education teacher in particular.

A survey was conducted to reveal the understanding of a value potential of the augmented reality. The attitude of Physical Education teachers to the use of the augmented reality in an educational process to preserve their students' health and develop their motion skills, intellect and creativity was determined. Analysis of the results of the questionnaire was performed, the aim of which was to determine the attitude of Physical Education teachers to the use of the augmented reality in an educational process for preserving their students' health and development of their motion skills, intellect and creativity. It is determined that most teachers (57%) treat positively this problem, 18 % – negatively and 25% were not sure about this question. We can explain such a division of answers by not sufficient awareness of Physical Education teachers of an educational potential of the augmented reality.

The ways of effective introduction of augmented reality in health preserving activity of a Physical Education teacher are more active bringing specialists to the development of software additions of the augmented reality as well as its introduction into an educational process. Important in this aspect is the use of the anthropology oriented approaches that assist humanization of an educational process and technological adaptation of the augmented reality to the nature of a person.

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The use of AR elements in the study of foreign languages at the university

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Abstract. The article deals with the analysis of the impact of the using AR technology in the study of a foreign language by university students. It is stated out that AR technology can be a good tool for learning a foreign language. The use of elements of AR in the course of studying a foreign language, in particular in the form of virtual excursions, is proposed. Advantages of using AR technology in the study of the German language are identified, namely: the possibility of involvement of different channels of information perception, the integrity of the representation of the studied object, the faster and better memorization of new vocabulary, the development of communicative foreign language skills. The ease and accessibility of using QR codes to obtain information about the object of study from open Internet sources is shown. The results of a survey of students after virtual tours are presented. A reorientation of methodological support for the study of a foreign language at universities is proposed. Attention is drawn to the use of AR elements in order to support students with different learning styles (audio, visual, kinesthetic).

Keywords: augmented reality, foreign language, QR code, virtual tour, communicative competence.

1 Introduction

1.1 The problem statement

One of the main tasks of educational institutions at the present stage is the search for new educational technologies that can help increase the efficiency of information assimilation, acquisition of professional knowledge, development of abstract thinking, the search for innovative solutions, etc. It should cause qualitative changes in the implementation of the competency-based approach to the organization of the educational process [14]. Undoubtedly, such educational technologies should be based on the use of information technologies, since their potential capabilities are inexhaustible in the processes of cognition of the surrounding world and which today can fundamentally change the traditional approaches to the presentation of learning objects, the ways of their study and research, the mapping of connections in real and virtual dimensions. One aspect of the combination of virtual and real is augmented reality (AR). Using AR technology allows a person to quickly find and receive information about real objects, which can be represented in a symbolic, sound, graphic or animated form.

In production, AR fundamentally changes the processes of designing and manufacturing technologically complex products, while increasing labor productivity and reducing errors. A special effect, as already shown by the practice of some large companies, is achieved by training personnel or improving their qualifications. In this case, first, timesaving is achieved because employees learn directly during work. In addition, the hint system is more understandable and accessible, since it can provide not only the provision of explanatory information, but even simulate the finished product based on its individual elements. Using such technologies in the professional training of specialists in higher education institutions, we can apply the latest forms of methodological support of the educational process, which will directly accompany the process of cognition and research.

The purpose of the article is to analyze the impact of the application of AR technology in the study of a foreign language by university students (using the German language as an example), to determine the advantages and possible difficulties of using this technology to develop students' foreign language communication skills.

To achieve this goal, a number of methods were used. The analysis of scientific and methodological sources showed the relevance of the issue selected for the study. Based on the comparative analysis method, the advantages of using augmented reality tools in the study of a foreign language were determined. The observation method during the execution of the task of preparing a virtual tour made it possible to see the difficulties encountered by students. The questionnaire method provided the basis for determining the attitude of students to the implementation of augmented reality elements in the study of a foreign language. The generalization method was used for a concise presentation of the research results.

1.2 Literature review

The technology of AR is not only increasingly used in various industries and fields of science, but attempts have already been made to apply it in the educational process. Features of using AR technology augmented in a higher education institutions are presented by Ukrainian researchers Albert A. Azaryan [24], Anna V. Iatsyshyn [7], Tetiana H. Kramarenko [10], Olena O. Lavrentieva [11], Yevhenii O. Modlo [17], Vladimir N. Morkun [15], Pavlo P. Nechypurenko [16], Vladimir N. Soloviev [18], Andrii M. Striuk [21], Elena V. Vihrova [25], Yuliia V. Yechkalo [9] and others. The use of augmented reality technology is quite common in foreign universities, and is reflected in a number of publications by scientists. In particular, according to Omer Sami Kaya and Huseyin Bicen [8], AR applications can be used in almost any educational environment, and their use in the educational process increases the level of students' knowledge.

According to Matt Bower, Cathie Howe, Nerida McCredie, Austin Robinson and David Grover [4], AR can cause a profound transformation of modern education. Overlay multimedia on the real world to see via web devices such as phones and tablet devices, means that information can be made available to students at any time and in any place. Scientists believe that this can also reduce students' cognitive overload.

Japanese researchers Marc Ericson C. Santos, Angie Chen, Takafumi Taketomi, Goshiro Yamamoto, Jun Miyazaki and Hirokazu Kato [19] identified the benefits of AR technology, which included real annotation, contextual visualization, and haptic visualization. Scientists substantiate these advantages with several latest theories – multimedia learning, experimental learning and the theory of animation visualization.

In the context of our study, the developments of scientists and practical teachers on the use of AR in the study of foreign languages are of particular interest. In particular, Robert Godwin-Jones [6] focuses on the links between AR and modern theories of foreign language learning, which emphasize localized, contextual learning and semantic connections with the real world. The researcher considers this possibility using mobile games created using the ARIS platform (AR and Interactive Storytelling), a free open source game editor of the University of Wisconsin. From his point of view, there are various ways for teachers to use the AR, because it is advisable to study the language in connection with expanded digital spaces.

Pei-Hsun Emma Liu and Ming-Kuan Tsai [12] focused on building written writing skills in English at Taiwan universities using AR through the use of multimedia documents (such as photographs and videos) in the process of learning English with computer support to improve students' language skills, which are necessary for their written assignments (writing an essay).

Murat Akçayir and Gökçe Akçayir investigated the students' attitude to their use of AR applications in learning English, in particular, for learning new vocabulary. According to the results of the study, they found that the technology saves time by simplifying the search for a new word. In addition, AR programs help students remember words. The problem that students encountered during the study, the authors indicated the recognition of the QR code. According to students, the small screens of mobile phones make it difficult to use them in teaching and learning a language [1].

Considering the search by scientists for ways to intensify the study of foreign languages and the insufficient development of this problem in terms of the use of AR technology in general and in the study of foreign languages, in addition to English, where some attempts have already been made, the problem of using AR technology in the process of learning foreign languages is relevant and requires a separate study. In addition, as the analysis of the above works shows, the application of AR technology in the study of English is mainly concentrated on the study of vocabulary, which significantly limits the use of this technology, because its potential is much greater.

2 Result and discussion

2.1 The use of elements of augmented reality for the formation of communicative competence through a virtual tour

The process of gaining knowledge usually requires the use of different methods and tools for working with information, depending on the technological possibilities and basic didactic and pedagogical models. The development of cognitive didactics has led to the emergence of a new concept of learning, based on taking into account the way people process information. At the same time, the main attention is paid to such cognitive structural and process components of learning as thinking, perception and problem solving. In the process of training aimed at obtaining new knowledge, cognitive structures should change taking into account motivational and affective factors.

New technologies, which are becoming more accessible today, contain new didactic potential regarding the possibilities of working with information in the process of studying certain topics. In particular, the study of a foreign language is impossible without the inclusion in the educational material of linguistic and geographical information related to the country of the language being studied, its traditions, the specific historical or cultural influence of the representatives of this country and the reflection of all these aspects in the students' native country or city. Since it is not always possible to carry out a real excursion to a specific region or to a particular attraction, and sometimes this is impractical due to lack of time, there is the possibility of a virtual excursion that can thematically present the contents of the excursion regardless of time, logistic and human resources. The essence of modern cognitive excursion didactics is the orientation to independent actions, which accelerates the process of acquiring knowledge. An addition, due to its specificity, the excursion has a positive motivating effect [20]. This can increase motivation to learn a foreign language, which ultimately leads to a higher efficiency of learning it.

Based on the above considerations, we chose to create a virtual tour for students learning German, concentrating on the topic "Traces of German architects in the history of Kyiv" [3]. It is worth noting that, since Kyiv is an attractive city for German-speaking tourists, several virtual tours in German have already been developed. In particular, this is the Reisen Kiew project of the Kiewer Stadtführer, which covers the most famous historical monuments of the Ukrainian capital. However, we invited students to consider the outstanding sightseeing objects of the city from a different angle, namely, as indicated in the topic – in terms of the contribution of German architects to their design and construction.

At the initial stage, the selection of objects for a virtual tour was carried out. For this purpose, a number of materials were analyzed regarding historical objects in the territory of the city of Kyiv. The following architectural monuments were selected:

1. St. Volodymyr's Cathedral. The construction of the cathedral began in 1862 and lasted 40 years. Its construction involved several architects and painters. In 1853-1859, the prominent architect of German origin, Ivan Strom, designed the St. Volodymyr's Cathedral; architects P. Sparro, A. Beretti and V. Nikolaev amended

the design. Later, German engineer Berengardt was involved in solving technical problems.

2. St. Sophia's Cathedral. The cathedral, built in 1037, was destroyed several times. In 1736-1740, the Ukrainian architect of North German origin, Johann Gottfried Schedel reconstructed the main bell tower. He also built a stone wall around the St. Sophia's Monastery, very successfully combining Western style elements with elements of the Cossack Baroque and folk motifs.
3. Kyiv Pechersk Lavra. Until 1745, the architect and engineer Johann Gottfried Schedel worked on the construction of the bell tower of the Kyiv Pechersk Lavra, which became one of the best bell towers in Eastern Europe of the 18th century. Schedel developed a project in a transitional style from baroque to classicism. The bell tower of the Assumption Cathedral was built according to his design in the form of an octagonal four-tier tower with a height of 96.5 meters.
4. St. Andrew's Church. The foundations of St. Andrew's Church were built according to the design of I.G. Schedel; however, the design of the temple itself, submitted by him, was not approved. Carved details of the iconostasis, according to sketches and drawings by F.-B. Rastrelli, created by the master (J. Domash, A. Karlovsky, M. Manturov, D. Ustars, H. Oreidah, J. Zunfer), among which there were several Germans. German master Johann Friedrich Grot led installation work.
5. National Opera of Ukraine. After the old theater building burned down in 1896, an international architectural competition for the design of a new opera house was announced. More than twenty well-known architects from different countries – Italy, Germany, Russia and France – attended the competition, and the winner was the project of the architect of German-Baltic origin Victor Schröter, a representative of the rational direction of eclecticism in architecture. The new city theater was built from 1898 to 1901 in the style of rationalism, baroque and neo-Romanesque style.
6. Klov Palace. The architects J. G. Schedel and P. I. Neyelov built Klov Palace in 1756. The German painter and jeweler Benedict Friedrich performed a number of works, in particular, the painting of the ceiling in the large hall of the Klov Palace. The German garden master Johann Blech worked on the Klovsky garden.
7. Kyiv Polytechnic Institute. Famous architects took part in the competition for construction projects at the Polytechnic Institute, including Germans and Austrians, in particular: Benoit, Gauguin, Kitner, Kobelev, Pomerantsev, Tsender and Schröter. The jury recognized the best project of Professor I. S. Kitner, under the motto "Prestissimo" ("Very Fast"). The construction of six university buildings in the Romanesque style began on August 30, 1898 and was completed in 1901.

After determining the content of the future virtual tour, that is, the selection of the outstanding architectural structures of Kyiv associated with the work of German architects, engineers and decoration painters, information resources were identified that students can use to prepare and conduct a virtual tour. Providing students with assistance in information resources was determined, on the one hand, by the desire to reduce the time for them to complete the task, since local history aspects are only part of the German language classes, and, on the other hand, to limit the amount of information for processing by directing it to certain subtopics. Interactivity, a variety of materials and multimedia play an important role in creating a virtual tour. Another important aspect was also the understanding that when integrating information into a virtual tour, we should respect copyrights, that is, use only those sources that are publicly available or those for which a permit is granted.

First, we suggested that students include the use of a digital map of Kiev in the structure of a virtual tour, since the maps provide an understanding of the integrity of the territory with objects located on it and possible connections between them. They form a sense of scale and improve spatial orientation. Using digital maps, students can easily create virtual sightseeing tours, combining sightseeing objects with routes according to certain signs: the chosen topic, the chronological period, the place of a historical event, the sequence of location, the logic of movement. In our study, we used the Google Maps application as a tool for creating a virtual tour map. One of the advantages of this tool is the ability to clear the position of the excursion object on the map using built-in search tools based on addresses. Colored markers were superimposed on automatically identified points on a digital map to conveniently identify each virtual tour object. At the location of the excursion objects, we applied color marking for convenient use (fig. 1).

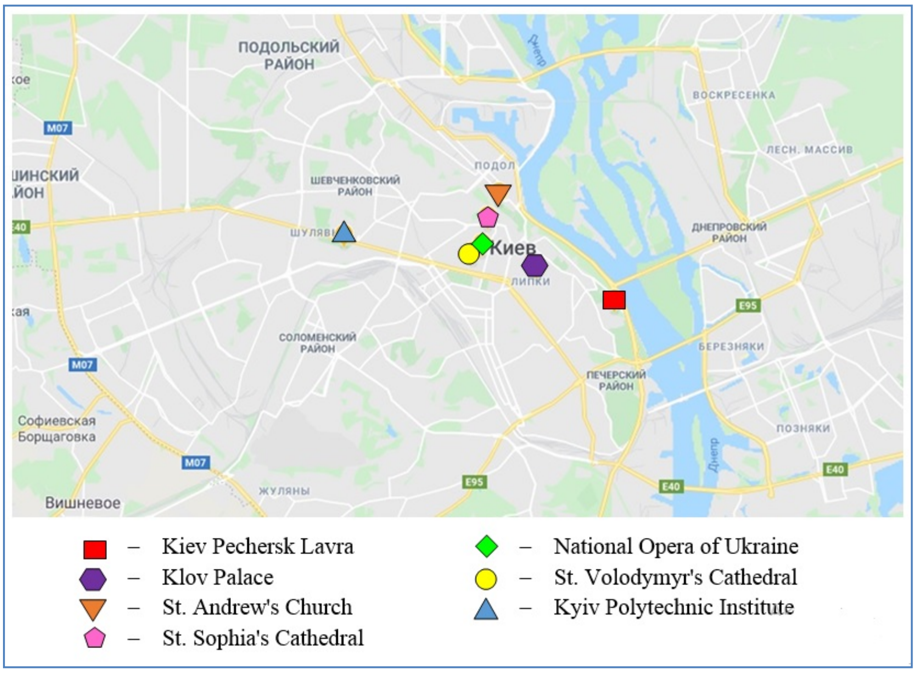

Fig. 1. Digital map of Kyiv with printed objects proposed for a virtual tour (Google resource).

The main task of students was to develop their own excursions based on the use of the proposed map. At the same time, each group selects one of the characteristics for building the route. As already noted, the virtual tour was to maximize the achievement of the main goal, in particular, the deepening of the study of the German language by acquaintance with architectural monuments built with the participation of German architects. In this case, the informative part about the objects of the virtual excursion had to combine text, photo and video information into a single, complementary information case [2; 22; 23], formed using AR technologies. Guided by these conditions, access to the necessary information on mapped architectural monuments should be provided throughout the tour. One of the ways to obtain information, quickly and conveniently, in various forms is the use of modern mobile devices that are capable of reproducing multimedia information concentrated on various web pages. An important issue remains the search for the right information and quick access.

We asked students to solve this problem by creating a system of QR codes that provide information support for a virtual tour, providing quick access to information about a particular object of the tour in different forms. It is known that a QR code can be generated for textual information, a URL, an e-mail, a phone number, etc. They can be easily and stably scanned by special scanners and provides quick access to encoded information.

At the initial stage, we conducted a training for students to develop the skills of generating QR codes for these types of information using freely available systems. After that, students processed open Internet resources with text, photo and video information about the objects of the excursion, selected the most successful of them, and then, using QR-code generators, formed the corresponding set of codes. We show an example of a set of QR codes for information about one of such excursion objects, the bell tower of the Kyiv Pechersk Lavra (fig. 2).

a b c

Fig. 2. A set of QR codes with text (a), graphic (b) and video (c) about the bell tower of the Kyiv Pechersk Lavra.

The main condition for the preparation of textual information was that it should be in German. One of the sources that students used for this purpose was the open electronic encyclopedia Wikipedia (fig. 3). This approach had a double effect, since students, on the one hand, processed German sources in the process of searching and selecting the necessary information, and on the other hand, created the opportunity to receive extended information in German about objects during the virtual tour for her “visitors”, which were students from other groups.

However, for many people, information in the form of a graphic image is more informative than text. In particular, many facts can be presented more fully and clearly in the photograph than in words. Therefore, in a virtual tour the use of images is especially important. In order for the image to be used in a virtual tour, they must be presented in digital form. The range of such images can be very diverse and range from simple photographs to interactive maps, managed panoramic images, 3D images and the like. Image types such as satellite images are also well suited for inclusion in virtual tours. The use of mobile devices in the process of conducting virtual excursions with access to images about the object has significant advantages compared to providing these images in print, primarily due to the possibility of increasing images, changing their brightness and contrast, making even small details visible. When preparing virtual excursions, students sought to provide access through a QR code not to individual images about the object, but to a collection of photographs that would allow them to get the most out of a particular architectural landmark (fig. 4). For this purpose, students used the resources of Google Images, Wikiway and the like.

Fig. 3. A fragment of a web page with textual information about the bell tower of the Kyiv Pechersk Lavra, access is generated by a QR code.

The advantages of video resources are that the presentation of information on the corresponding excursion space is almost realistic and relatively uncomplicated. Like photographs, especially panoramic photographs, films and videos very closely convey the atmosphere of real visits to places of excursion objects. In addition, in the case of using video, there is not only visual perception, but also perception of information by ear.

On this basis, when designing virtual excursions, students integrated thematic films and videos by linking to video portals such as You Tube and Google Video. We show an example of a link to the corresponding video fragment encoded by a QR code (fig. 5). Topically relevant videos can be quickly found using targeted keyword searches. As with photographs, we also need to respect copyrights regarding videos and films.

It is worth noting that the communication of the group members during the preparation of the virtual tour also contributed to the formation of teamwork skills among students and provided them with the opportunity to develop communication skills in foreign languages. In addition, working together on one topic and intending to achieve a common goal, students learned from each other to build sentences of different types with the correct word order, learned conversational vocabulary options, trained pronunciation of individual words and phrases.

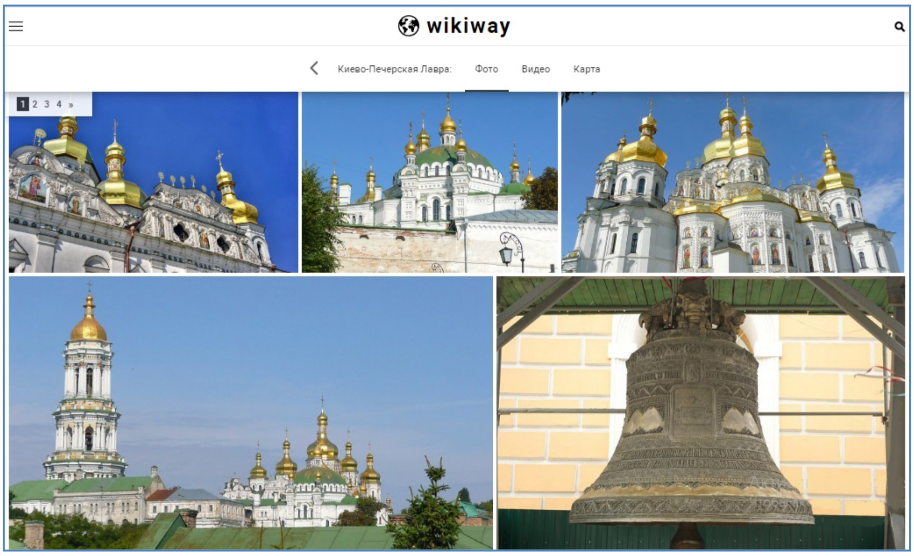

Fig. 4. A fragment of a web page with graphic information about the bell tower of the Kyiv Pechersk Lavra, access is generated by a QR code.

2.2 Augmented reality as a modern educational solution for studying foreign languages

Upon completion of the development of virtual tours of each group, students who did not take part in their preparation tested them. After passing these excursions, a questionnaire was proposed, which was aimed at assessing the effectiveness of a virtual excursion with elements of AR in studying the German language. This questionnaire contained questions grouped into four blocks: motivational, informative, linguistic and technological. 39 people attended the survey. The results of the answers to the questionnaire are shown in table 1.

The results of the survey indicate that the use of virtual excursions with elements of AR aroused interest among students, which manifested itself to different degrees and in different aspects when studying the German language. In particular, this approach has most positively affected the substantive aspect of this process. A rather high percentage of students (76.9%) noted that the elements of AR provided them with extended information about the excursion objects presented.

It is gratifying to note that the level of positive answers in the technological unit was also quite high (58.1%), which indicates students' readiness for new forms of organizing the study of a foreign language. However, some aspects of this process caused quite serious technological difficulties. In particular, 61.5% of students were not able to use fully the capabilities of the proposed elements of AR due to insufficient technical characteristics and an inappropriate software set for their own smartphones.

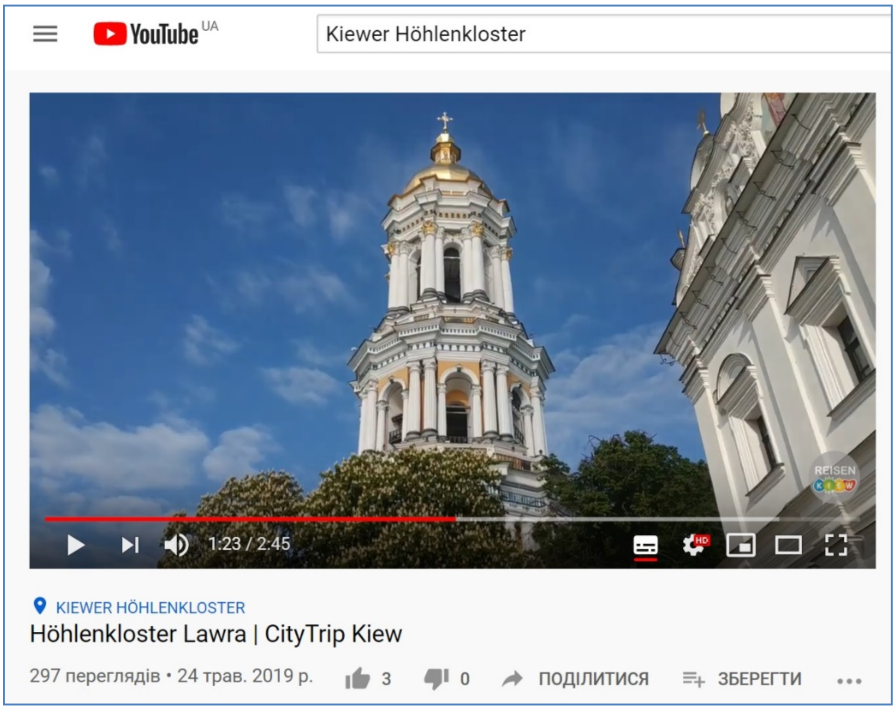

Fig. 5. A fragment of a web page with video information about the bell tower of the Kyiv Pechersk Lavra, access is generated by a QR code (Reisen Kiew).

An undoubtedly positive result of using virtual tours is the desire expressed by 79.5% of students to learn German, including in this way. Therefore, it is advisable for teachers to use the influence on the motivation to learn a foreign language, which is created using AR elements in the educational process.

Another confirmation of the advisability of using elements of AR in the study of a foreign language is the low level of positive answers to the questions of the linguistic block of the questionnaire. This indicates that the general level of students' linguistic knowledge is quite low and therefore needs to be improved, including through the search for new approaches and forms of learning a foreign language.

Thus, the use of AR technology contains great potential for the formation of a holistic, realistic view of objects outside the classroom. Owing to the student's independent actions and his emotional impression, when perceiving the educational object, an active approach of the educational content to the student occurs, which leads to better assimilation and longer memorization of knowledge.

Improving the effectiveness of training and longer memorization of the studied content is achieved through higher motivation for learning, active, and direct interaction with a real educational object based on AR technology. Since there are different types of students depending on the channel of perception of information (audial, visual, kinesthetic, mixed types, etc.) [5; 13], thanks to the holistic representation of objects based on AR technology, a higher level of assimilation of educational information and the formation of multimodal representations can be achieved.

Table 1. Results of answers to questionnaire questions.

Question	Response rate	
	Yes	No
Motivational block	**66.7**	**33.3**
Did the virtual tour contribute to the desire to learn German?	79.5	20.5
Are you ready to continue learning the language this way?	66.7	33.3
Have you been encouraged by the existing elements of AR to depth study of information in German about the excursion objects presented?	53.8	46.2
Content block	**77.8**	**22.2**
Have elements of AR provided you with enhanced information about the excursion objects presented?	76.9	23.1
Did German videos provide understanding of the information about the object of the excursion?	74.4	25.6
Were the text materials sufficient to obtain information on the topic of the tour?	82.1	17.9
Linguistic block	**53.8**	**46.2**
Did the information presented in the form of elements of AR make it easier for you to understand excursion materials in German?	61.5	38.5
Did elements of AR help to understand the meaning of new words in context?	56.4	43.6
Have elements of augmented reality contributed to better memorization of terms?	43.6	56.4
Technological block	**58.1**	**41.9**
Were there new ways for you to obtain additional information using QR codes?	71.8	28.2
Have you possessed sufficient skills in using smartphones to receive information presented as elements of AR?	64.1	35.9
Did the specifications and software set of smartphones make it possible to utilize fully the capabilities of the proposed elements of AR?	38.5	61.5

The use of AR technology requires appropriate methodological didactic reorientation, which will create the opportunity for students to independently organize research, collect, evaluate, process and present information, apply complex hypertext structures, develop network thinking, work within flexible, group, project-oriented forms of training.

3 Conclusions

In the course of the study, a number of advantages of using AR technology in the study of the German language were identified. In our opinion, such advantages can be used in the process of learning other foreign languages, in particular:

- The technology of AR allows to achieve a higher level of assimilation of educational material, since various channels of perceiving information are involved, because it is important for studying a foreign language what type of perception of information the student belongs to, whether he is an audial, visual, kinesthetic, and the like.
- Due to the integrity of the representation of the studied object, the student can get a more complete picture of it, and then learn, for example, a larger amount of new lexical material, since memorizing new words, especially terminology, takes place faster and remains in memory longer when new words are not used in isolation, but in context.
- Based on the application of AR technology, students can familiarize themselves with objects, unique or inaccessible due to spatial remoteness (for example, located in another country). It helps them to understand the essence or purpose of these objects and to remember the vocabulary associated with them, which would be much more difficult to use other information sources.
- Faster memorization of new vocabulary is also facilitated by the parallel presentation of information case together with selected objects for study, which allows students to quickly receive extended information using AR technologies.
- The use of AR technology, in particular in the form of a virtual tour, which involves working in a group, allows students to develop communicative foreign language skills.
- AR technology can be a good tool for learning a foreign language, because it allows the student to learn at his own pace. The assimilation of new knowledge and skills takes place based on previous knowledge of the language, the level of which, as shown by pedagogical practice, is very different even within the same academic group.

The main problem of using AR technology when learning a foreign language by organizing virtual tours, in our study, as in other cases of using digital information, is the dependence on the technical infrastructure and software. Since each student used his own smartphone with different technical characteristics and his own software set, sometimes this led to problems with receiving and reproducing information in accordance with the used technology. Most of these problems were related to ensuring stable access to the Internet, improper operation of QR scanners and the lack of some software installation skills.

In order to understand better the transfer of knowledge through virtual and AR and to be able to develop appropriate methods for using these technologies, further research is needed. In particular, it is advisable to compare augmented and virtual reality technologies with traditional teaching methods and other latest information processing tools, as well as study and compare various methods that offer augmented and virtual reality.

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Methodology of using mobile apps with augmented reality in students' vocational preparation process for transport industry

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Abstract. In the paper the current state and trends of use AR technologies in transport industry and in a future specialists' vocational training process have been reviewed and analyzed. The essence and content of the AR technologies relevant to transport industry have been clarified. The main directions of the AR introduction for the various spheres of transport industry including design and tuning, mechanical and automotive engineering, marketing and advertising, maintenance and operation, diagnostics and repair of cars have been determined. The AR mobile apps market and the features of the mobile apps with AR have been outlined. The pedagogical terms of effective organizing the students' cognitive activity for transport industry via AR technologies have been determined and researched, namely: to provide each student with the position of an active actor of study and cognitive activity, to switch the study information in a mode of the project activity, the educational content professionalization and to teach students to use the modern ICT purposefully, to manage students' cognitive process by means of ICT. The methodology of using mobile apps with AR in students' vocational preparation process for transport industry has been presented. It covers the system of educational tasks, updated content of lectures, practical and laboratory classes for specialized disciplines.

Keywords: vocational training, ICT in transport industry, students of transport area of expertise, mobile learning, AR technologies.

1 Introduction

Today is the era of computer-rich life. Thanks to developments in IT industry, materials in science and cybernetics, the fields of modern manufacturing, business, medicine, advertising, design, engineering and science are widely deploying augmented (AR) technologies and virtual reality (VR). With the development of smart technology, there are many mobile apps with AR and VR that are unfortunately mostly used for entertainment. The flagships of the transport industry and world-renowned manufacturers implement the benefits AR technology as tools and advertising to improve and enhance the design and tuning, engineering and automotive, marketing and advertising, vehicles maintenance, automotive repair and operation. The scientific and technical laboratories of BMW Group, Bosch, Caterpillar, Genesis, Hyundai, Porsche, Volkswagen, Volvo Group and others focus considerable attention to the training of staff and clients to use modern ICT in the operation and repair of vehicles, as well as the arrangement of transportations. This fact, in turn, highlights the problem of updating the content of future specialists' vocational training for transport industry.

Meanwhile, in the practice of vocational training there are some contradictions. One is between rapid development of computer focused pedagogical and industrial technologies and low efficiency of their use in the practice of students' vocational training for transport industry. Yet another is between personal orientation of the vocational training process and insufficient working up of methodological supply for the shaping of the future specialists’ professional competencies via VR and AR technologies.

The purpose of the paper is to review and analyze the current state and prospects of using AR technologies in the transport branch, as well as presentation of the methodology of usage the mobile apps with AR during the students' vocational training process for transport industry.

2 Materials and methods

Today, the training of specialists for transport industry is considered as one of the priorities of national education. However, as Valentyna V. Kochyna points out, one of the most significant problems in the professional education in the transport area of expertise is the predominance of theoretical learning. Courses and disciplines that are offered to students are not always based on up-to-date information and do not realize the necessary types and methods of professional activity [20]. As a result, the students do not have a clear idea of the future profession and the requirements that are made in the transport field in practice. The lack of hands-on training eventually leads to the fact that a sufficiently successful student is unable to carry out professional functions and withstand high competition in the labor market.

Ihor O. Arkhypov [23], Victor V. Aulin [4], Nataliia O. Briukhanova [7], Roman M. Horbatiuk [15], Igor E. Kankovskii [18], Olena E. Kovalenko [21], Yuri M. Kozlovskii [22], Olexander P. Krupskyi [14], Olexander I. Kuchma [23], Olena O. Lavrentieva [29], Olexiy V. Pavlenko [27], Aleksandr D. Uchitel [11], Denys O. Velykodnyi [5] and others emphasize in their works the need to create terms for mastering by students all types of professional activity (that means automotive design, operational, repair, logistics, organizational and management etc.) including the implementation of modern VR and AR technologies. Researchers point out the requirement to use special software, to create on its basis complete environments to shape importance for students' professional competences in transport area of expertise [18; 22].

To create a fundamentally new vocational training methodology with AR technologies we have explained the significant experience and real achievements of the world's automotive brands – BMW Group [6], Bosch [8], Caterpillar [34], Genesis [16], Hyundai [17], and Volvo Group [37]. It has been also taken into account the considerable technical and information supply in this context, provided by the scientific and technical centers of Apple [1], Google [13], Microsoft and others [25]. Some aspects and technologies which are widely covered in the publications by scientists of Sumy State University [39], Kryvyi Rih State Pedagogical University [32], Kryvyi Rih National University [19], company HQed [3], as well as Chris Bruce [9], Masahiro Hara [12], John Lyon [24], Yevgen Paschenko [26], Serhiy O. Semerikov [31] and others have been considered. However, all learning innovations will confront with opposition from the teaching staff until the external stimulating influences and the lecturers' own needs for educational services will be in consensus [14].

The study of existing experience and the review of online sources have shown increasing introduction e-learning and mobile technologies into the educational process of future specialists' vocational training for transport industry. It should be noting the pedagogical effectiveness of mobile apps with AR is currently underestimated [25]. However, nowadays, with the growing development of the smartphone technical base, free or shareware educational, information and advertising software products for transport branch are widely distributed by means of Google services [13].

Further, the essence and content of AR technologies that are actual to the transport industry, will be revealed; the directions of their implementation for different areas of transport branch will be outline; the market of mobile apps with AR, as well as the experience and methodology of using such software in the practice of students' vocational training process for transport industry will be determined.

3 Theoretical background

Modern advanced AR technology has many varieties. However, all existing diversity used in the transport industry can be divided into four main types. These are marker-based technology, markerless, projection-based, and overlay or superimposition-based ones [32].

Marker-based AR or image recognition technology can use as a marker anything from QR-code to special characters (like those worked out by the Volvo Group). In some cases, the AR device also calculates the marker's position and orientation for the content or content placement. Accordingly, the marker initiates digital animations for viewing by the user, resulting in images being transformed in 3D models [26].

Despite some evident benefits of marker-based AR, their visual appearance like black marker turned out unattractive for users. This fact had reduced the popularity of marker-based AR solutions in the market and so the *markerless AR* was specifically developed for commercial usage [32]. Sometimes such modern technologies are also called coordinated or GPS oriented ones. To provide data, they may exploit a GPS, a digital compass, a speed sensor, or an accelerometer equipped by a computer device. Thanks to the smartphones and tablet PC widespread, such technologies are extensively used to identify destinations, to find the right places like office or point of a cargo delivery, as well as in the location-based apps to monitor the vehicle.

Projection-based AR exploits a video projector to display information on a screen or on various physical surfaces. At the heart of this technology is the exploitation of real-world objects as a base for the projection of virtual images. It is usually used in industrial warehouses, factory shops, as well as for objects of logistic chain to visualize products, goods, cargos, cars etc. It should be noted the portable projection-based AR has certain disadvantages in terms of the quality of projection on heterogeneous surfaces of unusual shape due to differences in reflectance, color, and geometry [32].

Overlay or superimposition-based AR performs full or partial replacement of the original real object image via graphical additions. It allows to get an augmented view of the real object. A visual example of such technology usage is vehicle technical inspection. In this way user can, for instance, superimpose the images of units and aggregates of a vehicle on the real vehicle image [3].

To put it simply the AR uses animations, videos, 3D models as images, then transforming and providing them to the user in a natural or artificial way. By using AR technologies, users do not feel immersion into the virtual environment, they fully recognize their presence in the real world. To this end, AR exploits a variety of devices to display information: screens, displays, special glasses, smartphones, tablets, and a lot of other interesting things. AR technologies, in particular for transport industry, cover following:

- ICT, in particular processor, GPU, memory, communication devises (Bluetooth / Wi-Fi, GPS), which must process input date, provide space orientation, measure speed, angle, direction of motion of the investigated objects (it can be vehicles, automotive units and aggregates, transport systems etc.).
- SLAM technology, which literally translates as “simultaneous localization and map construction”. It involves constructing a map in an unknown space or restoring it in a known space with simultaneous control of the current location and the traveled track of an object [38]. The technology is quite relevant for a logistic analysis of transport systems.
- Cameras and sensors (mechanical, acoustic, optical, biological, etc.) that scan environment, find physical objects, collect data about them, generate 3D models, and provide user interaction.
- Depth monitoring technologies with the use of sensors.
- Software that allows to exploit, in addition to existing I/O tools, voice commands to control the operation of the vehicle or to communicate with other experts of transport branch.
- Data projection technology is a miniature projector on AR headsets that outputs processed data for user's viewing. It should be born in mind the aspect is not yet sufficiently developed and is mostly used for promotional purposes including automatic shows. However, this AR feature makes it possible to magnify real-world objects for study by any medium, allowing users to enjoy projection as if on-the-go by displaying AR elements in the environment [3].

- Information display technology ensures the user aligns the virtual image correctly to generate photorealistic images. Some AR devices exploit a system of mirrors or double-sided mirrors which reflect light from the camera and the user's eyes.

AR-assisted devices integrate the above technologies into a single complex that usually includes sensors, cameras, accelerometer, gyroscope, digital compass, GPS, processor, displays [3].

As reviewed by Internet sources, devices for realizing AR can be classified as following types, namely [25; 33]:

- Mobile devices (smartphones and PC-tablets) that are operated on the basis of special mobile apps.
- Special AR devices which designed exclusively to create an augmented reality, among these are HUD (head-up display) that sends data to a transparent display, AR laboratories for vehicle design, a screen is built into helmet and others.
- AR Glasses (or smart glasses, or 3D glasses), as an instant Google Glass, Meta 2, Laster See-Thru, Laforge AR, and others.
- AR contact lenses (or smart lenses) which already allow even photography and data storage [25].
- Virtual Retina Displays (VRD) that create and project images directly into a person's eye via a laser.

Indeed, AR technologies had been initially used to create a fundamentally new type of computer games; however, quite quickly their advantages were noticed in the business field. Further many powerful tools for manufacture and marketing were developed, and then they were included to production and vocation training in transport industry. Today it is seen the emergence and spread of a new scope in their use due to the development of the mobile software apps market, the technical improvement of smartphones and other gadgets. This trend is based on the use of QR technologies, which has greatly simplified the access process to the relevant apps and allowed organization of extracted vocational training [40].

QR Code (abbreviated from Quick Response Code) is a trademark for the type of matrix barcodes (or two-dimensional barcodes) originally developed by Denso Wave (then a division of Denso Corporation) in 1994 for the Japanese automotive industry. Although the “QR Code” designation is a registered as “Denso Corporation” trademark, the use of the QR Code is not subject to any license fees. It is being described and published as ISO standards [12].

In general, as early as the last century, Denso Corporation responded to a request from the Japanese industry to develop a new type of barcode that would contain more than 20 alphanumeric characters and might be quickly readable [12].

The developers have solved this problem by adding positional information to the code. Eventually, a square QR Code model has appeared. The modeling had proceeded by a careful analysis and search for patterns in the ratio of black and white areas on the printed matter, in order to prevent mistaken scan of similar images in the future. Thus, a device was created to identify the object regardless the scanning angle. The created QR Code model is capable of encoding about 7.000 numerals with the additional possibility to encode Kanji characters. This code can also be read as likely 10 times faster as other codes [12].

Through the efforts of Masahiro Hara-led labs, the automotive business has adopted a QR Code for use in their electronic Kanban (it is a communication tool used in production management systems). This made it possible to increase the efficiency of car production, improve transport systems beginning from cargo delivery and finishing a receipt obtains. The main advantage of QR Code is the easy recognition by scanning equipment, which enables it to be exploited in trade, production, logistics, services, tourism etc. The QR Code is used for transparency of production processes, for product monitoring and quality control, for navigating and tracking the movement of vehicles and individuals [12].

So far new types of QR Codes have been created to meet the more complex needs of manufacturing, the service industry and ordinary people. Micro QR Code allows place compressed information in a small space. The IQR Code occupies a small area, but even so it has large encoding capacity. The SQR Code enforces restrictions on reading sensitive information. FrameQR Code permits freely combine illustrations and photos. The new High Capacity Colored 2-Dimensional (HCC2D) Code and a color 2D matrix symbology JAB Code have also been proposed.

The QR Code specification does not describe the data format. The most popular QR Code viewers support the following data formats: URL, bookmark in browser, Email (with letter subject), SMS to number (with subject), MeCard, vCard, and geographical coordinates. Some apps can detect GI, JPG, PNG, or MI files of less than 4K and encrypted text. Without exaggeration, any smartphone equipped with a workable camera is able to read the QR Code generated by the manufacturer. And every person, even the most ignorant person in ICT, can use it to solve a variety of problems including vehicle operation. Today, QR Code technology not only allows read new information exiting fairly simple apps, but also to create someone own codes for specific needs. The QR Code can be save relevant information or links to it.

The aforementioned features of AR technologies and the technical and software solutions for their implementation make it possible to qualitatively update the transport branch and the vocational training system for respective area of expertise. It makes sense if the above-mentioned means will be adapted to the university study conditions.

4 Results and discussion

4.1 Use AR technology in transport industry

A survey of online sources shows that widely recognized world's automotive brands invest heavily in AR technology and create dedicated laboratories for these purposes. Next, we are going to look at the most general ways of AR used in transport industry (see fig. 1).

It's a vehicle design and tuning. Engineers exploit AR technologies to complete design faster by working on a virtual vehicle, developing new components and units of it in real time and in natural sizes, changing as needed and color solutions, as instant at

Volkswagen's virtual engineering laboratory in Wolfsburg. Modern ICTs allow different project teams to do synchronously one draft at a distance [26].

It's mechanical and automotive engineering. AR technologies allow rapid development and introduction of unique production assembly instructions for a vehicle, which, unlike papery ones and their analogues, are interactive and richly illustrated. They provide quick text navigation and even connection with third-party consultants [8].

It's vehicles marketing and advertising by means of virtual automotive shows, virtual manufacturing tours or dealer networks. AR-based apps activating via components and units of vehicle or manufacturer markers, permit users to visualize their full size, even open and close the trunk and doors, look inside and, to some extent, tuning the car [30]. For example, today BMW Group is using *iVisualizer* to sell *I3* and *I8* make of vehicles. The app places branded models in front of a potential buyer, who can evaluate and validate the model functionality by virtual tools including viewing available colors and kinds of body processing [6].

It's vehicle maintenance and operation. The field of AR exploitation in this sphere is expanding every day. In general, it can be represented in two main directions. One is usage of additional visualization tools to increase the comfort of vehicle operation. Yet another is usage a virtual Guide that works on the above-described AR tools. The first direction is well illustrated by the development of Apple and Hyundai [1; 17]. The two companies have independently offered some ways to use the windshield of a vehicle like a powerful navigation display [9]. It should be emphasized the virtual Guides are being developed by all well-known car brands. For example, the Volkswagen Mobile App *MARTA* allows the user to see the details of the car and how to solve certain issues [26].

It's vehicle diagnostics and repair. It is believed that the first experience of using AR-technology for this purpose belongs to BMW Group. In 2009 the company offered AR glasses for car diagnostic and the BMW Augmented Reality Car Repair App (CRP). Attention should be paid to smart glasses which make technician's hands free and simplifies establishing and current repair of a vehicle. The idea is that wearing these glasses gives opportunity to look at the BMW Group engine, with its separate units highlighted in different colors, which allows to notice general mechanical problems [6].

Obviously, regardless of the hardware used, AR technologies have many significant advantages then traditional instructions and manuals and simplify vehicle maintenance even for beginners [9]. It is likely that in the near future, with mobile apps or smart glasses, it will be possible to keep up the engine and detect problems in a timely manner, illustrating step-by-step solutions with support and graphics AR [25].

The Bosch research has found that the use of AR technologies accelerates technical maintenance processes by 15% [8]. This idea is being developed by Porsche Service, which had developed smart glasses helping mechanics address complex peripheral maintenance issues with the support of Atlanta-based US headquarters. It is quite possible to transmit videos and describe the problem in real time and to receive advice from more qualified specialists [30].

We found a lot of other projects to create integrated AR laboratories for specialist training. AR-based laboratories like virtual ones significantly reduce the time spent on training and the cost of materials. For example, Bosch uses AR and tools and a dedicated platform with educational content for technicians' training so called CAP (Common Augmented Reality Platform). Developed apps by Bosch experts allow to see the necessary elements, units and aggregates of the car, refer to watching videos, text instructions and moving 3D objects, do self-control of knowledge level. The CAP can publish new contents and apps for engineering and training sectors in a straightforward manner. The platform compiles the required data for each specific AR app and implements different training scenarios both in “Trainer Mode” and in “Trainee Mode” [8].

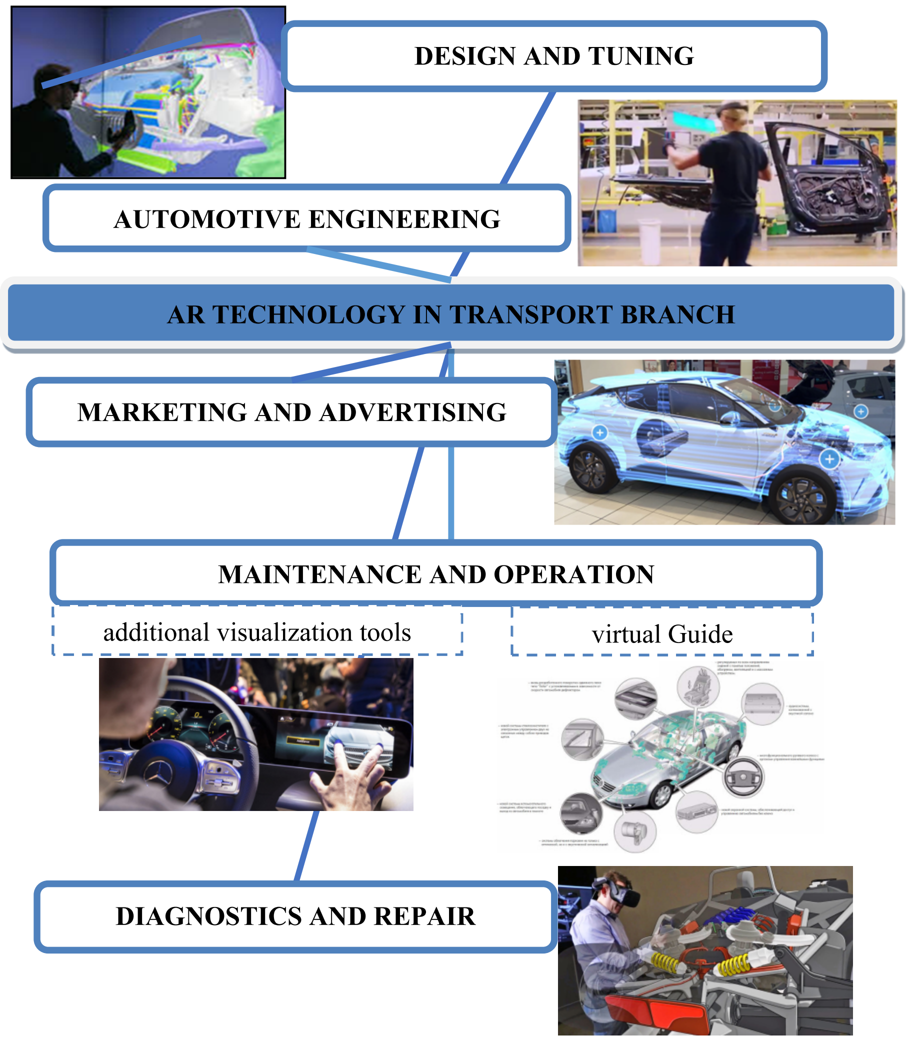


Fig. 1. The most general ways of AR exploiting in transport industry (prepared by the authors with use of freely distributed advertising images).

Volvo Group's contribution to the development of AR ideas for training is powerful enough. We mean AR markers for the study of separate components and units of vehicles, guidance for current repair and operation. The developed *Meet the Virtual Engine* app allows to study the smallest features of the *D11* engine [36].

It should be considered the most significant projects with the use of AR for educational and advertising from leading automotive brands.

4.2 Review the market of mobile apps with AR for vehicle operation and maintenance needs

In the matter of fact nowadays mobile apps are widely used in the transport industry for improvement carriage and development in the transport systems functioning. Clearly, the AR technologies based on them, arouse the particular interest for study purposes. Below we are presenting mobile apps that are freely available in Google Play Market [13] and Apple App Store Support [1].

Cat® VR Learning [10] is an interactive multilingual app that allows to explore key features of Caterpillar. After selecting the scope and model, the app permits 360° view and with the help of "hot" points to find out the peculiarities of certain components and units of Caterpillar. Each access point is equipped with text, graphic, audio and video information (shown on fig. 2).

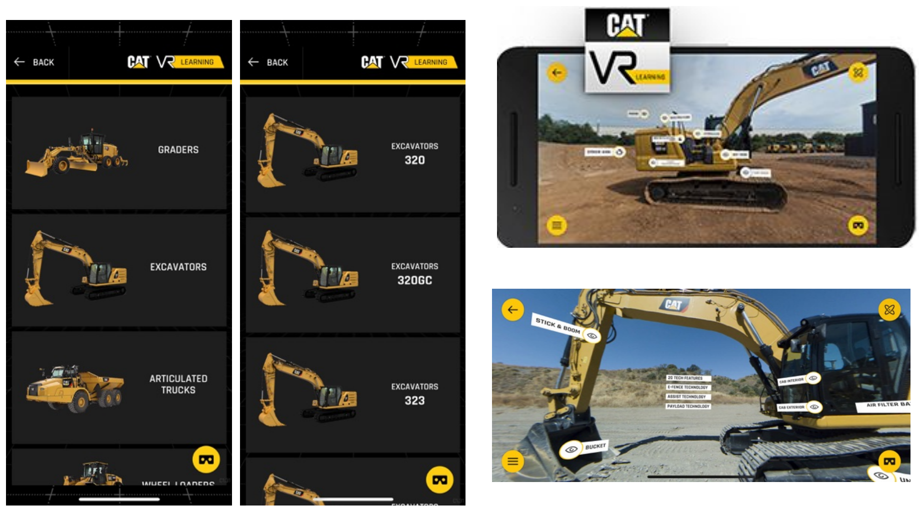


Fig. 2. Studying the construction of Caterpillar vehicles with the exploit of *Cat® VR Learning* app (prepared with use of [10]).

In conjunction with the smart glasses *Cat® VR Learning* app can create full virtual environment. The app "puts" the user into the vehicle, creating a sense of physical presence. The virtual Guide, navigated by the user's look, provides up-to-date information, gradually organizes the study of a particular vehicle unit, even with the training of driving skills.

The *Hyundai Virtual Guide* [17] is an AR smartphone app that Hyundai owners can download and exploit as an illustrated instruction manual. Instead of browsing through the guidance, it will be enough to point smartphone camera at the car containing the company markers and view the overlay digital information. The *Hyundai Virtual Guide* can virtually identify and provide instructions for the following features: air filter, Smart Cruise Control, Bluetooth phone pairing, warning indicators, clock, engine oil, brake fluid, fuse box, SMART trunk (fig. 3).

Fig. 3. Separate functionality of the *Hyundai Virtual Guide* app (prepared with use of [6]).

I-Mechanic – AR Car Repair App is car repair software offering the same instruction manual like Hyundai, but for any other vehicle make. With the help a mobile device, it makes it possible to view a convenient AR graphic "imposed" on an actual engine in real-time that allows pinpoint important maintenance aspects [2]. The app can help to check the level of oil or coolant, as well as skillfully top up the coolant and charge the battery even to a beginner (fig. 4).

Genesis AR Manual [16] helps owners understand the features of a vehicle explaining how to connect their phone via Bluetooth, how to use cruise control, and what the warning indicators mean. At the same time, AR capabilities allow the user to orient their smartphone or tablet to engine operation and maintenance, and to receive step-by-step instructions to help check the oil level or top up the wiper (fig. 5).

Genesis Virtual Guide app [9; 16] is a modern look at traditional manuals that allow customers to exploit their smartphone to get information on car repair, maintenance and features. Typically, the 2D and 3D AR technologies are used for these purposes, providing an in-depth level of information according to the user needs (see fig. 6).

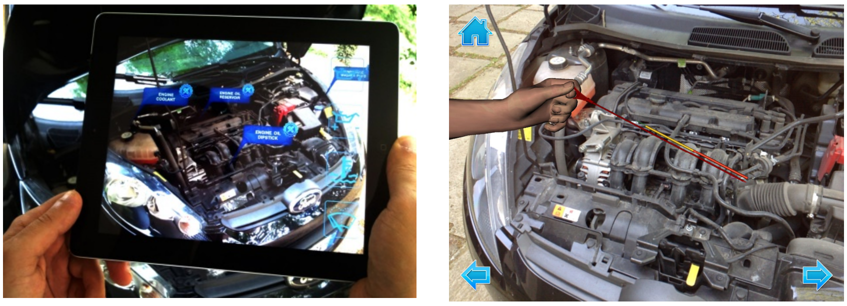


Fig. 4. Working with help of *I-Mechanic* (prepared by the authors with use of [2]).

Fig. 5. Oil level control with the use of *Genesis AR Manual* app (prepared with use of [16]).

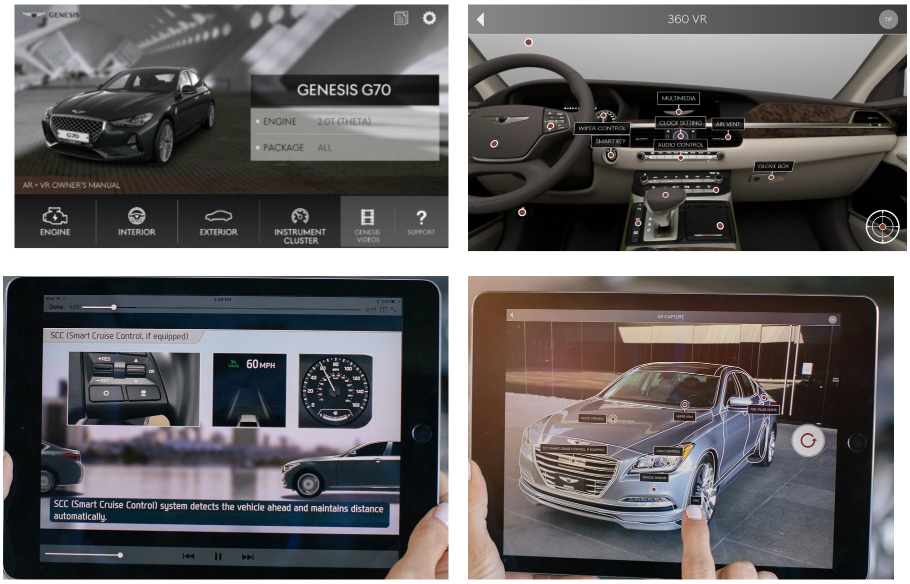
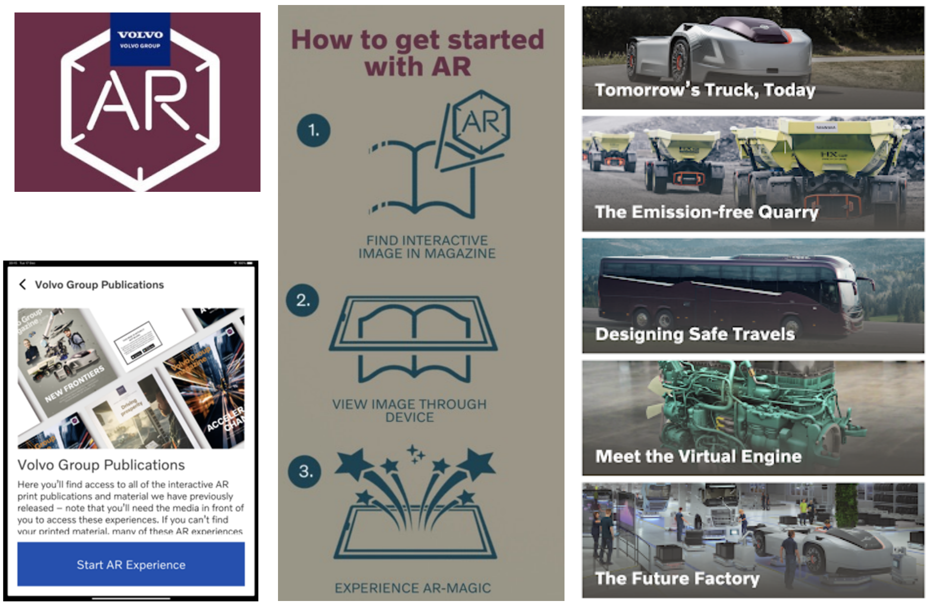


Fig. 6. Separate functional properties of *Genesis Virtual Guide* app (prepared with use of [16]).

The guidance contains up about 135 videos with practical recommendations and 25 three-dimensional layering for units and aggregates of Genesis such as engine compartment and dashboard, cabin functions and signal indicators, ways to use an adaptive cruise control, Bluetooth phone pairing, a clock, and a lot of other interesting thigs. The app helps owners do simple maintenance tasks such as checking oil, replacing filter elements, adding process fluid to various vehicle units according to operating requirements [9].

Volvo Trucks Corporation offers many mobile apps with AR that can be used to operate and repair a vehicle, familiarize with its components and aggregates. One is the *AR Stories* [36]. The fig. 7 shows the algorithm for working with the app [37]. It involves the app installation, searches in the logs of the corresponding images or QR Codes in Volvo Group magazine [35] and works with them via the *AR Stories* app. Obviously, the most of the presented menu items (fig. 7c) are primarily advertising kind and to a greater extent work without AR. Meanwhile, for vocational training purposes, the issues such as *Meet the Virtual Engine* and *Engine room fuse box* are interestingly enough. About their usage we are going to report in next part of the paper.



A B C

Fig. 7. The algorithm for working with the *AR Stories* app.

It is significant the Volvo Group magazines always contain new AR markers that illustrate the manuals for vehicle maintenance and repair, as well as cognitive materials about transport systems, environmental and road safety, manufactory organizing with the use of Volvo vehicles [35] (Fig. 7a).

The apps described above are mostly English-language that quite the contrary is their advantage. We mean that as for transport industry specialists English language skills are the key to their successful professional career. It should be emphasized the mobile apps with AR don't have clear educational purposes. The effectiveness of their use in the vocational training process is conditioned by the development and implementation of a special methodology.

4.3 Experience of organizing students' cognitive activity via AR technologies

In the professional activity of lecturers of the General Sciences and Vocational Training department of Kryvyi Rih State Pedagogical University a students' mobile learning is widely practiced [23]. Continuous monitoring of the mobile apps market allows to update the content of lectures gradually, practical and laboratory classes in special disciplines in transport area of expertise such as “Vehicles operation and repair”, “Vehicles maintenance”, “The transport vehicles engines” “Transport logistics”, “The freight and passenger transportation technologies” and others.

As a result of the analysis of practice experience, it was found that during organizing students' cognitive activities with the use of AR technologies certain pedagogical terms should be created, namely:

- it needs to provide each student with the position of an active actor of studies and cognitive activity. It means the freedom to choose forms, methods and directions of engineering and pedagogical creativity, implementation relevant ICT into studies and professional activity in line with the students' level of vocational knowledge and their mastery degree in mobile learning tools area (e.g. student can use ready-made apps, improve them, create their own methodological techniques based on them);
- it must facilitate the switch the study information in a mode of the project activity, to introduce and distribute design tasks in the form of cases, game projecting, web-quests, creative competitions with the use of the AR technologies;
- to do professionalization of educational content and purposefully teach students to use the modern ICT in the study process in line with requirements of up-to-date vocational school. It assumes mastering by student the professionally important knowledge and computer focused pedagogical technologies;
- to manage students' cognitive processes by means of ICT, to variably select VR and AR technologies and to combine them with traditional study. It signifies justified introduction of ICT for the realization of educational, professional and developmental goals during vocational training process.

It should be remembered that the professional properties that are shaped as a result of these terms do not guarantee mastering the profession by a student. To do this, a student must be an informed carrier of “norms” and “freedoms” within the relevant professional culture. A “norm” concept we correlate with the students' conscious requirement to acquire professionally meaningful knowledge, and “freedom”– with the conscious need to choose from among the various public, intellectual, social, and other stimuli precisely those that make it possible to become a professional, but not a “high-stepper” [28].

As a result of testing, set of study and cognitive tasks based on the matter of some mobile apps with AR including *Cat® VR Learning, Cat Technology Experience, Hyundai Virtual Guide, I-Mechanic – AR Car Repair App, Genesis AR Manual, Genesis Virtual Guide* ones, as well as Volvo Group publications, has been introduced into the special subject content. New approaches to teach and to organize lectures, laboratory and practice classes have been developed.

As an example, next we will consider the series of laboratory work in the course “Vehicles operation and repair” with the use of the *Genesis Virtual Guide* mobile app.

Students can scan the engine (fig. 8) by means of a smartphone camera then they will be able to work with the engine menu via pictorial cues at certain units or aggregates of a vehicle. Next, following the virtual Guide instructions, students will do the car maintenance on the example of checking the oil level in the crankcase (Engine oil check), adding detergent (Adding the washer fluid), cleaning the air filter (Air cleaner filter), checking the brake fluid (Brake fluid check), doing coolant checkup (Coolant check).

Fig. 8. Studying vehicle engine with the help of *Genesis Virtual Guide* app (prepared with use of [16]).

Evidently, it is the Volvo Group's mobile app *AR Stories* that has a great potential in experts' vocational training for transport industry. The company distributes AR tokens in the media by means of QR Codes. After reading them an image is downloaded and processed via AR Stories app. The app contains full AR instructions and a built-in photo marker reader [36]. The main features of this app have been described above, and further we are going to cover only some of them.

By way of illustration it will have a look at the laboratory work on topic “The structure, operating properties and methods of current repair of a Common Rail fuel feed system”. To study the Common Rail replacement methods *Meet the Virtual Engine* and *Engine room fuse* box tabs in *AR Stories* can be used as likely as an additional dynamic means of clarity. Access to them is shown in fig. 9.

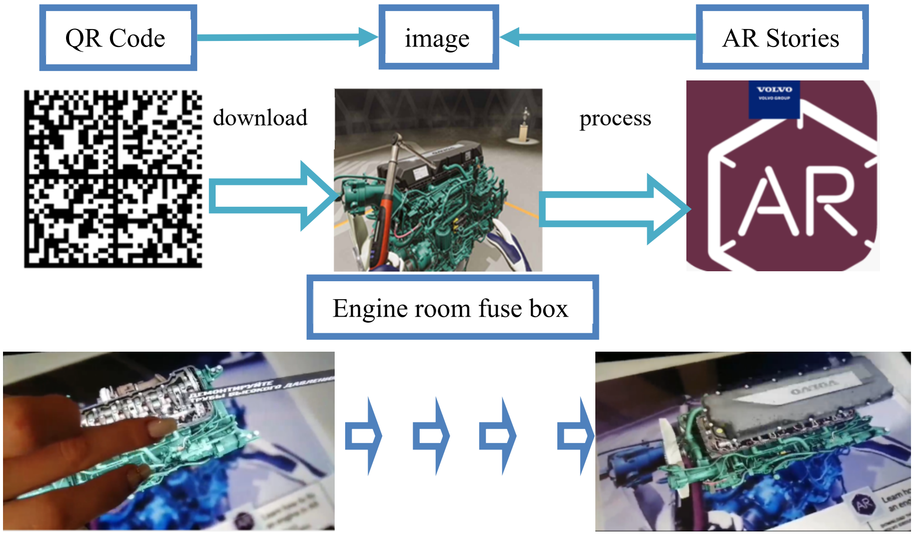


Fig. 9. The algorithm for working with the *Engine room fuse box* (prepared with use of [35; 37]).

In addition to technical products, the Volvo Group also offers advertising with AR. Their exploitation can greatly enhance any study material. For example, with the help of a photo marker on a career in Gothenburg (Sweden), VOLVO offered to consider the operation of electric dumpers with remote control (Fig. 10).

Fig. 10. The photo marker on a career for *AR Stories* app [37].

The company also proposes companion videos that are accessible by means of a QR Code. They can help look at a career and prototypes of unmanned dump truck. As part of an advertisement for the Electric Site project aimed at creating a fully autonomous quarrying process, Volvo has started testing unmanned electrical machinery in the Vican Cross career in Gothenburg, Sweden. Each stage of the mining cycle including extraction, primary crushing and transportation will occur automatically. For that, Volvo and the Skanska Company will use prototypes of autonomous dump trucks, a cable-driven hybrid excavator and a diesel electric forklift. All of these aspects are accessible via VR and AR and tools, and can be used for theoretical training of future professionals for transport area of expertise [35].

Volvo Group's Future Transport Solution concept is interesting for working out the main traffic and logistic ideas. With the help of the AR Stories mobile app, students can get acquainted with the latest development; this is Volvo Vera that is autonomous freelance freight electric vehicle – robo-truck [36].

The *Cat Technology Experience* app has significant advantages in organizing theoretical and practical students' vocational training for transport industry [34]. The app offers virtual guidance on Caterpillar engineering into a simulated career with smart glasses. It should be noticed that it is perhaps the only AR tool to study methods of operation, repair maintenance of career transport (fig. 11).

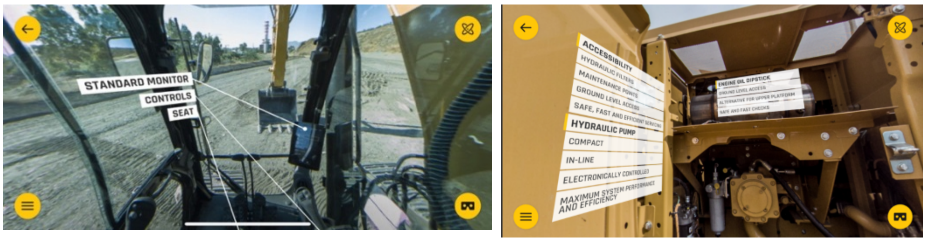


Fig. 11. Familiarization with components and units of a Caterpillar vehicle in the *Cat Technology Experience* app (prepared with use of [34]).

Sitting on the operator's seat will make it possible to learn about the features and benefits of Cat Payload on wheel loaders, Cat Grade on excavators and bulldozers, Cat Grade with Assist on excavators and Cat Grade with Slope Assist on bulldozers. User has a good chance to look around to get the full 360° ride [34].

Thus, based on the founded on experience and theoretical elaboration of the issue, a step-by-step methodology of application the mobile apps with AR in the students' vocational training process for transport industry has been developed. It has been concluded that at *the preparatory stage of the methodology* it is necessary to ensure the following activities:

1. It should examine the topic features and the possibilities of using AR technologies during the learning study material.
2. Introduce to students and provide them with general knowledge of the AR technologies features and methods of working up with AR-based hardware and software (smartphones, tablets, mobile apps, AR markers, 3D glasses etc.).
3. Mastering by students the main mobile apps with AR that will be used during the study of the topic.
4. Forming to students' skills and competences of independent study and cognitive activity on the basis of work with the AR-focused mobile apps market. This process assumes search and analysis of existing apps with AR, their scopes in future specialists' vocational training.

5. Work on the development of students' educational and vocational motivation for the use of AR-technologies, as well as forming the goals of students' project activity.

At the *substantive stage* of the methodology it is necessary to ensure following:

1. To master the content and specifics of the selected for educational purposes apps with AR in classroom work.
2. To organize students' independent study activities with the AR-focused mobile apps.
3. To prepare and elaborate the individual study projects based on the AR technologies.
4. To organize and provide the pedagogical management of students' extra-curricular independent cognitive activity with the use of AR-technologies. It means students involve in the execution of service and material projects, in web-quests, do topic blogging, and the analytical activities on the fields of transport industry.

Finally, it is advisable to introduce it in the students' classroom and independent work and their research activities in the elaborated projects which concern the solving professional problems with the use of AR and it's tools.

5 Conclusions

A review of the primary sources and analysis of experience show that the AR technologies are being stood out among modern computer focused means of vocational training due to the creating with their usage exceptional conditions for organizing mobile, high-quality and intensive students' professional preparation for transport industry. Such training, realized via mobile devices and up-to-date software, provides students with the acquisition of professionally important knowledge in the fields of design and tuning, mechanical and automotive engineering, marketing and advertising, maintenance and operation, diagnostics and repair of cars.

Based on the experience of organizing students' cognitive activity for transport area of expertise the step-by-step methodology has been elaborated and presented in the paper. The methodology covers a system of training tasks based on mobile apps with AR (e.g. *Cat® VR Learning, Cat Technology Experience, Hyundai Virtual Guide, I-Mechanic – AR Car Repair App, Genesis AR Manual, Genesis Virtual Guides*, as well as apps and publications from the Volvo Group), and it was implemented during the preparatory, substantive and final stages. Over and above, the possibilities of mobile apps with AR to qualitative update of lectures, practical and laboratory classes for specialized disciplines for students of transport area of expertise.

The methodology has been tested within the students' vocational preparation for transport industry based on General Technical Sciences and Vocational Training department of Kryvyi Rih State Pedagogical University and its effectiveness has been confirmed by experiment results. Future experts have pointed out the expediency of the usage of VR and AR elements and organization on this background independent study activities and research, game forms of work (web-quests, competitions, quizzes etc.), as well as creation of a new type of laboratory and practical classes. As a result, the students' knowledge quality in specialty subjects has increased by 15%.

We emphasize that the information in this paper reflects only certain aspects of the use of modern ICT in the vocational training of future professionals in transport area of expertise. The daily hard work of scientists around the world introduce new ideas to this process. However, a specialist with a high level of professional competence and information culture is able to pick up these ideas and adapt them to the professional activities conditions.

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New effective aid for teaching technology subjects: 3D spherical panoramas joined with virtual reality

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Abstract. Rapid development of modern technology and its increasing complexity make high demands to the quality of training of its users. Among others, an important class is vehicles, both civil and military. In the teaching of associated subjects, the accepted hierarchy of teaching aids includes common visual aids (posters, videos, scale models etc.) on the first stage, followed by simulators ranging in complexity, and finished at real vehicles. It allows achieving some balance between cost and efficiency by partial replacement of more expensive and elaborated aids with the less expensive ones. However, the analysis of teaching experience in the Military Institute of Armored Forces of National Technical University "Kharkiv Polytechnic Institute" (Institute) reveals that the balance is still suboptimal, and the present teaching aids are still not enough to allow efficient teaching. This fact raises the problem of extending the range of available teaching aids for vehicle-related subjects, which is the aim of the work. Benefiting from the modern information and visualization technologies, we present a new teaching aid that constitutes a spherical (360° or 3D) photographic panorama and a Virtual Reality (VR) device. The nature of the aid, its potential applications, limitations and benefits in comparison to the common aids are discussed. The proposed aid is shown to be cost-effective and is proved to increase efficiency of training, according to the results of a teaching experiment that was carried out in the Institute. For the implementation, a tight collaboration between the Institute and an IT company "Innovative Distance Learning Systems Limited" was established. A series of panoramas, which are already available, and its planned expansions are presented. The authors conclude that the proposed aid may significantly improve the cost-efficiency balance of teaching a range of technology subjects.

Keywords: 360° panorama, VR glasses, simulator, vehicle cabin, academia-industry collaboration.

1 Introduction

Technology plays a vital role in modern world. At present, most occupations and activities imply utilization of some devices and equipment. Among the variety of classes, an important representative is vehicles. A wide assortment is designed and extensively used in civil (transport, building, service etc.), military, and paramilitary (emergency, police) fields. The following features are typical for modern vehicles and their exploitation process:

- Increasing complexity of the chassis itself and the installed equipment;
- Fast development, resulting in frequent appearance of upgraded and novel models;
- Often, hard use conditions (especially for military and paramilitary vehicles);
- High costs of repairing and replacement of broken samples.

Consequently, extensive knowledge about the proper exploitation of the vehicle and related skills must be delivered to trainees during education in order for them to become qualified users.

2 Related work

In the teaching of vehicle-related subjects, there is an established and accepted hierarchy of teaching methods and corresponding aids [3]. It is summarized in table 1.

Table 1. The accepted hierarchy of teaching aids in teaching vehicle-related subjects.

Stage	Teaching aids	Goals
1	Common visual aids (posters, animations, videos, scale models etc.)	Provide the knowledge about the constitution, functioning, appearance, and exploitation of the vehicle. No skill developing is assumed.
2	Simulators	The purpose is two-fold. Firstly, providing information about appearance and exploitation of the vehicle. Secondly, a more or less wide range of skills may be trained, depending on the class of simulator.
3	Real vehicles	Providing real-world driving experience and developing exploitation skills.

An extensive literature, both pedagogical and technical, is available about the problems of design and use of simulators [19; 22; 23]. The transition from the first-stage aids to the last-stage ones is characterized by two features. On one hand, the trainee's experience becomes more relevant to the real-world use experience. On the other hand, expenditure for material resources and time per one trainee increases, as well. The reasons are manifold:

- A vehicle and, to a lesser extent, a simulator are expensive to obtain and maintain;
- Exploiting vehicles is material-expensive;

- Each vehicle or simulator is able to accommodate a single trainee only and, thus, have very low throughput: each trainee has to enter and leave it one by one.

The above hierarchy is aimed to balance the quality and cost of training, which is to provide the best training for a given budget, by partial replacement of more expensive aids with the less expensive ones. The stated aim is actually achieved.

3 Statement of problem

Nevertheless, the analysis of teaching experience collected in the Military Institute of Armored Forces of National Technical University “Kharkiv Polytechnic Institute” (Institute) reveals that the reached balance is still suboptimal. The identified deficiency is extensive use of simulators just as advanced visual aids, when they act simply as 1:1 scale models. Their purpose here is familiarize trainees with the appearance of the vehicle cabin (show the location of controls, indicators etc.). This fact leads to the next problems:

- Trainees are able to occupy the simulator one by one only, extending the duration of the class (i.e. the throughput is very low);
- The time available for using the simulator at its full capacity for developing skills by other trainees is, thus, reduced;
- In education establishments, which do not possess a simulator, the trainees are actually unable to receive this kind of training.

Let us consider a simple example. In a group of 15 trainees and one teacher, during a 75 minutes class, each person will receive just 5 minutes of experiencing the simulator in the best case (i.e. no preliminary instruction is needed, entering and leaving the cabin occur rapidly etc.). Importantly, the teacher is focused on a single trainee sitting in the cabin and, thus, cannot perform teaching with the rest of the group. Simultaneous utilization of 3-4 simulators at the same time may improve the situation, but requires corresponding expenses. The reason of such unpractical use of simulators is the absence of other teaching aids, which may be employed instead. In other words, there is a pronounced gap between the first and second hierarchy positions, which is forcedly filled by simulators. It is illustrated in fig. 1, where the particular sensational features, provided by the discussed teaching aids, are listed.

In the described situation, only two basic sensational features of simulators are used out of four, that is evidently suboptimal. The situation may be illustrated by a case from the Institute experience.

Trainees, who learn subject “Basics of driving combat vehicles”, have their module finishing with exam “Preparation to starting-up and starting-up of the engine”. The education is organized as follows. Firstly, trainees are acknowledged with the appearance of controls in the driver’s cabin by means of posters, slides, videos. Secondly, the order of engine starting-up is explained using text descriptions and posters. Then, trainees are allowed to enter a simulator in order to perform the operation practically. The drawback of this approach is that actually trainees require considerable time to familiarize with the driver's cabin. "To familiarize" here means to establish the connection between the remembered flat two-dimensional pictures of the cabin with its actual spatial three-dimensional appearance and to work out the head, arms, hands movements needed to activate the learned controls. Because, as was shown before, the total time available for each trainee in a simulator is short, there remains too little time to work out the exam operation. The only way to increase it is to devote more classes at simulators in the curriculum.

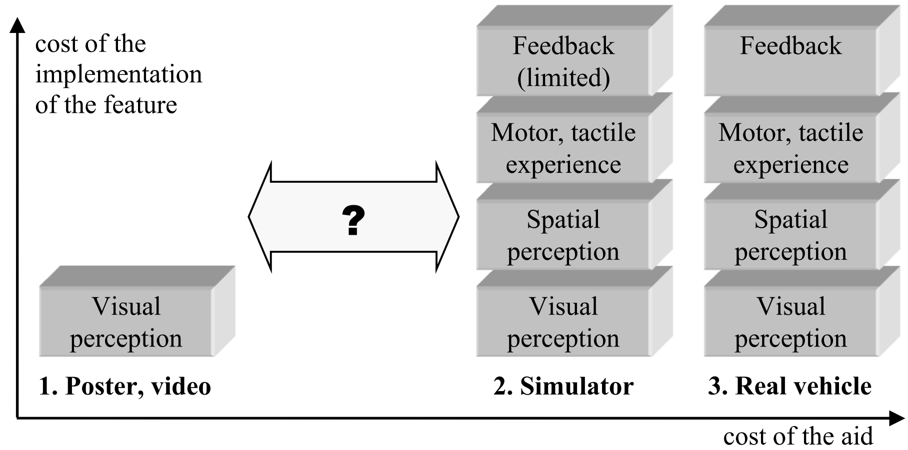

Fig. 1. Sensational features provided by the teaching aids in the accepted hierarchy, ordered by the cost of their implementation in the teaching aid. The question mark represents the gap.

Summarizing, the available range of teaching aids is markedly incomplete, which limits the quality of teaching vehicle-related subjects. The goal of our work is to introduce a new teaching aid in order to increase the stated quality.

4 Proposed solution

We propose a new teaching aid that constitutes a spherical (360°) photographic panorama and a Virtual Reality (VR) glasses. It is able to provide both visual and spatial perceptions plus limited motional experience, hence, it is located in between posters and simulators in the diagram (fig. 1) filling the described gap. Below we describe both components of this aid and their functioning.

4.1 Spherical panorama: Overview

Spherical panorama (also called 360° or 3D panorama) is an image that covers and contains the full horizontal and vertical field of view around a fixed point. It may be either artificial (i.e. drawn manually or computer-generated) or photographic. The photographic ones are created by processing a number of ordinary photographs (each having field of view less than 180°) shot from the same position to all the directions around; the principle is shown in fig. 2. Specialized software is used for this sake. Unlike ordinary images, 360° panoramas obviously cannot be viewed as a whole at a time (without slicing); therefore, during viewing on displays it is scrolled to the position of interest using computer mouse or other input device. At present, they are widely used for advertisement and entertaining purposes; some educational use is also present, e.g. panoramas of museum interiors [6; 30; 32].

Fig. 2. The principle of composing a spherical panorama. The camera is located in the center of the field of view. A single photograph shot is shown explicitly, while for the rest, only borders are shown.

Spherical photographic panoramas possess some features, which make them favorable for application in teaching:

- In contrast to ordinary photographs, the whole field of view is contained in a single panorama. This allows teacher to smoothly and continuously explore the field of view in order to find the needed area, creating in trainee's mind a solid and coherent image of the vehicle interior.
- In contrast to 3D models drawn in graphics and engineering software (like 3D Studio MAX, SolidWorks etc.), the image looks exactly as it is in reality, making the content (controls, indicators etc.) easily recognized when the trainee meets the real vehicle or device.
- Fabricating a photographic panorama is much less labor-intensive and time-consuming than drawing a high-quality poster or a 3D model because it does not involve manual reconstruction of the image from scratch. Making a series of photographs is a routine process, and composing the panorama is almost completely automated by software.

Nevertheless, the full potential of 360° panoramas may be utilized only if they occupy the whole field of view of a trainee instead of being viewed at a distant display.

4.2 Virtual reality: Overview

Virtual reality (VR) is the technology that allows achieving this effect. The goal of VR is to create the effect of the person's presence in some environment, either artificial or having a real counterpart, by specific affecting their sensors (eyes, hears, skin etc.) via VR equipment. It is usually called "immersion" in the literature. The central component of the equipment is a head-mounted display (called VR glasses), which form the person's field of view by displaying the picture, provided by VR software. The most important feature of the glasses is their interactivity: the movements of the person's head are monitored, transferred to the software and processed by it for the sake of updating the image in accordance with the new direction of the head [27]. Hence, it becomes advantageous to employ VR glasses for viewing 360° panoramas. The following benefits may be reached:

- The image of the spherical panorama completely surrounds the trainee, convincingly imitating staying in a vehicle cabin;
- The panorama becomes interactive, i.e. responding to the look-up movements of the trainee's head.

These features turn a passive spectator to an active viewer, who is able to look around. Also, the viewer is able to perform movements of arms and hands in order to imitate using controls seen in the field of view. Although the trainee's hands are not visible in VR glasses (without involving additional elaborate VR equipment), this is still useful and provides correct (through incomplete) motor experience because the location of controls in the field of view created by VR glasses is the same as in that inside the vehicle cabin. This feature even more distinguishes the proposed teaching aid from common visual aids (posters etc.), which are unable to provide reasonable motor experience.

In general, the possibilities of utilizing VR in teaching various subjects have been actively discussed for several decades, and different software and hardware solutions were proposed. Mostly, the fields where practical study involves large hazard or expenses were worked out, for example, medicine [5; 21; 25], technology and fire safety [16; 20; 24; 31; 33], driving [1; 9]. At present, it became accepted, particularly, in medicine and military training [2; 13], while at other fields, its usefulness is still discussed. For detailed reviews of the place of VR in education, the reader is referred to subject papers [7; 8; 10; 11; 12; 14; 15; 17; 18; 26; 28; 29; 31].

However, despite the opportunities VR may provide, its practical application is hindered by the following major obstacles:

- Creating content is in general case complicated and labor-intensive, demanding developed 3D design, art, and programming skills for creating the virtual environment;
- Costs of VR equipment are generally high.

Here we show that both these obstacles may be successfully overcome, having the introduced teaching aid as an example. Considering the first one, the problem is largely simplified by the fact that the content is created by photographing the existing vehicle, and the process of composing a 360° panorama is largely automated (see above). Some programming is still necessary but it is rather limited because no visual effects or virtual scenes is needed to implement. The second obstacle is solved by a proper choice of the equipment among the available, as will be shown below.

Next, wearing VR glasses by a trainee during teaching process introduces two important difficulties. Firstly, the teacher is unable to monitor the actions of the trainee because they is unable to see the image on the display. Therefore, in order to allow control over the trainee's actions, it is required to involve a secondary display, whose purpose is to demonstrate the image that is displayed at a moment by VR glasses.

The second difficulty is the very limited ability of the trainee wearing VR glasses to answer teacher's questions about the image seen (e.g. "indicate the button named X on the control panel"). It is caused by the fact that by default, the surrounding is interactive just to some extent: it responds to the rotations of the user's head, but the user is unable to affect it in any other way. To solve the problem, the trainee has to be provided with a separate device called controller. Its purpose is to receive user's input and affect the image seen in the VR glasses and, as a result, on the teacher's display.

Taking all the above into account, the proposed teaching aid consists of four components, which are depicted in fig. 3. It may be implemented using a range of hardware; the author's choice is stated in paragraph 4.5.

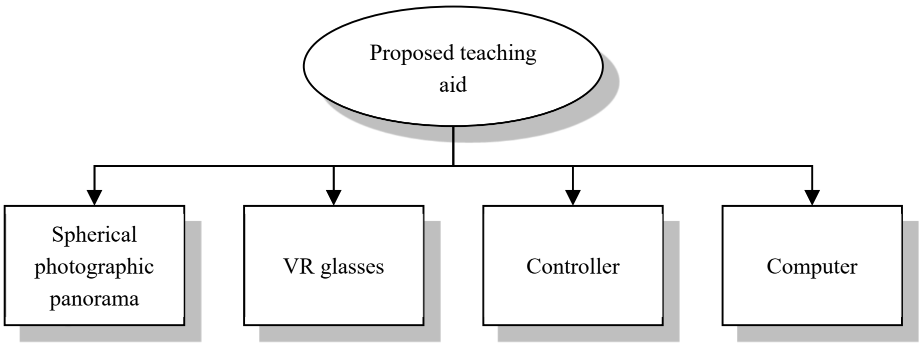

Fig. 3. Composition of the proposed teaching aid.

4.3 Application in teaching

The described features of spherical photographic panoramas suggest that the most precise and realistic result may be achieved for small, confined premises designed for one, at most two persons, where all the points of interest (labels, controls, indicators etc.) are located at about arm's length from the viewer. Actually, this is a case for most vehicle cabins. Another case is portable equipment, transported by truck (e.g. portable chemical laboratories). Therefore, the aid is most suitable for teaching subjects considering the above things. Particular examples in the military field are:

- Armored armament;
- Exploitation of combat vehicles;

- Renewal of armored armament;
- Technical support;
- Driving combat vehicles;
- Armament and firing;
- Electric equipment of armored armament.

Considering the financial side, the total price of the aid is very limited (hundred to thousand times less than a price of a single simulator), which makes feasible for educational establishments to obtain the aid. Moreover, the price makes readily possible equipping specialized classes for groups of 10-20 trainees. This option proportionally increases the time a trainee spends in the teaching aid and, thus, further improves teaching quality.

4.4 Test of effectiveness

In order to test the efficiency of the proposed aid, a teaching experiment was carried out at the Institute. The points #1 “Location and operation rules of controls and indicators” and #2 “Preparation of the vehicle to engine starting-up and movement» of the practice lesson “Training at simulators on preparatory exercise #1” belonging to the credit module “Driving basics” of the subject “Basics of driving combat vehicles” were chosen. The exercise #1 in this module is “Preparation to starting-up and starting-up of the engine” (further called “the exercise”), its procedure contains 19 steps.

The experimental class was held at an experimental multifunctional room. For comparison and estimation of efficiency, the reference class on the same lesson was held in a traditional way using common teaching aids (simulators).

Both classes started from learning the general structure of the BTR-4E transporter, its cabins, controls, and exploitation basics. The trainees were provided with the general information about the purpose of the control cabin and the driver operating procedure by means of distance course “Structure and exploitation basics of BTR-4E” (experimental group) [4] or posters and textbooks (reference group).

Then, the training was continued either with the help of simulator (in the reference group) or using the proposed teaching aid further called “a VR simulator of the driver cabin” (in the experimental group). In the latter case, the procedure was as follows. The teacher divided the group to pairs, and in each pair, trainees were assigned with #1 and #2. Then, the following tasks were specified to #1 and #2:

Actions of #1: Help #2 to wear a VR simulator and take a controller. Read the text of the exercise procedure step by step making pauses after each step to allow #2 find the needed control. Check the correctness of #2’s actions by watching the laptop, do corresponding notes and write down the results of training into the control sheet.

Actions of #2: Wear a VR simulator and take a controller, repeat the steps read by #1, find the needed control and point it with the controller. Then, pronounce each step of the procedure by memory, find the needed control and point it with the controller.

When the actions were completed the trainees #1 and #2 exchanged their roles.

The success of teaching during the experimental and reference classes was assessed by the results of the next class, when both groups of trainees had to execute the exercise at a BTR-4E simulator. This class has been carried out identically with both groups. The main results are as follows.

The marks for completing the exercise are summarized in table 2. Here, the mark is determined by the consumed time: “excellent”, “good”, “satisfactory” corresponds to no longer than 1 min 30 sec, 2 min, 2 min 30 sec, respectively. It is seen that both groups have similar distribution of marks that indicates they received equivalent training before. This proves that the proposed teaching aid is able to successfully replace simulators in the task of familiarizing trainees with vehicle cabin.

Further, the occupation of the simulator by the experimental group was 4 times lower than by the reference one. Hence, application of the proposed aid allows free substantial amount of the simulator time, which then can be used for conducting other classes where full range of its capabilities is employed.

Table 2. The success rates of the two groups of trainees.

	Control group	Experimental group
Total trainees	25	25
“Excellent” marks	10 (40%)	11 (44%)
“Good” marks	8 (32%)	6 (24%)
“Satisfactory” marks	7 (28%)	8 (32%)
“Unsatisfactory” marks	–	–

4.5 Details of implementation

For the implementation of the software part, a tight collaboration between the Institute and IT company “Innovative Distance Learning Systems Limited” was established. The Company developed the viewing software, and the experts of the Company performed photographing the interiors of vehicles, fabrication of 360° panoramas, and loading them to the viewing software. The Institute took part in developing the content, carried out approbation, and developed methods for the most efficient application of the product in teaching.

The access to the program is provided after registration procedure: the user has to fill the registration form with their contact details, affiliation, and International Mobile Equipment Identity (IMEI) code of their device. This information is manually processed by the responsible staff at the Institute. This measure allows control the distribution of the program and limit it to trusted persons and organizations only. The association with IMEI code of a device prevents illegitimate copying the software to devices belonging to unregistered persons.

The hardware part was chosen in accordance with the following considerations.

The VR glasses are of two kinds. The first kind comprises a built-in display; such glasses must by connected to a source of video signal, which is usually a computer running VR software. The second kind of glasses is called “VR boxes”. There, the role of display is played by a smartphone, which has to be installed (reversibly) into the VR box. In this case, the source of video signal is the same smartphone, which runs VR software.

The teacher's display must be attached either to the computer that generates the image for VR glasses of the first kind, or to the computer that receives the image from the smartphone installed in VR glasses of the second kind.

The simplest kind of controllers is computer mouse: when attached, a pointer is shown on the image, and the trainee is able to move it and set to the needed position (e.g., to the position, at which some control is seen at the moment).

Taking this into account, we used the following hardware in our implementation:

1. A VR box because it does not require a computer to work, is much cheaper than VR glasses, and still provides the ability to view 360° panoramas;
2. A smartphone running Android operating system, where VR software is installed and 360° panoramas are uploaded;
3. A computer mouse as a controller because it is a common and inexpensive device requiring no adaptation for trainees;
4. A laptop running Windows 10 operating system because we concluded that it is the most convenient option: the needed configuration is relatively simple, and the image from VR glasses may be received wirelessly via Wi-Fi.

5 Conclusions

A deficiency in the available range of teaching aids for vehicle-related subjects is identified, which decreases the teaching quality of the subjects. For the sake of its increase, a new teaching aid is introduced that constitutes a spherical panorama of the vehicle cabin joined with Virtual Reality glasses. Its main feature is the possibility to provide visual, spatial, and motor experience that is approaching to the provided by simulators, by much lesser cost. The efficiency of the aid was proved by a teaching experiment that showed it can serve as an alternative of simulators on the stage of trainee's familiarizing with vehicle cabin appearance.

At present, we have completed the 360° panoramas of a series of armored vehicles (BM "Oplot", BMP-2, BTR-4E) and emergency vehicles (fire engine). Under development are the ones for trucks.

In general, the study provides new evidence that VR technologies may be effectively used in education and, hence, deserve attention from researchers in the field. The additional motivation is that at present they became available and affordable to obtain by educational establishments. Several practical difficulties appearing during use at classes are shown to be non-critical and solved by means of additional devices.

We think the proposed aid may significantly improve the cost-efficiency balance of teaching a range of technology subjects, where vehicles or mobile equipment are considered, and may receive wide application in civil and military education establishments, emergency and military units, enterprises using special equipment.

Because the aid is new and rather unusual, our further research in the field is focused on working up advices for teachers regarding the technical aspects of the aid use at classes, developing methods of application of the aid in teaching various subjects, optimizing the choice of hardware constituents.

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Numerical methods for handling robotic arms using augmented reality

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Abstract. This document presents an augmented reality application for mobile devices, as a contribution to education through a technological learning tool that allows the management of industrial robotic arms, implementing advanced control algorithms, which allows the simulation of several selected desired trajectories by the user; and the incorporation of animations that allow to know its operation and to verify the follow-up of the proposed trajectory, as well as the visualization of control errors in each trajectory taken. The application is oriented to the simulation of industrial robotic arms within an intuitive and friendly augmented reality environment, which allows users a great interaction with the robot's structure, providing simulation programs with new immersion technologies, in the educational field. Tests in the augmented reality application demonstrate ease of use and user intuition, providing a better understanding of the operation and structure of programmable manipulators.

Keywords: augmented reality, industrial robots, 3D animation, numerical control methods.

1 Introduction

Education in recent years has been developing new milestones and ways of teaching, the use of new technological tools immersed increases the interest and learning experience [17], these tools allow the student to interact with the environment, naturally promoting their interest in discovering things [4]. The development of AR and VR applications has increased enormously in the last decade, these technological tools have as main axis, the interaction of the user with a virtual environment, the great difference is that the augmented reality provides the user a mixed, approach since it allows manipulating the virtual environment through a technological device without leaving the physical world [12]. The applications in a virtual environment are huge because it allows the construction of any object without being limited by dimensions, which causes that students have new learning tools in different contexts and topics [14].

AR applications are developed for specific tasks [9], and can be grouped into two main groups. Firstly, the applications focused as training assistants [7; 10; 11; 15; 18], are applications that provide step-by-step assistance for manual assembly processes, [15] compare the impact of AR assistants with video-based assistants, concluding that it reduces the amount of errors in production, and operation failures due to erroneous maneuvers, requiring less effort to memorize the execution steps, in addition to optimizing the time of training or onsite courses in the field. The use of AR assistants has a wide range of uses, allowing users to interact with different processes, whether educational or industrial, among others. Authors of [8] presents a system that allows collaboration to collaborate in real time to successfully carry out a mechanical maintenance task, this system unites the paradigmatic interaction that allows simulating the presence of the expert with an operator in an assistance situation.

Second, the entertainment applications [3; 6; 13; 16]. In [3] presented an application intended to teach the metabolism of the human body, especially the metabolism of glucose. The application is full of animations that provide a very immersive and very realistic environment, allowing the understanding of metabolism, from the moment food enters the mouth and its respective journey through the digestive system. Article [16] describes an AR game based on vision and interaction with non-contact movements, in which users through dynamic hand and foot gestures, interact with the virtual elements of the scene in front of a camera, activating an event of interaction predefined. Author of [6] makes an analysis of what are the technological, pedagogical characteristics of mobile AR games focused on education, there they describe characteristics about Calory Battle AR, a location-based game that combines physical exercise with possibility to include educational content, and Leometry which is a story-based geometry learning AR game.

This work aims to assist in learning about industrial robots through the development of an AR application. The application allows the visualization of the components of the manipulators by means of animation and visualization of multimedia files through the 2D recognition of identification codes, as well as the simulation of the behavior of the robot structure through the implementation of advanced control algorithms that allow the mobility of the operating end towards the path desired by the user.

This work is divided into IV sections, the first section includes the *Introduction*, the second section called *Development*, details the detection technique used, the characteristics of the mobile application environment and the laws of closed loop control, the third section details the *Results obtained* when using the AR application through a smartphone with its respective analysis of results and, finally, the fourth section describes the *Conclusions* of the work done.

2 Development

The proposed workflow diagram for the creation and development of the AR application is shown in figure 1, it considers five main stages with a specific task each, plus one or more processes that allow to execute the workflow tasks of the application for the smartphone:

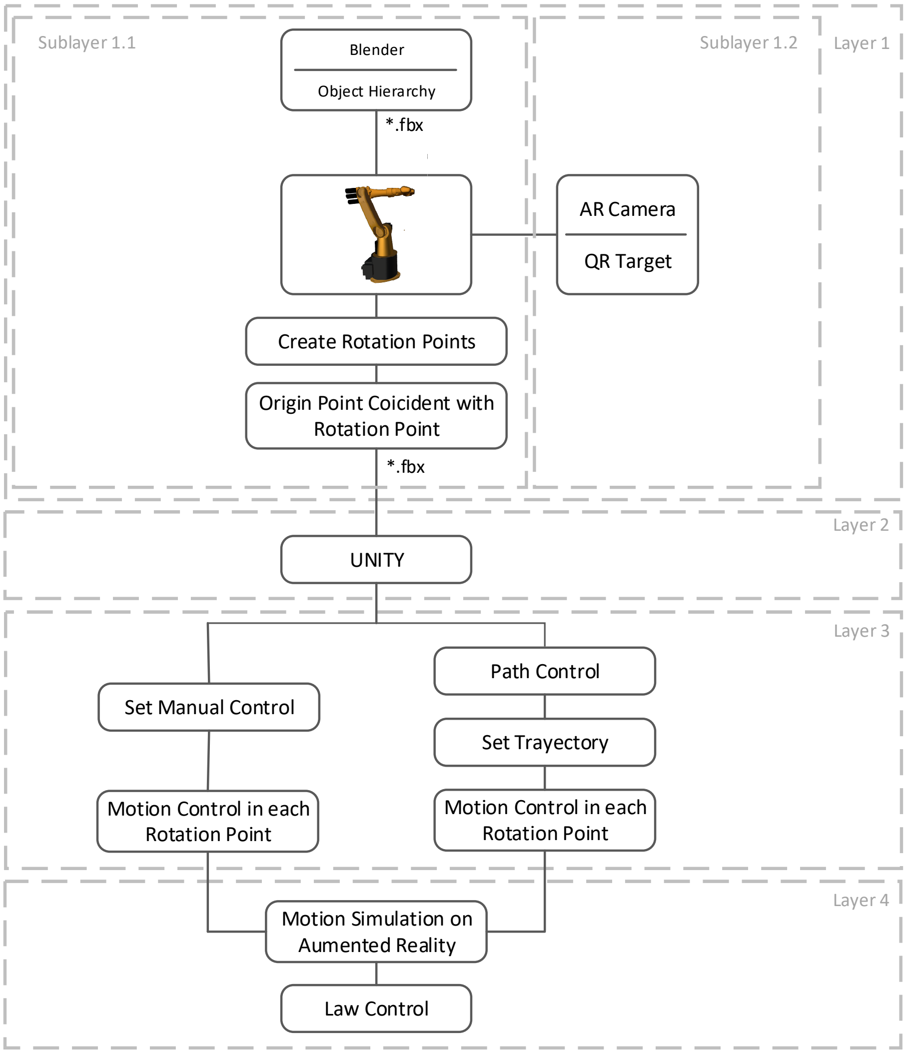

Fig. 1. Mobile application development workflow diagram.

i) Layer 1.1 allows 3D development using Blender software, which is a program specifically designed for the development of 3D objects, rendering, animation, special effects, etc. [5]. The 3D model of the robotic arm is shown in fig. 2, in which each of the elements or parts is made to coincide with the rotation points, in order to generate a correct movement of the elements within the Unity platform; the file is exported in *.fbx format.

ii) Layer 1.2 describes the 2D recognition technique, which allows the detection of images and text. This image is loaded into Vuforia Developer Portal's Target Manager, which allows the creation of databases and the generation of a Unity-compatible file, as seen in fig 3. Vuforia processes each image and generates characteristic points, according to these characteristic points the recognition quality is given. Fig. 4 shows the standard image to be used and fig. 5 shows the image characteristics that will determine the recognition quality.

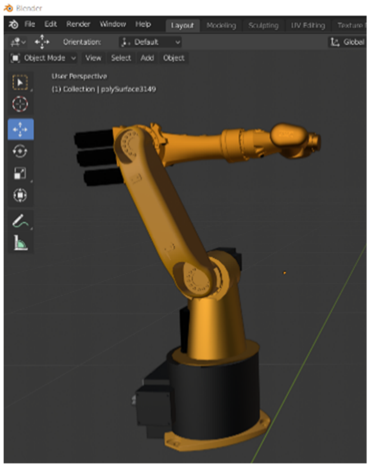

Fig. 2. 3D model of the robotic arm in Blender.

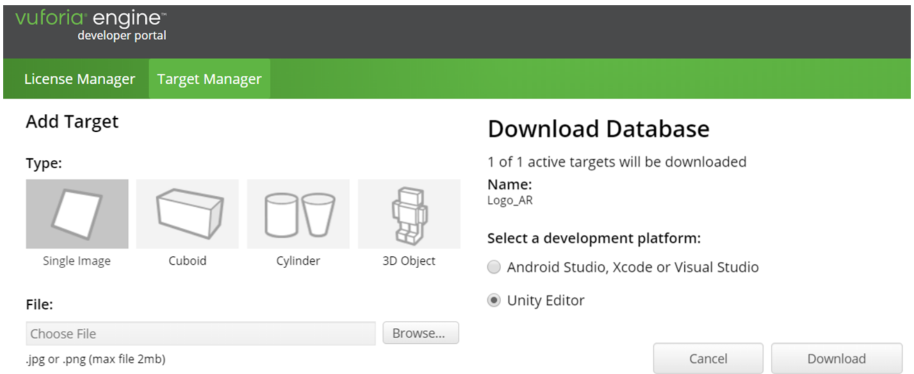

Fig. 3. Vuforia Developer Portal's Target Manager.

Fig. 4. Developed QR code.

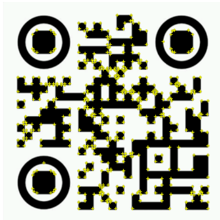

Fig. 5. Pattern image with characteristic points established by Vuforia.

iii) Layer 2 this layer describes the characteristics of the mobile application environment and the incorporation of the animations.

Characteristics of the environment, the implementation of a simple but intuitive interface allows a quick handling and navigation in the mobile application, for which Table 1 shows the icons that were used for the realization of the AR application with their respective description; and 3 main scenes are created: the first scene is presented in fig. 6 and contains the main menu of the application, the second scene allows to visualize the introduction on robotic arms through video and animation, as shown in fig. 7, the third scene allows to perform manual and path control its environment is presented in fig. 8.

Table 1. Icons.

Name	Icon	Action
Introduction		Navigate to the introduction scene.
Control		Navigate to the control scene.
Video		Play video.
Animation		Play animation.
Play		Play the path control.
Graphics		View the trend graphs of the controller.
Return		Return to the previous scene.
Exit		Exit application.

iv) Layer 3 this layer details the advanced control laws that are implemented in the AR application. To meet this objective, the kinematic model of the robotic arm and its respective stability analysis are described.

2.1 Kinematic model

The diagram proposed in fig. 9 shows a robotic arm with generalized coordinates and with a position at the operating end, where h is the position of the operating end in space, l is the length of each link and q is its rotation angle, is given by:

$$\begin{cases} h_x = l_2 C_{q2} C_{q1} + l_3 C_{q2,q3} C_{q1} \\ h_y = l_2 C_{q2} S_{q1} + l_3 C_{q2,q3} S_{q1} \\ h_z = l_2 S_{q2} + l_3 S_{q2,q3} \end{cases}$$

The first-order differential equation is considered (1).

$$\dot{h} = f(h, v, t) \text{ with } h(0)=h_0 \tag{1}$$

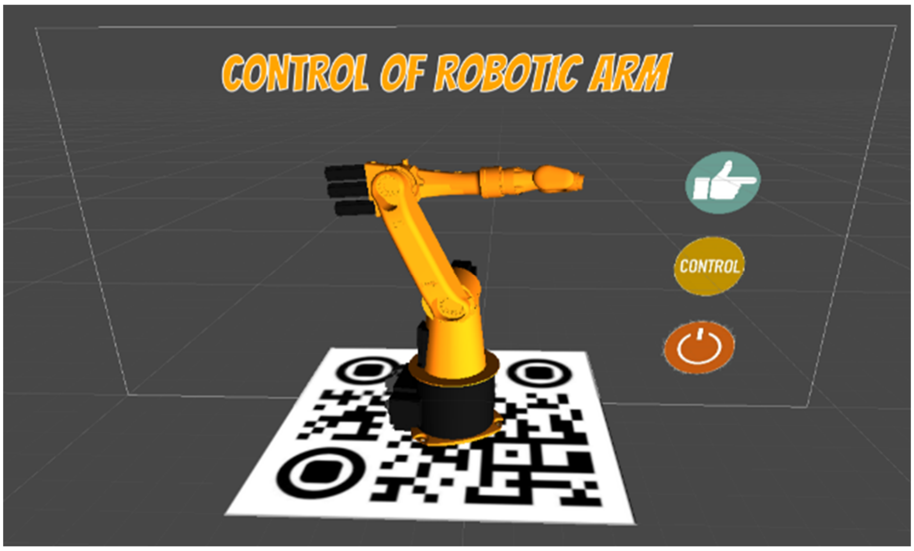

Fig. 6. Main scene environment.

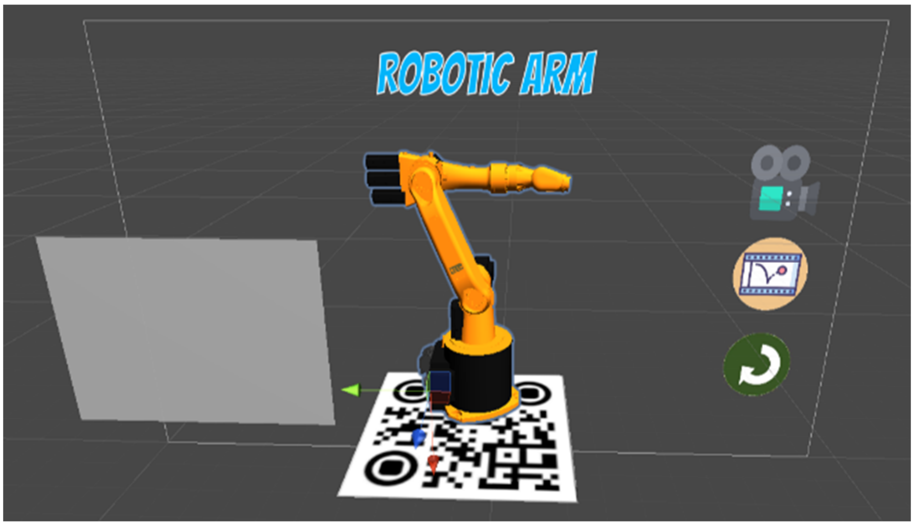

Fig. 7. Introduction scene environment.

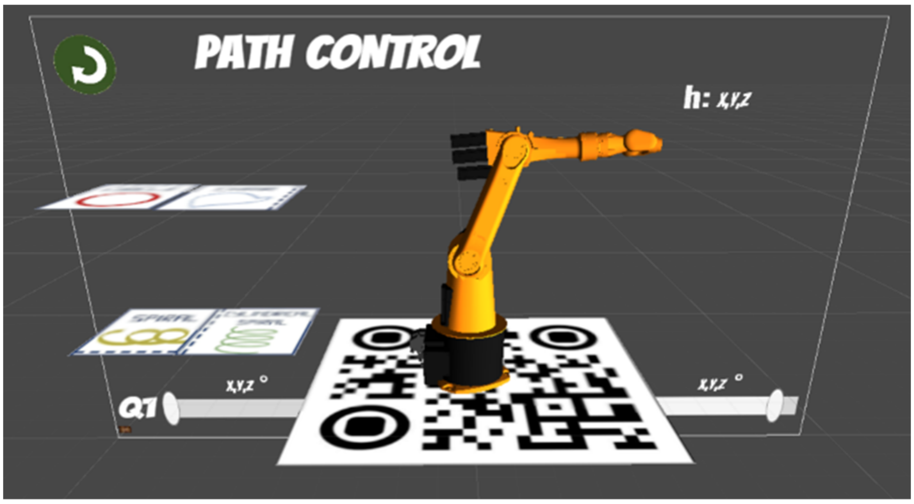

Fig. 8. Scene environment manual and path control.

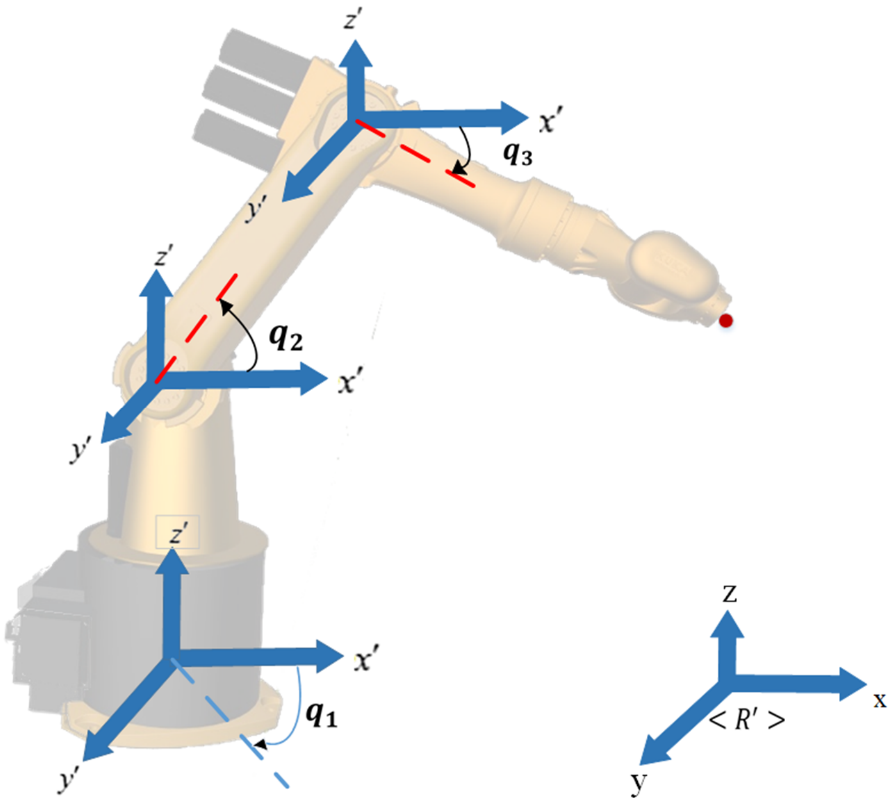

Fig. 9. Robot arm coordinate space.

2.2 Controller

The implemented controller is based on numerical methods given in publication [1], in equation (1) the output of the system to be controlled is represented by h, $\dot{h}$ the first derivative, u the control action, and t the time. The values of $h(t)$ in the discrete time $t = kT_0$, is called $h(k)$ where T_0 represents the sampling time and $k \in \{0, 1, 2, 3, 4, ...\}$.

The use of numerical methods to calculate the evolution of the system is mainly based on the possibility of approximating the state system at the instantaneous moment k+1, if the state and control action over time at the instant k are known, this approach is called Euler's method.

$$h(k+1) = h(k) + T_0 f(h, u, t) \qquad (2)$$

Thus, the discrete model can be expressed by

$$h(k+1) = h(k) + T_0 J(q(k))\, v(k) \qquad (3)$$

The following expression is used, so that the tracking error tends to zero.

$$h(k+1) = h_d(k) - W(h_d(k) - h(k)) \qquad (4)$$

In which, W is the diagonal matrix and its values $0 < \text{diag}(w_{hx}, w_{hy}, w_{hz}) < 1$ are parameters for the proposed controller, h_d is the desired path.

Recital (1) and (2), the system can be rewritten as $Au = b$.

$$\underbrace{J\big(q(k)\big)}_{A}\underbrace{v(k)}_{u} = \underbrace{\frac{h_d(k+1) - W\big(h_d(k) - h(k)\big) - h(k)}{T_0}}_{b} \qquad (5)$$

Therefore, the viable solution method is to formulate it as a constrained linear optimization problem.

$$\frac{1}{2}\|v\|_2^2 = min$$

v) Layer 4 this layer allows the rotation angles obtained from the sliders as well as from the position and trajectory controls developed, to be incorporated to the links (extremities) of the 3D model in order to generate the respective movement that complies with the trajectory entered by the user.

3 Results obtained

This section shows the augmented reality interface and the usability that it has as a technological tool to manage industrial robots, as well as the simulation of a control algorithm that allows users to follow the desired path. To get started with the app, you need to pre-install the APK on your smartphone.

When the application is run and the QR code is focused, the main scene is shown as shown in fig. 10, to exit the AR application press “exit”. Clicking on “introduction” presents a new environment called introduction, pressing the "animation" icon starts the animation of the constituent parts of a robotic arm, as shown in Fig. 11.

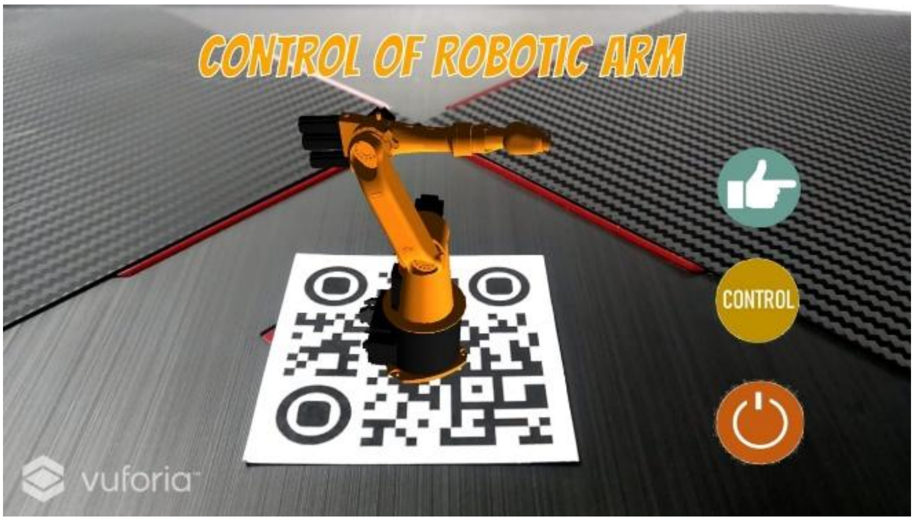

Fig. 10. Main scene of the application when focusing the QR code.

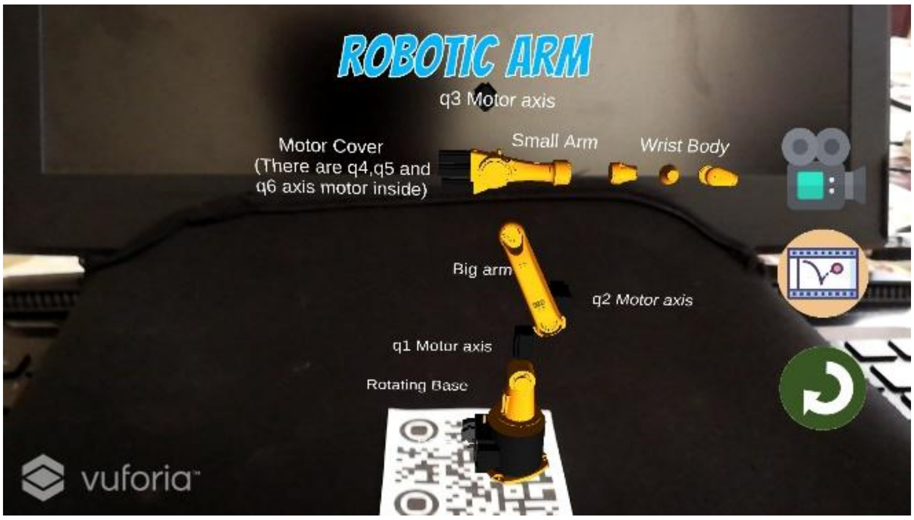

Fig. 11. Animation of robot arm parts.

By clicking on "video" an introductory video is presented containing: general characteristics of a robotic arm, constitution and mathematical modeling, as shown in fig. 12.

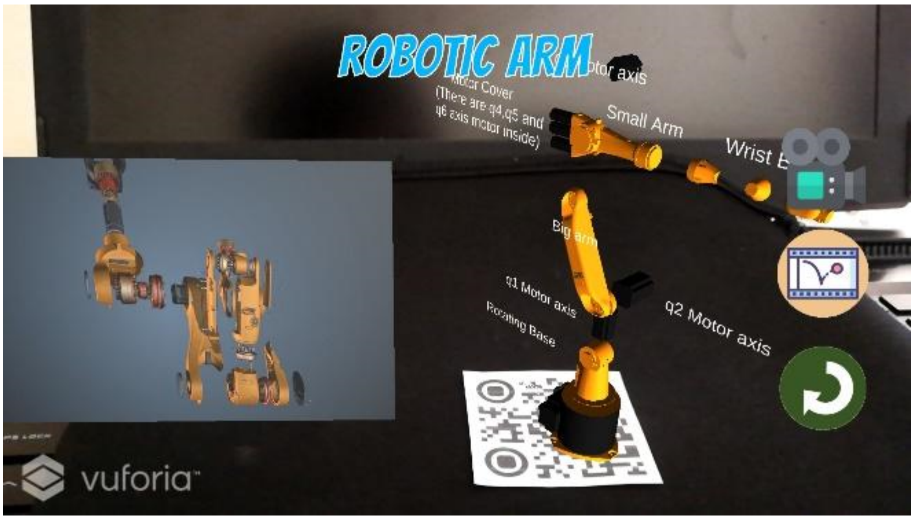

Fig. 12. Video display in AR.

To control the robotic arm, press "control", this shows a scene that contains 3 sliders, as shown in fig. 13, these sliders allow to move the rotation angles of the 3 links, thus performing the manual control, as shown in fig. 14.

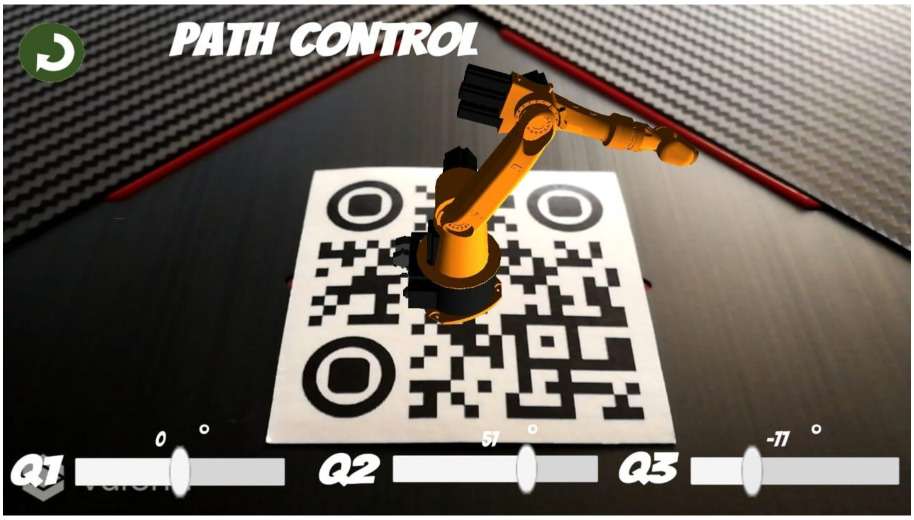

Fig. 13. Robot arm control scene.

For the robot to perform path control it is necessary to focus the path target next to the QR image of the robot arm, when the image is recognized its path appears in 3D, fig. 15 shows the circular path. Clicking on "play" starts the trajectory control in which the operating end of the arm follows the circular trajectory as shown in fig. 16.

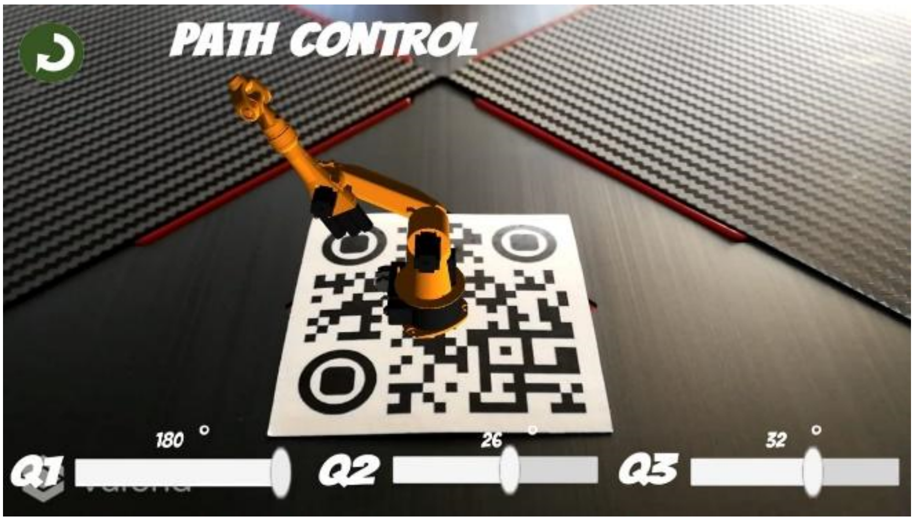

Fig. 14. Manual control of the robot arm when changing parameters q1, q2 and q3.

Fig. 15. Display of the circular path on the robot arm.

The graph of the *x*, *y* and *z* position errors in the AR application as in software Matlab can be seen in fig. 17 and Fig. 18, respectively.

The spiral path of the robot in the AR application can be seen in fig. 19. The fig. 20 and fig. 21 show the graph of the *x*, *y* and *z* position errors in the AR application as in the Matlab under the same conditions respectively.

The cylindrical spiral path of the robot in the AR application can be seen in fig. 22. The fig. 23 and fig. 24 show the graph of the *x*, *y* and *z* position errors in the AR application as in the Matlab under the same conditions respectively.

Fig. 16. Motion of the robot arm on the circular path when applying control.

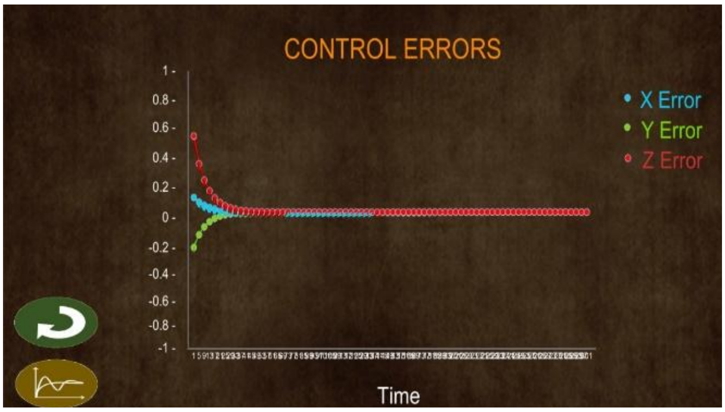

Fig. 17. Position errors *x*, *y* and *z* in the AR application circular path.

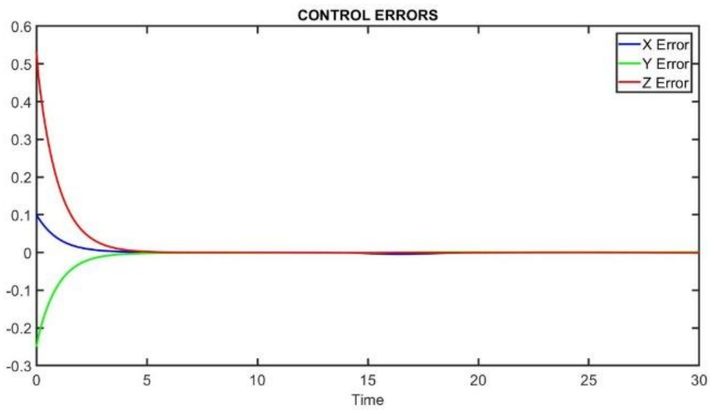

Fig. 18. Position errors *x*, *y* and *z* in Matlab circular path.

Fig. 19. Robot arm movement on the spiral path when applying control.

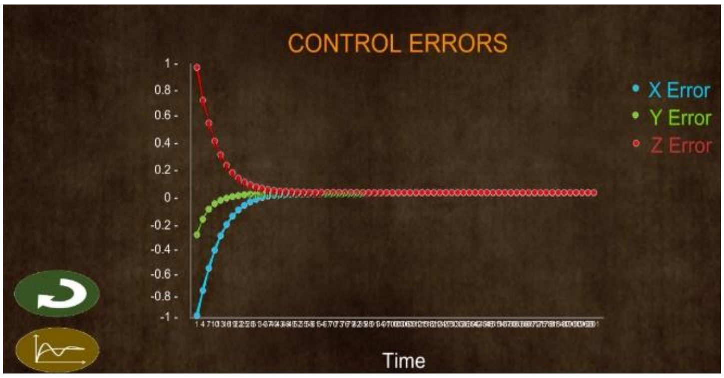

Fig. 20. Position errors *x*, *y* and *z* in the AR application spiral path.

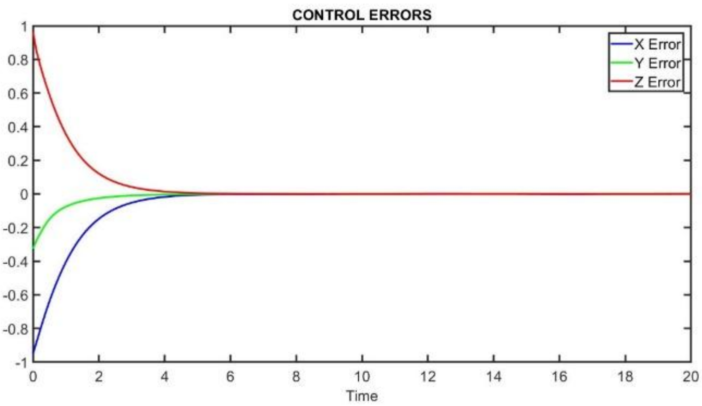

Fig. 21. Position errors *x*, *y* and *z* in Matlab spiral path.

Fig. 22. Motion of the robot arm on the cylindrical spiral path when applying control.

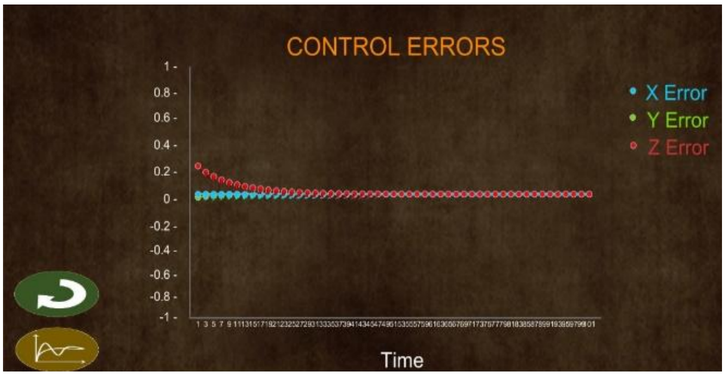

Fig. 23. Position errors *x*, *y* and *z* in the AR application cylindrical spiral path.

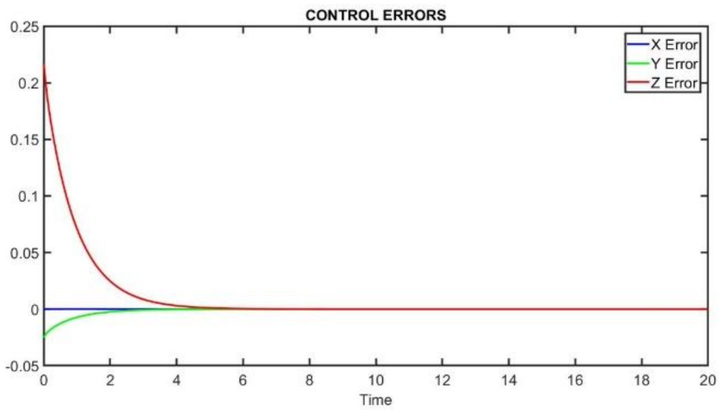

Fig. 24. Position errors *x*, *y* and *z* in Matlab cylindrical spiral path.

Next, the obtained results are shown, that that indicate the validity of the usability of augmented reality, for handling of industrial robots, in a punctual way; in the one of handling and training of industrial robots of three degrees of freedom. The SUS summary evaluation method was used, whose weighting characteristics are described in the document [2]. The sample for the survey is 13 students of the Universidad de las Fuerzas Armadas ESPE of the Electronic Engineering career that are in the last semesters to which a survey of 10 questions was applied according to their experience when using the application. In which it is appreciated in a general way in the scale of styles that generates only a number, the same that represents an average composed by the usability of the application for mobile devices (smartphone), as it is indicated in table 2.

Table 2. Results obtained from the survey.

Questions	Score					Operation
You would like to use the application moderately often				3	10	3.77
Considers that the application is complex and unnecessary	11	2				3.85
The use of the augmented reality application was easy to use				3	10	3.77
You need help or assistance using the application	13					4
The application's functionalities are correctly integrated			2		11	3.69
There is flexibility in using the application			1	2	10	0.31
You think most people would quickly learn to use the application				1	12	3.92
Using the application made it very difficult for him to use	10	2	1			3.69
User interaction was friendly when using the application				3	10	3.77
Considers it necessary to have previous knowledge to use the application	11	2				3.84
TOTAL						34.61

The weighting for the odd questions has a value of 1 to 5, being 1 the worst and 5 the best, while for the even questions, it has a value of 5 to 1, being 1 the best and 5 the worst, these values are multiplied by the number of answers in each question and finally the arithmetic average is obtained. The total obtained, from the sum of the operation of the 10 questions gives as result 34.61; the SUS score is calculated and expressed by means of a multiplication of 2.5 to the total obtained, with which it is determined if the application is feasible for the handling and training of industrial robots, obtaining a percentage of 86.53%, this result represents a high usability for this type of technological tools.

4 Conclusions

The work presents an augmented reality application for smart phones that allows scanning 2D objects and later interacting in the handling of the robotic arm and each of its links, in addition to knowing its parts through animations and multimedia files. Finally, the application allows the visualization of the 3D animation of the robotic arm in the different trajectory control tests established by the user, such as, circular trajectory, spiral and cylindrical spiral, as well as the visualization of the 2D graphics of the control errors, in which it can be seen that the error reaches zero, which indicates that the arm arrives and performs the desired task.

For subsequent works, we will contrast the impact and influence of the application of applied RA in education versus the general teaching methodology, without the implementation of AR technologies; as well as the advantages and disadvantages of learning using this technological tool focused on the assistance and training of industrial robotic arms.

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Using a web application to realize the effect of AR in assessing the environmental impact of emissions source

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Abstract. Revolutionary technologies of nowadays are virtual and augmented reality. Humanity's concern for nature may be affected by their ability to combine reality with the simulated effects of human impact on the environment. An urgent task today is creating software applications to assess the impact of human activities on the environment. Recently, most scientists have been trying to model the impact of various factors on environmental change today and for decades using information technology. Visual models are very impressive and they also make a deep impression on the psychological state of the person. This forces people to use natural resources wisely. In this article we have considered the sequential process of building and implementing models for assessing the impact of pollutants from a stationary emission source. We have created a software product that helps to show visually how the emissions of a chemical plant are spreading to the surrounding city. The harmfulness to the city of the cloud into which emissions are converted can also be calculated by the program. We have implemented a number of functions responsible for emission modeling, taking into account different conditions.

Keywords: web application, pollution, emissions.

1 Introduction

In the era of revolutionary technologies of VR and AR, students have many opportunities for development and learning [17; 24].

In the context of the COVID-19 pandemic, education around the world is making a leap and urgently moving away from traditional learning. Every day more and more applications are created to work in virtual classrooms, to perform virtual laboratory work and conduct experiments [11; 3].

These teaching methods can become a major tool in education and revolutionize learning [12; 7]. Teachers can use VR and AR to interact with different objects in three-dimensional space.

Augmented reality through the educational environment can eventually be crucial to the future of our planet.

Computer visualization is a powerful tool for demonstrating to mankind the crisis state of the planet. The ability to master modern methods and tools of computer visualization allows you to present information in forms that enhance perception, greatly simplifying and accelerating its analysis, synthesis, evaluation and forecasting, which makes these skills an integral tool of modern scientific research and practical activities in the field of nature management and environmental protection.

In the modern world, environmental problems in their social significance have come to one of the first places. The rapid development of human activities led to an intense, often destructive, environmental impact. Human influence on nature occurs both through the transformation of natural systems that have developed over millennia and as a result of pollution of soils [6], water [9], and air [19], [4]. This led to a sharp deterioration in the state of nature, often with irreversible consequences [20]. The environmental crisis is a real danger: in almost every region we are witnessing the rapid development of crisis situations [2].

The development of information technology in particular information tools (services) makes it clear the need to increase the intellectualization of tools for visualization of research results in environment as well as the creation of software that meets the requirements of modern IT which could be easily modified and adapted to constantly changing research conditions [18]. The emergence of a new approach to the visualization of result information can bring systematic environment research to a new level of information perception [8], [23].

The main reason of the work was to develop a mobile application that allows you to minimize the calculation of the range of pollution spread from emission sources and visually understand the algorithm of this dependence

The use of virtual and augmented reality for environmental awareness is not the first tool. But it is difficult to ignore its potential to reach a new audience and effectively educate its impact on pollution.

2 Literature review

Modern visualization technologies using VR and AR are very fully described in works [1; 10; 15].

Augmented and virtual realities are just beginning to be used in environmental education. Here are some examples.

“Every Kid in a Park” is an initiative led by the USDA Forest Service. This application allows you to learn about natural resources, culture and history of the country [25].

“Agents of Discovery” – this game has 50 forests of America. Playing it, you can learn a lot of interesting things about the environment and master the possibilities of augmented reality. This game gives you the opportunity at an early age to start taking care of the environment, forests, their flora and fauna [25].

There is another application that allows you to immerse yourself in the world of the underwater kingdom – Our Ocean Life. This is an exhibit at the Art Science Museum in Singapore, which visually illuminates the huge amount of plastic that people dump [25].

Consider which popular software projects for environmental protection [14; 21] and ecology exist, and can be reformatted and supplemented by augmented reality.

Commute Greener – Offers is the most efficient route on the map, as well as travel sharing in your area [16]. Lea fully – this application warns you when your power consumption goes overboard and requires a reduction. Climate Counts – it is a database which contains most of the world's largest companies, where they are ranked according to their work on climate change [16]. Green Meter is an energy consumption tracker for your car that is designed to identify and change your driving habits in order to save fuel. Pollution is an application for measuring air quality. It also identifies potential sources of pollutants in the air, water, and soil, from plants to power plants. Green Travel Choice is an application that tries to minimize the environmental impact of your trips. Climate Wikience is a free application for fast 3D visualization and analysis of environmental data [16].

3 Research methodology

The distribution of pollutants in the atmosphere around the source of emissions occurs in general according to the laws of the material world, which are mostly known to science in its various fields (Physics, Chemistry, Climatology, Theory of Random Processes, etc.).

The conditions that affect this process can be conditionally divided into the following groups (factors of influence):

- source parameters;
- flare parameters (dust and air mixture);
- Conditions of exit of the torch from the source opening;
- Characteristics of the atmospheric air in the emission zone (external environment) and characteristics of the underlying ground surface.

Consider the simplest model for calculating the range of atmospheric contaminants for a point-in-station discharge facility (enterprise pipe).To do this, we consider 4 consecutive stages of its implementation [21; 23].

The simplest model for the propagation of an individual air pollutant into the air is to take into account the influence of the height (*H*) of the source (i.e. a separate pipe) on the range (*L*) of the air pollution by this impurity. As a rule, this estimate will be rather approximate, but it is used for relatively rough assumptions in the first approximation.

Stage I. The range of propagation of a substance from the source of its release into the atmosphere, depending on its height (*H*) can be estimated by the expression

$$L(H) = K_n \cdot H, \quad (1)$$

where H – is a pipe height, m;

K_n – is a coefficient taking into account the aggregate state of the substance (for gases $K^g{}_n$=120, for solids $K^s{}_n$=90).

As a rule, the effect of the aggregate state is taken into account fairly approximately according to empirical evidence. However, at this stage it is possible to estimate the range of the contamination zone with a fairly satisfactory approximation. Nevertheless, this model allows us to investigate the effect of the height of the emission source on the spread of pollution in the ground layer of the air under unknown other conditions.

As a result of the first stage, we can conclude that by changing the height of the source of emissions into the atmosphere, it is possible to regulate in some limits both the magnitude of the concentration of the substance and the range of its distribution, and therefore the size of the contamination zone.

Stage II. Substances by aggregate state can be attributed to one of the following types: solid, gaseous, liquid and the like. Each of them is characterized by a different rate of sedimentation in the air. This directly affects the residence time of the pollutant in the atmosphere from the moment it is released into the atmosphere until it is deposited on the Earth's surface (or water surface).

It is known that the longer the impurities are in the air, the further they can be attributed to the source of its emission. That is, those over a larger area, different objects will be adversely affected by the polluted atmosphere.

Taking into account the settling velocity of substances of different aggregate state, it is possible to specify the model of the range of impurity propagation in the air. In this embodiment, the model looks like

$$L(H, F) = 30 \cdot (5 - F) \cdot H, \quad (2)$$

where F – is a rate of sedimentation rate of a substance in the air.

It is clear that the heavier the particles of matter, the greater the rate of their deposition, the closer to the source of their emission they fall to the surface of the earth (table 1).

Table 1. Values of the sedimentation rate of some substances in the air F.

Substances	F
Gaseous, aerosols, fine solids with a particle radius $r \leq 0{,}1$ µm (which are the germ of fog droplets and clouds)	1
Aerosols and fine solids at $r \leq 0.1 - 0.5$ µm (with a more than 90% emission purification rate)	2
Extremely solid at $r \geq 1$ µm (less than 75% or in the absence of purification)	3

Stage III. There is a physical pattern that more heated objects (gases, objects, layers of air) rise upwards (at least until their temperatures equalize) with respect to the less heated environment. The force of this direction is greater, the greater the difference between the temperatures of the environment and this object.

In relation to the dust-air mixture emitted by the sources into the atmosphere, this difference is called the torch overheating and is measured by

$$\Delta T = T_f - T_a, \quad (3)$$

where T_f – is the temperature of the torch of the dust-air mixture at the mouth of the source of its emission into the atmosphere;

T_a – is the ambient air temperature.

The magnitude of the lifting force determines the lifting height of the emission torch until the difference between the temperatures of the mixture of emission and ambient air disappears, i.e. $\Delta T \rightarrow 0$. This is a visual explanation of the behavior of the smoke pipes from the pipes of the facilities.

Taking into account the influence of temperature characteristics on the range of contamination, the model gives this expression

$$L(H, F, T) = 30 \cdot H \cdot (5–F) \cdot (1+ \Delta T / 75). \quad (4)$$

Stage IV. Not only air temperature, but also the direction and strength of the wind affects the nature and range of pollutants in the atmosphere. As the wind blows in different directions, as a rule, at different times, with different force throughout the year, impurities from the source spread at different distances in different directions.

The pattern of recurrence of wind directions during a year in certain directions is called the wind rose. We have spread eight octagon, which characterizes 8 directions: north (Mon), northeast (PNS), east (C), southeast (PdS), south (Pd), southwest (PZZ), west (C), north the West (Mon).The average frequency (P) of wind in a particular direction (% or fraction of a unit) is determined according to hydro meteorological statistics and can be used for different periods of time (average annual, season, summer, winter, day, etc.) for different terrain.

Taking into account the wind rose, the model of the range of pollution spread in the emission zone into the atmosphere of a point stationary source is refined.

$$L(H,F,T,P) = 30 \cdot H \cdot (5–F) \cdot (1+\Delta T / 75) \cdot P_i / P_c, \quad (5)$$

where P_i – is the recurrence of wind in the i-th direction;

P_c – is the recurrence of wind in circular wind corners (12.5%).

In recent years, web applications are developing rapidly, gradually replacing desktop solutions and becoming the most important component of the program development in the modern world [5].

A web application is traditionally divided into two parts: client and server [22]. The client part, or just the client, is the “face” of the application, what the user sees. It is responsible for the interface and direct interaction with users. The client prepares responses to it and processes responses from it. It’s providing to make a fast and universal application, which can be used from different devices [13]. That is why, that was chosen for the further development of program, which visualize clouds form changing and emissions from its according to special model of the spread of pollution in the emission zone.

In general, modeling of clouds form changing and emissions from it according to special model of the spread of pollution in the emission zone is divided into the next major steps: Validate Input, Get Wind Side, Calculate Model, Create Cloud, Show Result. Processing of texture objects involves the following: analysis of objects and the selection of appropriate textures, materials or their creation, and then their placement in a scene for each object.

The main method for modeling 3D objects is modeling based on standard sets of devices, which, as a rule, serve as folding objects for folding objects. The process of visualizing objects, as a rule, consists of the following steps: preparing scenes for visualization and setting the appropriate settings.

Nowadays, when the computing power of computers has become quite high, the visualization of various natural phenomena is considered quite demanded by the task, since objects, connected with our environment as the sky or clouds are an integral part of almost any natural scene. All these details have a significant impact on realism and their implementation finds itself in various fields (development of computer games, special effects modeling, and animation creation). In a special way in this series modeling of the sky and clouds is highlighted.

Clouds are dynamic objects whose structure is complex and heterogeneous: their particles are uneven, both on the border and inside the clouds. They are constantly changing and often depend on additional factors. But when rendering attention is paid to particles on the surface of the clouds, as for effects associated with cloudiness, then one of the possible solutions to this problem can be considered the use of particle systems. This method is applied if necessary visualize a large number of small objects that do not have clear boundaries. And its principle is that all parts of the system have a similar appearance, a certain lifetime, and obey the same law of resizing, colors, speeds, etc. This method is often used in modeling such effects like a smoke, fog, and explosion. In our case, this is a suitable way for precipitation modeling.

The first preparation step is checking the side of the wind, which we will use in the future to visualize our system (fig. 1).

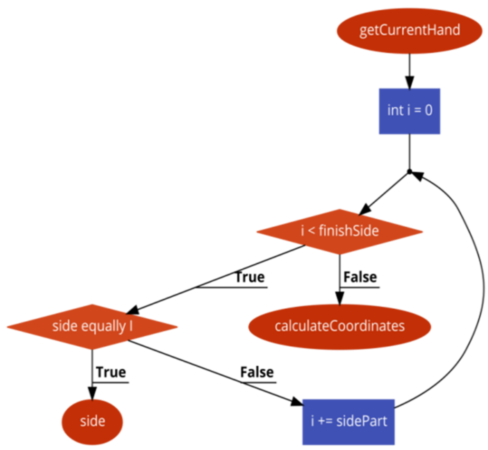

Fig. 1. Checking the side of the wind.

To calculate the distribution distance of clouds form changing and emissions, we use the following model (fig. 2).

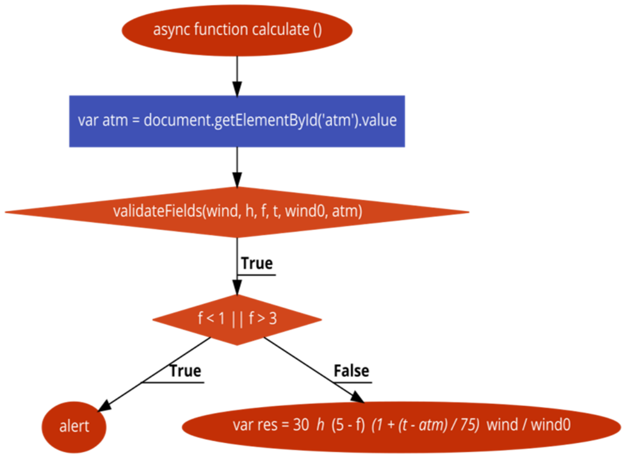

Fig. 2. The distribution distance of clouds.

After calculating we need to prepare some data, which need for visualizing. You can adjust the orientation of the polygon as follows. The vector product of the direction vector of the gaze and any other vector is no collinear with the first. The resulting vector lies in the desired plane. Turning it the right number of times, we get the tops of the panel responsible for the given particle (fig. 3) and (fig. 4).

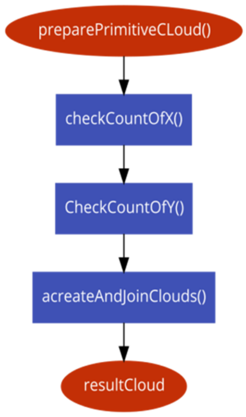

Fig. 3. Visualize cloud.

When implemented, the most important issue is the choice of the number of particles simultaneously present in the scene and the way they are renderings. For cloud's modeling, we use small circle of elements. This allows you to achieve a good visual effect. It is also worth noting that when turning the scene, the particles representing regular polygons can degenerate into segments, so the use of panels (fig. 5).

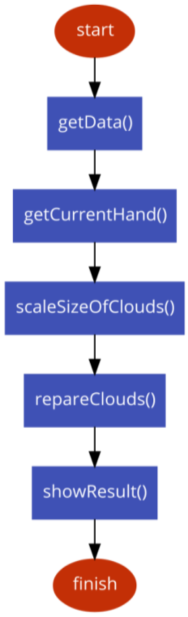

Fig. 4. The general block-scheme of the program.

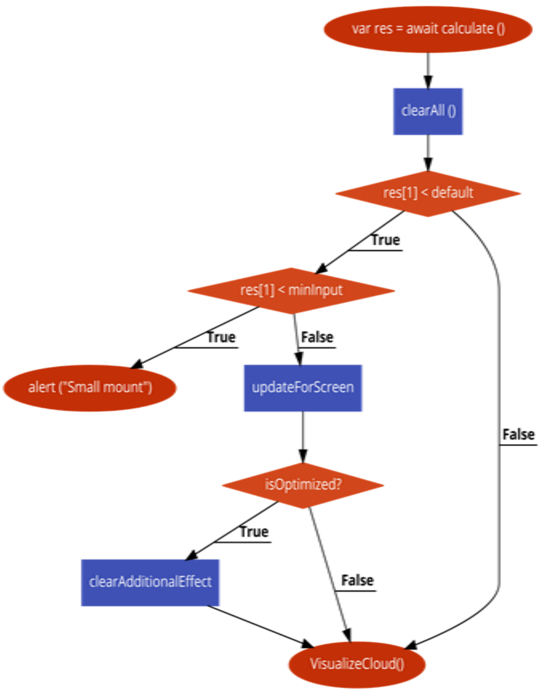

Fig. 5. Degeneration of regular polygons into segments *m*.

4 Results

This application architecture allows you to create a flexible WEB – application quickly. To start working with program you need to follow the link https://emissionvisualizer.herokuapp.com/ First of all, you need to enter data into the appropriate fields. Data will be validated by special function, which shows result for user. The next step is to choose the side of the wind. It is available to choose one of 8 sides. After that you need to click on "Calculate" button to see the results of calculating and visualized cloud (fig. 6).

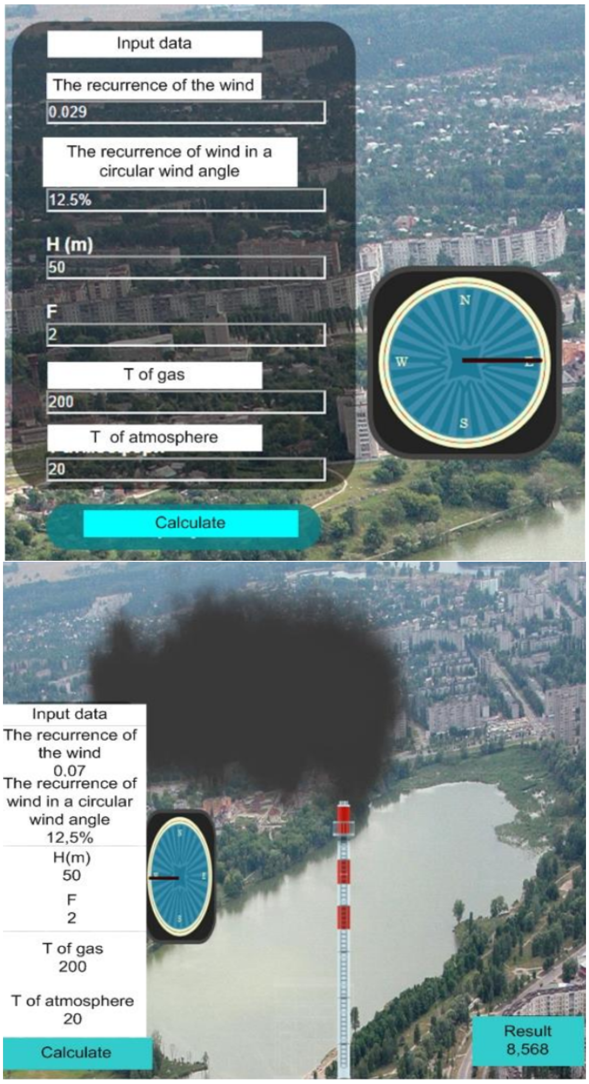

Fig. 6. The appearance of the program.

5 Conclusions

Therefore, different recurrence of wind in different directions causes different range of pollutants spreading from the source of their emission and accordingly influences the peculiarities of the shape of the zone of pollution.

The considered model of estimation of the range of pollutants from the source of their emissions is the basis for the calculation of the sanitary protection zone of the enterprise and used to develop a mobile application (a computer program) for the convenience of calculating the possible impact on a real business entity.

This model provides opportunity to calculate the range of distribution for different clouds. Using it we can show 3D object for the cloud scale analysis.

The next project will be devoted for studying environmental pollution by all chemical factories in our country. The number of photographs of chemical enterprises in various cities of our country will be increased and wind roses for them will be calculated with the help of this application. The next step is the photos will be used as markers for creation AR, which will combine the image of the pipe with which the emission moves with the territory of the city. We can see ourselves at any factory in our country while being at home or in the classroom. The development of this laboratory work will be introduced into the educational process of students of the specialty Environmental Protection Technologies.

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Development of AR-applications as a promising area of research for students

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Abstract. The article substantiates the importance of using augmented reality in the educational process, in particular, in the study of natural and mathematical disciplines. The essence of AR (augmented reality), characteristics of AR hardware and software, directions and advantages of using AR in the educational process are outlined. It has proven that AR is a unique tool that allows educators to teach the new digital generation in a readable, comprehensible, memorable and memorable format, which is the basis for developing a strong interest in learning. Presented the results of the international study on the quality of education PISA (Programme for International Student Assessment) which stimulated the development of the problem of using AR in mathematics teaching. Within the limits of realization of research work of students of the Borys Grinchenko Kyiv University the AR-application on mathematics is developed. To create it used tools: Android Studio, SDK, ARCore, QR Generator, Math pattern. A number of markers of mathematical objects have been developed that correspond to the school mathematics course (topic: "Polyhedra and Functions, their properties and graphs"). The developed AR tools were introduced into the process of teaching students of the specialty "Mathematics". Prospects of research in development of a technique of training of separate mathematics themes with use of AR have been defined.

Keywords: augmented reality, mobile application, math, student research, computer science.

1 Introduction

As practice shows, the traditional forms and methods of realization of educational process, which was effective for another 10–20 years ago do not always work efficiently in today's digital realities. Today's youth, who are accustomed to routinely working with mobile technology and gadgets, which provide excellent visualization of the phenomena and processes of the environment [8; 24; 28; 29], is faced with a situation of extremely limited use of digital technologies in the educational process. Occurs a significant contradiction – the powerful technological, methodological and didactic tools through which students learn about the world outside of the educational process are not actually used in school. However, the results of international studies of education quality PISA by 2018 [13] described a disappointing picture of the Ukrainian school education: the level of mathematical and scientific literacy among high school students is assessed lower than average.

Improving the quality of school readiness, we see in the skillful implementation of digital technologies in the educational process, the harmonious combination of the latest technology with the best practices of traditional high school. In addition, the powerful capabilities of digital technology, for example, in the context of visualization of the educational material using AR can increase the interest of pupils to learn, especially in the context of the study is not popular enough now subjects of natural science and mathematical area. Therefore, training of future teachers to the development and use of digital technologies in professional activity is considered an important task of modern higher education.

2 Literature review

Recently, a number of studies have been carried out outlining various aspects of the use of AR in educational and scientific processes. Thus, H. Kravtsov, P. Nechypurenko, V. Potkonjak and A. Striuk described the directions of work of virtual laboratories for education in science, technology, and engineering [9; 18; 20; 25]. S.-C. Chang and G.-J. Hwang revealed the possibilities of using AR in student research and substantiated the benefits of augmented reality-based educational process [4; 6]. D. Furió et al. carried out a comparative analysis of mobile learning (including AR technology) with traditional [5]. E. Kurilovas, O. Lavrentieva and V. Tkachuk considered the use of VR, AR and MR in the educational process [11; 12; 30]. In the study of M.-B. Ibáñez, S. Delgado-Kloos, theoretical and methodological foundations of the use of AR for the organization of STEM learning were revealed [7]. M. Shyshkina disclosed augmented reality as a tool for open science platforms by research collaboration in virtual teams [22]. N. Rashevska, A. Striuk, Yu. Yechkalo and S. Zelinska explored the methods of using AR in training engineering students [21; 26; 31; 32]. O. Merzlykin et al. outlined the problem of developing key competencies in the application of AR [14]. S. Semerikov and others presented a historical and pedagogical excursion of the use of AR in educational and scientific activities [27], etc. The problem of developing applications for AR has become the subject of research by a number of scientists, with particular attention to the researches of L. Midak et al. for the development of primary school applications [16; 17;].

Noteworthy are the scientific explorations on the use of various aspects of AR in the process of mathematics teaching: S. Shokaliuk and H. Sollervall – implementation of mobile mathematics teaching [15; 23], K.-E. Chang and L. Bilousova – the use of game techniques in teaching mathematics [3; 19], K. R. Bujak – research of psychological aspects of mathematics training [2], K. K. Bhagat and T. H. Kramarenko – application of GeoGebra for teaching geometry [1; 10] and others.

3 Research methodology

The purpose of the article is to discover the possibilities of using augmented reality technologies in education and to develop a mobile augmented reality application for teaching mathematics.

In the course of the research the following methods were used: analysis of the scientific and pedagogical literature on the separation of theoretical foundations of the use of augmented reality in the educational process; analysis of online resources, methodological literature on generalization of augmented reality opportunities and benefits; study and generalization of pedagogical experience on the use of augmented reality in the educational process; a survey on the effectiveness of augmented reality tools in the educational process.

The article is performed within the scientific topic of the Computer Science and Mathematics Department of Kyiv University Borys Grinchenko “Theoretical and practical aspects of the use of mathematical methods and information technologies in education and science”, state registry number 0116U004625.

4 Results and discussion

Augmented Reality (AR) is a technology that uses fixed or mobile camera devices (smartphones, tablets, AR glasses, etc.) to enrich the real world with computer content. Unlike Virtual Reality (VR), which ensures complete immersion of a person in a virtual space, AR lets you superimpose on top of environmental virtual information (graphics, video, sound and so on). That is actually augmented reality can be viewed as a complement to the physical world with digital data in real-time.

In order to establish a link between the real world and computer content, you need to read the Image Target (marker) and link coordinate systems of the real (recorded) and to imaginary computer content.

Under the marker is usually understood as the object of a special image (e.g., QR code), which is located in the surrounding space. It’s analyzed by special software for further reproduction of virtual objects. The program is using the camera receives information about the set-another marker in space and projects it on a virtual object that simulates the effect of his presence in the surrounding space. It should be noted that the program shows the programmed result when the sensor for-a system reads the marker. This makes it possible to distinguish virtual objects from the real world. So, the app works on the principle of detection of markers. They are used as the basis for creating the computer system of coordinates through which to display augmented reality. For convenience, the markers can be plotted on a sheet of paper or presented on a computer screen.

Typically, researchers use various algorithms of image recognition in accordance with the markers, which can vary greatly. So, markers can be three-dimensional figures, and even the eyes or the face of a man. If you use high-quality models and additional graphics filters, you can achieve that the virtual object will become almost real and difficult to distinguish from the surrounding interior.

Today in the pedagogical literature allocate the various areas of research AR. The first direction is connected with studying of VR and AR technologies as a trend in the information technology industry, the basics of creating applications. The second area is the pedagogical design of learning tools based on the technology of virtual and augmented reality. Third is selection and experimental validation of organizational and pedagogical conditions and methods of effective use of AR in the educational process.

Hardware components for augmented reality is the CPU, display, sensors and input devices. Augmented reality types of devices used can be divided like this:

- HMD (head mounted display) – unit which is fixed on the head of the user and gives the opportunity to see the image of the virtual, augmented or mixed (hybrid reality MR as synthesis, VR and AR), creating a maximum effect of the presence;
- mobile device that has more computing power, various sensors, make this device suitable platform for augmented reality; the display of the mobile device implements profound methods of superimposing graphics on the real scene, in the general case is called a portable or handheld augmented reality display (handheld displays);
- personal computer, which in the presence of a web camera allows the user to see themselves when interacting with virtual objects;
- video projector, an optical element, a hologram, etc. means to overlay graphical information of the physical real objects without the need for a person to wear or hold the display; this means they form the so-called spatial augmented reality. Note that the choice of a particular device depends on the specific goals and objectives of using AR.

In addition to the considered marker AR technology (or image recognition), there are the following types of augmented reality:

- markerless AR uses technologies such as GPS – global positioning system, compass, speed sensor, gyroscope and accelerometer to provide information in accordance with the position of the user. Sometimes this technology is also called a base axis coordinate or GPS-axis. Thanks to the massive use of smartphones and tablets this technology is quite popular (for example, refer to directions in the process of finding the location of objects on the map);
- projection AR, which involves the design of artificial light on an object (physical surface) and allows it to interact with it (called holograms);
- AR-based overlay that allows you to completely or partially replace the original object with an enlarged one. This technology is considered to be the most promising area of AR development.

There are various augmented reality libraries available today that you can use to create your own application. Let's highlight the ARToolkit library, the first and most popular open source augmented library. This library has a number of sub-libraries. An ARTag sub-library, has sophisticated marker search algorithms that allow you to find markers more efficiently, even with variable lighting and minor bends or overlaps of the marker. In addition, the ARToolkit library has many sub-libraries written in a specific programming language, such as NyARToolkit for Java and JSARToolkit for

JavaScript. Therefore, the choice of application development tools, as well as display devices, depends on the ease of use of certain libraries when solving a particular problem.

Table 1. Summarizes the augmented reality libraries [27].

AR-Framework	Company	License	Platform Support
Vuforia	Qualcomm	Free and paid	Android, iOS, Unity
ARToolkit	DAQRI	Free	Android, iOS, Windows, Linux, macOS
Kudan	Kudan Limited	Paid	Android, iOS, Unity
Wikitude	Wikitude GmbH	Trial and paid	Android, iOS, Web
EasyAR	VisionStar Information Technology	Free	Android, iOS, Windows, Linux, macOS, Web

Augmented reality has a significant, but not yet up to the end opened potential for use in the educational process of institutions of secondary and higher education. However, the experience of the authors regarding the use of AR in educational process allows highlighting the benefits of such use:

1. *Visibility*. Any object or process that is created by using AR it is possible to study the detailed, under different angles.
2. *Concentration*. A person that uses AR focuses on the material study and is not distracted by other external stimuli.
3. *Manageability*. AR allows the educator to fully control and change the learning scenario according to the students' abilities, the problem solving process, and the like.
4. *Safety*. With AR technology it is possible to conduct experiments in a safe mode.
5. *Effectiveness*. Sufficient motivation of pupils and students to study a discipline using AR is the guarantee of quality education.

To date, scientists have developed a many of programs for the use of augmented reality technology in mathematics, physics, chemistry, biology, astronomy, foreign languages, etc. Consider some of the AR applications for implementation of the educational process in mathematics. So, the "Academy of intellectual development SMARTUM Ukraine" developed a mobile application with augmented reality for the course "Mental arithmetic". In addition, it is worth highlighting the application of 3D Graphics GeoGebra that allows you to create geometric constructions in 3D, save and share your results. The program allows you to create 3D objects, to build section and find the point of intersection. Among the programs that also let you work with 3D models in augmented reality for basic geometric shapes is to provide the following: Geometry – Augmented Reality, AR Geometry Geometría – Realidad, Aumentada, CleverBooks Geometry, ARGEO so forth. At the same time, it should be noted that it is still underdeveloped remains the development of AR programs for learning algebra.

We have a deep belief that AR allows better actors learning to absorb information, store it in large volumes. Contribute to this are highlighted above the benefits of AR, which promote increase of interest of students to academic discipline, development of creativity, and the like. Thus, AR is actually acts as a kind of unique tool set that allows teachers to present learning material for the new "Digital Natives" in convenient for perception, understanding, learning and memorizing the format that is the basis of formation of steady interest in learning.

It is clear that the development of the content, forms and methods of realization of educational process using AR is an important task of modern researchers-methodologists. We believe that special emphasis should be placed on the use of AR in the study of natural and mathematical disciplines, in particular, mathematics. The importance of the outlined task has been driven by the disappointing results of the 2018 International PISA Education Survey [13]. This study, which was launched by the Organization for Economic Cooperation and Development (OECD) for over 20 years, is one of the most respected sources of information on secondary education in the world. To date, more than 80 countries are participating in the study. Government officials trust the PISA results and use them to adopt sound education development strategies and tactics. Detailed information on the results of educational achievements of Ukrainian 15-year-old teens in mathematics, which were rated lower than average, outlined a number of problems:

- Students are mostly only able to answer mathematics questions about a known context where information is provided in full and the question is clearly formulated.
- Students are only able to perform simple procedures, such as arithmetic operations, according to direct instructions in obvious situations.

The obtained results of an international study of the quality of education PISA [13] allowed us to draw attention to the problem of development and use of AR in learning mathematics. In fact, we see AR technology as a means of improvement of mathematical training of students.

Given that one of the most important components of professional training of students is the research work, we were set the task of developing AR-applications of mathematics in the research activities of CS-students at Borys Grinchenko Kyiv University.

The key to the implementation of such assignments were made by the following methodological principles:

- Augmented reality in the study of mathematics, first of all, helps to visualize mathematical objects (geometric shapes, bodies of function graphics, etc.). Let's notice also that the augmented reality in the course of studying of mathematics gives such possibilities, as moving, rotation, scaling of 3D-models, their consideration under any angles, connections and disconnections of virtual objects and studying of the received results and so forth;
- The research work of students is a mandatory, integral part of professional training at the university. Development of students' research work system is the most

important function of the educational system and important statutory activity of the university as an educational institution.

Despite the above advantages of augmented reality in the educational process, denote the number of weighty issues. First, remain insufficiently developed techniques of using AR. Second, the existing limitations in methodological and didactic literature on the implementation of learning through AR technology. Third, the significant lack of AR – applications of mathematics as learning tools. The problem of the limited teaching facilities, we partially tried to solve by attracting students to design their own augmented reality object using specialized software. Note that this activity has a pronounced interdisciplinary character, because it promotes effective integration of such industries as information technology and mathematics.

To develop the application used the following tools:

- Android Studio (the IDE for Android platform) and the SDK (a set of development tools, utilities and documentation that allows you to create application programs on a particular technology or platform-specific);
- ARCore (set to develop software from Google that allows you to build apps AR);
- QR Generator (a tool for creating QR codes);
- Pattern Math (library of the mathematical models).

Let's present the code of the program for rendering of the image in AR space (fig. 1).

The next step in organizing the research work of computer science students was to develop a bank of models that fit the school math course. We chose two topics: polyhedra for grade 11, as well as functions, their properties and graphs for grade 10. What caused the choice of these topics? Polygons are known to be the central subject of stereometry training, which has a variety of material for the development of spatial representation, imagination combined with logic, and the like. Considering that one of the main tasks of mathematics teaching is the formation of abstract thinking students, it is necessary to pay attention to such important aspects of mathematics teaching as making connections between a function that is given in analytical and graphical form, plotting functions by means of transformations, etc.

In fig. 2, you can see examples of our developed QR code images to display augmented reality models.

The developed application and markers for it were tested by students of the specialty "Mathematics" of the Borys Grinchenko Kyiv University during December 2019 - February 2020 within the study of the discipline "Methods of teaching mathematics". Users were offered a printed set of algebra and geometry problems containing AR markers. Capturing the camera turned on when you started the app on your mobile device. The user points the camera at a task so that the marker is within the camera's viewing area, a three-dimensional object, which is a visualization of the mathematical task, is displayed on the screen. Examples of images obtained with markers (fig. 2) are shown in fig. 3, 4.

As the analysis of the use of the application developed by us in the process of studying the discipline "Methods of teaching mathematics" shows, didactic materials enriched with AR have a number of advantages:

- the teaching methodology only needs correction, its cardinal revision is not required;
- paper manuals used by the participants in the educational process are not canceled, but their capabilities are significantly expanded;
- the features of traditional paper educational materials are increased in the direction of presenting information through text, three-dimensional animation and sound, etc.

```
public class MyARNode extends AnchorNode {

    private AugmentedImage image;
    private static CompletableFuture<ModelRenderable> modelRenderableCompletableFuture;

    public MyARNode(Context context, int modelid)
    {
        if (modelRenderableCompletableFuture == null)
        {
            modelRenderableCompletableFuture = ModelRenderable.builder()
                    .setRegistryId("my_model")
                    .setSource(context, modelid)
                    .build();
        }
    }
@SuppressLint("NewApi")
public void setImage(final AugmentedImage image){
        this.image = image;
        if (!modelRenderableCompletableFuture.isDone()){
            CompletableFuture.allOf(modelRenderableCompletableFuture)
                    .thenAccept((Void aVoid)-> {
                        setImage(image);
                    }).exceptionally(throwable -> {
                        return null;
            });
        }
        setAnchor(image.createAnchor(image.getCenterPose()));

    Node node = new Node();
    Pose pose = Pose.makeTranslation(0.0f, 0.0f, 0.25f);

    node.setParent(this);
    node.setLocalPosition(new Vector3(pose.tx(),pose.ty(),pose.tz()));
    node.setLocalRotation(new Quaternion(pose.qx(),pose.qy(),pose.qz(),pose.qw()));
    node.setRenderable(modelRenderableCompletableFuture.getNow(null));

    }

    public AugmentedImage getImage() {
        return image;
    }
}
```

Fig. 1. Image rendering code in AR.

Fig. 2. Specially created labels for reading information.

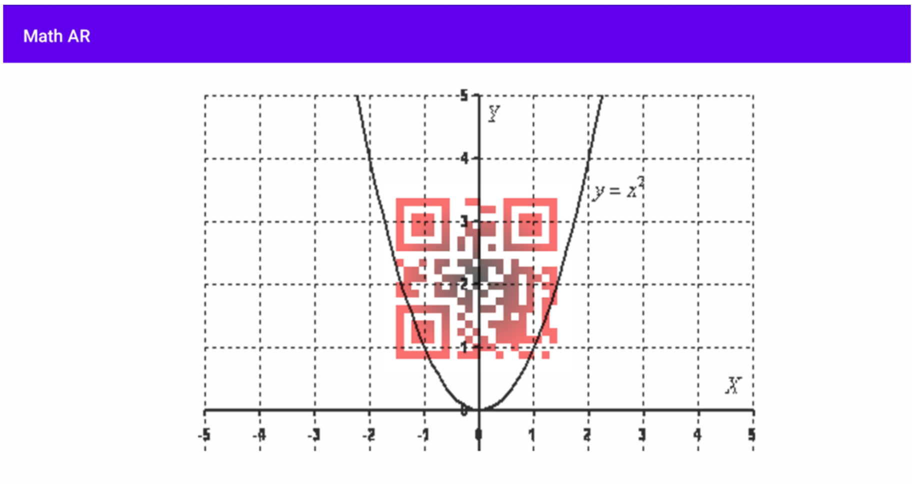

Fig. 3. Parabola in the application, polygonal view.

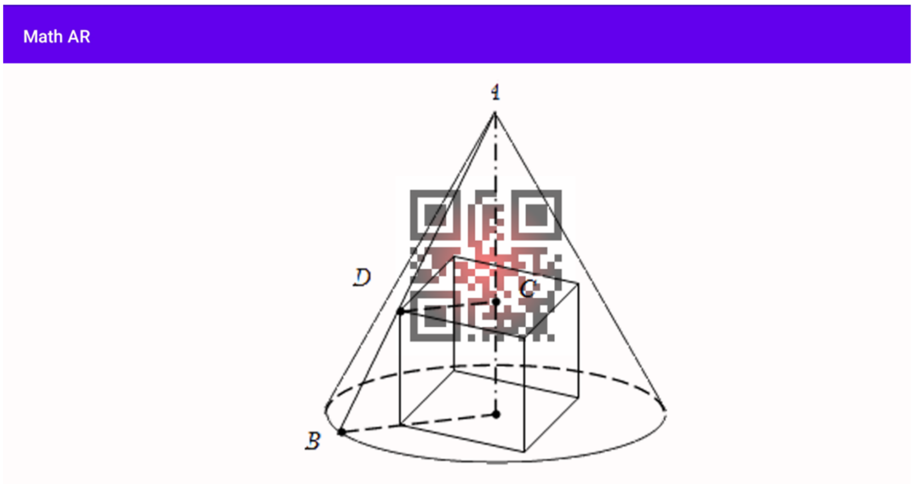

Fig. 4. The parallelepiped is inscribed in a cone in the application, polygonal view**.**

In April 2020, the application developed by us was proposed for testing to 114 individuals, namely: 52 students of 10th grade, 38 students of 11th grade, and 24 students of higher education institutions. All respondents are students of different schools and courses in programming in Kyiv. The survey found that 94 people were comfortable using the app. However, only 48 students are sure that they would like to have augmented reality subjects. This may be due to the fact that the vast majority of respondents do not yet have experience in using AR in the educational process. This clearly indicates that the problem of organizing the educational process with AR requires further scientific and methodological research.

5 Conclusions

As a result of separation of essence, technical and software, directions of use of AR, the advantages of using AR technology in the educational process (clarity, focus, controllability, safety, efficiency) are established. It is proven that AR is a unique tool that allows educators to teach the new digital generation in a readable, comprehensible, memorable and memorable format, which is the basis for developing a strong interest in learning.

The results of an international study of the quality of PISA education have become the basis for the development of the problem of using AR in the process of teaching mathematics. Within the limits of realization of research work of students of the Borys Grinchenko Kyiv University of the AR-application on mathematics was developed as an important component of their professional preparation. To create it, you have used the following tools: Android Studio, SDK, ARCore, QR Generator, Math pattern. A number of math markers have been developed to fit the school's math course (Topics: Polyhedra and Functions, Their Properties, and Graphs). Surveys of people who tested the application (students of the specialty "Mathematics" of Borys Grinchenko Kyiv University and Internet users) received positive feedback.

The prospect of further research is seen in the development of a methodology for teaching specific topics in mathematics using AR.

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Development of a model of the solar system in AR and 3D

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Abstract. In this paper, the possibilities of using augmented reality technology are analyzed and the software model of the solar system model is created. The analysis of the available software products modeling the solar system is carried out. The developed software application demonstrates the behavior of solar system objects in detail with augmented reality technology. In addition to the interactive 3D model, you can explore each planet visually as well as informatively – by reading the description of each object, its main characteristics, and interesting facts. The model has two main views: Augmented Reality and 3D. Real-world object parameters were used to create the 3D models, using the basic ones – the correct proportions in the size and velocity of the objects and the shapes and distances between the orbits of the celestial bodies.

Keywords: augmented reality, virtual reality, ARCore, planet, solar system.

1 Introduction

1.1 Problem statement

The development of technology in the 21st century is extremely fast. One of these technologies is Augmented Reality (AR). This technology has a direct vector in the future. The urgency of the introduction of augmented reality technology, especially in the educational process, is that the use of such a new system will undoubtedly increase students' motivation, as well as increase the level of assimilation of information due to the variety and interactivity of its visual presentation.

Augmented reality is a concept that describes the process of augmenting reality with virtual objects. Virtual reality communication is performed on-line, and only the camera is required to provide the desired effect – images that will be complemented by virtual objects. The relevance of the introduction of augmented reality technology in the educational process is that the use of such a new system will undoubtedly increase students' motivation, as well as increase the level of assimilation of information due to the variety and interactivity of its visual presentation [12]. ARCore is a state-of-the-art cross-platform kernel for application creation, designed for the entire development process to take place in the bundled integrated development environment.

1.2 Literature review

Vladimir S. Morkun, Natalia V. Morkun, and Andrey V. Pikilnyak view augmented reality as a tool for visualization of ultrasound propagation in heterogeneous media based on the k-space method [9].

Mariya P. Shyshkina and Maiia V. Marienko considering augmented reality as a tool for open science platform by research collaboration in virtual teams. Authors show 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 [13].

Tetiana H. Kramarenko, Olha S. Pylypenko and Vladimir I. Zaselskiy view prospects of using the augmented reality application in STEM-based Mathematics teaching, in particular, the mobile application 3D Calculator with Augmented reality of Dynamic Mathematics GeoGebra system usage in Mathematics teaching are revealed [7].

Pavlo P. Nechypurenko, Viktoriia G. Stoliarenko, Tetiana V. Starova, Tetiana V. Selivanova considering development and implementation of educational resources in chemistry with elements of augmented reality, and as a result of the study, they were 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 [10].

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 view the application of augmented reality technologies for the preparation of specialists in the new technological era [4].

Lilia Ya. Midak, Ivan V. Kravets, Olga V. Kuzyshyn, Jurij D. Pahomov, Victor M. Lutsyshyn considering augmented reality technology within studying natural subjects in primary school [8].

Aw Kien Sin and Halimah Badioze Zaman [14] researching the Live Solar System (LSS), which is a learning tool to teach Astronomy. They are user study was conducted to test on the usability of LSS, in findings of the study concluded that LSS is easy to use and learn in teaching Astronomy.

Vinothini Kasinathan, Aida Mustapha, Muhammad Azani Hasibuan and Aida Zamnah Zainal Abidin in the article [6] presents an AR-based application to learn Space and Science. They are concluded that the proposed application can improve the ability of children in retaining knowledge after the AR science learning experience.

There are currently several software products that simulate the solar system. Consider some of them.

The AR Solar System application [1] uses AR technology, which was implemented using the Vuforia service. This application provides the opportunity to see the planets of the solar system directly in front of you. At the same time, there is no interaction with the user, except for the ability to choose the screen orientation: horizontal or vertical. When launched, the application automatically selects the location of the planets and this is not always successful. Besides, if you change your location, the location of the planets does not change. The planets revolve around the Sun and its axis, but this is the whole functionality of the application.

The Solar System AR application [11] involves printing or opening a special card on another device, which will then display the planets. At startup, you need to place an image in front of the phone's camera, which consists of squares in which the first letters of the name of the planet are written. As a result, the planets begin to appear along with the soundtrack. However, with the slightest movement of the phone's camera, all the planets disappear and begin to reappear, as does the soundtrack. Similarly, as in the first application, there is no interaction with the user.

The next analog is the Solar System (AR) [17]. The application has much more functionality than the previous two: there is a menu where you can go to the introduction, which tells some interesting facts; the very reflection of the solar system; quiz, which contains questions about the structure, characteristics, features of all objects. By selecting the transition to the solar system, the application places the Sun in the center of the screen, all the others – on their axes, which, incidentally, are located inconsistently with reality. By clicking on any planet, you can see minimal information about it with sound.

Another application that is worth noting is the Solar System Scope [5]. This application has good graphics: from the download bar to display the planets themselves. There are also constellations and a large number of stars that are not usually reflected in the solar system. The application has music in space style; there are enough settings to make the application convenient for each user. In particular, the planets can be enlarged, reduced, rotated 360°. Having chosen any planet or star, you can see it in section, read about it quite detailed information. There is a function to search for planets, stars, comets, constellations, etc., display in real-time or in the past or future, and accelerate the pace of rotation. That is, this application has many advantages and is very convenient for studying all space objects. However, it does not use augmented reality.

2 Methods

2.1 Why ARCore?

The *purpose* of the article is to develop an application that implements the Solar System model in AR and 3D.

Today AR is developing rapidly. There are already many platforms where you can create applications with this technology: ARToolKit, Cudan, Catchoom, Augment, Aurasma, Blippar, InfifnityAR, Layar SDK, Vuforia and more. This work will use ARCore, a platform developed by Google as a tool for creating augmented reality applications. Its advantages over others are: it is well-developed, provides many features, has content documentation, is free, compatible with the Unity engine [2; 3].

There are two main actions of ARCore: finding the current position of your device while moving and shaping your 3D world. For this purpose, technologies are used to track the position of the phone in the real world using its sensors; understanding of the shapes of the environment, finding the vertical, horizontal and angular surfaces of the plane; lighting assessment.

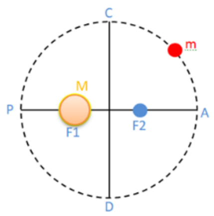
The position of the user along with the device is determined by various sensors (accelerometer, gyro) built into the gadget itself. At the same time, there are so-called key points and their movement is being explored. With these points and sensor data, ARCore determines the tilt, orientation, and position of the device in space.

To find the surfaces, move the camera. This is to help ARCore build it's real-world based on moving objects. Even if you leave the room and then return, all of the objects you have placed will remain in place, remembering their location relative to the key points and the locations relative to the world built by ARCore.

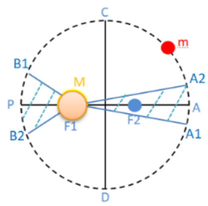
Lighting is also evaluated. This is done using signal recognition: the main light is the light emitted by an external source and illuminates all around; shadows that help you identify where the light source is; shading – is responsible for the intensity of illumination in different areas of the object, that is, helps to understand how remote from the source are parts of it; glares that seem to glow, that is, directly reflect the light stream from the source and vary depending on the position of the device relative to the object; a display that depends on the material of the illuminated object. By the way, the formed idea of illumination will influence the illumination of objects placed by the user. For example, if you place one 3D model by the window and the other under the table, the first will be bright and the other as if in shadow. This creates the effect of reality.

2.2 Modeling the movement of astronomical objects

Long-standing scientists have been trying to understand how objects move in the solar system. Most accurately the motion of planets, stars, asteroids – all objects – was characterized by Kepler, who discovered the three laws on which Newton derived the formula of gravity.



a)



b)

Fig. 1. Graphic representation of the first (a) and second (b) law of Kepler.

The first law states that all planets move in elliptical orbits (trajectories) in one of the focuses of which is the Sun. That is, all planets move around the center of mass, which is in the Sun because its mass is much larger than the mass of any planet. Figure 1 (a) show the elliptical orbit of the planet, the Sun with mass M, which is several times the mass of the planet m. The sun is in focus F1. The point closest to the Sun in the orbit of P is called perihelion, and the farthest A is aphelion or apogeal.

Another important concept is the eccentricity, which characterizes the degree of compression (elongation) of the orbit (table 1).

Table 1. The shape of the orbit depending on the eccentricity.

The value of the eccentricity	0	(0; 1)	1	(1; ∞)	∞
The orbit shape	circle	ellipse	parabola	hyperbola	straight

By Kepler's second law we learn that each planet moves so that its radius vector (the segment connecting the planet and the sun) passes the same area over the same period. Figure 1(b) shows that for the equivalent time *t*, during which you can go from point A1 to A2 and from B1 to B2, the identical areas S are throws.

This law explains why the movement of the planet accelerates as it approaches perihelion and decelerates when it reaches aphelion. That is, for these areas to be the same, the planet must move faster if it is close to the Sun and slower if far away. This law determines the speed of movement of the celestial body.

He also determined that the squares of the planets' rotation periods (*T*) refer to each other as cubes of the large hemispheres (*a*) of these orbits. This is Kepler's third law.

$$\frac{T_1^2}{a_1^3} = \frac{T_2^2}{a_2^3} \tag{1}$$

However, these laws are not enough to accurately describe the movement of all bodies. After all, they work only when the weight of one body in the group under consideration is significantly higher than the other. That is, if you consider the planet and its satellite, they will not work. Newton was able to correct it. He changed the third law by adding mass to it.

$$\frac{a_1^3}{a_2^3} = \frac{T_1^2}{T_2^2} \cdot \frac{M-m_1}{M-m_2} \tag{2}$$

The main force that controls the motion of the planets is the force of gravity. However, if bodies were attracted only to the Sun, they would move only according to Kepler's laws. In fact, the bodies are attracted not only by the sun but also to each other. Therefore, nobody in the solar system moves in a perfect circle, ellipse, parabola, etc.

Considering the basic algorithms of the program and the principles of motion of the planets, we can distinguish the basic parameters (table 2 and table 3) that you need to know about objects: eccentricity (ε), perihelion, a period of rotation around the Sun (orbital period), equatorial radius (the radius of the planet), the angle of inclination of the axis, the period of rotation about its axis (the period of rotation), the length of the ascending node (Ω).

2.3 Animation implementation

LeanTween was used to implement the animations, an efficient twin plugin used by Unity [15]. Its benefits are simple implementation, Canvas UI animation support, spline or Bezier curves, and event handler support available on the Asset Store [16].

Table 2. Object orbit parameter values.

	Eccentricity, ε	Perihelion	Length of ascending node, Ω
Sun	0	0	0
Mercury	0,2056	0,3075	48,3
Venus	0,0067	0,718	76,7
Earth	0,0167	0,9833	349
Mars	0,0934	1,3814	49,6
Jupiter	0,0488	4,950	101
Saturn	0,0542	9,021	114
Uranium	0,0472	18,286	74,2
Neptune	0,0086	29,76607095	131
Moon	0,055	0,00242	0,0

Table 3. The values of the parameters of planets and satellites.

	The orbital period, years	Radius of the planet	Axis angle, °	Rotation period
Sun	0	0,004649197	7,25	-0,7049998611
Mercury	0,241	0,00001630347	0,01	-0,15834474
Venus	0,615	0,00004045454	177,4	0,67
Earth	0,98329134	0,00004263435	23,45	-0,00273032773
Mars	1,882	0,0000233155	25,19	-0,0029
Jupiter	11,86	0,00047660427	3,13	-0,0011
Saturn	29,457	0,00040173796	26,73	-0,0012
Uranium	84,016	0,00017713903	97,77	0,0019
Neptune	164,791	0,00016544117	28,32	-0,00183775013
Moon	0,074	0,00001161764	6,69	-0,07945205479

The *ToggleBodies* method animates the appearance of a list of planets (on the left) when the corresponding key is pressed.

The *isOn* variable specifies whether to show the panel or hide it. *Value* method provides the necessary parameters for animation, such as color, size, etc. The example shows an animation of the panel placement variable. By default, it is located on the left side outside the visible window; it should be moved slightly to the right. The first parameter is the object, the second is the starting position, the third is the position to be reached, and the fourth is the time during which the transition will take place. The smoothness of the transition is governed by *setEase*(), which carries the name of the Bezier curve – *easeOutCubic*. In other words, the animation will be faster at first and slower at the end, and the panel will approach the destination smoothly. The *setOnStart*(), *setOnUpdate*(), *setOnComplete*() methods are required to manage changes. In this example, we use *setOnUpdate*(). That is, the position value will change with each frame. It calculates according to the distance, time, and curve that the subject should shift.

The *UIAnimationController.cs* script manages all the animations.

2.4 Design and implementation of individual modules of the system

The most important algorithm for organizing the motion of objects is to create an orbit for a planet, star, or satellite. Three scripts are responsible for this: *OrbitData*, *Orbiter*, *OrbitRenderer* (fig. 2).

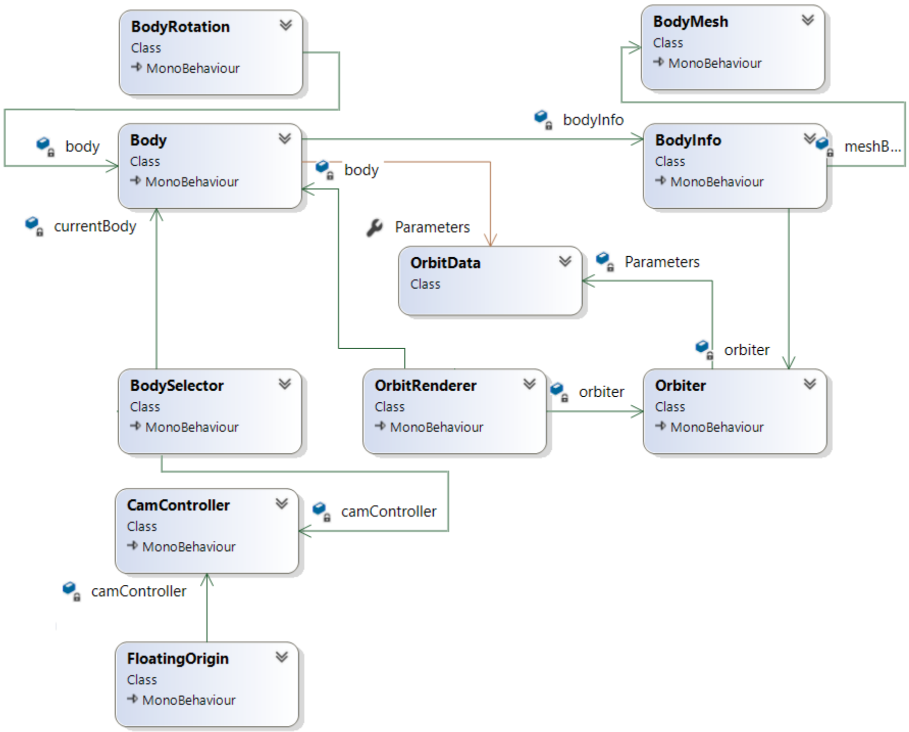


Fig. 2. Diagram of classes related to orbit creation.

OrbitData contains all the necessary data (parameters) about the orbit: eccentricity (degree of deviation from the circle), perihelion (closest to the sun orbit point of the planet), longitude, orbital period (period of the orbit), a period of rotation (around the axis), slope axis, radius, and mass (see table 2 and table 3).

Orbiter finds the shape of the orbit depending on the input parameters and moves the object along the found trajectory. Its main task is to form an array with a set of angles, each of which at some point in time must return an object to move in the trajectory of its orbit.

Consider in detail the process of performing the basic algorithms. The *time* variable contains the time elapsed since the application started. It will determine the position of the object in orbit. *Theta* is the angle at which time the object must return. *N* is the number of points that will merge into segments, thus forming an orbit. The *angleArray* array contains a list of angles from which one is required. *CosSinOmega* simply contains the values of the cosine and sine of the angle, created to avoid repetition in the code. *OrbitDeltaTime* (abbreviated as *OrbitDt*) defines the time it takes an object to move one step. The initial value of perihelion (*initialPerihelion*) is only used to work with the moon. Parameters include parameters from *OrbitData* for the current entity.

In *Start*, the necessary data is initialized, which will then be used in different methods. Variable *k*:

$$k = \frac{2\pi}{(1-e^2)^{\frac{3}{2}} \cdot orbitalPeriod} \tag{3}$$

where *e* is the eccentricity of the object, *orbitalPeriod* is the period of rotation of the planet around the Sun.

The *orbitDt* variable (the time in which one step is performed) is equal to the rotation period divided by the double number of steps that the object must pass:

$$orbitDt = \frac{orbitalPerod}{2 \cdot (N-1)} \tag{4}$$

The random variable from zero to the maximum value of the orbital period is written to the time variable. That is, when you launch an application, the object will appear in a different place, not every time in the same place.

Before selecting the time (time), you need to fill the *angleArray* array with angles. This is called the *ThetaRunge* method, which implements the fourth-order Runge-Kutta method, which gives more accurate results of differential equation calculations. Five steps are required to implement it: calculate the values of the four variables k_1 (5), k_2 (6), k_3 (7) and k_4 (8) and find the final result (9).

$$k_1 = f(x_i, y_i) \tag{5}$$

$$k_2 = f\left(x_i + \frac{h}{2}, y_i + \frac{hk_1}{2}\right) \tag{6}$$

$$k_3 = f\left(x_i + \frac{h}{2}, y_i + \frac{hk_2}{2}\right) \tag{7}$$

$$k_4 = f(x_i + h, y_i + hk_3) \tag{8}$$

$$y_{i+1} = y_i + \frac{h}{6}(k_1 + 2k_2 + 2k_3 + k_4) \tag{9}$$

The result we need – the value of the angle – is recorded at each step after finding the exact value of *w*. The last value is the number π because this is the end of the half orbit if the countdown starts from zero. That is, in the array are the values of the angles for half of the ellipse, and when the object begins to move in the second half – the angle will be counted in the opposite direction.

To prove the effectiveness of the Runge-Kutta method, we compare the values found with and without its algorithm (table 4). As a result of the calculations, we can conclude that using this method results in more accurate values and, at the same time, smoother displacement of the object.

Table 4. Comparison of angles.

	Runge-Kutta method			Simple calculation
	$i = 0$	$i = 1$	$i = 2$	
k_1	0,0127275451	0,0127273692	0,0127264807	
k_2	0,0127275012	0,0127271489	0,0127264447	
k_3	0,0127275012	0,0127271489	0,0127264447	
k_4	0,0127273692	0,0127268407	0,0127259605	
w	0,0127274865	0,0254546208	0,0381810508	
$a[1]$	0,0127274865	-	-	0,0127275451
$a[2]$	-	0,0254546208	-	0,0254550902
$a[3]$	-	-	0,0381810508	0,0381826353

After all the data in *FixedUpdate* have been calculated, the object moves in orbit. *FixedUpdate* was used because it is called a fixed number of times (fifty per second). As a result, the application will work the same on devices with different processors.

The current state of motion of the objects is checked and, unless paused, the time increases and the position of the object (*localPosition*) changes. That is, the object is constantly assigned a new position value, depending on how long it has been since the application was launched.

ThetaInt takes the time value and returns the angle you want to rotate. *Theta0* variable is the resultant angle, the value that returns the method.

```
public float ThetaInt (float t){
  float theta0 = 0;
```

We find the remainder of the division of time into the orbital period to obtain the value of elapsed time from the reference point – the starting point of the orbit. That is, if, for example, Mars has an orbital period of 1,882, and the value of elapsed time is 4,576, then it will be known that from the point of reference the planet has passed 0,812 years and to the endpoint, it is 1,070 years.

Next, we need to check which part of the orbit (in the first half of the second) is the planet. If in the first (0; π], find the number of steps completed:

```
  if(t <= Parameters.orbitalPeriod / 2){
    float i = t / orbitDt;
```

Since the variable *i* is of the float type and we mean an integer step, the exact value must be determined. To do this, use *Floor* and *Ceil* to round down the number found to the smaller and larger sides, respectively, and using *Clamp* to get the values:

```
    float i0 = Mathf.Clamp (Mathf.Floor (i), 0, N - 1);
    float i1 = Mathf.Clamp (Mathf.Ceil (i), 0, N - 1);
```

If the sequence number of the step is the same, select the value in the pre-formed array:

```
    if (i0 == i1) theta0 = angleArray [(int)i0];
```

If as a result of comparisonб we get two different numbers, then by formula (10) we find the value of the angle and return it:

$$theta0 = \frac{a|i_0|-a|i_1|}{i_0-i_1} \cdot i + \frac{i_0 \cdot a|i_0|-a|i_1| \cdot i_1}{i_0-i_1} \tag{10}$$

If the object is in the second part of the orbit (π; 2π), we already write to the variable *t* how much time it takes to get to the end of the orbit, and use the same algorithm to determine the current step:

```
    else { t = -t + Parameters.orbitalPeriod;
      float i = t / orbitDt;
      float i0 = Mathf.Clamp (Mathf.Floor (i), 0, N - 1);
      float i1 = Mathf.Clamp (Mathf.Ceil (i), 0, N - 1);
```

When calculating the *theta0* angle, we have the same formulas, but make the angle from the *angleArray* array negative and add 2π to it. This is necessary for the angle value to be selected in the opposite direction.

```
      if (i0 == i1)
        theta0 = -angleArray [(int)i0] + 2 * Mathf.PI;
      else
        theta0 = -((angleArray[(int)i0] –
          angleArray[(int)i1]) / (i0 - i1) * i + (i0 *
          angleArray[(int)i1] - angleArray [(int)i0] *
          i1) / (i0 - i1)) + 2 * Mathf.PI;
      return theta0;
```

ParametricOrbit takes the value returned by *ThetaInt*. Its purpose is to convert the received angle into coordinates (vector) because in Unity the object can be moved either by applying its force or by changing the current coordinates. At the beginning we find the values of cosine and sine of the angle:

```
public Vector3 ParametricOrbit (float th){
    float Cost = Mathf.Cos (th);
    float Sint = Mathf.Sin (th);
```

Next, we use the formulas (11) and (12) to calculate the values of the variables x and z that are needed to find the desired coordinates:

$$z = \frac{p \cdot (1+e)}{1+e \cdot cos\, t} \cdot \cos t \tag{11}$$

$$z = \frac{p \cdot (1+e)}{1+e \cdot cos\, t} \cdot \sin t \quad (12)$$

where p is the value of perihelion, e is the eccentricity.

The formulas for finding the velocity hodograph in the plane (13) and (14) find the resulting values of the coordinates x and z (y is always zero):

$$zp = \cos\Omega \cdot x - \sin\Omega \cdot z \quad (13)$$

$$zp = \sin\Omega \cdot x + \cos\Omega \cdot z \quad (14)$$

GetVelMagnitude translates the length of the Unity velocity vector in kilometers per second, called in other scripts.

Scales_ScaleModeChanged is an event handler that controls the distance between the Earth and the Moon. The Moon mustn't intersect with the Earth, that is, increases the distance between them.

OrbitRenderer uses the found data from *Orbiter* and outlines the orbit.

Starting is initialized. And *LateUpdate* draws a line by connecting the dots. You can edit the number of points by changing the value of the *lineRendererLength* variable. The greater its value, the smoother the line display. The dotted orbit is achieved by assigning it to the appropriate texture.

2.5 Steps of implementation of support for ARCore technology

First, you need to check your support for ARCore technology with the gadget. This is managed by the *ARSupportChecker* script. The *CheckSupport*() method records the current state of support.

If you want to install the ARCore application, then go to the *Install*() method.

If the previous method found the gadget to be supported, a button to go to the AR scene is unlocked and the user will see a message at the bottom of the screen.

If the user learns that his device does not support ARCore, then he can use the application in 3D mode.

One of the main scripts is *BodyManager*. Looking at its name, we understand that it controls all objects, i.e. planets, satellites, asteroids, stars, and more. Its main task is to create the object itself. This is done in the *CreateStar*(), *CreatePlanet*(), *CreateMoon*(), *CreateAsteroidsBelt*() methods. They are similar to each other, so let's look at creating planets and asteroids, for example.

```
private void CreatePlanet(string name,
  OrbitData orbitData, bool hasBelt){
  GameObject planet = Instantiate(planetPrefab)
    as GameObject;
  planet.name = name;
  planet.tag = "Planet";
  planet.layer = 9;
  planet.transform.Find("Planet").name = "Mesh" + name;
  planet.transform.Find("BB").name = "BB" + name;
```

```
planet.transform.Find("Mesh" + name).localScale =
  Vector3.one * orbitData.radius;
planet.transform.parent = transform;
planet.GetComponent<Body>().Parameters = orbitData;
if (hasBelt){
  GameObject rings =
    Instantiate(Resources.Load("Prefabs/Rings") as
     GameObject) as GameObject;
  rings.transform.parent =
    planet.transform.Find("Mesh" + name);
  rings.transform.localScale = new Vector3(5, 5, 5);}
}
```

Essentially, prefab information is being filled. The *Instantiate*() method creates a prefab instance and initializes values such as *name*, *tag*, *layer*, assigns a personal mesh, orbit, and more. If the planet has rings, then they are created similarly.

When creating asteroids, the scheme is similar, but you need to arrange them not in a proportional way, but chaotic.

```
for (int i = 0; i < asteroidCount; i++){
  OrbitData orbitData = new OrbitData{
    eccentricity = Random.Range(0.01f, 0.04f),
    perihelion = Random.Range(2.2f, 3.6f),
    orbitalPeriod = Random.Range(3.5f, 6f),
    longtitudeOfAscendingNode = 80.7f,
    rotationPeriod = Random.Range(-0.1f, -0.01f),
    radius = Random.Range(0.005f, 0.01f),
    axialTilt = Random.Range(0, 30)
  };
  orbitData.perihelion *= Scales.au2mu;
  orbitData.radius *= Scales.au2mu;
  orbitData.orbitalPeriod *= Scales.y2tmu;
  orbitData.rotationPeriod *= Scales.y2tmu;
  GameObject asteroid =
    Instantiate(asteroidPrefabs[Random.Range(0,
    asteroidPrefabs.Length)]);
  asteroid.transform.parent = asteroidHolder.transform;
  asteroid.transform.Find("Mesh").localScale =
    Vector3.one * orbitData.radius;
  asteroid.GetComponent<Body>().Parameters = orbitData;
}
```

That is, for each asteroid an orbit is created, for which the parameters are selected at random. We create a copy of the prefab and give it a mesh.

Let's look at the algorithm for increasing and decreasing the size of objects when going from real to enlarge. There are three methods to do this: *GrowUp*(), *GrowDown*(), *DoResize*(). It is clear that the first two cause the court into which two parameters are passed: *realScale* and *largeScale*. These methods differ only in the order of these parameters.

The *DoResize*() method with *Lerp* looks for the middle between the starting point and the one you want to reach. The size of each frame changes over a predetermined period.

```
private IEnumerator DoResize(float from, float to){
  float percent = 0f;
  float speed = 1f;
  Vector3 initial = Vector3.one * from;
  Vector3 desidred = Vector3.one * to;
  while (percent < 1f){
    percent += speed * Time.unscaledDeltaTime;
    transform.localScale = Vector3.Lerp(initial,
      desidred, percent);
    yield return null;
  }
  transform.localScale = desidred;
  if (ResizeComplete != null) ResizeComplete();
}
```

Equally interesting is the *CamController* method, which controls the main camera and directs the program's actions when you click on the screen or with a computer mouse. Some variables play the role of boundaries.

The first two limit the speed of rotation of the system so that there are no too sharp movements on the *Y*-axis. The other two limit the angle that we can deviate along the *X*-axis, that is, the user will not be able to rotate the system in a spiral, but only within the required limits.

RotateCamera() is responsible for rotating the camera.

```
private void RotateCamera(Vector3 move){
  if(UnityEngine.EventSystems.EventSystem.current.IsPoint
erOverGameObject(fingerId))
    return;
  xDeg += move.x * xSpeed;
  yDeg -= move.y * ySpeed;
  yDeg = ClampAngle(yDeg, yMinLimit, yMaxLimit, 5);
  transform.rotation =
    Quaternion.Lerp(transform.rotation,
    Quaternion.Euler(yDeg, xDeg, 0), Time.deltaTime *
    rotationDampening / Time.timeScale);
  targetRotation.rotation = transform.rotation;
}
```

ZoomCamera() is responsible for scaling the camera.

To smoothly shift the camera, we use the *Lerp* method. We calculate from what point you want to get to and assign the current position to the desired value and equate the desired one to the current one. As we zoom in, we need to check the distance to the planet, that is, we cannot approach endlessly, only a certain distance.

When moving to some planetб the camera is fixed on it. This state is captured in the *isLocked* variable.

Touch controls are performed by the *HandleTouch*() method.

```
if (Input.touchCount == 1) {
  Touch touch = Input.GetTouch(0);
  ray = Camera.main.ScreenPointToRay(touch.position);
  mode = Mode.Rotating;
}
else if (Input.touchCount == 2){
  mode = Mode.Zooming;
}
if (DoubleClick(Time.time) && Physics.Raycast(ray, out
  RaycastHit hit, float.MaxValue) == true) {
    if (LockedTransform !=
      hit.collider.gameObject.transform.parent.transform)
      LockObject
    (hit.collider.gameObject.transform.parent.transform);
}
```

If one-touch enters the input, then you need to rotate the system or object, if two – enlarge or reduce the size. According to this variable mode is assigned the appropriate value: rotating or zooming. If a double click is made, then the planet is clicked and we can see it close, it is fixed. And then with the switch, depending on the value obtained in mode, the camera is shifted to the appropriate position.

The *HandleMouse*() method has a similar algorithm but has an excellent implementation. We also check which button is pressed or the scroll wheel is engaged and set the appropriate value in mode.

As described above, you can double-click to go to a planet or satellite. Already in the switch is further processing.

If no action is taken, the camera does not move. If you try to rotate the object, the coordinates of the cursor are read and the *RotateCamera*() method rotates the camera. *ZoomCamera*() method is called for scaling.

Figures 3 and 4 shows the relationships between classes responsible for implementing ARCore technology, localization, correct operation of different menus, and adjusting object data.

3 Results

We launch the application on a smartphone (fig. 5). Select the menu item AR. The first time you launch the application, you will be asked for permission to use the camera, you must confirm it. It is necessary to move the phone slowly so that the application finds a solid surface. The white spots along the entire found surface will be a sign of finding (fig. 6).

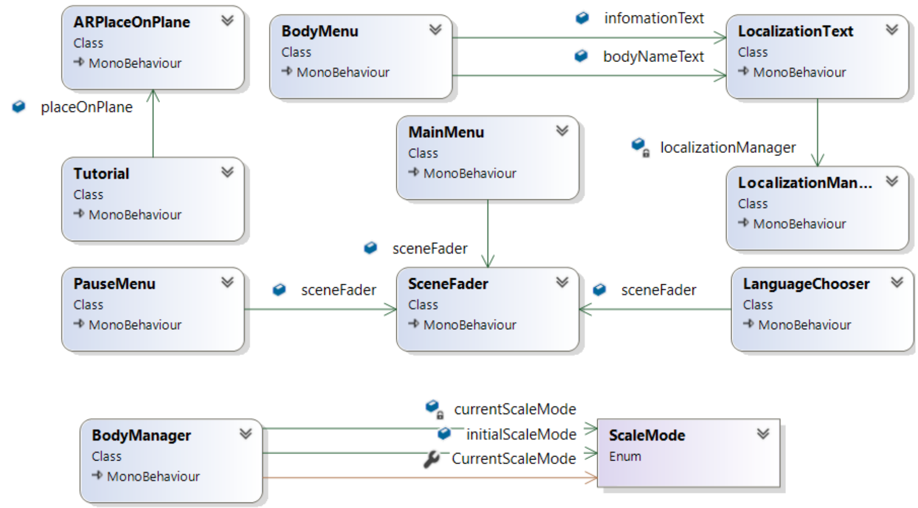


Fig. 3. Class diagram of the software application (part 1).

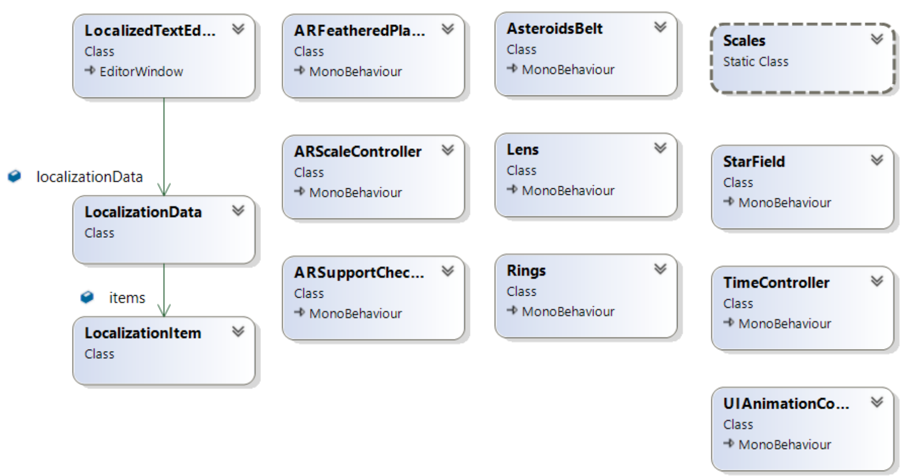


Fig. 4. Class diagram of the software application (part 2).

Then you need to click in the place where the center of the solar system – the Sun – will be. Depending on the selected point, the whole system will be located (fig. 7).

Let us try to walk, go around some planets, and get closer, for example, to Venus (fig. 8). As you get closer, the size of the object you are going to will increase, otherwise it will decrease accordingly. You can look at objects from above, below and from any side. To do this, just walk with the phone in hand.

Fig. 5. The main menu of the application.

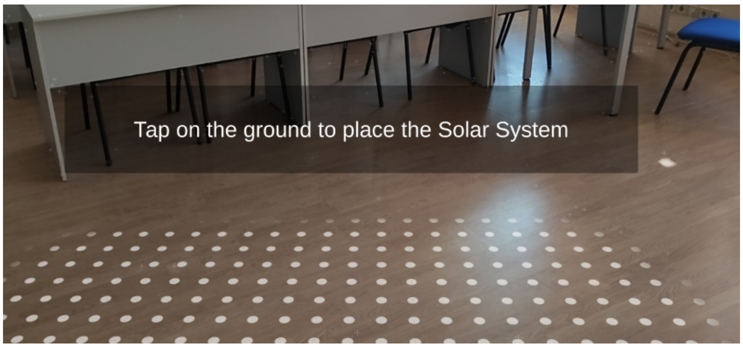


Fig. 6. The result of finding a solid surface.

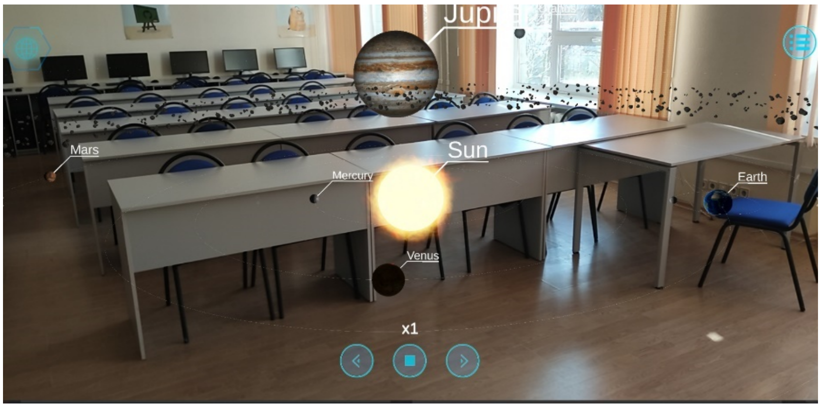


Fig. 7. System location.

In AR mode, you can read information about planets and satellites. You should click on the button from the top left and select the desired object from the list. We choose

Mercury (fig. 9). Again, the item Description is active by default.

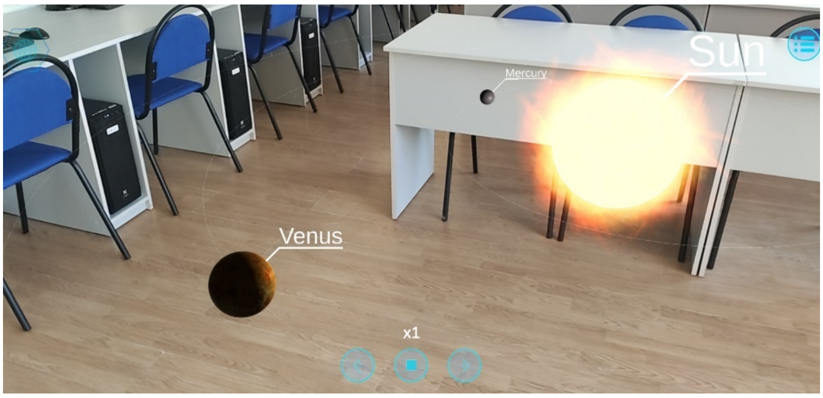


Fig. 8. The result of the approach of the camera to Venus.

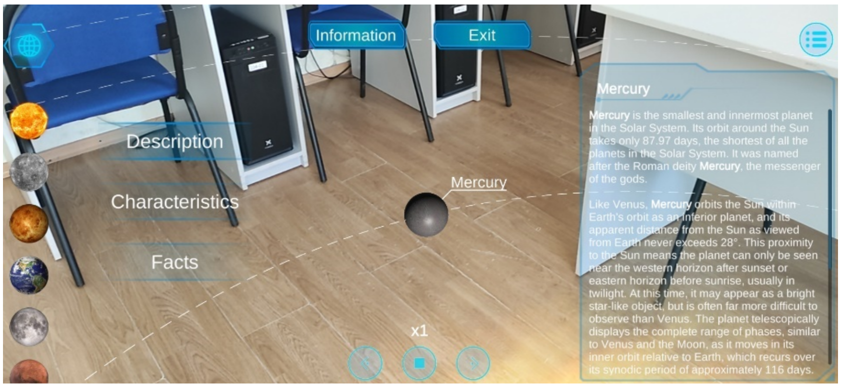


Fig. 9. Description of Mercury.

Let's try to select other menu items "Characteristics" (fig. 10) and "Facts" (fig. 11). By the way, if the amount of information is too large and does not fit into the panel, there is a scrollbar on the side by which the text can be scrolled up and down.

If we want to close the information, all you have to do is press the Exit button (fig. 12). The peculiarity of the software application may be the fact that all the planets are represented in scale to the real size (fig. 13).

Selecting the 3D menu item displays the solar system in 3D (fig. 14).

Spreading two fingers up and down do zooming. Let us approach, for example, Venus. We see a display of brief information about the speed of its movement and the distance from the Sun (fig. 15).

Click the button at the top left. A list of planets appears. By selecting one of them, you can track its movement. Two additional Info and Exit buttons appear at the top of the screen.

By clicking on the "Information" button, you can select the menu item

(“Description”, “Facts”, “Characteristics”) and read the relevant information (fig. 16). The description will open by default.

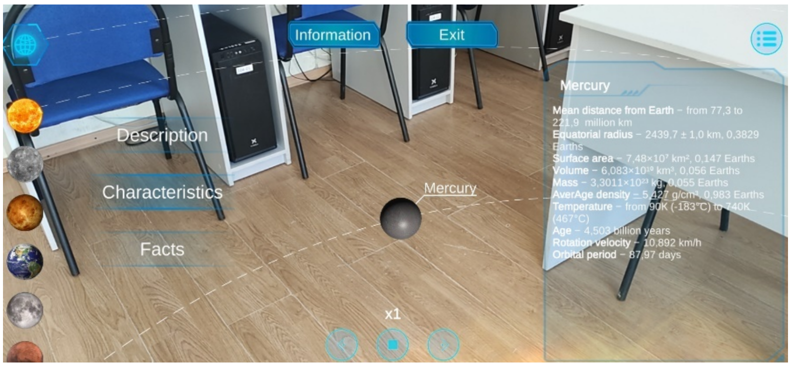


Fig. 10. Features of Mercury.

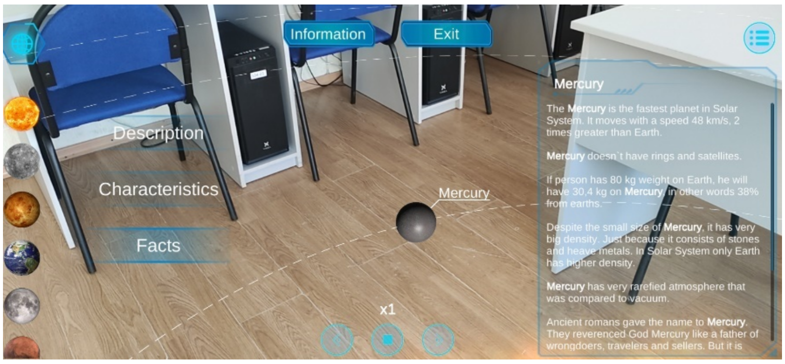


Fig. 11. The facts about Mercury.

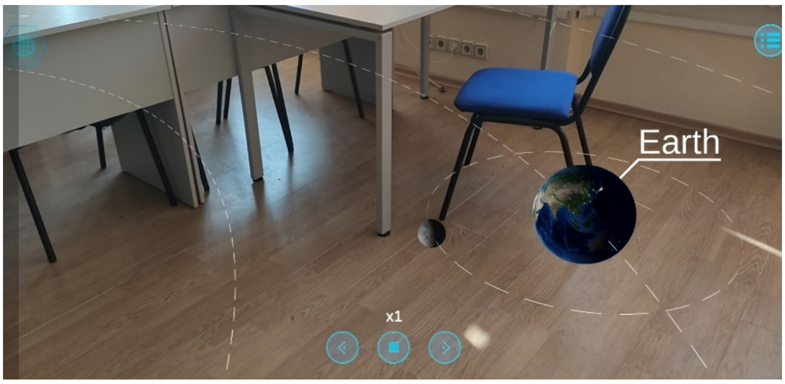


Fig. 12. Result of exit from information viewing mode.

To exit the viewer mode, you must press the “Exit” button, and then you can view all objects of the solar system from a distance.

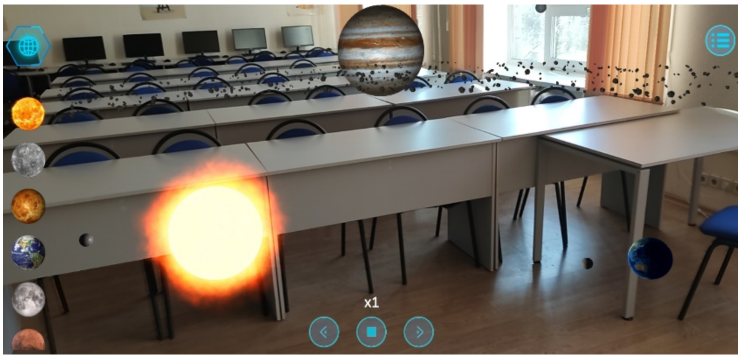


Fig. 13. Size of the Sun and planets.

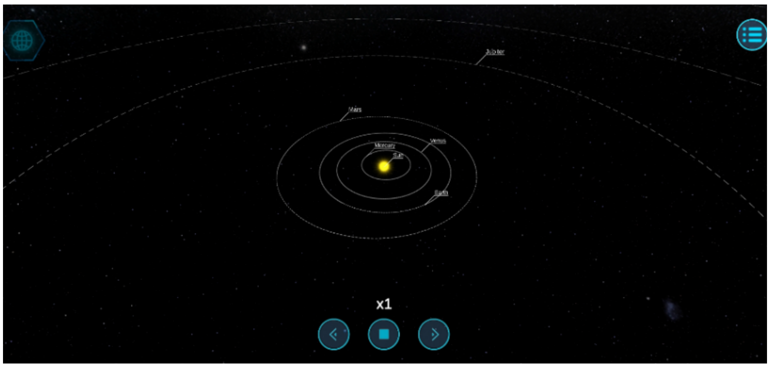


Fig. 14. The appearance of the solar system at startup.

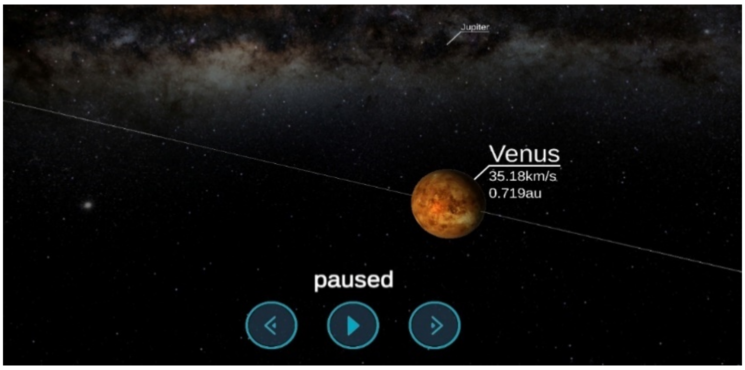


Fig. 15. Zoom in on Venus.

Settings button on the top and a settings bar will appear after clicking (fig. 17). Settings allow you to turn off music, orbits, and names, turn on Enlarged mode, and change the language from Ukrainian to English and vice versa.

Fig. 16. Information about Earth.

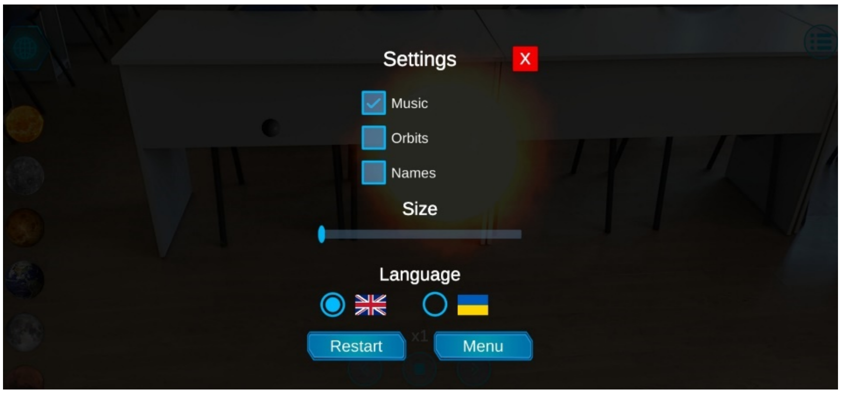


Fig. 17. Settings.

If you go into the settings, then go to the main menu, and press the button “Exit” – the application will shut down.

4 Conclusions

The developed software application demonstrates the behavior of solar system objects in detail with augmented reality technology. In addition to the interactive 3D model, you can explore each planet visually as well as informatively – by reading the description of each object, its main characteristics, and interesting facts.

The model has two main views: Augmented Reality and 3D.

After analyzing the capabilities, disadvantages and advantages of existing platforms for the implementation of augmented reality in the software application, ARCore technology was chosen. After all, it combines rich functionality, the ability to implement the necessary ideas in this case and its optimized, well-established work.

Studying the principles of objects in the solar system was worked out different theories physicists and taken as a basis Kepler's laws.

To create 3D models, real parameters of objects were used, with the help of which the main thing was realized – the correct proportions in the sizes and velocities of objects and shapes and distances between the orbits of celestial bodies.

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Augmented reality in process of studying astronomic concepts in primary school

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Abstract. The objective of the research is development a mobile application (on the Android platform) designed for visualization of the Solar System with the AR technology and the alphabet study, applying the astronomic definitions, which can be used by the teacher and the students for an effective training for studying the subjects of the astronomic cycle in primary school. Augmented Reality cards with the images of the Solar System planets and other celestial bodies were developed, as well as the “Space alphabet” was created. In the developed alphabet every letter of the alphabet becomes a certain celestial body or a different astronomic definition. Augmented Reality gives the opportunity to visualize images of the Solar System as much as possible, in other words to convert 2D images into 3D, as well as “make them alive”. Applying this tool of ICT while studying new data gives the ability to develop and improve the pupils’ spatial thinking, “to see” the invisible and to understand the perceived information in a deeper way, which will be beneficial for its better memorizing and development of computer skills. Studying the alphabet in the offered mobile app will definitely help nail the achieved knowledge and get interesting information about celestial bodies that are invisible and superior for kids; to make a journey into the space, prepare a project on “The Space Mysteries” subject; to stimulate the development of curiosity, cognitive motivation and learning activity; the development of imagination, creative initiative, including speaking out.

Keywords: augmented reality technology, mobile education, mobile application, astronomy, 3D-visualisation.

1 Introduction

1.1 The problem statement

Nowadays, the development of information and communication technologies gives the opportunity to upgrade the study process in general education establishments, using various trends of modern education. New methods of teaching natural sciences have to keep up with contemporary requirements for applying information technologies [9]. Applying information and communicative technologies (ICT) while studying natural sciences allows to intensify the educational process, accelerate the transfer of knowledge and skills, as well as raise the quality rate of study and education [9]. Applying multimedia presentations, Internet resources during the lessons, give the teacher the ability to explain the theory properly, increase the interest of students for study, keep their attention in a better way.

At the same time, natural sciences require high-quality demonstration data. An effective development of the knowledge of natural concepts in the primary school, and later on physics, chemistry, biology, geography and astronomy depends not only on the size of theory, but also on the methods of its presentation that require a decent theoretic training for the teacher.

In primary school, there is often lack of objective natural science knowledge of the primary school teachers. As far as they are not specialized in natural sciences (physics, chemistry, astronomy, biology, etc.), a good quality explanation of the study material in the natural science direction requires additional training [2]. Partially, these issues can be solved applying ICT within the study process. One of the most contemporary trends of ICT in education is the Augmented Reality (AR) together with mobile learning [11; 19; 21; 24].

1.2 The objective of the research

The objective of the research is development a mobile application (on the Android platform) designed for visualization of the Solar System with the AR technology and the alphabet study, applying the astronomic definitions, which can be used by the teacher and the students for an effective training for studying the subjects of the astronomic cycle in primary school.

2 Discussion and results

Modern ICT are parts of all the aspects of human lifestyle, especially in the education. The modern age requires new approaches to the teaching and learning, new methods, forms of presentation the learning information. Particularly, new approaches are necessary in the natural sciences training overall as well.

Using ICT in school education [1; 19; 21; 24] gives the opportunities of development a new learning environment, where the abilities of the ICT resources and new generation learning materials are used along with the traditional materials and activity types.

During the natural sciences lessons ICT are used as an education resource and as a tool, designed not only for automation of the educational activity, but also for the development of critical thinking [18].

Critical thinking primary education receivers are notable for the following features: are able to find the necessary and important information easily; underline the key information and interprets it; ask questions in order to get more exact information or for investigation purposes; examine problems from different points of view and compare different opinions and approaches while solving these; bring out personal opinion, choose linguistic tools to develop own statements precisely; settle correlations between objects, processes, phenomena; generates new ideas; solve problematic situations easily; make sound decisions; understand that a mistake is an integral part of a successful study; consider every single option and make a personal choice; set up interpersonal relations with classmates without any issues; business-oriented; tolerant; realize the responsibility for their own lives; discover the environment curiously. This gives the ability to make it clear that all these features are genuine for a person, capable of critical thinking, are a must-have for carrying out investigation activities and developing experimental skills of primary pupils, particularly first-form pupils [8; 12; 16].

The contexts of natural, social and healthcare, civil and historical, technological, informational education branches in the New Ukrainian School come together with an integrated course "I discover the world" [23].

The nowadays level of computer technologies requires applying new approaches to the education process in the primary school, new methods, forms of presentation of the study data in order to activate the cognitive activities of the pupils [15]. Applying the ICT in primary school allows to intensify the education process, accelerate the transfer of knowledge and experience, enables the development of pupils' critical thinking [9].

It is a common fact that the natural science component requires illustration of the theory. Proper demonstration data helps understand various processes and phenomena in a better way, the structure of chemical compounds and mechanisms of physical correlations. While studying astronomic objects is not only appropriate, but crucial, because studying the definitions and objects that are impossible to be seen in the daily routine, makes learning more complicated. In this way, visualization of the study material makes its perception and memorizing easier. Unfortunately, usual 2D images of the traditional handbooks and textbooks do not give the ability to understand the mechanisms and the basics of physical and chemical phenomena, structure of the planets and other celestial objects etc. completely. That is why, for an effective learning of the study material of the natural science direction, in the modern era, there is an essential objective to apply numerous demonstrations in the learning process, that are impossible without using multimedia presentation, Internet resources, mobile applications and Augmented Reality programs.

Ronald T. Azuma et al. [2] defines the Augmented Reality as a system that: 1) combines the virtual and the real; 2) correlates in real-time; 3) operates in the 3D.

A new age implementation of this technologies in the most cases looks like the following: a special marker-image is placed in front of the web-camera, plugged into the computer [9; 20]. It can be a 2D image, printed on a regular sheet of paper. A special software is analyzing the image, scanned from the camera and augments it with virtual objects on the monitor screen (fig. 1).

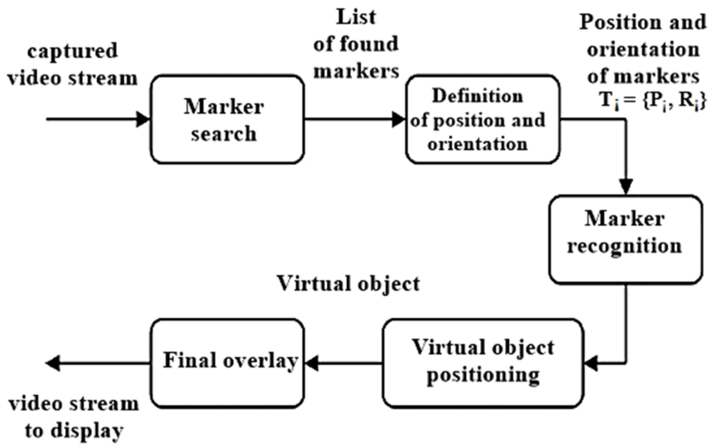

Fig. 1. Schematic algorithm of the augmented reality system.

The opportunity to use AR in education is obvious. The relevance of applying Augmented Reality into the education process is proved by the fact, that implementation of such a modern system will in fact increase the motivation of students, as well as raise the level of memorizing information by means of variety and interactivity of its visual presentation [4; 6; 10; 13; 14; 17; 20; 22].

With the development of AR there will also be changes to the set of manuals, because the necessity of bulky models will decrease. The teacher will only have to place a small image-marker in front of the camera and to project the augmented by the computer image on to the screen, which is beneficially different in the ability to be modified, turned around, zoomed in and out. There will be a possibility to view 3D objects, superior in the daily routine [7; 5; 10].

Implementation of these technologies is designed to reveal the individual personality of the pupil; to create situations for personal discovery of the world by the child; to ask problematic questions and questions, made for critical thinking; to learn pupils how to develop a question logically and correctly; to provide the ability to speak out and prove their opinion; to set up pupils conscious choice etc. [8; 12; 16].

This investigation is dedicated to studying “The Space Mysteries” subject in the first form (week 14) of the New Ukrainian School [3]. According to the program requirements of studying the subject above includes the following questions and tasks:

Approximate investigation / problematic questions:

- What is to be seen in space?
- Can the day “catch up with” the night?

- Is life on Earth possible without Sun?
- How do I imagine other planets?

Tasks for the fourteenth week:

1. To learn how to observe natural day and night changes.
2. To investigate the value of the Sun for the life on Earth.
3. To find out cause-and-effect connections between the Earth's rotation around its own axis and the change of the day part.
4. To form investigation skills, classify, summarize the achieved knowledge and use it in the daily routine.
5. To teach speaking out personal opinion, to listen actively with the conditions of verbal communication.

Results, expected at the end of the fourteenth week:

At the end of the week the pupils *will know:*

- the reasons of day and night change on Earth;
- the value of the Sunlight for the development of plants.

And they will be able to:

- observe the day and night changes and explain them;
- determine hours on the clock;
- set up the connection between the objects and phenomena of Nature;
- explain, why the Sun is necessary and what is its role in the life of mice and men.
- dream about life on other planets;
- prove their own point and listen to the others;
- follow the safe working methods;
- explain the advantages of healthy nutrition.

For the purpose of studying "The Space Mysteries" subject, the authors [3] recommend using the following types of work with pupils: creation of an associative "Space" bush, a fantastic journey into the space, creation of the layout "Space Mysteries" etc. At the same point, they found out, that a combination of the types of activities, named above and demonstration material in Augmented reality would be more effective and proper.

Augmented Reality cards with the images of the Solar System planets and other celestial bodies were developed, as well as the "Space alphabet" was created. In the developed alphabet every letter of the alphabet becomes a certain celestial body or a different astronomic definition. Every letter goes with an image of the applied celestial body or the other astronomic definition (fig. 2).

As a result, for the purpose of visualization the study material, a mobile application LiCo.SolarSystem was developed; it can be uploaded with the QR-code (fig. 3).

At the first stage, 3D-images of the Solar System planets and other celestial planets were developed.

Augmented Reality gives the opportunity to visualize these objects as much as possible, in other words to convert 2D images into 3D, as well as "make them alive".

Applying this tool of ICT while studying new data gives the ability to develop and improve the pupils' spatial thinking, "to see" the invisible and to understand the perceived information in a deeper way, which will be beneficial for its better memorizing and development of computer skills. This method has advantages above using computer applications, because it gives the ability to visualize images at any physical location of the pupil (in class, during a walking tour at the street, at home etc.) on a cellphone or tablet and does not require to be present in front of a computer or a laptop. In order to apply the AR technology, the Augmented Reality markers were developed [7] on the "Vuforia" platform; 3D-objects were realized with a multi-platform tool, designed for development of two- and three-dimensional mobile applications "Unity 3D".

Fig. 2. Images of celestial bodies and different astronomic definitions, used in the alphabet.

Fig. 3. QR-code to download the mobile app LiCo.SolarSystem.

When a mobile phone or tablet with the uploaded mobile app is pointed at the marker (Fig. 4), the picture becomes "alive", its three-dimensional model appears on the screen, it can be manipulated (rotating, zooming in, viewing from different angles, cross-section of the object) for better understanding of its structure.

At the second stage, the "Space Alphabet" was developed in the form of a mobile app and printed out cards, that will help to learn new letters and discover interesting facts about the Solar System objects and other celestial bodies. In order to boost pupils' curiosity and to set up decent contact with them, the explanation in the mobile app is provided by a virtual first-form pupil (fig. 5).

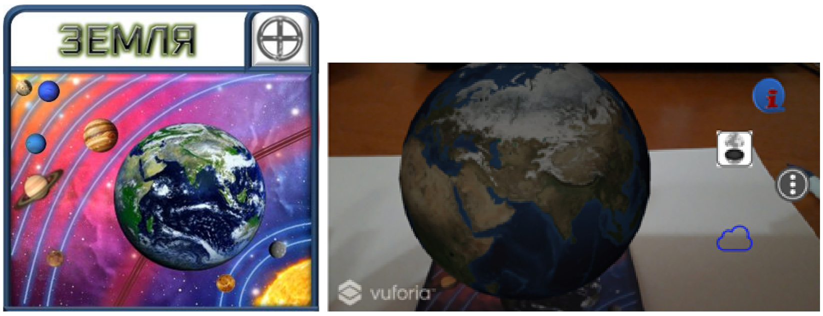

Fig. 4. Image-marker of the planet Earth, that is played with the AR technology in the mobile application LiCo.SolarSystem.

Fig. 5. Getting acquainted with the virtual first-form pupil.

In this way, the developed app works in two separate modes: studying the astronomic objects with the Augmented Reality and learning the alphabet (Fig. 6).

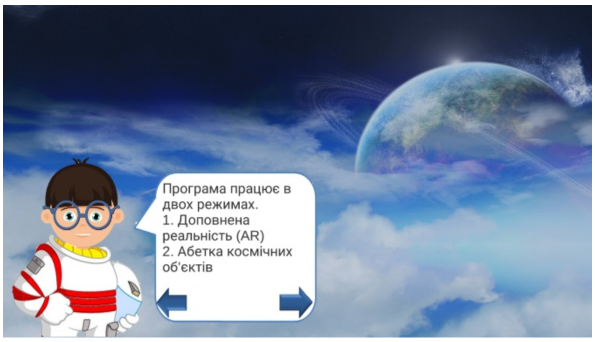

Fig. 6. LiCo.Solar System operating modes.

The first mode is the Augmented Reality mode and it has a particular symbol 

(fig. 7).

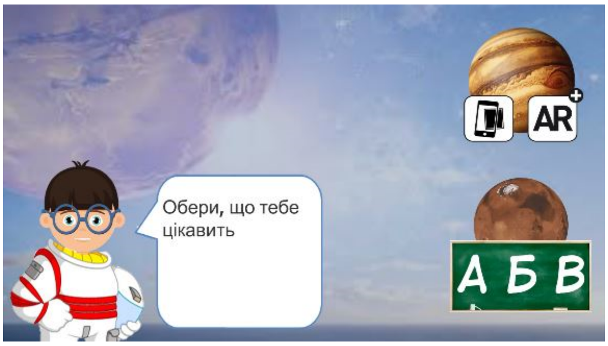

Fig. 7. Marking the operating modes of the LiCo.SolarSystem app.

While using this mode (AR), the pupils can view the external picture of the planets in 3D in details, do their cross-cut section (fig. 8), find out about the structure of the internal beds, "hold" the investigated celestial bodies in hand.

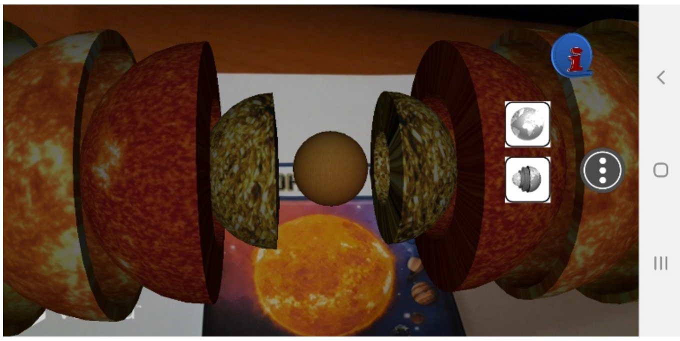

Fig. 8. Studying the internal structure of the Sun using LiCo.SolarSystem.

The information button, that appears while playing the 3D-object, helps receive additional text information about it (fig. 9).

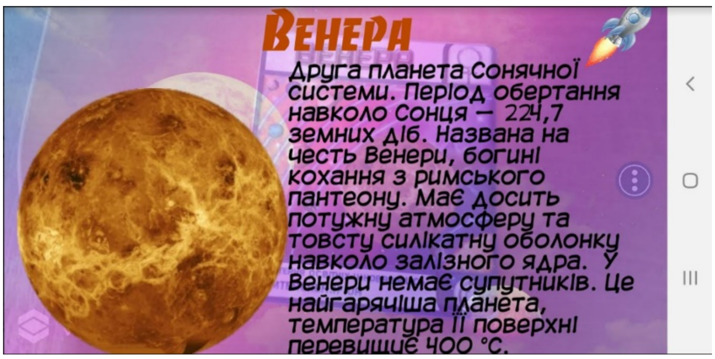

Fig. 9. Displaying text information about the investigated celestial body.

The second mode, which is the alphabet study mode, involves the choice of the letter (fig. 10).

Fig. 10. Work through the alphabet study mode in LiCo.SolarSystem.

After the letter choice is made, the virtual first-form pupil narrates about the celestial body, the name of which is connected with the chosen letter (fig. 11). During the narration, an image of this astronomic object appears. A detailed picture can be reviewed on the printed-out cards, as well as sentences can be made out with these.

Fig. 11. Learning alphabet in LiCo.SolarSystem.

Taking into consideration the age-related specifics of the first form pupils, the information is provided in a short form. The navigator in the offered application is an image of a space rocket that helps the pupil to switch the modes back and forth and return to the main menu (fig. 12).

Fig. 12. Navigation in LiCo.SolarSystem and in the Augmented Reality mode.

3 Conclusions

A mobile application (on the Android platform) has been developed for visualization of the Solar System with the AR technology and the alphabet study, applying the astronomic definitions, which can be used by the teacher and the students for an effective training for studying the subjects of the astronomic cycle in primary school.

Applying the augmented reality objects gives the teacher an opportunity to explain a huge volume of new theory quickly and understandably, with a good quality demonstration material, and the pupils to memorize it effectively, it develops critical thinking, the ability to ask problematic questions and boosts motivation for study.

Studying the alphabet in the offered mobile app will definitely help nail the achieved knowledge and, at the same time, get interesting information about celestial bodies that are invisible and superior for kids; to make a journey into the space, prepare a project on “The Space Mysteries” subject etc.; to stimulate the development of curiosity, cognitive motivation and learning activity; the development of imagination, creative initiative, including speaking out.

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The augmented reality portal and hints usage for assisting individuals with autism spectrum disorder, anxiety and cognitive disorders

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Abstract. The augmented reality applications are effectively applied in education and therapy for people with special needs. We propose to apply the augmented reality portal as a special tool for the teachers to interact with people at the moment when a panic attack or anxiety happens in education process. It is expected that applying the augmented reality portal in education will help students with ASD, ADHD and anxiety disorder to feel safe at discomfort moment and teachers can interact with them. Our application with the augmented reality portal has three modes: for teachers, parents, and users. It gives the ability to organize personalized content for students with special needs. We developed the augmented reality application aimed at people with cognitive disorders to enrich them with communication skills through associations understanding. Applying the augmented reality application and the portal discovers new perspectives for learning children with special needs. The AR portal creates illusion of transition to another environment. It is very important property for children with ADHD because they need in breaks at the learning process to change activity (for example, such children can interact with different 3D models in the augmented reality modes) or environment. The developed AR portal has been tested by a volunteer with ASD (male, 21 years old), who confirmed that the AR portal helps him to reduce anxiety, to feel calm down and relaxed, to switch attention from a problem situation.

Keywords: augmented reality, autism spectrum disorder, anxiety disorder, augmented reality portal, innovations in education.

1 Introduction

On 27 March 2020 the Centers for Disease Control and Prevention had published a report alleging that the number of people with autism spectrum disorder (ASD) diagnosis were increased and there were identified the ASD for 1 out of 54 eight-year old children from USA [4]. Besides, throughout the world the number of people with anxiety disorders and panic attack is increased. For example, 25.1% of the children from USA between the ages 13 and 18 have anxiety disorders and 2.7% of the adult population from USA has panic disorders with twice as many women as men [3]. The development of methodologies and innovative technologies usage for assisting people with ASD and anxiety disorders are the pressing challenges.

1.1 The problem statement

The augmented reality technology (AR technology) is one of the innovative technologies in education and therapy and proved itself to work well in the different applied fields [17; 18; 26; 29; 34; 39; 47; 48]. In particular, it is being used successfully to support the education of persons with disabilities, including individuals with ASD and anxiety disorders [16; 31]. The AR technology usage fosters the social, physical and everyday skills to empower the persons with special needs to realize the educational purposes [5]. The AR application efficiency is achieved through the mixed environment use, where the real objects interact with virtual objects [8; 24].

The aim of the article is to develop a methodology based on the augmented reality portal usage for assisting individuals with ASD and anxiety disorders. This article offers the augmented reality portals usage as teachers support tool that allows students "to hide" at the moment of a panic attack, obsessive-compulsive disorder (OCD) and other negative reactions caused by anxiety disorders. AR application has been further developed to acquire the skills of the associative thought process for individuals with cognitive disorders.

1.2 Analysis of recent research and publications

The results of systematic review Quintero et al. [32] have shown that augmented reality usage leads to the development of social interaction (communication) skills (24% from analyzed publications, covering the period 2008-2018), to increasing of the interest, attention, motivation and academic performance for people with special needs (22%). Most of the studies devoted to AR technology are based on marker technology and geolocation detection. The Vuforia library (8%) and Aurasma (HP Reveal) (10%) are often used for AR application development. When the review [32] was published, the markerless technology was not studied. Approximately one-fifth of research (18%) was devoted to augmented reality usage for teaching individuals with ASD.

According to the International Statistical Classification of Diseases and Related Health Problems 10th Revision, ICD-10, ASD diagnosis involves the impairment in social interaction and communication models as well as a limited, stereotyped, repetitive scenario of the interests and actions [14].

The directions of the augmented reality usage for teaching individuals with ASD are extremely diverse. So, the methodology for learning content development for the people with ASD based on augmented reality is considered in the article Vullamparthi et al. [44]. The Android application allows capturing and images recognition of surrounding objects and set their connection with AR content (photo and video). The results of research Chen et al. [8] showed that augmented reality usage for individuals with ASD to improve emotions recognition and to foster adequate feedback on emotional expressions of faces. Tentori et al. [40] conducted complex research devoted to smart environment usage based on augmented reality for therapy of the children with ASD. The results of experiment indicated that there exists a positive impact of new environment on motor skills development. To reduce the burden on teachers the AR environment MOBIS for enhanced visual support was developed by Escobedo et al. [9]. Experiments have found that environment MOBIS usage provided multi-tasking and helped teachers to work with individuals with ASD. The web-application AR Layar to facilitate the independent navigation in the unknown place is described in research McMahon et al. [23]. Lee et al. [19] showed experimentally that augmented reality technology jointly with a mental map was effective to learn children with ASD that had problems with social skills, especially, to answer on greetings from other people.

People with ASD prefer stability and familiar sequence in their activity and environment. The changing of routine habits provokes anxiety and can lead to inability to function [30]. Besides, ASD results in sensory hypersensitivity that also leads to increased anxiety and stress [2; 12; 13; 36]. It is recommended the sensory-neutral environments to use in teaching process for children with ASD [38]. Besides, the cognitive abilities are improved in the natural habitat compared to the extreme sensory stimuli of the urban environment [6]. It is necessary to provide quiet and peaceful places for students with ASD who are anxious due to increased sensory sensitivity on stage of training organization in the open educational space of an educational institution [38].

The people who have anxiety disorders not related to ASD also may need a calm environment. In case of phobic anxiety disorders (code F40 ICD-10), the main symptom is the fear of being in a certain situation, which, in fact, is not dangerous at a moment. Other anxiety disorders (code F41 ICD-10) are characterized by manifestations of anxiety that are not limited to and are not directly related to a specific situation. Anxiety disorders can provoke panic attacks, depressive episodes, obsessive symptoms and other negative reactions that limit a person's life [15].

The augmented reality applications can be useful in neutral, calm environments creation for people with ASD and anxiety disorders, and without the use of special expensive equipment.

1.3 The purpose of the article

On the basis of analysis of papers devoted by augmented reality application for people with special needs we propose to use the augmented reality portal as tool for teachers and parents to interact with students at the moment when panic attack or anxiety happens. We also propose to use the augmented reality application for children with cognitive disorders to enrich their associations knowledge about the real objects based on the hints in augmented reality mode.

2 Theoretical background

The augmented reality technology based on "aliving" and embedding content in real environment helps people with ASD and anxiety disorders to feel ongoing concern and support. AR/VR/MR-applications help to improve the communicative, emotional and cognitive skills based on appearance of unexpected augmented reality content in real environment for test subject. Let's consider the brief review of AR/VR-applications aimed at learning of individuals with ASD and anxiety disorders to acquire the social and cognitive skills and to mitigate anxiety.

AR application to acquire the skill for orientation in a new environment. Using a mobile application HP Reveal, the teachers and parents can create audio and video content that will be displayed above the markers. The pictures as markers with the image of a favorite hero are placed in new environment. The individuals with ASD receive hints in the augmented reality mode that help to navigate in a new environment [10].

AR applications to acquire the social skills. The books with the games and elements in augmented reality mode contribute to the development of cognitive and social skills. The book involves the children to interact with AR character through the different scenarios of social behavior to learn the emotions recognition that they feel [7]. The AR RPG system aimed at participating in various role game to involve children with ASD in atmosphere of "miniature theatre" with the goal to create the game with virtual environments that reconstruct the child familiar environments to develop the behavioral skills in the classroom and in society based on scenarios. An improvement in the skills of behavior and understanding of gestures and expressions was observed for three children after AR RPG usage [20].

AR applications to acquire the cognitive skills. The AR technology is actively used for the formation and development of cognitive skills in various fields of knowledge. Thus, an experiment to check the effectiveness of using augmented reality for teaching the English alphabet showed the advantages of using the teaching based on augmented reality content over the traditional full-time methodology. The AR applications "AR Flashcards Animals-Alphabet" and "AR Alphabet Flashcards" available at AppStore were used for the research [37]. When pointing the smartphone's camera to the first letter the child can see the name of the pet or predator and three-dimensional picture of the studied letter, accompanied by the sound of the animal's cry and a small animation. The AR video game "Gremlings in my Mirror" was developed based on NyARToolkit and Unity3D to acquire logical skills for children with special needs [43]. By moving a pre-printed marker, the child must have time in the game situation to order the characters by size or to sort by color. As a result of comparing the game experience of two groups of children – with and without special needs – the same success indicators are obtained.

AR applications to acquire the skills for emotions and facial expression recognition. The Brain Power System is based on emotions recognition algorithms and special equipment usage such as Google Glass. A person with autism puts on glasses and begins to communicate with a teacher or mother in a playful way. There are two options for emoticons depicting the right and wrong emotions associated with the face in the augmented reality mode. The task for the child is to learn how to choose a smiley with the right emotion. Google Glasses have built-in special sensors that record the level of stress and anxiety. This kind of application in a playful way allows children with autism to improve communication skills and understanding of emotions, establish eye contact in the communication process and increase self-confidence. The System efficacy results, described in [22], showed that for two boys during the experiment the decrease of autistic symptoms after using the Brain Power System was observed.

AR applications to reduce the anxiety. AR/VR/MR technologies are effectively used to combat various phobias, for example, arachnophobia [28], claustrophobia, etc. Claustrophobia belongs to the group of the anxiety disorders, manifested by unreasonable fear in enclosed spaces. One of the effective methods for the treatment of claustrophobia is the use of virtual reality technology.

It is used to immerse a patient with claustrophobia in a problematic situation at the time of the therapy under the supervision of a psychotherapist. For example, the "Claustrophobia Game" allows to move from an environment with worrying increase to a relaxation room in the virtual reality mode. According to experiments and estimates based on the Spielberger questionnaire, the level of apparent anxiety in 14 patients before and after using the game application was decreased [33].

3 Research methodology

To clarify the status of the problem and objectives of the study the scientific papers about the usage AR/VR/MR technologies for learning of the people with special needs such as individuals with ASD and anxiety disorders were analyzed, covering the period 2011-2019.

In the practical part of the research, the mobile applications were developed: the AR portal to reduce anxiety and the AR application to develop cognitive skills. To create the AR portals for people with ASD we used React Native framework with Viro AR and to create AR hints application for people with cognitive disorders we used ARKit and SpriteKit frameworks.

4 Results

In this section the results of the practical part of the study based on the development of mobile AR applications for people with ASD, hyperactivity and anxiety and the modern approaches to the design of immersive environments, in particular, AR portals are discussed.

4.1 About development of the augmented reality portals

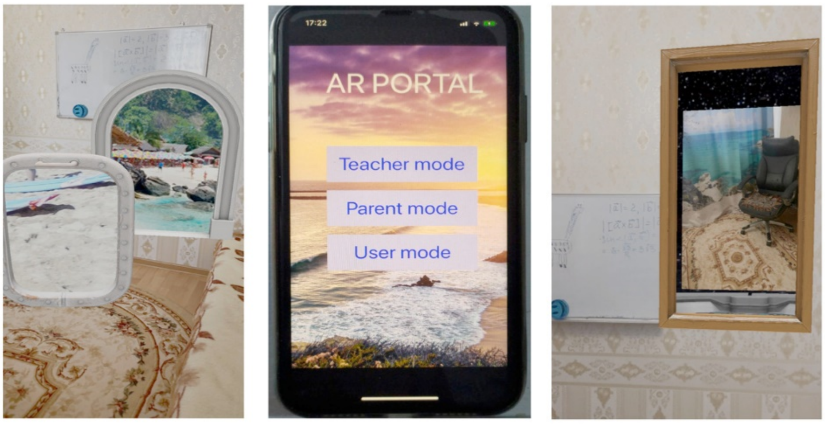
Let's consider the possibility of the augmented reality portals usage to combat claustrophobia and anxiety disorders. AR portals create the illusion of a transition from one reality to another in order to decrease the anxiety and to feel safe. The studies demonstrate the effectiveness of anxiety therapy based on immerse to the virtual reality, but the use of such therapy is impossible without the special equipment. The results of our study can be used in problem situations associated with anxiety in the presence of any gadget. Besides, there are no significant differences between virtual and augmented reality technologies to treat the induced anxiety. As shown in [46], the participants with induced anxiety feel almost the same discomfort, frequent heart rate and level of anxiety when immersed in an artificial environment using these two technologies during the experiment. So, we offer to use a methodology based on the augmented reality portal to help the teacher in case the students start to feel anxiety in the learning process.

The approaches to the augmented reality portals development are considered.

1. *The AR portal development based on ARKit and SceneKit frameworks*. The stages of AR portal development include the detection and rendering of horizontal planes; the handle of session interruption and visual 3D objects placement on View based on SceneKit; the creation of three vertical planes for walls of portal and creation node for floor placement with the help of the objects from basic classes SCNNode и SCNBox; the determination of their position and angles of rotation, texture and transparency; the detection of doorway. For realistic portal creation it is needed to create light sources using objects from basic class SCNLight [35]. Another approach to AR portal developing is to use the Unity3D game engine in conjunction with the ARKit, ARCore, and ARFoundation frameworks.
2. *The AR portal development based on Figment AR application and using Snapchat Lens Studio*. The iOS Figment AR application is a convenient user application with the ability to create several augmented reality portals in a room and place your favorite 3D heroes in real environment. To create a portal, just select the type of portal door (hatch, door, arch) in the menu, determine the contents of the portal based on the 360 video and 360 photo templates and click on the smartphone screen to place it in the desired part of the room (Figure 1a). Snapchat Lens Studio allows you to create augmented reality applications based on predefined templates, for example, portal template.
3. *The AR portal development based on React Native and Viro AR*. The Viro AR platform is designed for the rapid development of augmented reality applications based on ARKit and ARCore and contains convenient components for developing an augmented reality portal: the <Viro3DObject> component for working with 3D objects, the <ViroPortal> and <ViroPortalScene> components for creating a portal and setting up scenes followed by adding to ARScene [27].

4.2 AR portal and AR hints for people with special needs

A mobile application for iOS has been developed. Three modes are available in application: a mode for a teacher, a mode for a parent, and a mode for a user. In teacher mode it is possible to create training content for AR portal based on 360^0 video and 360^0 image to acquire students with various ecosystems. The teacher in this mode can tag the content in the portals that caused to student discomfort. In parent mode, you can create 360^0 video and 360^0 image to fill the portals with content, which creates a student's safe and home environment. In this mode, the user can select content for augmented reality portals based on templates approved by teacher and parents. This application allows you to customize personalized content for individuals with special needs. The menu of our application and portal loading with the home environment approved by parent are shown in the figure 1b, 1c. In addition to visualization, all three modes of the portal are provided with audio recordings such as relaxing music. As known the music therapy helps to reduce depression, stress, anxiety and nervousness [21; 42; 45].



a b c

Fig. 1. The augmented reality portals and app for people with special needs.

The augmented reality portal can be used by therapists and teachers as a sensory room to reduce the student's anxiety level. It has been shown that the safe space of sensory rooms helps children with ASD and emotional problems learn how to independently regulate their behavior, which helps to improve concentration on tasks in learning process [41].

Let's enumerate the target audience for the augmented reality portal usage:

1. people with ASD, faced with an unexpected situation for them, are pinched and try to find support in their environment. In such case, the augmented reality portal can serve as a transition to a protected space for them and can help to reduce the level of strain and anxiety with ability to continue interaction with student through the portal;
2. people with anxiety disorders can move to the augmented reality portal at the moment of panic attack or anxiety increasing through illusion of environment change;
3. people with ADHD feel significant difficulties in the learning process. Teachers need to create a special learning environment to exclude distractions; to control impulsive behavior; to redirect excessive physical activity to other activities; to provide an opportunity for movement (training individuals with ADHD requires breaks with the possibility of outdoor games and a change of scenarios); to promote positive social interaction in the learning process [1] and to develop interactive learning content. The augmented reality portal can help people with ADHD to change environment in the classroom.

Additionally, to the augmented reality portal we develop mobile application to help children with cognitive disorders. Persons with ASD perceive and process information in different manner than other people. Temple Grandin (2009) distinguishes three types of people's thinking: visual thinkers; verbal/logical thinkers; and musical/mathematical thinkers [11].

For visual thinkers, the process of the associations detection for the presented object is similar to photos recognition in a search engine. Moreover, the emerging associations are often not obvious to others, as they are associated with pictures from the past that are understandable only to people with ASD. As shown in [25], people with ASD have difficulties to form new categories. For the formation of skills to categorize data, it is important to enrich the visual associations knowledge [11]. The hypothesis of the research is an attempt to expand the category knowledge for children with ASD through photorealistic and sound associations in the augmented reality mode. Such augmented reality application will help children with ASD to interact with teachers, parents and peers, i.e. their communication skills.

The proposed mobile application allows children with ASD to see associations for selected object in augmented reality mode. The application was developed based on ARKit framework. As static learning content is ill-defined for children with ASD, we develop interactive augmented reality application that aimed at interest and motivation increasing in learning process. The augmented reality application with associations demonstrated as augmented reality hints is shown on figure 2. When child with ASD hover a smartphone screen on cat image, he can see popup hints with association, for example, mouse image and milk image. The augmented reality hints are considered as miracle by children with ASD and can be applied to decrease cognitive disorders.

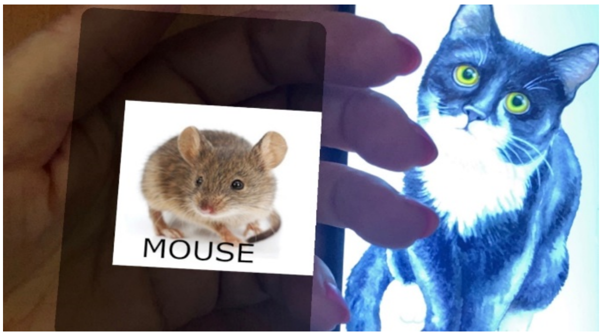


Fig. 2. The mobile application to demonstrate the associations cards in the augmented reality mode.

5 Conclusions and prospects for further research

At the final stage of the project, the two experiments will be conducted:

1. to study the response of individuals with ASD and increased anxiety to the use of the new augmented reality portal;

2. to test the AR application that presents associations in augmented reality mode for categorization development and communication skills increasing for children with ASD.

As an experimental group, it is planned to attract children and adolescents with ASD that receive a special education at the center of correctional pedagogy and the students of secondary schools from Simferopol. The results of the experiments will be processed by methods of mathematical statistics, analyzed and published.

At the moment, the portal has been tested by a volunteer with ASD (male, 21 years old), who confirmed that the AR portal helps him to reduce anxiety, to feel calm down and relaxed, to switch attention from a problem situation. The effectiveness of the portal usage for people with ASD has been proved by the observer with pedagogical education and degree, certified in the use of information and communication technologies in the training of individuals with disabilities.

The beta-testing phase for AR application based on demonstration of association in augmented reality mode was completed. According to evaluations of the application prototype by specialists in the field of correctional pedagogy, the developed product can be used as a didactic game for children with cognitive disorders. Such application is recommended by educators that teach children with cognitive disorders and psychologists at the center of correctional pedagogy from Simferopol. So, the developed AR application is ready to approbation on target audience.

An analysis of the literature showed that the usage of AR / VR / MR technologies in education and quality life improvement for individuals with ASD is very perspective direction especially for people with special needs. It is no found the studies devoted by the augmented reality portal usage to reduce anxiety. We propose the augmented reality portal usage as tool to help teachers to interact with people with anxiety disorder, ASD and ADHD.

The proposed applications will be shared for free, without payment for use. They can be used by parents and teachers as the tool for effective interactive and teaching of people with special needs. It is expected that further introduction of AR portal and AR application in learning process for individuals with disabilities will allow to improve the quality of life and academic performance, to reduce anxiety in new learning environment and to improve cognitive skills.

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Features of implementation of modern AR technologies in the process of psychological and pedagogical support of children with autism spectrum disorders

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Abstract. The article deals with the actual issue of the specificity and algorithm of the introduction of innovative AR technologies in the process of psychological and pedagogical support of children with autism spectrum disorders (ASD). An innovative element of theoretical and methodological analysis of the problem and empirical research is the detection of vectors of a constructive combination of traditional psycho-correctional and psycho-diagnostic approaches with modern AR technologies. The analysis of publications on the role and possibilities of using AR technologies in the process of support children with ASD (autism spectrum disorder) and inclusive environment was generally conducted by surfing on the Internet platforms containing the theoretical bases for data publications of scientific journals and patents. The article also analyzes the priorities and potential outcomes of using AR technologies in psycho-correction and educational work with autistic children. According to the results of the analysis of scientific researches, Unified clinical protocol of primary, secondary (specialized), tertiary (highly specialized) medical care and medical rehabilitation "Autism spectrum disorders (disorders of general development)", approaches for correction, development and education of children with ASD, AR technologies were selected for further implementation in a comprehensive program of psychological and pedagogical support for children with ASD. The purpose of the empirical study is the search, analysis and implementation of multifunctional AR technologies in the psycho-correctional construct of psychological and pedagogical support of children with ASD. According to the results of the pilot study, the priorities and effectiveness of using AR technologies in the development of communicative, cognitive, emotional-volitional, mnemonic abilities of children and actualization of adaptive potential and adaptive, socially accepted behaviors are made. The possibilities and perspectives of using AR technologies as an element of inclusive environment, with regard to nosology and phenomenology, need further investigation.

Keywords: inclusion, autism spectrum disorders, AR technologies.

1 Introduction

1.1 The problem statement

The processes of reforming special education in Ukraine require interdisciplinary research and finding new optimal ways to develop and shape the personality of children with autism spectrum disorders. The organization of complete and timely care for children with general development disorders (F84 according to the International Classification of Diseases of ICD-10). The main purpose of helping children with autism is their habilitation. Habilitation is the creation of new opportunities, building social potential, i.e. the child's ability to be realized in this society [30; 34]. All social, psychological, informational and educational work should be aimed at enhancing the personal, cognitive and social status of such a child. The prevalence of autistic development disorders is, according to various data, from 6-17 to 57 per 10,000 children. According to foreign studies, with the timely organization of complex psychological and pedagogical support, 60% of autistic children get the opportunity to study under the program of general school, 30% – under the auxiliary program, almost all of them reach the level of socialization necessary for life in society. In cases where appropriate support is not provided, only 2-3% of autistic children can study in the education system, the rest do not reach the required level of intelligence and socialization. The analysis of psycho-corrective, therapeutic and developmental directions of organization of psychological and pedagogical support of a child with ASD (autism spectrum disorders) indicates the focus on the individual psychological features of the respective child, not focusing on the introduction of rehabilitation cases. Most programs also include elements of the child's direct communication lines with a specialist that may be a problem for children with ASD. The relevance of the study of the given problem is due to the search for integrative components of the organization of psychological and pedagogical support, focused on a complex combination of leading psychological and pedagogical approaches and innovative AR technologies in the process of habilitation and further integration of the child with ASD.

The aim of the study is to analyze the features and best practices of augmented reality technologies for the psychological and pedagogical support of children with autism spectrum disorders.

1.2 Literature review

Since the 1990s, special efforts have been made to study the specificity of the mental dysontogenesis of autistic children, to search for the natural causes and the logic of autistic development, which revealed the "pervasive" (cross-cutting or spectral) nature of this disorder [19]. More and more researchers are thinking that autism is affecting all levels of mental organization. It should be noted that at present there are no generally accepted theoretical and methodological grounds for studying the features of disorders of different structures and functions of the psyche in the case of autism, and also - the relationship between them [20; 21; 22]. Autism is a general (pervasive) developmental disorder that affects verbal and non-verbal communication and social interaction, and complicates the formation of adaptation processes; Autism spectrum disorders generally occur at the age of three. Other characteristics that are often associated with autism: limited repetitive stereotyped movements, intolerance to environmental changes or everyday life, unusual reactions to sensory stimuli [26]. The researchers consider Autistic spectrum disorders as a violation of mental development, characterized by an intense lack of social interaction, the ability to communicate and cognition of the environment, loss of interest in reality. Generalization of symptomatic manifestations of autism spectrum disorders according to DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, fifth edition) is presented in fig. 1 [24].

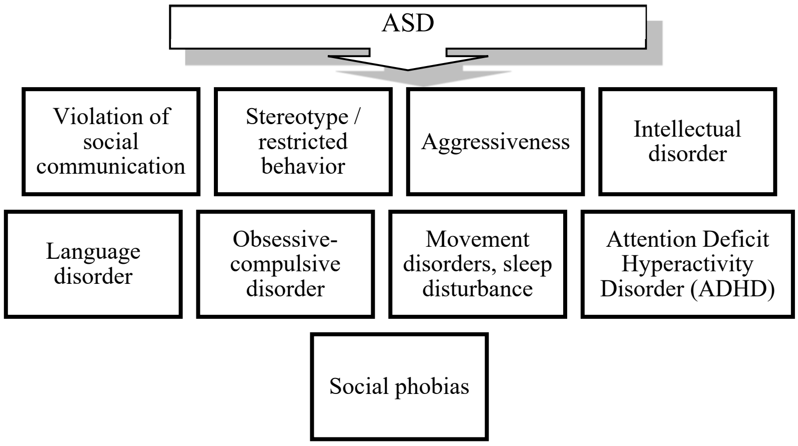


Fig. 1. Main DSM-5 autism symptoms and related problems.

Emphasizing on the phenomenological aspects and symptomatic manifestations of the autism spectrum disorder, recent studies have focused on the use of information, computer resources and modern AR technologies to improve the organization of psychological and pedagogical support and the development of adaptive capacity of children. Wedyan et al. [42] quite thoroughly discuss the use of augmented reality (AR) in the diagnosis and treatment of autistic children with a particular focus on the effectiveness of AR in assisting autistic children with communication, social, mood and attention deficit disorders. The authors identified the main design features that enable AR systems to achieve high levels of efficiency of autism therapy. The authors also classify different systems of AR technologies for corrective process support with children with ASD based on different criteria. Particularly valuable is the analysis of an empirical study of the implementation of a method for the diagnosis of autism in children, focused on the measurement of upper limbs movements [15]. The new method described by the authors used AR to create a virtual object to encourage children to move their hands. The system records all movements of children using the Microsoft Kinect sensor [23]. Thus, the key two components of the system are the AR game and the motion recorder.

In their turn, Marto et al. [32] conducted a systematic review of the use of augmented reality in patients with autism, considering not only the social and psychological construct but also the medical aspect. In the era of information and improving the existence of vulnerable sections of the population, including children with ASD, Tang et al. [39] research on the use of a mobile application based on the main object recognition module implemented within the deep learning platform – TensorFlow, which promotes improved learning and communication skills in children with ASD. Chung et al. [10] offer to adjust the deficit of social interaction and the development of soft-skills using augmented reality (AR) technology for visual conceptualization of social stories. Interactive social stories are played with several tangible markers and AR technologies that mark the corresponding virtual images. Researchers also suggest the use of three-dimensional (3-D) animation to simulate emotional expressions on the face, which aims to develop the emotional spectrum and social skills of autistic adolescents. Lorenzo et al. [31] own research aimed at determining the effectiveness of augmented reality curriculum based on visual support for children with autism spectrum disorder to improve their social skills. Su Maw et al. [35] conducted a systematic review and meta-analysis of the effectiveness of cognitive, developmental, and behavioral interventions in the context of corrective effects on preschool children with ASD. Bai et al. [3] focusing on the deficit of symbolic thinking in children with ASD (autism spectrum disorder), suggested an interactive system that explores the potential of Augmented Reality (AR) technology to visually conceptualize image representation in an outdoor gaming environment. The results of an empirical study involving children with ASD aged 4 to 7 showed a significant improvement in interactive play [3]. Cai et al. [6] offered to integrate the classic Dolphin Therapy model with innovative AR technologies by developing an innovative Virtual Dolphinarium design for potential rehabilitation support for children with ASD. Instead of imitating dolphin swimming, a virtual dolphin interaction program will allow autistic children to train by the pool for dolphins and learn (non-verbal) communication with virtual dolphin gestures. Boccanfuso et al. [5] and Billard et al. [4] focus on the effective use of robotics in the process of psychological and pedagogical support for children with ASD.

Researchers empirically argue that the use of robots in the interactive game to promote the development of movement coordination in children with autism spectrum disorders and encourage the manifestation of verbal and non-verbal communication [13; 22]. According to the analysis of the existing scientific and practical tendencies and developments concerning the introduction of modern AR technologies into the complex system of psychological and pedagogical support of children with autism spectrum disorders [18], the question of finding vectors of the combination of traditional psychological and pedagogical approaches as well as modern approaches remains a far-reaching aim.

2 Results and discussion

Interdisciplinary research was carried out within the framework of the implementation of research work, which is performed at the expense of the General Fund of the state budget: “Development of methodology for psychological and pedagogical support of families raising children with special needs" – the state registration number: 0119U002003, "Adaptive system for individualization and personalization of professional training of future specialists in blended learning" – the state registration number: 0120U101970 [30; 33] and with the support of the NGO "Special Parenthood. Protecting the Rights of Special Families". Methods used in the research process: method of theoretical analysis of literary sources, analysis of current experience of psychological and pedagogical support of the integrative process of adaptation and development of children with autism spectrum disorders, generalization and conceptualization of leading domestic and foreign studies, the introduction of VR technology / psychophysical development of a child with ASD, analysis of studies of the practical experience of triad interaction "specialists – parents – child with ASD" [15] in the process of development and integration child in society.

Table 1. Information on tools for exploring pervasive development.

Diagnostic area	List of psychodiagnostics tools
Screening procedures for development research	CHAT M-CHAT (age – 16-30 months) CASD (screening of children 1-16 years old) Questionnaire for children "CSBS DP™ Infant-Toddler Checklist" (screening of drawings) ASQ (screening of children and adults) CAST (screening of children 4-11 years old) ASDS (screening of children 5-18 years old) SCQ (screening of adults and children from 4 years old) CARS-2
Basic tools for the diagnosis and dynamics of autistic disorders	ADI-R ADOS CARS 2
Additional tools	
Cognitive functioning and school skills (quantitative assessment)	BSID-II WPPSI-IV SBT-4 MSEL KABC M-P-R
Cognitive functioning and school skills (qualitative assessment)	Development Profile II "Screening tools for assessing of general development" The well-being profile of prerequisites for development in children under 36 months of age, revised edition
Assessment of the level of social adaptation (adaptive behavior)	Assessment of the development level of adaptive behavior is one of the main tools of the clinical diagnostic program. VABS assessments may be conducted for this purpose. The scale is valid for children aged 0 to 18 years, adults – 19 to 99 years SIB-R ASQ: SE
Other additional tools of the clinical diagnostic program	
For assessment of behavior	BOS EOS

Diagnostic area	List of psychodiagnostics tools
For assessment of speech development	ROWPVT EOWPVT SICD-R PRE-CELF PLS RDLS
For assessment of sensory development and sensory disorders	Sensory profile for children aged 3-10 years old Sensory profile of toddlers Analysis of sensory behavior
Tools or special screening available in Ukraine	
ADI-R ADOS-2 The Modified Checklist for Autism in Toddlers (M-CHAT) Checklist for Autism in Toddlers –CHAT) CASD (screening of children from1to 16 years old) SCQ (screening of children and adults from 4 years old) STAT – The Screening Test for Autism in TwoYear-Olds WISC-IV International Performance Scale Leiter-3 PEP-3 Bayley Scales of Infant Development-II Mullen Scales of Early Learning) Conners-3	

Table 1 presents a thorough list of psychodiagnostics programs, clinical diagnostic programs and screening programs. The presented list of psychodiagnostics methods is presented in the unified clinical protocol of primary, secondary (specialized), tertiary (highly specialized) medical care and medical rehabilitation “Autism spectrum disorders (general developmental disorders)”, developed taking into account modern requirements of evidence-based medicine and psychological care. The document considers the features of the diagnosis and treatment of autism spectrum disorders in Ukraine from the standpoint of ensuring the continuity of medical and psychological care. The relevant list of psychodiagnostics bases is developed on the basis of adapted clinical guidelines “Autism in children” and “Autism in adults”, which are based on the principles of evidence-based medicine and psychological principles, taking into account modern international guidelines reflected in clinical guidelines:

1. NICE CG 128 – Autism: recognition, referral and diagnosis of children and young people on the autism spectrum (2011);
2. NICE CG 142 – Autism: recognition, referral, diagnosis and management of adults on the autism spectrum (2012);
3. Practice Parameter for the Assessment and Treatment of Children and Adolescents With Autism Spectrum Disorder, the American Academy of Child and Adolescent Psychiatry (AACAP) Committee on Quality Issues (2014);
4. Diagnostic criteria for research. The ICD-10 Classification of Mental and Behavioral Disorders, WHO, 1992. You can read the adapted clinical guidelines at link http://www.dec.gov.ua/mtd/reestr.html.

Diagnosis of ASD is based on medical history, clinical examination of the patient, standard psychological assessment, as well as interviews with the subject and caregivers. Clinical evaluation of the patient should be aimed at identifying disorders of social interaction, communication, limited repetitive behavior and stereotyped movements. The patient's age and level of development should be taken into account when choosing tools for the study of pervasive disorders of the client. The use of special standardized evaluation procedures (table 1) complements but does not replace clinical judgment. Psychologists and psychiatrists should consider ethnic, cultural, or socioeconomic factors that may influence assessment. They also coordinate appropriate multidisciplinary assessment of children with ASD. The purpose of the assessment is to standardize the detection of signs of ASD and compare them with the "Research Diagnostic Criteria" International Classification of Diseases – 10 and diagnostic criteria DSM-V. DSM-V diagnostic criteria are used as additional. This assessment provides a diagnosis of RAS from 2 years. Formalized assessment is performed using the Semi-Structured Parental Interview (ADI-R) and the Semi-Structured Assessment of Autistic Behavior (ADOS). Functional diagnosis of ASD includes assessment of cognitive levels functioning, speech functions, school skills, development of fine and gross motor skills, visual-motor coordination and the level of functioning of the child in the field of adaptive behavior with the use of tools for the study of pervasive disorders of client development. Diagnosis of autism is made according to certain criteria, in comparison with which a psychologist, correctional teacher, speech therapist, doctor can assess the behavior and condition of the child [24]. Early diagnosis and timely treatment and psychological and pedagogical assistance will improve the quality of life of a child with ASD [19]. Given the priority perspectives of the use of innovative computer technologies in psycho-diagnostic practice in the process of research of children with ASD, the use of a computer complex for psycho physiological testing is a priority - the HC- Psycho test. Today, there are a number of efficient approaches to constructively support children with ASD and the development of adaptive, sensory, emotional-volitionary and cognitive capabilities of the child [41].

Table 2. Classification of approaches for correction, development and education of children with ASD.

Name of approach	General characteristics and areas
Behavioral approaches	
ABA – Applied behavior analysis (authors: Ivar Lovaas, Donald Baer, Sidney W. Bijou, Jim Hopkins, Jay Birnbrauer, Todd Risley, and Montrose Wolf)	The ABA method primarily focuses on positive reinforcement strategies, which are essential support for children in difficulty in learning or developing new skills. Also, ABA therapy deals with the correction of problem behavior, which impedes the normal functioning of the child, through the process of so-called "functional assessment of behavior". ABA therapy is used to improve language and communication skills, as well as attention, memory and academic skills.
VBA (Verbal behavior analysis)	The verbal-and-behavioral approach is based on studies related to the field of applied behavior analysis and the theory of behavioral scientist B. F. Skinner. The VBA develops the child's ability to learn a functional language.

Name of approach	General characteristics and areas
PRT – Pivotal Response Treatment (authors: Dr Lynn and Robert Koegle)	PRT is aimed at developing motivation, social initiative and ability to respond to multiple signals, self-government. It contributes to further facilitating the perception of educational information.
TEACCH – Treatment and Education of Autistic and Related Communication Handicapped Children (author: Eric Schopler)	1. Maximizing the independence of the child. 2. Helping the child to interact effectively with others 3. Increasing and developing intellectual skills, school skills and individual abilities 4. Stimulating generalization of skills (new skills the child will be able to use most often and effectively in different situations at home, in the garden, at school). 5. Developing feelings of self, understanding of self (development of emotional sphere). Work with children is in the following areas: imitation; perception; great motor skills; fine motor skills; coordination of eyes and hands; elementary cognitive activity; language; self-service; social relationships.
Developmental approaches	
Emotionally-meaningful approach (developed by experts of the Institute of Correctional Pedagogy of RAE)	This approach aims at normalizing the affective development of a child with ASD. The approach involves establishing emotional contact with the child and engaging him/her in interaction with her loved ones and making sense of what is happening. Development in emotional community with a close adult allows the child to become more enduring, active and interested, joint reflection and organization of life experience gives him/her greater freedom and constructiveness in contacts with the environment, opens the possibility of advancement in the development of the cognitive sphere.
DIR Floortime (author: Stanley Greenspan)	“Floortime” is a technique focused on the development of a child’s initiative in play and social interaction. The concept of DIR and the “Floortime” technique are based on the assumption that by working with emotional or affective manifestations, we can have a beneficial effect on the basic capacities responsible for relationships, thinking and communication.
Son-Rise (authors: Barry and Samaria Kauffman)	The essence of the approach is to create a comfortable environment for the child, which includes both a positive psychological attitude to him/her from loved ones and willingness to contact him/her in accordance with his/her needs, interests and organization of environment, which contributes to the gradual, consistent development of the child’s research and cognitive activity. The idea of the program is to develop relationships with the child through play therapy. The purpose of the program is to change the attitude of the parents towards their child from negative to positive, which is capable of changing himself/herself.
Daily life therapy (author: Kiyo Kitakhara)	The main purpose of this approach is to develop the necessary skills for children in everyday life, including communicative ones. Adaptive behavior training and correction of maladaptive behaviors are done through physical activity, emotional regulation, and academic skills in the group.

Name of approach	General characteristics and areas
RDI – The Interpersonal Relationship Development Program (authors: Stephen Gatstin and Rachelle Shealy)	RDI is a method of behavioral therapy based on a child's motivation for communication, interaction and friendship. The approach is based on studies of the human brain that confirm that the brain is able to adapt to any problem. People with disabilities can adapt and learn to function in a "normal" way. The purpose of the RDI technique is to complete a step-by-step accelerated path of development for a normally developed child.
Sensory-and-perceptual approaches	
Sensory integration (author: Gene Aires)	The method is aimed at stimulating the work of the sensory receptors in the coordination of different sensory systems. Sensory-and-integration therapy is a rigorously dosed and clearly constructed specific training system of impaired function in a specially organized therapeutic environment.
Tomatis therapy (author: Alfred Tomatis)	Tomatis therapy is a means of audio-vocal training. Tomatis therapy is a means of stimulating brain activity through the use of music based on any polyphonic sound.
Eclectic approaches	
Model SCERTS (authors: Barry M. Prizant, Amy M. Weatherby, Emily Rubin and Amy Laurent)	SCERTS is an innovative educational model for working with children with ASD and their families. It provides specific guidelines for helping your child become a competent and confident social communicator while preventing problematic behaviors that interfere with learning and relationship development. The approach also aims to help families, teachers, and therapists work together as a team, closely coordinated to make the most progress in supporting a child. The abbreviation "SCERTS" stands for: SC – Social Communication is development of spontaneous, functional communication, emotional expression, safe and trusting relationships with children and adults; ER – Emotional regulation is development of the ability to maintain a well-regulated emotional state to cope with daily stress and to be the most open to learning and interaction; TS – Transactional Support is development and implementation of support that helps partners respond to their child's needs and interests, change and adapt the environment, and provide tools to enhance learning (e.g., image sharing, writing schedules, and sensory support).
The Miller Method (author: Arnold Miller)	The method is based on a "cognitive-and-developmental systemic approach for children with ASD". Miller's method employs two basic strategies for the development process: one involves the transformation of behavioral systems that are abnormal, into functional behavior; the other – systematic and regular use in the process of developing occupations of certain activities involving objects and people.

Table 2 constructively describes the main classical psychocorrectional and psychotherapeutic approaches that are actively used in the process of psychological and pedagogical support of children with ASD. Appropriate approaches are reflected in various correction programs, such as:

1. Programs and techniques for young children:

- “Early Bird” Program
- Denver Model for Early Intervention for Children with Autism – “Early Start Denver Model”
- ASSERT program
- “Carolina” program for infants and young children with special needs.

2. Programs and Methods for Preschool Children:

- “Behavior Modification in Autistic Children: A Guide for Parents and Professionals”
- Teaching Developmentally Disabled Children: “The Me Book” by Lovaas
- The program “Support for autistic and underdeveloped children. A compendium of exercises for professionals and parents under the TEACCH program” [18]

3. Programs and techniques for school-age children and children with functional autism:

- Orientation in the Social World – “Navigating the Social World” [41]
- “Mind Reading” Program – Teaching Children with Children’s Autism Syndrome, Understanding Another Person)
- “Teach Me Language” Program – Teach Me To Speak

4. Programs and techniques for children with ASD who have communication problems:

- Picture exchange communication system (PECS)
- Facilitated communication

Integrated implementation of modern AR technologies, free software, unlike other means of psychological and pedagogical support, allows to realize aspects important for the rehabilitation process of children with ASD: first, differentiation, because there are no two identical children with ASD; second, the ability to work with meaning; third, the visibility [26]. Using tablets and special software is a good teaching and communication method for children with ASD who find it difficult to get in touch with others, and sometimes even with loved ones. With technique, a person with autism feels calmer, they do not need to worry about their behavior and fear questions that an autistic child does not know the answers to. It is believed that a child with ASD will not be able to talk to peers and adults after computer lessons.

An analysis of the research and theoretical and methodological reviews revealed four major components of the beneficial effects of AR technologies on the process of psychological and pedagogical support of children with autism spectrum disorders: cognitive, motivational, emotional and social ones. Computer training has seen an increase in speed and increased concentration of attention; improved learning, memorization, executive functions, creativity; problem solving skills appear. Motivational benefits include improved work efficiency and persistence. Emotional benefits are mood enhancement and adaptive regulation of negative emotions management strategies such as anger, anxiety, and depression. The introduction of AR technologies is driving such positive social changes as enhancing cooperation, support, mutual assistance, and improving behavior and activity [38]. It is important for AR developers to support the learning of a child with ASD, taking into account and applying the principles of accessibility and ease of use of web content, as outlined, for example, in the ISO / IEC40500: 2012 standard offered by the World Wide Web Consortium (W3C). Considering the principles of universal design for correction and development support (Universal Design for Learning, UDL), it is advisable to further visualize the content. Accordingly, in the process of selecting AR technologies for the further implementation in the process of psychological and pedagogical support of children with ASD, we were guided by the following criteria: accessibility, instructiveness, understandability, visualization, complexity, availability of correction-developmental and psychological construct, logic, systematic, structural properties, available clear interface, the ability to implement an individual approach, and multi-functionality [21]. To summarize, we suggest dividing AR technologies of psychological and pedagogical support for people with autism spectrum disorders into those that will support communication skills, social communication and traditional ones themselves.

AR technologies to improve communication skills. According to recent scientific studies, about 25% of children with ASD are non-verbal, i.e. they have limited or do not use speech to communicate. The Makaton Charity is a language program that enables people with disabilities to communicate. It is a unique language program using gestures, symbols and oral speech that helps to communicate people with communicative difficulties. The use of gestures makes communication possible for people who do not speak or their speech is indistinct. Symbols can help communicate with those who are unable to gesture or prefer graphic expression. With the exception of verbal language, all communication is considered Assistive and Augmentative / Alternative Communication (AAC) [9; 27; 36; 37; 38; 40]. Therefore, when a child with ASD has severe verbal problems, supportive and alternative communication strategies may be able to express themselves. The complexity of communication has a significant impact on the quality of life, education, development of social relations. The use of appropriate AR technology makes communication possible for people who do not speak or their speech is indistinct. Symbols help communicate to those who cannot gesture or prefer graphic expression. The program also teaches children to communicate with adults and peers, hear and understand others, inform about their needs and desires. Gesticulation stimulates the lingual areas of the brain, which promotes the development of the child's articulation apparatus [35]. As a result, the emergence of a form of communication in the child's life leads to social development and reduces the manifestation of behavioral disorders. It can be used by preschool teachers, teachers, speech therapists, psychologists and other specialists. A support of alternative communication covers advanced technologies and may be low-tech, such as the Picture Exchange Communication System (PECS) or high-tech, such as Voice Output Communication Aids (VOCAs) [11]. VOCAs are portable electronic devices that can produce a synthetic language for the user and can be used with graphic symbols as well as text. VOCAs can be used effectively by ASD children. Chien Hsu Chen [10] described the effectiveness of this technology and focused on the design features of such AR technologies in the psycho-pedagogical support.

The most popular alternative online communication tools for Apps are SceneSpeak, which creates interactive displays and stories with voices and text broadcasts added to stories and devices using the Milo language to help children develop communication skills by creating an interactive history journal. In turn, it should be said that there are hundreds and thousands of developments, both online and mobile, so it is urgent to choose the best application for the user. One way to get a more informed view of the available AR technologies is to explore web resources that look at developments and applications for people with ASD. For example, DART (Development Autism Research Technology) reviews about 100 programs and has its own 5-point rating scale. DART also offers a very useful wheel of applications for selecting the proper Apps for PWD (Sue Fletcher-Watson researcher) [14]. Examples and comparisons of some well-known developments in communication technology by The University of Bath, one of the UK's leading universities, are SMART-ASD: Matching Autistic People with Technology Resources [42]. An even greater level of visualization can be achieved with the example of PECs using the augmented reality technology suggested by Taryadi and Kurniawan [18]. This technology offers a new system for developing communication skills, a sensory system, and an emotional-volitional sphere that uses augmented reality technology for PECS training techniques. This helps teach kids how to use new images or objects with the proper keywords or phrases, resulting in faster engagement and better social adaptation.

AR technologies for stimulating the development of social skills. Learning technologies based on the iPad and other mobile technologies are common to acquire social skills. Kolomoiets [28], Brandão [25] and other researchers offer the use of augmented reality technology in support of children with ASD to increase their motivation and involvement in interactive learning activities to improve their cognitive and social skills. Particular attention is paid to the use of augmented reality for learning and reproducing social skills, but with a minimal number of "dangerous" environments that can be carefully designed and controlled, and support more realistic and less didactic interactions. The Internet and Multimedia Technology Innovation Center (AIM Tech Center) at Hong Kong City University has developed a training program to study the effectiveness of virtual reality technology for teaching emotional and social skills. The program has six augmented reality scenarios depicting the everyday lives of typical Hong Kong children, research described by Yuan et al. [43] of the University of Kansas created the augmented reality technology, "Animated Visual Amplifiers for Social Skills" (AViSSS). This system has enabled people with ASD to work on social skills using different environments and situations. The participants should simulate behavior or select specific objects. This platform has given them the opportunity to deal with various social situations without tension or anxiety related to the real world. In the context of the analysis of modern mobile and computer applications based on augmented reality use, the most common and accessible ones should be identified. In 2013, Autism Soft was founded, which develops specialized software for people with ASD, mainly for tablets. The developers emphasize that their programs are built on the needs of future users. At the moment, the company has introduced two software products: Autism Communicator and Visual Schedule. Autism Communicator is an application for children with autism that provides non-verbal communication with other people through cards. Visual Schedule is the first planner for children with ASD. All the events in it are complemented by vivid illustrations: drawings, photographs, etc. This form of timetable gives a clear structure of the sequence of events, removes the anxiety of the child in the future, and takes his activity to a new level. Both applications run on the iOS platform, but in late July 2015, Autism Communicator migrated to the Android platform. Appropriate technologies can be actively used in conjunction with behavioral approaches [29] within the framework of psychological and pedagogical support for a child with ASD, namely as an element of the ABA, Pivotal Response Treatment, TEACCH (Treatment and Education of Autistic and Related Communication Handicapped Children) method, and as a component of the SCERTS model. The implementation of ABA Math, an application-based behavioral analysis technique developed by Loveas [42], helps autistic children to learn arithmetic mechanically. For each example (for example, 1 + 2 = 3), the program creates different situations for the child in discrete tests until the student is able to cope with the task. Appropriate technology is an important mechanism for the development of mnemonic abilities of the child, facilitates the learning process. The ABA Math program is a synergistic factor in the complex implementation of eclectic approaches in the process of accompanying a child with ASD, namely, as a component of the SCERTS model, Miller method, as a multifunctional component of the development of the cognitive and emotional-and-volitional spheres of the personality. It is quite innovative to use special training programs developed by Palito [42] in training and psychological support of children with ASD, which completely eliminated the mouse and keyboard, leaving only the space bar command. Children can manage their own learning. The programs are divided into topics. For example, the Colors! is devoted to the study of color, its differentiation. Children learn to understand what colors some objects have, what colors are the main ones, which are derived.

Within the implementation of AR technologies, appropriate developments can be effectively used in the development of Emotional-Meaning Approach (DIR Floortime, Daily life therapy), Sensory-Perceptual Approach (Sensory Integration) and Behavioral Approach (TEACCH (Treatment and Education of Autistic). These programs are focused not only on the development of competence, cognitive and mnemonic functions in a child with ASD, but also on the development of emotional-and-volitional regulation, self-organization, self-control, and the formation of constructive adaptive mechanisms of interaction with others [16].

Autistic children think of images, poorly memorize the sequence, so to teach them it is necessary to correlate the word and the subject and record the sequence. For this purpose, it is very convenient to use a computer. It is much easier for them to correlate a word with a picture if they see a word and a picture printed on the screen. Some do not understand abstract drawings, so we recommend that you first work with real objects or photos [17]. Educational games in the “Logo” environment are addressed to children of primary and secondary school age. Many different programs have been developed for autistic children using ABA therapy and high-quality imaging. But, as a rule, they are designed for iOS devices. For example, Autism Emotion is a free and useful program for autistic toddlers to train them to recognize emotions. This program can be actively used in the process of correctional and developmental work with a child with ASD. An appropriate program promotes the development of positive motivation, the correction of emotional rigidity, the formation of elements of empathy and the skills of establishing cause-and-effect and causal relationships between the relevant case and the life situation that a child with ASD is facing.

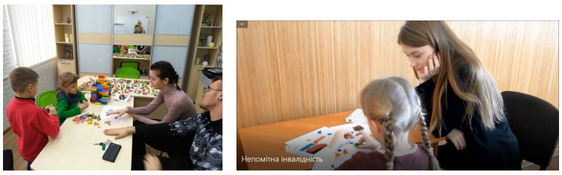
The use of Smart Board in psycho-correction work with children with ASD is seen as an augmented reality platform for empowering autistic children to play with their siblings, classmates, and friends, and building the communication process [7]. Children with autism are often described as thinking with visual images, so by embodying the imaginary image with augmented reality, it can help them understand the concept of imagination and effective engagement, and expand their personal social experience. The open play environment and augmented reality system work as a playground for imaginary play to help children with ASD visualize a particular activity algorithm in their mind. The use of modern AR technologies gives an opportunity to take into account the individual characteristics and capabilities of each child with ASD (for example: individual pace of activity, methods of learning knowledge, interests, etc.); to save personal resources; to correct developmental disabilities. The use of computer programs and augmented reality technologies promotes effective interaction, formation of positive motivation; development of intellectual and creative abilities, cognitive abilities [29].

An interdisciplinary pilot study aimed at the implementation of AR technologies in the concept of traditional psycho-correction effects on a child with ASD has developed and tested a psycho-correction program based on the SCERTS model and augmented reality elements at each session. The corresponding research was carried out in the process of cooperation with parents who raise children with ASD and are members of the Special Parenthood PO "Protecting the Rights of Special Families". In the course of the research, a preliminary theoretical and methodological analysis of the effectiveness of the introduction of psycho-correction programs and elements of augmented reality in the process of supporting a child with a disorder of the autism spectrum was used. The following techniques were used in the psycho-diagnostic unit:

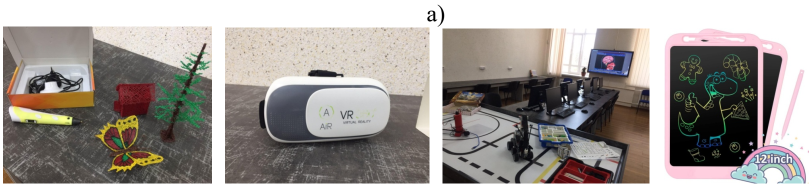
"C.A.R.S Autism Rating Scale", "Routine Interview ", "M. Durand Behavioral Motivation Survey Scale", "The Communication Matrix". The total number of participants in the psycho-correction program is 29 children. As a result of the distribution, two groups were formed: soft and moderate autistic manifestations had 17 children (62.7%) belonging to Group 1, severe autistic manifestations – 10 children (37.3%) belonging to Group 2. The psycho-correction program consisted of four units, and an element of augmented reality was introduced into the structure of each lesson:

1. Developing parental competence: understanding the signals of the child, recommendations for the development of social and everyday skills and communication, developing attention, the ability to structure their space and activity.
2. Updating the adaptive capacity of the child with ASD, development of social skills.
3. Adaptive behavior training and correction of maladaptive behaviors.
4. Teaching children the skills of additional and alternative communication in subgroups.

Classes with children with ASD were held at the Laboratory of Psychology of Health of the Department of Psychology and the STEAM-Laboratory of the Department of Informatics and Cybernetics, Bohdan Khmelnytsky Melitopol State Pedagogical University (fig. 2).



a)



b)

Fig. 2. Elements of implementation of complex psycho-correction program using AR technologies (*a* – traditional psycho-correction techniques and methods; *b* – means of introduction of elements of AR technologies in psycho-correction process).

Observation of the behavior of children during the lessons showed that the multimedia computer program and AR technologies contribute to the emergence of motivational effect in children with ASD (the main task in teaching children with ASD is the development of social motivation). The data of the results of primary and secondary psycho diagnostic procedures were processed and accumulated in table 3.

Table 3. Psycho-diagnostic results before and after psycho-correctional exposure using AR technologies.

Subgroups of subjects	**Prior to correctional impact**	**After correctional impact**
Group 1	1. Domination of the fourth and fifth levels of communication (78.6%) 2. Manifestations of atypical stereotypical behavior (75.8%) 3. Behavioral hazards (Auto Aggression) (11.8%) 4. Most children demonstrated "achievement" as the predominant type of behavioral motivation (52.3%) 5. Attention motivation behavior (19.3%) 6. The manifestations of atypical behavior of children were motivated by insufficiency or excess of sensory feelings (14.1%)	1. The number of children with manifestations of atypical, stereotypical behavior decreased by 39.6% 2. Completely managed to overcome behaviors that were dangerous to themselves (auto aggression) 3. Children learned to use PECS cards and information resources, which helped to increase their communication level by 12.6% 4. After the psycho-correction program, the children had gestures of "congratulations," "goodbye," "give," "yes," "no." The group learned how to use a visual interactive schedule and developed own communication cards

Subgroups of subjects	Prior to correctional impact	After correctional impact
Group 2	1. Domination of the first and second levels of communication (85.6%) 2. Manifestations of atypical stereotypical behavior that impedes task accomplishment (98%) 3. Behavioral hazards (auto aggression) (44.1%) 4. Only 9.7% of respondents showed motivation for “achievement” 5. Attention motivation behavior (4.8%) 6. The manifestations of atypical behavior of children were motivated by insufficiency or excess sensory sensations (30.7%)	1. The number of children with manifestations of atypical, stereotypical behavior decreased by 48.6% ($p \leq 0.05$) 2. It was completely possible to overcome the manifestations of behavior that was dangerous (auto aggression) 3. After corrective actions, 54.70% of the children in this group reached the third level of communication 4. Children learned to use the gesture system, they used the following gestures: “greetings”, “goodbyes”. They learned to use the subject interactive timetable. A “give” gesture and pointing gesture, as well as functional gestures, were formed

As a result of such correctional work, children learned how to use PECS cards and gestures, use visual timetables and AR technologies to explain and express their emotional states, improve interaction with loved ones, expand social interaction experiences and instrumental skills in adaptive living and independent living skills. Prior to the corrective program, most children had atypical behaviors. After the corrective interventions, the number of children with atypical behavior in both groups decreased. Through a comprehensive integrative psycho-correction program using AR technologies, we were able to completely overcome behaviors that were dangerous to ourselves or others. In both groups the level of communication interaction increased significantly.

3 Conclusions and prospects for further research

In the process of employing AR technologies, autistic children learn to overcome difficulties, control their activities, evaluate results. When deciding on a computer-programmed case-study, the child strives for positive results, subordinates his actions to the goal. Thus, the use of modern AR technologies in the process of implementation of psychological and pedagogical support of a child with ASD helps to develop such strong-willed qualities as independence, alertness, concentration, personal control. The results of the pilot empirical research aimed at integrating the combination of traditional psychological-pedagogical methods and AR technologies in the process of psycho-corrective work with children with ASD, confirmed the need to introduce a component of additional reality in the process of supporting such children. According to the results of psycho-correcting influence and complex use in each lesson an element of augmented reality in children increased motivation, significantly developed communication skills, social skills and ability of organizing and self-regulation of their own actions and emotional reactions, and a manifestation of atypical, even auto-aggressive behavior has decreased. Combining AR technologies and traditional approaches achieves individuality and maximizes the effectiveness of corrective action.

Educational and corrective work should be directed mainly to the development of emotional contact and interaction of the child with adults and with the environment, affective development, the formation of internal adaptive mechanisms of behavior, which in turn, increases the overall social adaptation of the autistic child. Thus, the use of AR technologies in psychological and pedagogical support allows children with ASD to feel confident in themselves, helps them to adapt, promotes general socialization; develops skills of constructive interpersonal and communicative interaction. Prospects for further research are the development and testing of a comprehensive model of implementation of AR technologies in the psychological and pedagogical construct of accompanying children with disorders of the autism spectrum according to the nature and degree of disorders of interaction with the external environment, as well as the type of autism itself and individual characteristics of the child.

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Augmented reality books: concepts, typology, tools

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Abstract. The article discussed the usage of augmented reality books in educational process. *The object of research* is augmented reality books. The *subject of the study* is the concepts and classification of augmented reality books; digital story making tools that emphasize child-teacher co-operation; difficulties in augmented reality using. *The methods of research* are: the analysis of publications about the issue; the analysis of digital tools capabilities; systematization and generalization of research information. In the article the facet classification for augmented books is proposed; the main facets are: reality-virtuality continuum, type of augmented materials, device types, type of interaction, spatial space of book, book’s category. Content for a module of a specialty course about augmented reality books for the system of professional training and retraining for educators in postgraduate education is discussed. Some samples of tasks for educators are presented: audio augmented book about world’s books monuments; analysis augmented reality examples in the textbook of the New Ukrainian school (subject name, topic, didactic tasks, quality of implementation, directions of expansion etc.), search and analysis augmented books according to the professional interests of the educators; discussion how augmented reality can help to improve student motivation with accent to attention, relevance, confidence and satisfaction; group work about design and creation a fragment of own textbook with augmented reality.

Keywords: augmented reality, augmented books, classification augmented reality books, professional training and retraining.

1 Introduction

Augmented reality allows you to combine the real world with virtual objects, and possesses vast and diversified didactic learning opportunities. The use of augmented reality in education has been analyzed by numerous world scientists and Ukrainian researchers in frameworks of the scientific conferences AREdu 2018 [19], AREdu 2019

[18] and AREdu 2020 [9]; discussed in the massive open online courses [12; 15; 16]. A promising area for the use of augmented reality in education is augmented books.

We think another important task is to train teachers to create and use these books during the educational process.

While solving the scientific problem of training educators for using the augmented reality books in education, the following main results were obtained in past author works: the potential of the massive open online courses (MOOCs) about Augmented reality was investigated, the content and program of the specialized course "Augmented Reality as a Storytelling Tool" for the professional development of teachers was described [21], the difficulties of using storytelling in education and ways to overcome them were outlined [22].

2 Research objective and methods

The purpose of this article is to explore the definitions of augmented books, their classification, and tools. Moreover, tools that can be used by children, students, teachers both on their own and together with the purpose to use AR books in a module of a specialized course for the system of professional training and retraining for educators in postgraduate education. This module is proposed as the unit of the author's specialized course "Digital Storytelling in Adult Education" in the Central Institute of Postgraduate Pedagogical Education (CIPPE) of State Institution of Higher Education "University of Educational Management" of NAES of Ukraine. The mission of CIPPE is "in providing social and pedagogical requests and needs in quality new professional level of pedagogical, scientific and pedagogical and leading personnel of education, public officers, able responsibly and efficiently to execute professional activity in conditions of high competition, instability and permanent changes in professional environment" (http://umo.edu.ua/en/institutes/cippo). Categories of specialized course's listeners are: methodists of district (city) methodical offices or centres and heads of methodical associations; the teachers of academies and universities.

The methods of research are: the analysis of the publications on the problem of use augmented reality in education; the analysis of concepts regarding AR books; the analysis of software related to augmented reality books; systematization and generalization of research information.

3 Results and discussion

An augmented book represents 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" [13]. When a reader accesses the book page for which additional content is provided, the smartphone or other device reads it and displays this additional content on the screen. Additional content may be an image, a video or an audio (fig. 1) recording, and can also be complex, such as animation, game, or interactive activity.

Fig. 1. Augmented book example in Coursera’s course “Getting start with augmented reality”.

Researches place augmented books between virtual and mixed reality books on the corresponding reality–virtuality continuum, presented in the typology: Virtual Book > Virtual Augmented book > Mixed-Reality book > Reality book [13].

Mark Billinghurst proposed the magic book concept [6; 7]. The Magic Book use an ordinary book as the main interface object. Child can turn the book pages, look at the pictures, and read the text without any additional technology. When children look at the pages through a handheld Augmented Reality display, they see three dimensional virtual models appearing out of the pages. Users can switch between the virtual models. When they see a scene they particularly like, they can fly into the page and experience the story as an immersive virtual environment. In the VR mode, users are free to move about the scene at will and interact with the characters in the story. Thus, users can experience the full “Reality-Virtuality continuum”.

Mark Billinghurst notes that the Magic Book interface supports collaboration on three levels [7]:

1. as a Physical Object: multiple users can read together;
2. as an Augmented Reality Object: users with AR displays can see virtual objects appearing on the pages of the book;
3. as an Immersive Virtual Space: users can fly into the virtual space together and see each other represented as virtual avatars in the story space.

By Mark Billinghurst, the interface of Magic book supports collaboration on multiple scales. There are egocentric and exocentric view. Egocentrism is the inability to differentiate between self and other. Readers can fly inside the virtual scenes and see each other as virtual characters (egocentric). Exocentric view also allows a non-immersed reader to see the immersed readers as small virtual characters on the book pages. This means that a group of collaborators can share both egocentric and exocentric views of the same game or data set, leading to enhanced understanding [10].

Raphael Grasset, Andreas Dünser, Hartmut Seichter and Mark Billinghurst [14] proposed a mixed reality book concept. In this concept the experience with an augmented book can be defined in terms of the spatial properties of books. The four elements, which can be explored by a reader are: inside, outside, outside to inside, inside to outside. So, Inside is augmenting the material in the book pages; Outside is augmenting the space around the pages; Outside to the Inside show interacting from the space around to the content of the book; Inside to the Outside can extracting content from the book.

The author's prototype of mixed reality book consisted of the book, standard desktop computer hardware, a multimodal handheld device, tangible interaction devices (cube, paddles), and an additional green screen. In this prototype with the help of a handheld device the user can naturally get immersed into the mixed-reality book. This device provided visual and aural feedback. As prototype the developers chose the book "The House that Jack Built". This book has contained a lot of images related to the history of New Zealand, the relationship between Maori and European settlers [14].

According to the paper [14], the virtual books are "books completely prepared in an electronic format and involving minimum physicality. Traditional AR books are used by adding virtual elements to physical books. Mixed reality books are composed of virtual insertions at the meaningful level in the manner most similar to physical books".

Tangible AR interfaces [4; 5] combine the enhanced display possibilities of AR with the intuitive manipulation and interaction of physical objects or Tangible User Interfaces. Authors say that experiences with these interfaces show that "the Tangible AR metaphor supports seamless interaction between the real and virtual worlds, and provides a range of natural interactions that are difficult to find in other AR interfaces" [4]. A Tangible AR interface provides true spatial registration and presentation of 3D virtual objects anywhere in the physical environment, while at the same time allowing users to interact with this virtual content using the same techniques as they would with a real physical object.

These are the design principles learned from TUI interfaces:

- The use of physical controllers for manipulating virtual content.
- Support for spatial 3D interaction techniques.
- Support for both time-multiplexed and space-multiplexed interaction.
- Support for multi-handed interaction.
- Support for Matching the physical constraints of the object to the requirements of the interaction task.
- The ability to support parallel activity where multiple objects are being manipulated.
- Collaboration between multiple participants. Authors central hypothesis is that AR interfaces that follow these design principles will naturally support enhanced face-to-face collaboration [4].

Hakan Altinpulluk and Mehmet Kesim [1] analyze augmented reality books of academic nature prepared in the field of education through the literature review technique. They classified 46 augmented books as AR book, augmented desk/paper augmentation approach, 3D pop-up book, tangible AR approach and MR book. Authors determined 8 studies as MR books and 38 studies as AR books. The researchers say, that augmented desk/paper augmentation approach and game-based children's books called interactive 3D pop-up books go away nowadays. The second tendency they noted, transition from special glasses and head mounted displays to view the books to web cameras integrated to desktops and mobile devices. Another situation noticed when analyzing the studies is that most augmented book studies are not prepared by a single author, and the development of augmented reality books is supported by certain organizations and collectives.

The growing list of books from various authors, platforms, organization, and universities, which is being presented to the world community today, raises questions about the search and selection of the necessary books, their classification.

We have tried to provide a facet classification of digital books, a fragment of which is shown in table 1.

Table 1. Fragment of the facet classification of virtual books.

F_1 Virtuality continuum	F_2 Type of augmented material	F_3 Devices	F_4 Interaction	F_5 Book Spatial space	F_6 Category book	F_7 Type interface	F_8 Developer
F_{11} Virtual Book	F_{21} Text	F_{31} Only desktop or mobile devices	F_{41} Time-multiplexed and space-multiplexed interaction	F_{51} Inside	F_{61} Story book	F_{71} Marker	F_{81} Educational institution
F_{12} Mixed Book	F_{22} Audio	F_{32} With special glasses and headsets	F_{42} Parallel activity where multiple objects are being manipulated	F_{52} Outside	F_{62} Text-book	F_{72} Marker less	F_{82} Binary (Educational institution + organization)
F_{13} Augmented Book	F_{23} Video		F_{43} Collaboration between multiple participants	F_{53} Outside to inside	F_{63} Tutorial	F_{73} Projection	F_{83} Consortium of educational institutions
F_{14} Reality Book	F_{24} 3-D models		F_{44} Mixed	F_{54} Inside to outside	F_{64} Map	F_{74} Visual Initial Odometry	F_{84} Company
	F_{24} Mixed				F_{65} Encyclopedia		F_{85} An individual or group

The facet classification system, as we know [11; 26; 29], consists of the parallel division of a plurality of objects into independent subsets – facets. It is also called the "colon", the Ranganathan classification. The analysis of scientific sources made it possible to present each such augmented book in the form of a structural formula, which includes 7 facets. Thus, books can be classified according to the level of virtuality; the type of augmented content, the types of devices, interaction, spatial space of book, category etc. For example, some augmented book can be described the following formula:

$K = (F_{12}, F_{21}, F_{31}, F_{41}, F_{53}, F_{64}, F_{71}, F_{81})$, where F_{ij} is the *i*-th focus of the *j*-th facet.

Note that facet classification is easily expanded depending on the book search tasks, for example, within this fragment, we did not knowingly include a subject field; type of education, free or limited access to book materials etc.

The use of AR applications improves motivation of students. One of model of motivation design is proposed by John M. Keller [17]. His model [17] divides learner motivation into four components (attention, relevance, confidence and satisfaction) and called ARCS (fig. 2). This model provided strategies for instructors to incorporate each component into their courses and to choose relevant augmented books.

Fig. 2. Model of motivation design by John M. Keller.

Natalia Kucirkova outlines a theoretical rationale of why children's self-made digital books can be important to their learning and wellbeing, and give practical examples of how adults can support children's digital story-making [20]. She introduces the five parameters for children's personalization: authorship of their own stories, autonomy in producing them, authenticity of their contribution, attachment to the final product and aesthetics in its creation. She summarized also the key ways in which the teachers used digital personalized books in their classrooms and proposed the list of question to guide the children's activity as storymakers (table 2).

Table 2. Question to guide the children's activity as storymakers [20].

Parameters for children's personalization	Questions
Authorship	To what extent are the stories based on children's own content?
Autonomy	To what extent was the creation of the final product the child's independent work?
Attachment	Who owns the final product?
Authenticity	To what extent do children's stories capture content that is genuine and responsive to the child's own situation?
Aesthetics	To what extent does the final product reflect the child's own taste and preference?

She notes, that depending what digital and human resources are available, children’s digital story-making can be of 4 types: guided by the teacher or a teacher’s assistant; guided one to one by an older child; collaborative story-making with peers; individual story-making with an app or digital story-making program.

Teachers can combine the various audiences and possibilities for children’s self-made stories [20]:

— the whole class with the help of an interactive whiteboard;
— children’s parents: as printed booklets or e-books emailed to parents;
— on the screen in a one-to-one with the child’s friend or teacher;
— on the screen in a small group with the child’s peers;
— electronically with a remote group of children or distant family members;
— electronically or, in the case of a classroom visit, in person with a child books author or illustrator;
— orally at a classroom assembly with other children, teachers, parents and local community members;
— the story is not shared and remains the child’s private personal story.

Good foundations for creating stories and teaching this area are presented in [8; 28]. Fig. 3 shows Story Kitchen from Bruce Van Patter [27]. User can pick one hero, one place, and one villain and can read the beginning of history and get to finish it.

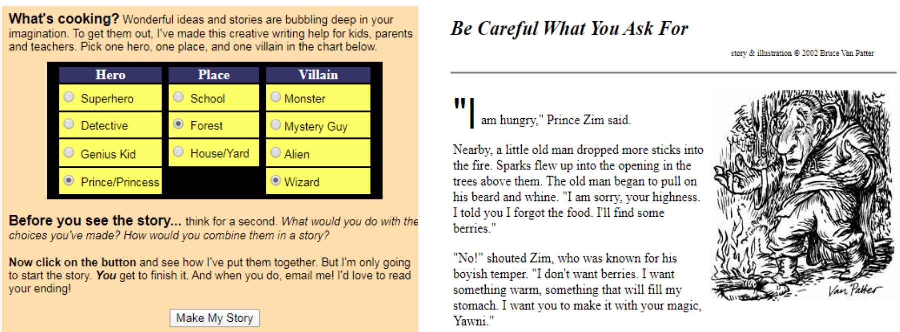

Fig. 3. Pick Prince, Forest and Wizard: story kitchen from Bruce Van Patter [10].

Some other useful applications for Augmented education are: Aumentaty Scope / Aumentary Creator, Wikitude, Quiver Vision / Quiver Education, Star Map / Star Chart AR, Skyview, AR Planet Earth / Geography, 3DBear, CoSpaces Edu, JigSpace, MERGE Cube, Metaverse, Asturica Emerge, Castellones del Ceal AR, Cástulo Virtual, Cisneros Go!, Fuendetodos, La Alhambra - Castillo Rojo, Museo Carlos V and Sorolla Museum AR, Geocaching [24].

Natalia Kucirkova [20] analyzes content of popular software for child story making. Some of such resources are presented in table 3. We agree with the author that the final choice of the tool remains with the teachers, depending on their skills, inclinations, goals, class situation etc.

Table 3. Children story making tools.

#	Name	Free or Not	Brief Description	Link
1	StoryJumper	free, but paid for printed version	May be more useful for US-based teachers, since the community resources offer advice specifically linked to the Common Core curriculum.	storyjumper.com
2	Storybird	free	Storybird is a platform for writers, readers, and artists of all ages and is a powerful resource for illustrated stories. The illustrations can be used to inspire children's own picture books or even novels with older writers. Story starts with pictures as prompts for children's own stories.	storybird.com/educators/
3	Story Maker	free	Story Maker available on the British Council's website. Children can choose the type of story, props and characters' names and print the final story out. The resource's focus is on children's learning of basic English vocabulary.	learnenglishkids.britishcouncil.org/games/story-maker-1
4	Little Bird Tales	free and paid option	Little Bird Tales is a subscription site with a choice of a school or home account. Paid membership includes the option for children to use their own photos, voiceovers, text and drawings to make their digital stories.	www.littlebirdtales.com/info/premium/section/teacher
5	My Storybook	free	My Storybook is suitable for the preschoolers and lower-primary-school children. The user interface is very child-friendly, with large icons and pictorial navigation. Final stories can be printed out as a PDF and stored in a library.	www.mystorybook.com
6	Toontastic 3D	free	The Toontastic 3D application is based on story templates and pre-designed props and advertised as a creative storytelling app. It allows children to create 3D cartoons using the app's set of characters, props and backgrounds. The app is managed by Google.	toontastic.withgoogle.com
7	Comic Life	free 30 days version	Comic Life can be used to create comic books using one's own photos. Children's comics can be enhanced with the Comic Life template that can add light effects or specific comic themes. Finished stories can be printed out or saved in the digital library.	comiclife.com
8	MIT App Inventor	free	The MIT App Inventor initiative at the Massachusetts Institute of Technology allows children as evaluate application as well to develop it.	appinventor.mit.edu/explore

Criteria for selecting children's digital books include ordinal criteria and such specific criteria:

- relevant enhancements that support narrative;
- seamless integration of features and enhancements;
- sound effects that don't interfere with voiceover or other features;
- technical polish, stability, ease of use and navigation settings, flexible use;
- no ads, in-app purchases or links that leave the app (unless under sufficient parental gate);
- clearly identified author, illustrator, producer;
- quality games or other activities that do not interrupt narrative or reading comprehension [20].

The author's course module "Augmented reality as a tool for storytelling" contains thematic plan of the module; content of the module by themes; lecture and practical classes plan; independent work of students; practical tasks for self-control; recommended reading [12]. The thematic module unit about augmented books is presented in table 4.

"Augmented books: concepts and classification" lecture plan.

Augmented reality in education. Augmented books. Magic book concept. Mixed reality book concept. Typology of augmented reality books. Facet classification. Interface of Augmented books.

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

Examples of augmented books. Children's books. Digital stories with augmented reality. Criteria evaluation of digital books. StoryBird. Story Maker. Story Kitchen. App Inventor.

Table 4. Thematic module plan.

Thematic module unit	**Class format, hours**			
	Lections	**Practices**	**Independent work**	**Total**
Augmented Book concepts and Augmented Book classification. Facet classification.	1		1	2
Digital books tools for pupils. Digital books tools for teachers. Student and teacher co-creation.		1	1	2
Total	1	1	2	4

Sample practice tasks for educators:

1. create a sample audio augmented book about book monuments of the world (according to the guidelines of course "Getting started with Augmented Reality")

Augmented reality is manifested in the form of the author's accompanying text about the monument of the book, for example for fig. 4. "*In Berlin at Bebelplatz on Unter den Linden Boulevard, in front of the Humboldt University building, a twenty-meter monument weighing 35 tonnes was opened, consisting of 17 books by German authors. The sculpture is set in memory of Johann Gutenberg, the inventor of modern printin*g".

Fig. 4. The sculpture is set in memory of Johann Gutenberg, the inventor of modern printing: 17 books by German authors (https://lesoteka.livejournal.com/78147.html).

2. analyze augmented reality examples in the textbook (fig. 5) of the New Ukrainian school (subject name, topic, didactic tasks, quality of implementation, directions of development etc.);

Fig. 5. Augmented reality example in the textbook of New Ukrainian school (https://www.youtube.com/watch?v=rWLWkKkV1SQ).

3. find and analyze some augmented books according to the professional interests of the student;
4. discuss how augmented reality can help to improve student motivation: attention, relevance, confidence and satisfaction;
5. group work: design and create a fragment of their own textbook with augmented reality.

We also think that the use of AR technology will facilitate the co-creation of students and teachers. We understand co-creation [23; 24; 25] as a joint creative activity of a teacher and a student, aimed at developing the educational environment and ourselves in this environment.

The scientist's research of difficulty to use AR is presented in [2]. Julio Barroso Osuna, Juan Jesús Gutiérrez-Castillo, Mª del Carmen Llorente-Cejudo and Rubicelia Valencia Ortiz present, that experts pointed out what might present the most difficulty:

- lack of teacher training;
- lack of educational experience;
- lack of conceptual foundation;
- lack of educational research;
- institutional difficulty / lack of institutional support.

In our research [22] we study the problem of the use of storytelling technology in educational process. According to the survey of teaching staff and methodologists of different professions while they were taking retraining courses, only a quarter of respondents use or have used this method, and about 72% of respondents are ready to consider it. A 3-factor model on possible barriers that impede the use of digital storytelling in education was developed on the basis of the empirical data with the help of a factor analysis tool. The first factor was related to the lack of necessary resources, the second one – to resistance to change, the third one – to the lack of time and lack of technical and methodological support from the educational institution. As we see, the last factor is the same as in research [2].

What are possible ways to overcome these barriers? According to some scholars [30], an inappropriate level of professional development can also be a barrier to the use of information technology in general and digital staging in particular. Peter G. Taylor proposes a strategy for engaging a critical mass of staff in a technology-augmented educational practice and identifies 5 required steps: orientation, acceptance, evaluation, innovation, and institutionalization for professional development programs [30, pp. 275–276]. Let's look at these steps in more detail, with a focus on using AR books.

At the orientation stage, teachers are considering approaches to integrating augmented reality technologies into teaching and learning that meet current educational expectations, technology availability, and the requirements of the educational institution's curriculum and the subject matter they teach. During the adoption phase, educators adapt current intentions and practices to teaching and learning using augmented technology in a high-tech learning environment. They then evaluate these practices (evaluation phase). In the next phase, innovators and educators re-develop their practice based on their own experience of digital story technology in a high-tech environment of the educational institution and study the reactions of the educational recipients to them. At the institutionalization stage, educators and managers develop strategies to ensure that new teaching and learning methods are maintained in the medium and long term and thus become "traditional".

The first three phases (orientation, acceptance, assessment) – we relate to the first period of teachers training and retraining, which is full-time; the fourth phase (innovation) – with the inter-course period of teacher training and retraining; the fifth phase (institutionalization) – partly with the third period of teacher training, which is also full-time and with course work's presentation. We agree with Peter G. Taylor that each of these stages requires different approaches to professional development and should include time for reflection, specific training, discussion, consideration of alternative practices, and transformation of accepted practices. We consider it important - the organization of pedagogical support for teachers in these areas.

It would be interesting to apply Zane L. Berge, Lin Y. Muilenburg and James Van Haneghan [3] methodology (they studied barriers in distance learning) to the study of difficulties in using AR in education.

Note that recently there have been special programs that train specialists in augmented and virtual reality.

So, for example, Singapore University of Social Sciences offers a three-year program Virtual Reality and Augmented Reality (MTD369) [31]. The content of the first two years of preparation is shown in fig. 6. This list of courses gives an idea of the diverse training of specialists. We can take note of such courses as creativity and imagination, storytelling, narratives and experience for training teachers in this direction.

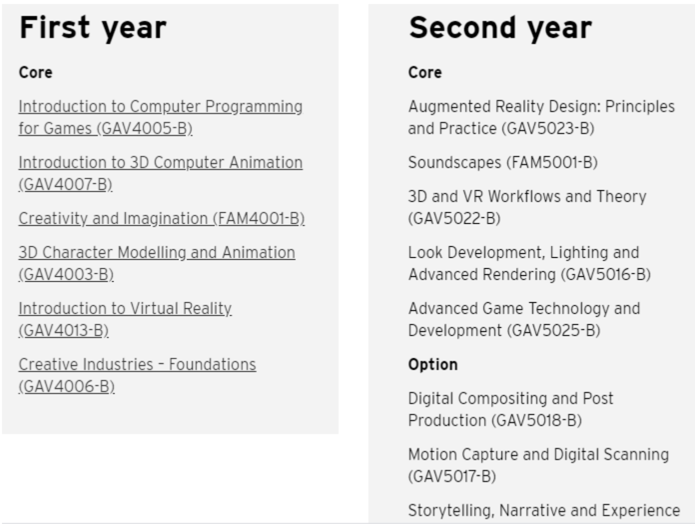

Fig. 6. VR Program and AR Program in Singapore University of Social Sciences [31].

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, and so make it acceptable for adults and people with disabilities. An augmented textbook is a new educational tool, it can contain fragments of video lectures, electronic pads such as Padlet, augmented quizzes, 3D models, animated tours in the history of the problem being studied, in-depth exercises, didactics games etc.

The facet classification of augmented reality books is offered on the basis of the analysis of the scientific sources about these books. The main facets are: reality-virtuality continuum, type of augmented material, devices, type of interaction, spatial space of book, book's category. The author's specialized course "Digital Storytelling in Adult Education" for the system of professional training and retraining of educators is updated with augmented book creation module.

The further development of the study is seen in the didactics analysis of the new apps for creating augmented textbook, clarification of the facet classification proposed and detail learning of barriers in the use of augmented reality in education, in particularly, by methodology of Zane L. Berge, Lin Y. Muilenburg and James Van Haneghan [3].

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Perspectives on the use of augmented reality within the linguistic and literary field of primary education

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Abstract. The article analyzes the scientific sources on the problem of augmented reality in the educational field. There is a fragmentary rationale for new technology in primary school, to a greater extent the experience of scientists and practitioners relate to the integrated course "I am exploring the world". The peculiarities of Ukrainian and foreign writers' works with AR applications, which are appropriate to use during the classes of literary reading, are analyzed. The authors substantiated the prospect of augmented reality technology for mastering the artistic image of the world of literary work, the relevance of use of AR to modern educational challenges, and also demonstrated the possibility of immersion into the space of artistic creation and activation of students' imagination with the help of AR applications. The article demonstrates the possibilities of use AR-technology for the development of emotional intelligence and creative thinking, solving educational tasks by setting up an active dialogue with literary heroes. The basic stages of the application of AR technologies in the literary reading lessons in accordance with the opportunities of the electronic resource are described: involvement; interaction; listening, reading and audition; research; creative work; evaluation. It is confirmed that in the process of using augmented reality technology during the reading lessons, the qualitative changes in the process of formation of the reader's culture of the students of experimental classes appears, as well as the increase of motivation, development of emotional intelligence and creative thinking.

Keywords: Augmented Reality technology, 3D-visualisation, creative thinking, emotional intelligence, creative imagination.

1 Introduction

1.1 Problem statement

Virtual and augmented reality technologies are gaining more are more popularity in the world. At North Carolina State University, students use virtual reality tools while studying science [17]. In the process of virtual field research, they find, observe and study organisms in their natural habitat [7]. At Penn State University in Pennsylvania, students in all disciplines attend practical classes in virtual reality technology classrooms. In such a way, they learn from situations designed for the future life [1; 27]. VR and AR are widely used in schools of America and Europe. Augmented reality technology has become particularly popular, as a regular smartphone is enough to work with it [16]. Students from near and far abroad with interest are moving in classes with phones in their hands, exploring the human body in virtual microcapsules, going on a journey [25], participating in historical events [9], watching physical phenomena [24], etc.

The modern development of ICT makes it possible to modernize the educational process in primary school as much as possible, in accordance with the challenges of time and the requirements of reformed education [12; 19; 26; 29]. The linguistic and literary sector is, at first glance, somewhat remote from ICT. However, the specifics of fiction, its imagery, its organic integration into the multimedia space, suggest that it is necessary to partially revitalize fiction with the help of augmented reality technology in the process of literacy and reading [8]. This hypothesis may also be confirmed with the examples of imaginative approaches to the virtual world, such as in the Lewis Carroll novel “Alice's Adventures in Wonderland”, or augmented reality, such as interactive pictures of Hogwarts in the Joanne K. Rowling series of “Harry Potter”.

While developing lifelong learning skills in primary school students, it is important to build interest in books, to learn how to feel beautiful in the artistic word. Depth of perception of a work depends not only on the development of critical thinking and aesthetic sense associated with the sense of beauty, understanding of values that are accumulated in the artistic image, but also on emotional intelligence. Therefore, the development of a dialogic interaction with works of art will be greatly facilitated by the use of augmented reality technology, which causes its visualization to be primarily emotional resonance and promotes creative imagination.

1.2 Literature review

We analyzed the current state of research on the use of AR applications in education [3]; studied the experience of combination of AR with learning based on games in primary school [21], the impact of integrating game approaches with augmented reality on learning [23], improvement of learning efficiency and students’ motivation through the use of AR applications on smartphones [4].

Possibilities of application of AR technologies in different fields of education were considered by Svitlana I. Pochtoviuk, Tetiana A. Vakaliuk and Andrey V. Pikilnyak [22]. The authors noted the great impact of presentation of educational material by augmented reality on the development of facial expressions, attention, stimulating thinking and increasing the level of understanding of information. Among the benefits, scientists point to realism, clarity, completeness, information and interactivity. The didactic potential of virtual information learning environment is determined by Olga V. Bondarenko, Olena V. Pakhomova and Włodzimierz Lewoniewski [2]. Scientists emphasize such features of VR and AR as immersion, dynamism, sense of presence, continuity, causality, intensification of the process of cognition, saving time for processing the material. While acknowledging the effectiveness of learning with the help of VR and AR, the authors also point out the disadvantages, including low computerization, low number and low quality of software products [2], difficulties in applying these technologies, such as: small experience in using this technology, lack of methodological literature, lack of developed methods of AR implementation [6]. Lacunae of augmented reality educational products are filled by practitioners who create mobile applications to visualize educational material, including the chemical structure of water and display video data from laboratory experiments to study subjects of the natural cycle [18] in the primary school. According to the authors of the LiCo.STEM application (can be downloaded from a publicly available GooglePlay Market resource), its contributes to the development of cognitive motivation of primary school students and educational energy, their imagination, creative initiative and research activity [14].

Joseph Walsh, David McMahon, Padraic Moriarty, Marie O'Connell, Betty Stack, Conor Kearney, Mary Brosnan, Cliona Fitzmaurice, Clare McInerney and Daniel Riordan offer the development and implementation of educational tools using virtual and augmented reality for language learning in primary school [28]. Vladimir D. Sekerin, Anna E. Gorokhova, Anatoliy A. Scherbakov, Evgeniy V. Yurkevich outlined the prospects for the implementation of the latest educational technologies that allow to increase the effectiveness of teaching. Thus, in the course of the study, they found that 20% of students are ready to receive educational information from conventional sources, and 80% of students need interactive perception of information based on augmented reality. Carrying out lessons with the help of virtual reality tools, according to scientists, contributes to the full involvement of students in the educational process and, accordingly, successes in the acquisition of knowledge [24]. For primary school students in Ukraine, a textbook and universal didactic material from AR for the integrated course "I am exploring the world", aimed at developing research skills [13], has already been created.

Thus, most of the publications on the identified problem testify to the possibility of using VR and AR technologies in the educational field for the purpose of visual modeling of educational material; supplementing its visualization; developing students' spatial ideas; research and experimentation skills; three-dimensional design, which saves time for learning information, accelerates learning and makes the process fun and engaging.

1.3 The aim of the research

Therefore, augmented reality is increasingly used in various fields of social activity and in particular in education. Special educational applications in physical, mathematical, natural, historical and other subjects have been developed, and AR textbooks have been created for primary school students in the "I am exploring the world" course. However, the methodology and effectiveness of its application in literacy and reading lessons remains poorly understood.

Recommendation of the European Parliament and of the Council on Key Competences for Lifelong Learning refer to the formation of basic competences that help a person to successfully socialize in the society. As the main competencies one can mention such reference frameworks as critical thinking, creativity, initiative, ability to constructively manage emotions, etc. [5]. We believe that such qualities of a personality are formed during the reader's activity, which will be activated by augmented reality.

The purpose of this article is to substantiate the prospects of using augmented reality technologies in the linguistic and literary field of primary education, to organize and test the effectiveness of younger students' literacy with the help of AR.

We used the following research methods: analysis of scientific sources, analysis of school programs and fiction with AR applications, synthesis of the obtained information – to determine the state of development of the problem and ways to solve it; problem-searching and pedagogical modeling – to create a methodical model of studying a work of art by means of augmented reality. Methods of observation, surveys, questionnaires of teachers and students were also used to determine the problems of application of augmented reality in the language and literature domain of primary school. Comparative methods, quantitative and qualitative analysis of learning outcomes were used to examine the effectiveness of augmented reality in the reading activities of primary school students.

2 Discussion and results

Augmented Reality (AR) technologies provide the introduction into the real world of a three-dimensional field of human perception of virtual information that can be assimilated as elements of real life. Augmented reality projects digital information (images, videos, text, graphics) beyond the screens of devices and combines virtual objects with the real world. Nowadays, thematic visualized content is being used by modern electronic devices to target audiences in a variety of fields, such as science, manufacturing, technology, marketing, design, entertainment, medicine, education, etc. [10; 11]

The importance of augmented reality in the initial process is determined by the immersiveness that is also inherent in Virtual Reality (VR) technologies. Quality augmented and virtual reality content balances the boundaries between an artificially created world and reality. With the help of gadgets, as if through a window, the student watches an amazing image of the world (scientific, technical, artistic, etc.), investigates, learns its laws, practices to change it for the better. Therefore, the use of these technologies results in the maximum expression of students, and, most importantly, allows them to actively interact with different objects of study in three-dimensional space. In this way, augmented and virtual reality technologies allow students to better learn the subjects in the entertainment form of the game, to gain useful experiences that are usually restricted to access. Scientists note the major benefits of these immersive technologies: clarity that allows one to seamlessly examine any process or object; focus that allows one to not be distracted by external stimuli and focus on the lesson material; maximum involvement of students in the educational process; the effectiveness of understanding and memorizing important educational information, etc. [1; 20].

In the linguistic and literary field of primary education, there is also the opportunity to use augmented reality technologies. Such products include interactive alphabets and fiction books by Ukrainian and foreign writers. Thus, “Kobzar Alphabet” (Kyiv, 2019) contains works of Taras Shevchenko for every letter of the alphabet, illustrations of which come to life, move and talk with the free FastAR Kids app on smartphones or tablets (iOS, Android, iPhone). This publication was produced with the support of the Ukrainian Cultural Foundation. “Kobzar Alphabet” is a successful attempt to introduce Ukrainian children to a prominent Ukrainian writer, to visualize the artistic world of his works. The interactive pages of the book show the beauty of Ukrainian landscapes, while audio playback of poetic lines broadcasts the spiritual values of Kobzar, nurtures a love for the mother tongue, the people and their traditions. Based on the works of the talented Ukrainian writer Taras Shevchenko, preschoolers and younger students have the opportunity to learn or deepen their knowledge of the native language alphabet, to feel its sweetness and beauty. In this way, the classic of Ukrainian literature, the energy and the spirituality of its artistic word becomes modern, clear and instructive for the students.

FastAR Kids provides a visualization of another “Living Alphabet” book. The online edition features a game platform with special labels on the pages of the edition that activate the augmented reality in 3D with plots of poems with amazing stories and animated characters. Students have the opportunity to explore living objects from different directions, expand the 360-degree image to help imagine a holistic vision, interact with characters, listen to verses, and memorize letters.

In primary school, it is appropriate to organize interactive reading lessons using augmented reality books. A series of books “Read and Play” by Ukrainian publishing house Art Nation Publishing have appeared in the book markets, including Lewis Carroll’s fairy tales “Alice's Adventures in Wonderland” (2017) and “Alice Through the Looking-glass” (2018), Ernst Theodor Amadeus Hoffmann’s “The Nutcracker and the Mouse King” (2018), Hans Christian Andersen’s fairy tales “Wild Swans” (2019) and “The Snow Queen” (2019), Charles Perrault’s “The Sleeping Beauty” (2019) and “Puss in Boots” (2020). The high quality of each book in this series is confirmed by the coordinated work of talented translators, artists, animators. For example, the fairy tales “Alice's Adventures in Wonderland”, “Alice Through the Looking-glass”, “The Nutcracker and the Mouse King” and “The Snow Queen” were illustrated by famous Ukrainian artist E. Gapchinska, others by O. Drachkovska, M. Koshulinska, and I. Kravets. With the free WowBox AR app on illustrated pages with special designation, the artwork scenes come to life, and the real images are combined with the virtual ones, which is demonstrated in fig. 1.

Wow-animations in augmented reality become interactive: carefully following the prompts, readers actively interact with the characters; take photos or shoot videos with your favorite characters; listen to a fairy tale by selecting Audiobook from the menu. Publishers accompany the augmented reality editions with interactive bracelets, coloring books, stickers that activate readers’ activity in the virtual art world.

We consider this approach justified, since it is becoming increasingly difficult to educate the interest of younger students in literary reading in the current conditions of informatization of society. From preschool, children are accustomed to a variety of gadgets that are gradually becoming one of the leading ways of knowing the world. At the same time, one cannot ignore in shaping the personal image of the world the undeniable benefits of fiction. The art of the word is one of the most important carriers of culture, which opens up the world of new knowledge, has a powerful educational potential, develops memory, critical thinking and emotional intelligence, promotes awareness of national identity and socialization of personality, gives unforgettable impressions and aesthetic pleasure. Therefore, it is necessary to attract the attention of younger students to fiction, to form readers' interests, to demonstrate the uniqueness of literary reading. This goal can be achieved by conducting interesting interactive literary reading lessons. The emotional perception of literary works is enhanced not only by the Wow-effect of augmented reality, but also by the involvement of the reader in interaction with the characters, which contributes to a deeper assimilation of the system of values accumulated in artistic texts.

Fig. 1. Combination of the realistic images with virtual ones, using the WowBow AR application.

A qualitative example of the digitization of contemporary Ukrainian literature for children is a small story for children by Kateryna Babkina called "The Pumpkin's Year", published by the Old Lion Publishing House in 2015. The Pumpkin's Year app available in AppStore or GooglePlay for iOS and Android platforms, respectively, helps to revitalize the Pumpkin's Year print edition. To activate the interactive pages of an animation book, one have to download it on the smartphone or tablet and place a gadget on the cover or one of Julia Pylypchatina's nine illustrations. A specially designed application attaches a virtual AR object to the tag and activates it on the screen. The augmented reality of the Pumpkin's Year story should be used in primary school reading lessons, as Kateryna Babkina's works have been recommended by the Ministry of Education and Science of Ukraine.

By creating a model for the use of augmented reality in primary school reading lessons, we analyze the state requirements for mandatory student learning outcomes. In assessing the linguistic and literary knowledge of the students of the New Ukrainian School, the emphasis is placed on learning activities in expressing their own attitude to works of art and reading, identifying readership interests, the ability to translate their ideas into artistic images and create artistic images by various means [15]. Thus, the New Ukrainian School fosters a personality capable of emotionally perceiving, thinking creatively, projecting, modeling, changing the world for the better. On the basis of such considerations, a methodological model of augmented reality application in reading lessons was developed. This model consists of the following stages: attraction; interaction; listening, reading and audition; research; creative work; evaluation.

Attraction. Thus, modern teachers are challenged to involve the "digital generation" in the reading activity, to form the need for students to learn the world through fiction in primary school students. The use of augmented reality technology in the process of reading works primarily visualizes the artistic world and provides a Wow-effect from the revitalization of illustrations to works of art.

Interaction. The next step is watching the literary heroes through the animation. AR technologies allow one to create gaming tasks that enable the sharing of impressions via mobile devices. Interactive applications are designed in such a way that readers can interact with the characters. For example, following the plot of the Hoffmann's fairy tale "The Nutcracker and the Mouse King", it might a good idea to ask students to release Nutcracker from mice, help characters find hidden objects in the virtual room, turn on music for the main characters' dance, etc. The activated AR applications by the students are shown in fig. 2 and fig. 3.

Fig. 2. First demonstration of augmented reality by Hoffmann's fairy tale "The Nutcracker and the Mouse King".

In the augmented reality of K. Babkina's story "The Pumpkin's Year", readers can click on the subject to make it move or make sounds. Thus, in particular, the students clearly visualize the personification of artistic images such as Bicycle, Pumpkin, Rook, perceived by different sensory organs. Therefore, the augmented reality in literary publications contributes to the development of students' creative imagination and the formation of their creative thinking.

To organize verbal interaction between students in a group, one may set the task of coloring the characters of a work of art from augmented reality fairy tales, drawing a smartphone or tablet with pre-installed augmented reality augmentations and activating images. Such observations give students the opportunity to tell a group about a literary hero, characterize him, create a text description.

Fig. 3. Second demonstration of augmented reality by Hoffmann's fairy tale "The Nutcracker and the Mouse King".

Listening, reading and audition. Most augmented reality books have audio. After listening to an excerpt of the piece, students are encouraged to go for a QR code to pass the Content Comprehension Test. Engaging younger students in the art world through augmented reality and engaging with a hero is a motivation to read a fairy tale to learn about the work's intersection. The students are tasked with playing the story, schematically reproducing the sequence of events by reading different parts of the work and recounting them in a group.

Research. With augmented reality applications, younger students have the opportunity to immerse themselves in the virtual world of a work of art, to explore it in detail. This approach allows students to visually imagine the reality portrayed by the writer, to get closer to understanding of the images, to learn more about the value accents while being in the virtual plane of the artistic world. This stage involves the analysis of a work of art, including explaining to students the content of what they have read, seen and heard through augmented reality.

Creative work. At this point, the teacher asks questions for reflection or fantasies. This stage involves the students expressing their own attitude towards the read, for example, what the artwork teaches. Pupils learn to think, write simple texts about their thoughts, impressions, observations. Also, based on the artwork, students are encouraged to fantasize about changing the end of the artwork or inventing a new story with the artwork hero.

It is appropriate at this stage to conduct games and theatricalization. In this case, one should invite the students to choose an interactive bracelet with any character of the work and in pairs to build a dialogue or in groups to play a part of the work.

Evaluation. The results of reading activities of younger students in the lesson using augmented reality are analyzed by the following criteria: motivational, emotional, activity, valuable. According to these criteria, the indicators are outlined in table 1.

Table 1. Criteria and indicators of results of reading activity of younger students using augmented reality.

Criteria for evaluating the performance of reading activities of younger students	Indicators
Motivational	Expressing interest in learning and being active during literary reading lessons. Motivation for thoughtful reading of a work of art. Focused reading. A desire to express opinions about what has been read and learned through augmented reality technology.
Emotionally reflexive	Enough sensual range for perception of a work of art. Adjusting to the appropriate level of emotional reflection in the process of reading, exploring augmented reality. Understanding the emotional state of literary heroes, the ability to reproduce a variety of emotions while reading, using voice, pantomime, facial expressions and more.
Activity-creative	The student understands the read text, explains the content of the read, heard and seen from the AR applications. Able to ask questions and engage in dialogue about what interests him/her or what remains unclear. Expresses his/her own attitude to the read, characterizes artistic images. Creates plain text as a continuation of a story or a variant of its ending.
Valuable	Formation of value system through aesthetic perception of works of fiction and products of augmented reality.

Analyzing the key competences identified by the European Parliament, we drew attention to such reference frameworks as critical thinking, creativity, initiative and the ability to constructively manage emotions. A survey among primary school teachers confirmed the effectiveness of the development of these qualities through the literary reading. However, research of the school library forms of students indicates a low level of interest in fiction. During the process of survey conducted on teachers, the factors that influence the activation of the reading activity of the younger students were identified. Among the received answers one can identify the following: meeting with the writer – 84%, interesting book-trailer – 82%, successful advertisement of the book – 75%, library lesson – 73%, high quality of the illustrated edition – 71%, the augmented reality book – 34%. The analysis of the respondents' answers showed the fact that the younger students were involved in the reading activity through visualization of the artwork (review of the book-trailer) and communication with the writers, and at the same time low level of knowledge of literary publications accompanied by AR applications.

The formative stage of the experiment took place in the Kyiv Gymnasium of Oriental Languages. Experimental learning involved 68 students from experimental classes (EC) and 67 students from control classes (CC). During its implementation, the author introduced a model of the study of artwork with activation of AR applications for students of 3rd-4th grades, methodical recommendations for teachers on the use of augmented reality in the language and literary field of primary education.

Taking into account the state requirements for the results of the reading activity of the younger students during the experimental training (formative stage), the attention was directed to the formation of stable motivation of students to literary reading by means of "animation" of the artistic image of the world by means of augmented reality. The objectives of the proposed model required the use of smartphones and tablets for the effective perception of artistic text. Visualization of the artistic image of the world provoked a casual expression of empathy by the younger students and facilitated the students' perception of literary work in the virtual world. Therefore, the proposed tasks have intensified the research and creative activity of younger students.

Presentation of augmented reality opportunities in literacy and reading lessons, approbation of methodical model of application of books with AR applications in reading lessons confirmed the increase of interest of younger students to the fiction by means of visualization of the figurative world of literature and, as a consequence, the teachers (91% of respondents), who noted positive impact of the augmented reality on the learning outcomes. The results of the survey conducted on the teachers are shown in fig. 4.

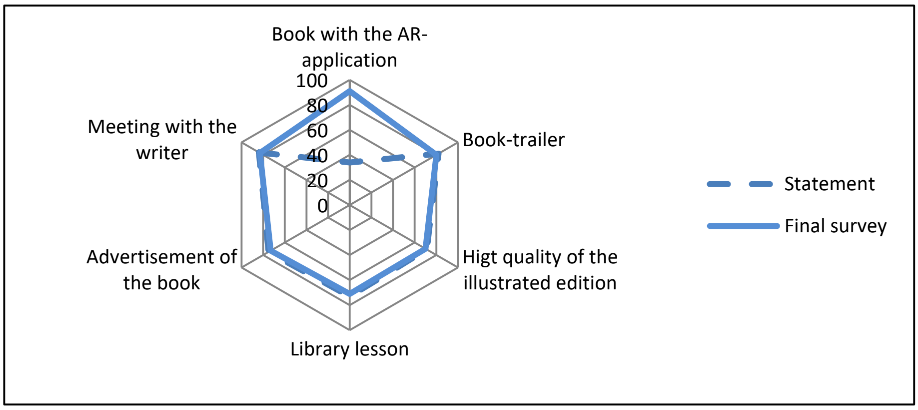

Fig. 4. Factors that influence the activation of the reading activity. The results of the survey.

According to the results of the educational achievements of the students of the experimental classes, the quality of their education was improved. To confirm this, the results of the final testing of the control phase of the experiment are presented, which demonstrate the qualitative positive dynamics. Therefore, according to the results of a comparative analysis of the experimental study, it can be stated that the emotional-reflexive (high and sufficient) level of reading activity in younger primary school students using augmented reality is higher than in the CC by 30.1%, which is illustrated in fig. 5.

The activity-creative level of reading activity of younger students with the use of augmented reality in EC (high and sufficient) is higher than in the CC by 15.3% (fig. 6.).

The value level of reading activity of younger students with the use of augmented reality in the EC is higher than in the CC by 10.9% (fig. 7.).

Thus, according to the results of experimental education in EC students significantly increased the overall level of reading activity, augmented reality contributed to the expansion of the sensory range of perception of the work of art, activating the need for reading and the development of critical thinking.

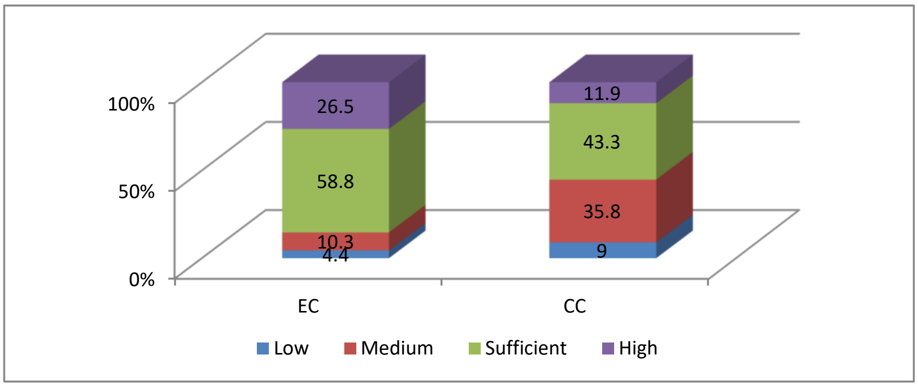

Fig. 5. Dynamics of emotional-reflexive level of reading activity with the use of AR applications.

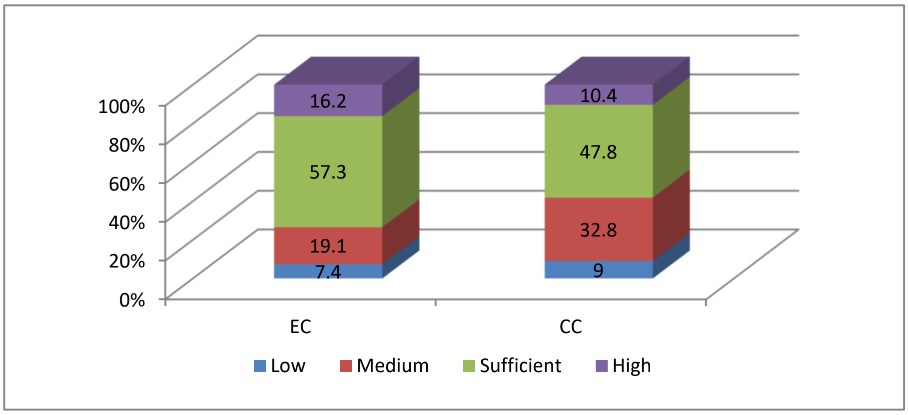

Fig. 6. Dynamics of activity-creative level of reading activity with the use of AR applications.

3 Conclusions and prospects for further research

The analysis of scientific sources on the problem of research indicates the creation of a new generation of education system, while the experience of using augmented reality applications in primary classes is described fragmentarily. Educational institutions are gradually changing their learning aids, textbooks that contain augmented reality elements, QR codes. Books of Ukrainian and foreign writers with AR applications are gradually appearing in the book markets, which should be used in literary reading lessons.

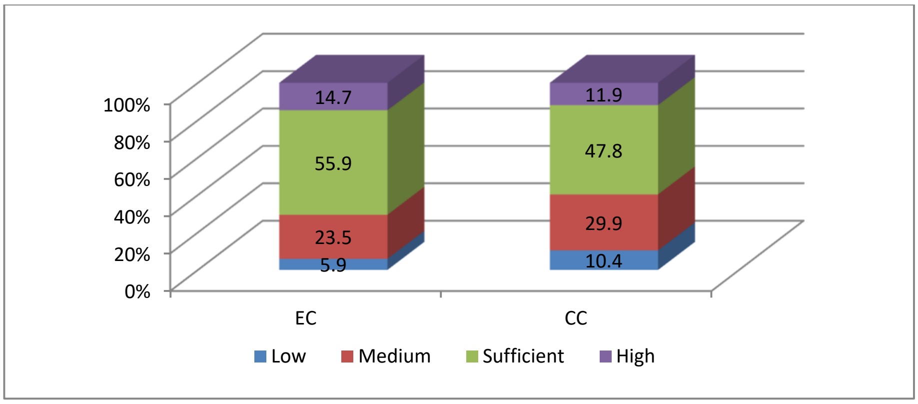

Fig. 7. Dynamics of the value level of reading activity with the use of AR applications.

The presented study confirmed the importance and relevance of the use of AR applications in the practice of literary education of primary school students. Augmented reality technologies are promising for the development of the artistic image of the world, reflected in the literature, meet contemporary educational challenges, provide an opportunity to immerse themselves in the space of artistic work and activate the creative imagination of students, and therefore their empathy. The article demonstrates the possibilities of using AR applications for the development of emotional intelligence and creative thinking, solving educational tasks by setting up an active dialogue with literary characters. The basic stages of the application of AR technologies in the literary reading lessons in accordance with the opportunities of the electronic resource are described: involvement; interaction; listening, reading and audition; research; creative work; evaluation.

It is confirmed that in the process of using augmented reality technology in the reading lessons of students of experimental classes, the qualitative changes in the process of formation of the reader's culture appear, as well as the increase of motivation, development of emotional intelligence and creative thinking. The results of the study, surveys conducted on primary school teachers and students proved the effectiveness of using AR applications, their advantages for activating the reading activity of students.

In our opinion, visualization of artistic image during the reading and writing lessons in primary school by means of augmented reality contributes to the effectiveness of learning in different directions, in particular:

- creates a Wow-effect, it is amazing how it deepens emotional resonance from reading a work of art;
- becomes a powerful motivation for the reader's activity;
- compensates for the lack of development of the creative imagination of younger students;
- provides perception of artistic image by different sensory organs;
- activates students' interest in reading fiction;

- demonstrates to students the benefit of gadgets for learning and personal development.

The expediency of further scientific research on a certain problem is seen in the direction of systematization, generalization and verification of the effectiveness of the experience of preparing future primary school teachers to apply augmented reality during the lessons of literacy and reading.

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Developing a 3D quest game for career guidance to estimate students' digital competences

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Abstract. This paper reveals the process of creating a career guidance 3D quest game for applicants who aim to apply for IT departments. The game bases on 3D model of computer science and information technologies department in the National Aerospace University "Kharkiv Aviation Institute". The quest challenges aim to assess the digital competency level of the applicants and first-year students. The paper features leveraged software tools, development stages, implementation challenges, and the gaming application scenario. The game scenario provides for a virtual tour around a department of the 3D university. As far as the game replicates the real-life objects, applicants can see the department's equipment and class-rooms. For the gaming application development team utilized C# and C++, Unity 3D, and Source Engine. For object modeling, we leveraged Hammer Editor, Agisoft PhotoScan Pro, and the photogrammetry technology, that allowed for realistic gameplay. Players are offered various formats of assessment of digital competencies: test task, puzzle, assembling a computer and setting up an IT-specialist workplace. The experiment conducted at the open house day proved the 3D quest game efficiency. The results of digital competence evaluation do not depend on the testing format. The applicants mostly preferred to take a 3D quest, as more up-to-date and attractive engagement.

Keywords: virtual reality, quest game, 3D model, career guidance, computer science, higher education.

1 Introduction

Augmented and virtual reality (AR and VR) are popular tools to introduce any concept more attractively or interactively. Utilizing AR and VR are most common for medicine, geospatial applications, manufacturing, tourism, and cultural heritage [7; 13; 22].

The choice of technology and how to apply it, in particular in the higher education field, depends on the research subject, resourcing, and the teachers' and students' competency. The experimental research on digital competency proved: the readiness level to start digital education is high enough [12]. Thus, arises a question of creating virtual objects and a methodology on how to utilize them in the educational process. For instance, the paper by Detlef Thürkow, Cornelia Gläßer, and Sebastian Kratsch [23] explains the experience of utilizing landscapes and excursions as a means of training in geography. Also, the research by Anoop Patiar, Sandie Leonie Kensbock, Emily Ma and Russell Cox [18] describes the students' experience with an innovative virtual field trip around hotels.

Among the virtual objects' representation formats, the gamification gains special importance, since it provides for additional motivation and active participation of the student [24; 25; 27].

The training games include quests, arcades, simulator games, virtual simulators, and interactive courses [4; 5; 11; 15; 19]. We considered quests to be the most interesting genre among the above mentioned [2; 3; 21]. Sergi Villagrasa and Jaume Duran [26] analyses the effectiveness of utilizing gamification to motivate Spanish students into studying with a 3D visualization as support for Problem-Based Learning (PBL) and Quest-Based Learning (QBL) to students' collaborative work. Yolanda A. Rankin, Rachel Gold and Bruce Gooch investigated the cognitive and motivational influence of 3D games on studying the second language and creating a digital learning environment for second language acquisition (SLA) [20]. Though, 3D games do not only boost motivation to study but also the motivation to build models and processes that the students go researching [9; 10; 16].

Since the career guidance of the future specialist is on-trend today, universities suggest many formats of how students can get to know the university, and use various forms of online communication with applicants. The career guidance is now on-demand, and recommendations on how to pursue a career path, in particular how to prepare for external independent evaluation, or recommendations on informal education, can be beneficial helping students to manage their education and career. This can influence the students' consciousness and help to improve the educational system's effectiveness, as well as the equation of demand and supply at the labor market [17].

The aim of the research is to create a career guidance 3D quest game to estimate the students' competency, and as well to attract more applicants and increase the visibility of the department.

2 The project implementation

2.1 Problem definition

The gamified application "Passcode" is a 3D quest game that bases on the 3D model of the computer science and information technologies department in the National Aerospace University "Kharkiv Aviation Institute".

Target audience:

- applicants: assessing the digital competency level to understand if the applicant is ready to enter the computer science department, career guidance, department promotion;
- first-year students: assessing the digital competency level to adjust the program of education, introducing the department' activities, career guidance;
- developers of the gamified applications: specification to the technical implementation of the gamified application "Passcode".

The technical implementation defines the following scope of tasks:

- free movement, acting and selecting players according to the game scenario;
- analyzing data on the users' actions;
- assessing users' actions, demonstrating the users' progress;
- the current score showing and saving feature;
- utilizing a database to simulate challenges.

Expected results of using the gamified application "Passcode":

- enlarging the target audience to provide for career guidance activities;
- boosting the applicants' motivation to study and providing them with career guidance;
- assessing digital competency of intendant IT-specialists for further adjusting the educational plans to suit their skills and level of knowledge;
- assisting in the development of gamified applications that utilize 3D models.

2.2 Means of technical implementation

To develop our 3D application, we leveraged Unity as the main engine [6]. Unity is a cross-platform tool for developing 2D and 3D games and applications that support several operating systems. We developed a game for MS Windows. The main language we use was C#, though we also utilized JavaScript and Boo for simple scripts. Also, we utilized the DirectX library, where the main shader language is Cg (C for Graphics) developed by NVidia.

The input data is not only the users' actions but the current condition of the game world, as the game is a sequence of conditions, where each iteration defines the following one. The artificial intelligence that controls the game characters, random events, and the game mechanics mathematical tool influence the game as well.

The game objects (including the characters, items, etc.) are samples of classes that define their behavior. The game actions (effects, scenes, etc.) are defined by scripts. The game process is defined by the combined action of managers where each controls a certain part of the gameplay:

- GameManager – controls the game cycle and serves as a linker for the elements of game architecture;
- InterfaceManager – controls the user interface, including the graphical interface and the input equipment;
- PlayerManager – controls the main character's behavior and condition (main character here is the one controlled by the player);
- UnitManager – controls the units;
- SceneManager – controls the game levels.

All of the managers are implemented based on the Singleton pattern. They are universal for the whole game, and each exists in a single copy. The managers are called by type. The main game objects base on the Finite State Machine pattern, that allows for easily controlling the game object and controlling its behavior.

The computer game is a complicated system build of separate subsystems integrated into a program architecture. Our game application has the following subsystems: for finding a way for a character; for user graphic interface; for objects interaction and an additional control subsystem.

We implemented the application in several stages and each stage has its tasks (table 1). In addition to Unity, we also utilized the Source Engine. Due to the utilities stated in table 1, we created an application for OS Windows and Android, and also WebGL library for running in browsers.

Table 1. Tasks and tools for implementation.

Tasks	Tools
Creating 3D models of rooms	Source Engine, Agisoft PhotoScan Pro, GUI StudioMDL
Editing objects	Hammer World Editor, MilkShape 3D
Creating the objects' textures	Adobe Photoshop, VTF Edit
Creating levels and lightning for some items	Hammer World Editor
Scenes editing, processing and exporting to the format	3D Studio MAX, plugin Wall Worm
Scenes optimization	Unity
Adding the physical model of connection	
Creating game objects and events	
Developing the game manager, interface manager, player, units, and levels	
Scripts writing	

2.3 Aspects of technical implementation

Creating the classrooms 3D models was the most complicated part of the development that is why further we describe some implementation details.

To create the classrooms' 3D models, we leveraged separate models of special photos made in advance. Then we utilized Agisoft PhotoScan, which provides for the photogrammetry function [1]. Due to some technology constraints at the moment, building a fully-featured rooms model was a complicated task. Every gleam, as well as translucent materials, causes significant miscalculations. That can be fixed with a flattening spray, though that won't work for rooms and that cost a penny. Thus, we utilized the photogrammetry technology to get objects of correct shapes and sizes (fig. 1). Also, we modeled the objects' textures, those we edited via Adobe Photoshop and attached to the models. Using Agisoft PhotoScan we created the model of a classroom and a model of a computer architecture showcase.

Figure 1 demonstrates the 3D-modeled output level of the department rooms. The rooms modeling was done by brushing geometry, as thus no additional physical attachment model is required.

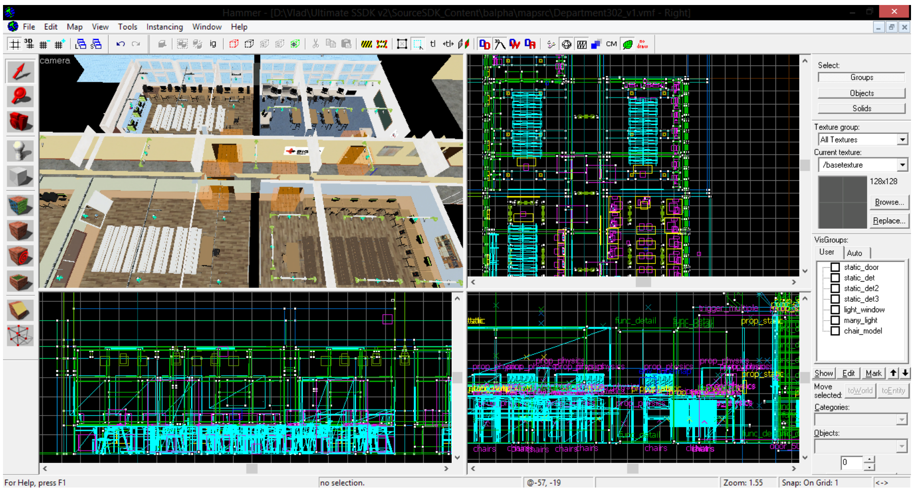

Fig. 1. Hammer Editor with a model of department rooms.

Figure 2 demonstrates a part of the level, one of the departments' classrooms. Most of the detailed parts were converted into special mdl format for models to allow for optimizing objects in a scene.

The detailed objects in figure 3 were converted into mdl via the propper plugin. After that, we could utilize the graphics power with the model reduction in distance technology – LOD.

When the scene is settled, we can import it into 3DS Max utilizing the WallWorm plugin (fig. 4).

3DS Max allows for exporting the scene in FBX format compatible with the Unity engine. In addition to the model itself, it stores data about lightning, materials, and structures.

To make sure that the scene was imported correctly we utilized the projection reflection modes. In figure 5 we can see that the grid is in its normal state.

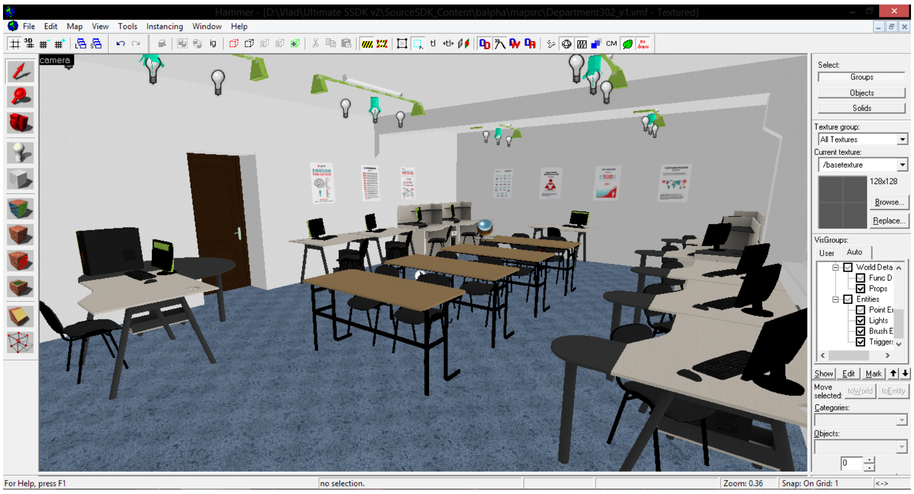

Fig. 2. Hammer Editor with a model of a classroom.

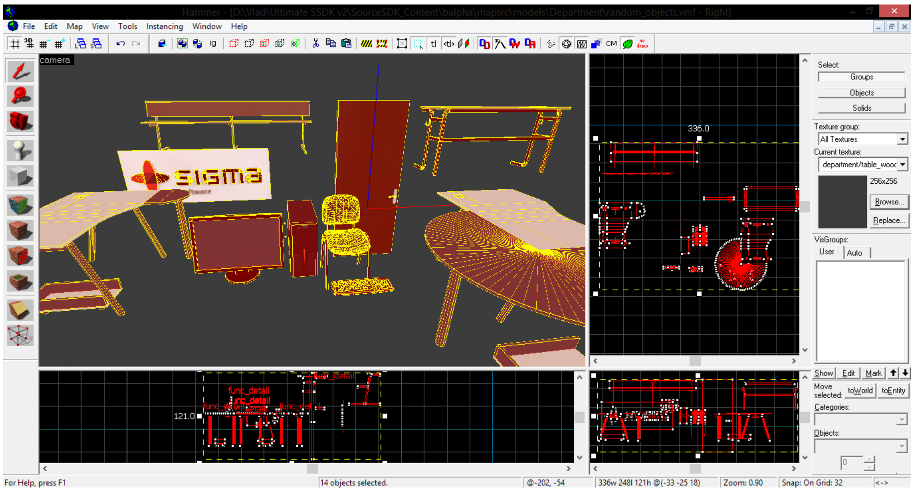

Fig. 3. Hammer Editor. The final objects and the grid.

Unity does not automatically create objects' physical models as it does not allow for brushing geometry. We have to optimize the model in the Unity scene and add a physical model of a connection mesh collider or box collider. The WebGL technology allows for running the project in the internet browser. This technology is yet imperfect, however, if we optimize the scene it will work well. The mobile systems require the controls to let the user run the game, for the mobile devices do not have keyboards and a mouse pointing device. Figure 6 demonstrates the controlling elements, the motion controls on the left, and the sight controls on the right.

The home screen interface is a menu that includes options "New game", "Load a game", "Settings", "Exit". After the user loads the game the menu extends with more options. The players can move with the mouse and the keyboard, or via sensor controls. The controls can be set in Settings, in the Keyboard tab. The graphical interface is an upper layer of the graphical system that allows for creating realistic 3D scenes on that basis. These scenes can have own scenario that may be changeable depending on the users' actions. The game's current version has a static background, though it can dynamically change to another background after each time the player reloads the game (fig. 7). Also, the vital part of the application development process was the scenario creation and quest development.

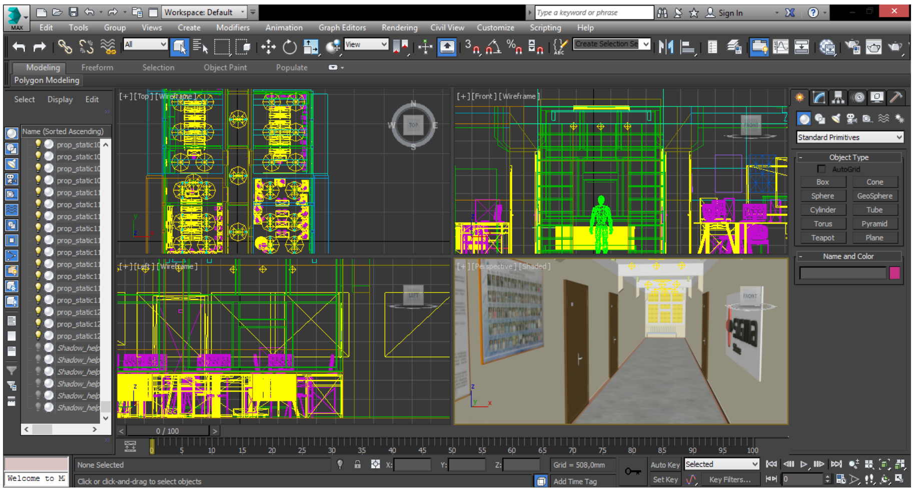

Fig. 4. 3D Studio MAX. Preparation and exporting into the Unity format.

Fig. 5. The Unity environment: Shaded Wireframe grid.

Fig. 6. The project runs on Android.

Fig. 7. Screenshots with different backgrounds after the game reload.

The scenario development: the game challenges utilize various objects, such as *scripted_sequence* that allows the characters for moving and performing the required actions; *logic_relay* that is used to create the series of events started with some item when it's necessary; *point_template* – a container for storing task objects; *ambient_generic* – used to play audio; *logic_compare* – compares the numbers to decide on what to do next; *info_node* – creates the navigation grid nodes for the non-game characters (the way searching system utilizes the key *info_node* elements), etc. We implemented these elements based on the Finite State Machine pattern, which allows for controlling the game object condition and its behavior. For the quest development there are several algorithms to utilize, though since the game model is 3D, we implemented the way search via the navigation grids algorithm.

The Navmesh or Node Graph navigation grid is an abstract data structure that is usually utilized by the AI applications, to allow the movement agents through big and geometrically complicated 3D objects. AI considers that objects that are not static to be a dynamic hindrance. This is another advantage of utilizing our approach to solve the challenge of searching the right way. The agents that can approach the navigation grid do not count these hindrances when building their track. Thus, the navigation grids method allows us to shorten expenses on calculations and makes finding the agents that encounter dynamic hindrances less pricey. The navigation grids are usually implemented as graphs, so we can utilize them for several algorithms defined for those structures. Figure 8 demonstrates the navigation grid utilized to calculate the way for non-game characters.

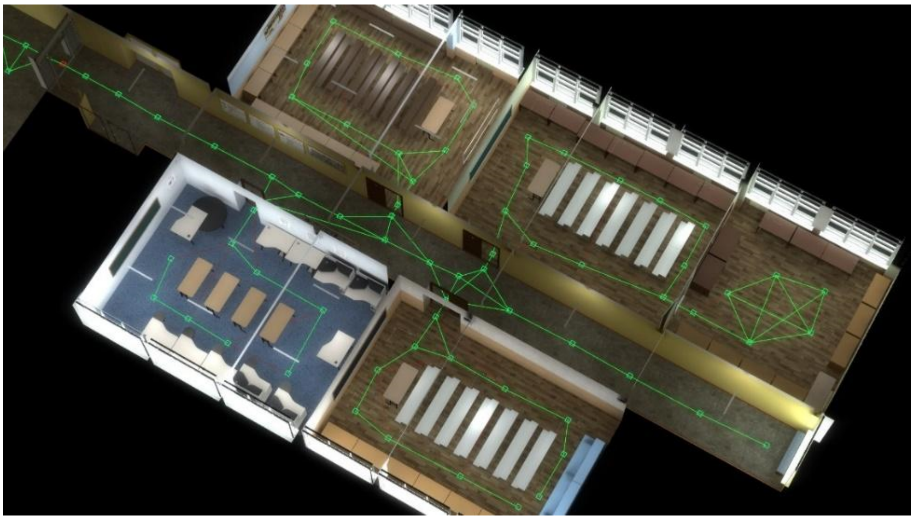

Fig. 8. Navigation grid.

2.4 Application scenario

The 3D quest "Passcode" can be downloaded via the following link: https://afly.co/xxn2. To start the quest, the user selects the language, as the game contains tips and subtitles, adjusts the keyboard settings, and on-demand can go to help for instructions in the corresponding menu section.

The quest contained different challenges to evaluate different groups of digital competences. For instance, estimating the level of competence working with data, the users have to answer on closed test questions that cover the information competency. These tests can have from two to four questions depending on the test. When the user selects an answer, it is supplied with a corresponding comment and highlighted red (for incorrect answers) or green (for correct answers). For both cases, the user receives a text message with the correct answer. After the user completed test questions, the program counts correct and incorrect answers and displays the results in a message, and voices it over.

To estimate the users' competence in problem solving and communication, we developed the "Find the academic record book" challenge (Fig. 9). The scenario supposes the user to communicate with the Student character, ask her questions on the educational process and decide where to go to find the academic record book. To provide for an additional challenge, this item randomly appears in one of the departments.

Fig. 9. The user got the task to find the academic record book and completed it.

When the user finds the object, he receives a message about discovery and he can go find the Student. After he gets the academic record book in his hands, he leaves the department and the challenge is over. The game counts the number of steps the user made to complete the task.

"Clean the classroom" challenge (fig. 10) aims to evaluate the user's ability to solve technical problems, follow the rules of safety, and treat the technical equipment and computers. The user has to place computers, screens, mouses, and keyboards around the classroom to the right places. The game counts the number of steps the user made to complete the task.

In another classroom, the user has to set up a computer out of suggested elements (the computer cabinet, processing unit, mother card, power source, cooler, graphics adapter, RAM, etc.). This challenge counts the order; thus, user can't place the cooler before settling the processing unit into the mother card. After the computer was set up, the user is told the number of a room where to take the computer. The task is considered to be complete when the user takes the computer to the given classroom.

To evaluate the users' abilities for self-education and career guidance, the user has to put together the "IT specialist jigsaw puzzle". The task is to group 30 suggested elements according to 10 given IT-related occupations: Mobile Developer Android, Mobile developer iOS, Frontend developer, Backend developer, Project manager, Java developer, .NET developer, UX/UI designer, QA tester, Database developer. The number of pieces for each occupation varies from 3 to 6, similar pieces can belong to different occupations. The order in this challenge doesn't matter, and the number of attempts is not limited. The pieces that do not match automatically drops away, denoting the mistake. The challenge is complete after all the pieces are together (fig. 11). During the challenge, the user can get tip messages by clicking the occupation name, and it shows up for 10 seconds. The tips number is limited, and the game counts how many of that user took.

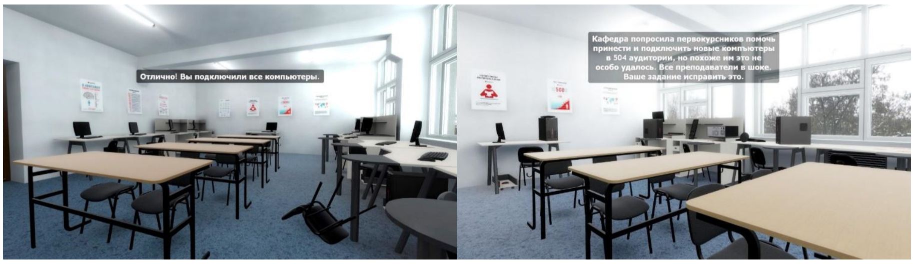

Fig. 10. The user got the task to settle the classroom and completed it.

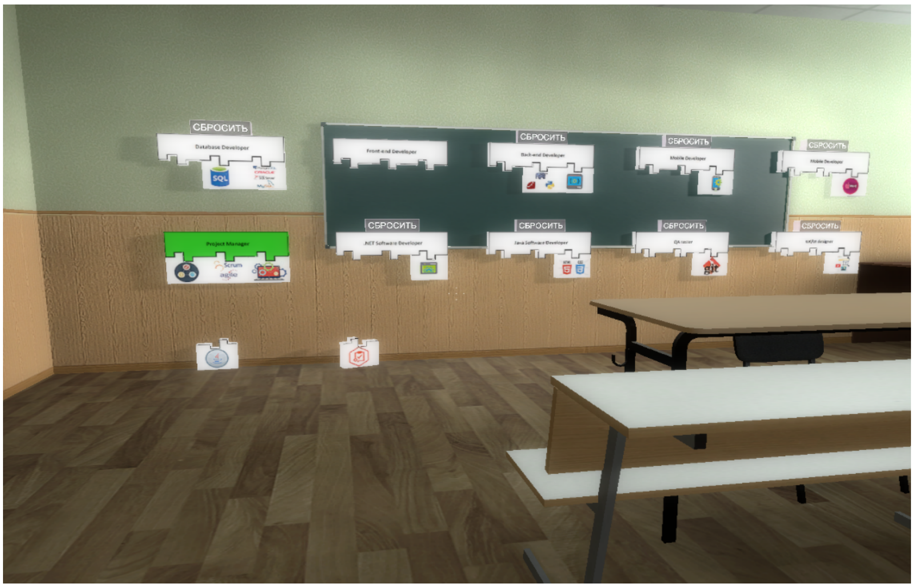

Fig. 11. The user processing the jigsaw puzzle task.

The tasks are meant not only to evaluate the users' digital competence but also to learn about the faculty life and educational system as the game models reflect real objects.

At the moment, the quest has 10 challenges, though we have an opportunity to make changes to the tasks pull. To succeed, the user has to complete all of the challenges, yet the order can be random. To choose the challenge the user just picks one with clicking on it, and the voice behind the scene explains the message and the point for him to go. As the user reaches the right classroom the voice behind the scene provides detailed instructions for the challenge. When already moving, the quit option becomes available for the user. To disrupt the challenge the user should press the corresponding button in the classroom or use a keyboard shortcut.

Completing each task is always written, its color changes from red to green. During the process, the user sees the score of the challenges he completed. There are certain evaluation criteria, though every task is scored 2 points. The maximum score is 20 points. Depending on the complexity the tasks value differently. The system defines the applicants who scored less than 10 points to have a low level of digital competence, from 10 to 15 points – the middle level, and those who scored above 15 – to have a high level of digital competence. Also, each challenge has no time limits, yet the quest time was limited. Thus, we could evaluate the users' ability to plan their time and decide on the order and timing for the challenges they take.

3 The experiment results

To evaluate the quest efficiency we held an experiment at the IT championship for the applicants at the computer science and information technologies department in the National Aerospace University "Kharkiv Aviation Institute" (https://sites.google.com/view/khai-itcup-2019). In 2019 the championship occurred in the University in the third time, and the applicants were suggested with a challenge. They had a choice, either to take a 3D quest game or to go take it in real life (go to the department, take their paper tests, complete a puzzle, set up a real computer). 115 applicants participated in the experiment, and 57 decided to complete the task in real life, with the guidance of elder students (this task was assessed with real measures, and 58 applicants completed these tasks via the application (https://is.gd/QvsDXN). The students split into two groups randomly.

There were 90 boys that equal to 78,3% and 25 girls that equals to 21,7% of participants. The group working with real equipment counted 12 girls (48%) and 45 (50%) boys. The group that chose the 3D quest counted 13 (52%) girls and 45 (50%) boys. Thus, the selection was homogenous and representative enough to research on (the measurement error is less than 10%). To process the overall applicants' results we applied statistical analysis from the SPSS package [8; 14]. We calculated the average for each group, and also the average for girls and boys. The obtained results are stored in table 2. Mostly, the applicants demonstrated middle-level digital competence. According to results in the table, the is almost no difference in points between the applicants of two groups (the Student's criteria for independent groups equals 0,71 at p=0,48, the distribution of students' estimates correspond to the normal distribution). Boys demonstrated better results than girls (the students' criteria equals 4,36 at p=0,01).

After the challenge applicants had to answer a 5-question survey (https://is.gd/icpwQY) that would help to reveal their motivation to choose the IT department, and also their attitude to the championship we arranged.

Table 2. Statistics on gender and evaluation format.

		Average	Standard measurement error	Minimum score	Maximum score
Format	Real equipment	13,9	0,4	6	19
	Application	14,3	0,4	8	20
Gender	Girls	12	0,6	6	17
	Boys	14,7	0,3	7	20

Thus, 74,8% of the applicants answered they liked the challenges they got during the championship, 14 applicants (that is 12,2%) didn't enjoy the tasks, and 15 of them (13%) found it complicated to answer, as the tasks appeared to be challenging for them. The student who didn't like the tasks had worse scores and significantly lower digital competence levels (scored 2 points less, $p<0,05$).

Answering what type of tasks, they prefer 43,5% of respondents said they like computer quests, puzzles, etc., 27,8% of respondents claimed they would prefer a real quest or puzzle, 9,65% chose online testing, 11,3% of respondents make no difference, and 7,8% of applicants preferred testing on paper.

The average on this challenge does not vary significantly, though the applicants who preferred paper tests scored 2 points less on average ($p<0,05$). Considering the time given to complete those challenges 87% of applicants said it was enough, and they also scored for better average comparing to the applicants who were out of time.

The answers distribution for "Do you plan applying for our department?" was the following. 52,2% answered "Yes, for I will gain practical skills here (I saw the faculty keeps up to date, and I saw what the students are capable of), 27,8% would like to enter though there were not sure their knowledge is enough, 20% were not going to apply or planned to enter another department.

4 Conclusion

Out of the aim of this research and the particular tasks we faced developing a 3D quest game, as well as the results of assessing the application efficiency in career guidance we came up with the following conclusions.

The game application development technology we suggest can be utilized by 3D models and game developers, in particular for training the future IT specialists.

We utilized various technologies to implement the application idea. Leveraging Unity 3D and Source Engine as the main engines allowed for creating a 3D model of a game and its main objects. We edited objects via Hammer Editor and created a realistic department's classroom model with the Agisoft PhotoScan Pro tool and the photogrammetry. Searching the right way was implemented via navigation grids, which allow through the geometrically complicate 3D objects.

The game scenario provides for a virtual tour around a department of the 3D university. As far as the game replicates the real-life objects, applicants can see the department's equipment and classrooms.

The quest includes several different challenges meant to evaluate the applicants' digital competence connected to the main components such as Computer and Information Literacy and Computational thinking. The tasks also allow for understanding the applicants' ability to work efficiently and to use computers in real life.

The experiment results prove the 3D quest to be effective. Yet the results of digital competence evaluation do not depend on the testing format, applicants mostly preferred to take a 3D quest, as more up-to-date and attractive engagement. Also, they claimed this up-to-date approach would influence their choice of a university.

Thus, our 3D quest application can grow the audience for career guidance activities and improve the public image of the university. Besides, applicants can use this 3D quest to decide on their future occupation.

In addition to campaigning and career guidance, this application can help to teach and test students. The prospective research aims to utilize the application to evaluate the digital competence of the future IT specialists for adjusting the educational plan for the university's first-year students.

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Conceptual model of learning based on the combined capabilities of augmented and virtual reality technologies with adaptive learning systems

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Abstract. The article is devoted to actual problem of using modern ICT tools to increase the level of efficiency of the educational process. The current state and relevance of the use of augmented reality (AR) and virtual reality (VR) technologies as an appropriate means of improving the educational process are considered. In particular, attention is paid to the potential of the combined capabilities of AR and VR technologies with adaptive learning systems. Insufficient elaboration of cross-use opportunities for achieving of efficiency of the educational process in state-of-the-art research has been identified. Based on analysis of latest publications and experience of using of augmented and virtual reality technologies, as well as the concept of adaptive learning, conceptual model of learning based on the combined capabilities of AR and VR technologies with adaptive learning systems has been designed. The use of VR and AR technologies as a special information environment is justified, which is applied in accordance with the identified dominant type of students' thinking. The prospects of using the proposed model in training process at educational institutions for the implementation and support of new teaching and learning strategies, as well as improving learning outcomes are determined by the example of such courses as “Algorithms and data structures”, “Computer graphics and three-dimensional modeling”, “Circuit Engineering”, “Computer Architecture”.

Keywords: adaptive learning systems, augmented reality, virtual reality, individual learning approach, individual learning path, educational modeling.

1 Introduction

1.1 Problem statement

The modern world is causing changes not only in the fields of economics and technology, as well as changes in the level of future students prior training, their needs and expectations. As a result, the education strategy is changing too. Virtual and augmented reality (VR and AR) technologies are the means of a fundamentally new level of human interaction with the digital world, which are playing an increasing role in the global economy, politics, social relations etc. The symbolic information world offers a wide range of ready-made patterns and styles of behavior that people choose and try to implement in their daily lives. Today, these samples are represented primarily by computer VR, virtual (computer) symbolic world, which provides the subjects of information space different motivational, cognitive, communicative, operational, creative, spiritual opportunities [63, p. 25]. VR and AR technologies have got the most serious development in the entertainment markets. This is not the limit, but only the first stage of their implementation. Products based on VR and AR technologies are promising in terms of economic effect in the fields of industry, health care, consumer services, and education. The variety of companies and institutions of higher education implementing AR and VR technologies testifies to the prospects of this technology. In particular, the Japan Online School VR was recently opened in Japan by the private institute Meisei High School [22]. Learning with AR and VR technologies could be considered a new way of knowledge transfer that corresponds to a qualitatively new content of learning and personal development of students, stimulates innovative aspects of teachers' activity and creates preconditions for the implementing new approaches to learning and improving education. AR and VR technologies are a new way of presenting information, making it much more visual and attractive. Their use helps to increase students' motivation in learning process through clarity, information completeness, interactivity and gamification of education [7].

1.2 Literature review

Some issues of design, development and application of educational software and simulators based on AR and VR technologies are considered in a number of scientific works, namely: the potential of AR to transform the educational process into smart learning [26]; development of augmented reality software for educational purposes in [2; 21; 24; 38; 61]; the use of virtual reality for learning [1; 28; 32; 42; 69]; application of augmented reality technologies for the professional training [23; 36; 49; 58; 71]; use of computer simulations and games in engineering education [3; 14; 35; 44; 48; 52; 67; 66]; application of virtual reality in foreign language teaching at higher educational institutions [59]; development an augmented reality simulator for studying algorithms [27]; features of the use of the virtual environment for the training of specialists in information technology [5; 45; 53; 57].

Application of adaptive learning systems is examined by a lot of researchers. In particular, the objects of these explorations are prospects of the implementation of blended learning in higher education [4; 20; 43]; use of intelligent systems in teaching [6; 15; 18; 29; 37]; principles of adaptive learning [33; 39; 41; 64; 65]; adaptive testing systems [46; 47; 54]; neural technologies for individualization of learning [16; 34; 62; 68], etc.

Review of research on the combined use of AR and VR technologies with adaptive learning systems lets us to notice some works devoted to the current state and new opportunities of adaptive learning in virtual reality [70]; improving massive open online course through augmented reality, adaptive learning and gamification [9]; design implications for adaptive augmented reality based on interactive learning environment for improved concept comprehension in engineering paradigms [25].

However, combined capabilities of AR and VR technologies with adaptive learning systems has not been thoroughly considered.

The aim of the article is design of a learning model based on combination of capabilities of adaptive learning systems and AR and VR technologies.

2 Research results

2.1 Learning model based on combination of capabilities of adaptive learning systems and virtual/augmented reality technologies

New orientations and values of modern education necessitate the understanding student as unique individual with his/her own individual learning needs. Therefore, educational content presented to students should be adapted to their personal skills and needs, as well as be interactive and dynamic. However, in recent years, distance e-courses are aimed at the simultaneous learning of a large number of students [60]. Therefore, significant heterogeneity of students' educational outcomes is noticed. This fact necessitates research in the field of individualized learning and improving of distance education.

We will focus on improving e-learning through the combining capabilities of AR and VR technologies and adaptive learning systems. These means have recently been adopted in various learning models and have shown a significant impact on students' learning experiences.

For our study, we chose AR and VR technologies because according with up-to-date research they make educational content more interactive, individualized, and motivating. AR and VR technologies provide interaction with real and virtual objects. Such content visualization keeps students active during the learning, as it increases their ability to understand and process information, as well as adds elements of gamification to learning environment. This is a prerequisite for internal motivation of students to study the material and do tasks, and for getting success.

Adaptive learning systems provide a wide range of tools for individualized training. Therefore, it necessitates development of measures to make learning experience of all participants more successful and to meet the diverse educational needs of students.

Using the combined capabilities of adaptive learning systems and AR and VR technologies, in our opinion, will provide the best results, because taking into account individual psychological and cognitive characteristics of students effects on their awareness and understanding of educational material. Flexible settings of testing tools provided in adaptive learning systems make possible to identify the psychological characteristics of the cognitive structure of personality for the best selection of educational content at the initial stage.

According to the Fleming's VARKH model the learning process is based on student interaction with educational content [17, p. 137]. It offers to classify students by main channel of perception of educational information:

- visual learners perceive the main part of the educational material by eyes. For this psychotype, it is advisable to get information through visual images. Such students need to see them to make it easier to remember or analyze;
- aural learners perceive information through sounds preferably, for example through audio lectures. Such students should listen to educational content or sound it for better memorization and assimilation;
- read-write learners prefer information presented in the form of words, text. These students should read and write educational content by different means;
- kinesthetic learners perceive educational material on a perception basis and tend to apply their knowledge.

Each category of students has its own preferable method of receiving and processing educational content [51]. So, design of individualized educational content should take into account the preferred channel of obtaining information and the dominant type of thinking of students. Conservative methods of content delivery (fixed video, audio, scripts) are not personalized and interactive, so advanced teaching methods are to be implemented to provide a more interesting experience for students. Based on the classification above, it can be considered that students who have visual or kinesthetic channel of obtaining information will best experience the educational material organized with the technology of AR and VR. So, it is desirable to deliver them educational content by simulators using AR and VR technologies.

The use of combined capabilities of adaptive learning systems and AR and VR technologies will provide the most adapted and individualized educational content to the student.

We offer a graphical representation of the model illustrating the combined capabilities of these methods in the learning scenario to create interactive, individualized and more interesting content (fig. 1).

Learning process based on using AR and VR technologies to deliver educational content has excellent opportunities to be gamified, in particular through awards and distinctions that motivate students. The game method, applied in learning environment created by means of augmented or virtual reality technologies, is a full life cycle of the educational process, which transforms and improves students' learning experience.

Curricula created using AR and VR technologies have a high potential for stimulating influence on the process and operational characteristics of students' thinking, creativity, the formation of specific cognitive motivation and interest in learning, creating positive, harmonious mental states. The developmental effect of AR and VR technologies is determined by three-dimensional objects, images of recognizable objects, a wide range of actions with objects, the effect of presence, interactivity, visualization of abstract models and more.

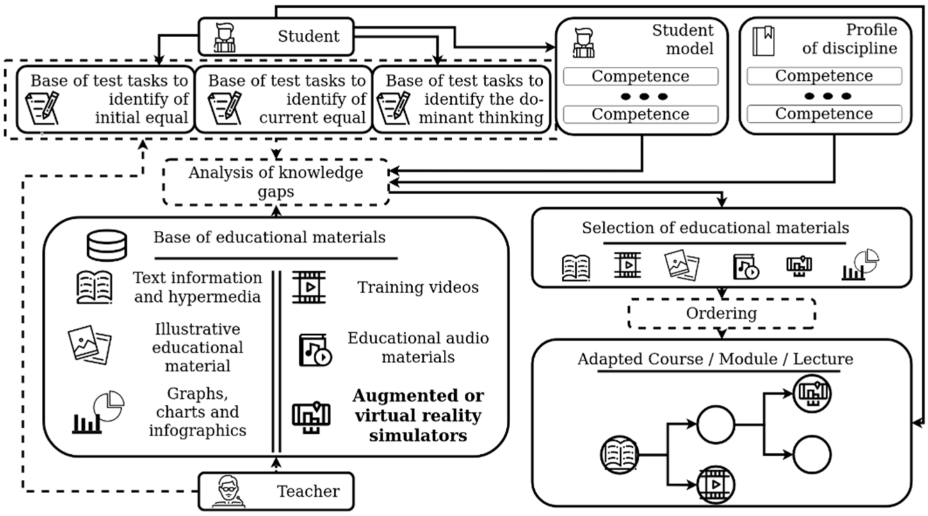

Fig. 1. Conceptual model of learning based on the combined capabilities of augmented and virtual reality technologies with adaptive learning systems.

2.2 Opportunities and perspectives of virtual and augmented reality technologies

At the present stage, augmented reality technologies affect the organization of learning, enrich tools and methods, expand didactic opportunities. Setting virtual objects in a specific environment allows to simulate unusual educational practices, get new ways to explore objects and related space, ensure better interaction. At the same time, augmented reality technologies are still an “exotic” tool for educational and methodological support of disciplines [19]. This is largely due to the limitations and features of human-computer interaction through the screen and graphical user interface. Learning is always more effective when there is interest in the subject and the process of cognition. This causes the desire of teachers to use elements of augmented reality for student training activities.

The latest research proves the effectiveness of implementing AR and VR technologies in the educational process. For example, Cerevrum Inc. [8] conducted an experiment in which 153 recipients took part: students aged 15-17 and their relatives. The study was carried out physics lesson in virtual reality. A test was conducted to check the remaining knowledge. Participants were also asked to evaluate the effectiveness of using virtual reality as a learning environment. According to the results of the study, 91.5% of participants passed the test successfully, and 97.4% of them reacted to using this technology in the educational process positively.

Examples of successful use of augmented reality in training are provided by the ideal partner Coimbra and Mateus [12], Shirazi and Behzadan [55], and others. In particular:

- insertion additional information to the educational content (compressed biographies, historical facts, photos from places of events, visual 2D and 3D models, etc.), that makes the animated content interesting and modern, contributes to a deeper understanding of the subject;
- support of tasks and educational text with teachers' methodological recommendations: students can scan certain elements of the book and receive text, audio/video advice or useful information about the schedule of studying the topic, control tests, ways to communicate with other students for discussion of training issues;
- visualization of complex objects in a 3D model with the ability to interact (setting transparency, color scheme, style) facilitates the perception of abstract information and understanding of the text (mathematics, physics, chemistry, drawings, technical science, etc.);
- addition of educational content with "teasers" (puzzles), problem or game task that helps to activate attention, develop intellectual abilities, stimulate positive emotions and interest in learning activities.

2.3 Combining virtual and augmented reality technologies with adaptive learning systems in Computer Science courses

AR and VR technologies are widespread in many education areas. However, in the process of teaching computer science, they are used rarely [11; 30; 40; 56]. Visualization of personal computer components (chipset, motherboard and other components) is mostly used in "Computer Architecture" course [13; 50]. Another approach is the use of videos, links, texts tied to labels.

In some educational institutions it is possible to study computer components on physical examples or specialized stands. However, this possibility is not everywhere, and in the case of distance learning, the student may not have such an opportunity at all, because not everyone has a motherboard or video card unnecessary, old or non-working. In such cases, it is advisable to use the simulator for clarity and visualization of the research topic. An example of the interactive manual for studying personal computer architecture by means of augmented reality is shown below (authors: E. Medvedev, master's degree student, 2 year of study, specialty 122 Computer Science and A. Marinov, master's degree student, 1 year of study, specialty 015.10 Professional education (Computer technology); scientific supervisor V. S. Kruhlyk) [31] (fig. 2).

The "Circuit Engineering" course can be supported by means of AR and VR technologies also. Simulators based on augmented or virtual reality technologies can help to design, create and configure electronic circuits.

It should be noticed that art professions have also migrated to the virtual environment. A lot of artists have chosen the path of XR art. For example, Liz Edwards, a designer from Montreal, Australian artist Stuart Campbell, known by the pseudonym Sutu. Exploring the relocation of contemporary artists to a virtual environment, it is worth noting the experience of Giovanni Nakpil, Art Director at Oculus VR, who teaches sculpting at the Online tutorial resource mold3D Academy. Based on his experience, it is possible to reorganize the process of studying the disciplines of “Computer Graphics” and “Three-dimensional modeling” [10] also in the direction of virtualization.

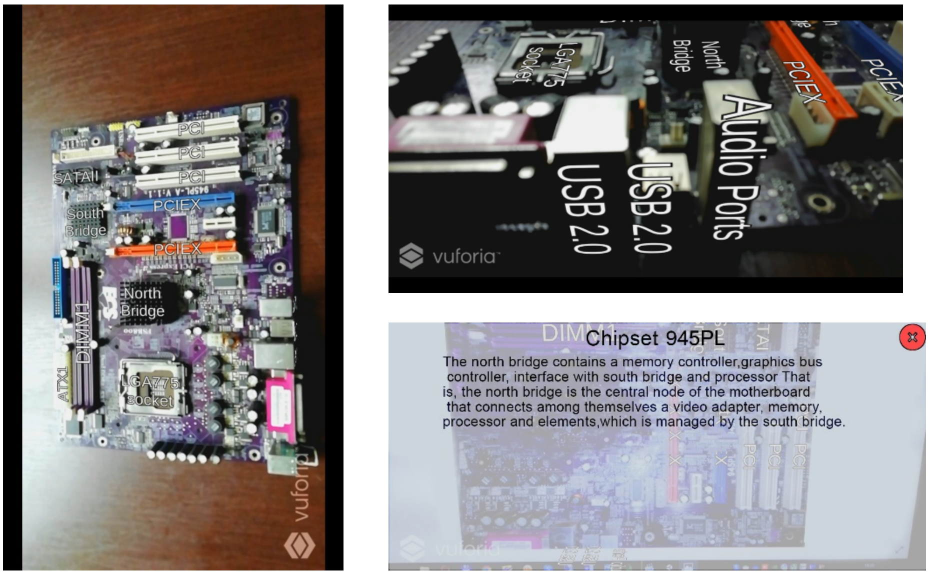

Fig. 2. Interactive manual for studying personal computer architecture.

It is appropriate to use virtual and augmented reality technologies for training students in “Algorithms and data structures” [53]. Augmented reality technologies could significantly improve students' knowledge, for example through visualization of sorting algorithms, such as bubble sorting. Visual maintenance of sorting process and using of simulator with augmented or virtual reality increase students' interest in this topic.

Let us give more detailed review of using adaptive learning in combination with AR and VR technologies on the example of studying the topic “Sorting algorithms” in “Algorithms and data structures” course. As a result of mastering this topic, students should have knowledge of sorting algorithms, such as bubble sorting, permutation sorting, insert sorting, and others, as well as skill to use them in professional activity. For example, student already has an idea about bubble sorting algorithm. This information was obtained from the student model as a result of testing previous knowledge, or was recorded as a successfully acquired skill from the previous course. So, it should not be taught again. Another part of information obtained from the student model is that the preferable channel of information perception is kinesthetic. Taking this into account, it is appropriate to choose educational content based on augmented reality, where student gives an opportunity to explore the principles of insert sorting and permutation sorting through simulation. Using student model allows to provide tasks and materials that are the best for perception. Gamification of training process decreases risk of student's disappointing in case of a failed attempt to reproduce examined algorithm. Student can be provided with additional video information of how such algorithms are implemented. After watching the video, the optimization component sets the student to the initial situation in the simulator. The user can now be succeeded in completion of learning task. Student model is updated according to results obtained during all of activities. It allows to ensure the optimization of the overall learning experience.

3 Conclusion

Based on the results of the research, an approach to creating an adaptive learning environment in the context of virtual reality is presented. It is founded on taking into account the goals, preferences, knowledge and dominant type of thinking of each individual student. The use of AR and VR technologies in conjunction with the capabilities of adaptive learning systems provides the best conditions for individualization of learning. As a result, it provides a better quality of educational process. Visualization is one of the key features of the proposed learning model based on the combined capabilities of the adaptive learning system and virtual and augmented reality technologies.

Prospects for further research are seen in the development of educational and methodological materials and improving the content of educational and methodological complexes for using the combined capabilities of adaptive learning systems and virtual and augmented reality technologies in the educational process.

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Personalization of learning using adaptive technologies and augmented reality

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Abstract. The research is aimed at developing the recommendations for educators on using adaptive technologies and augmented reality in personalized learning implementation. The latest educational technologies related to learning personalization and the adaptation of its content to the individual needs of students and group work are considered. The current state of research is described, the trends of development are determined. Due to a detailed analysis of scientific works, a retrospective of the development of adaptive and, in particular, cloud-oriented systems is shown. The preconditions of their appearance and development, the main scientific ideas that contributed to this are analyzed. The analysis showed that the scientists point to four possible types of semantic interaction of augmented reality and adaptive technologies. The adaptive cloud-based educational systems design is considered as the promising trend of research. It was determined that adaptability can be manifested in one or a combination of several aspects: content, evaluation and consistency. The cloud technology is taken as a platform for integrating adaptive learning with augmented reality as the effective modern tools to personalize learning. The prospects of the adaptive cloud-based systems design in the context of teachers training are evaluated. The essence and place of assistive technologies in adaptive learning systems design are defined. It is shown that augmented reality can be successfully applied in inclusive education. The ways of combining adaptive systems and augmented reality tools to support the process of teachers training are considered. The recommendations on the use of adaptive cloud-based systems in teacher education are given.

Keywords: personalization of learning, adaptive learning technologies, virtual reality, augmented reality, learning tools, assistive technologies, hybrid cloud solutions.

1 Introduction

Nowadays, augmented reality is being used in education to improve students' learning facilities as well as the quality of learning [18].

The Industrial Revolution 4.0 has changed how production processes are organized and economic development goals are achieved, and this has affected the education sector, and has given rise to the term Education 4.0. As noted in [1, p. 23] Education 4.0 consists of the personalized learning process, game-based learning using Virtual Reality/Augmented Reality (VR/AR), communities of practice, adaptive technologies, learning analytics, and E-Assessment. This has led to unlocking the potential of AR technology use as a component of students' adaptive learning environments [29; 30]. The use of AR can help students to learn better, improve learning settings and increase the quality of the educational process.

The tools of adaptive technologies and VR/AR make the educational process more interactive, actualize the cognitive interest of students, and enhance motivation for learning [7; 27]. In this case, VR/AR allows you to interact with real and virtual objects, vividly and realistically visualize didactic material [15]. Most current courses using this technology follow a "one size fits all" approach that addresses the common needs of different people. Instead, adaptive technologies are geared toward meeting the needs of each student, as they can get adjusted, adapt properly, depending on user behavior [39]. In our opinion, it is a promising trend of research for education to introduce teaching methods that will combine the adaptive technologies with VR/AR, as this will allow to achieve better personalization of the educational process.

2 Literature review

Numerous domestic and foreign scientists have addressed the study of various aspects of the creation and use of adaptive cloud-oriented systems. Vladimir G. Sragovich emphasizes that it is not necessary to simultaneously manage and assess the entity [37]. That is, the adaptive system changes its algorithm (or its structure) automatically, which assumes that the goal is achieved under all conditions. Elena V. Kasianova [16] believes that networked learning systems combine intellectual learning systems and adaptive media systems. Besides, according to Elena V. Kasianova's research, all adaptive hypermedia systems can be combined into one class, which can be considered as hypertext and hypermedia systems. Due to this, each user will have a workplace adapted with individual tools and customization of various aspects of the system itself (without affecting the work of other users). Aleksander A. Gagarin and Sergiy V. Tytenko considered adaptability in systems of continuous learning [11]. Therefore, in their work adaptability is considered first of all as a symbiosis of purpose and result. At the same time, the goal is considered by the one that the user of the system puts forward for himself, and as the result is the educational result obtained by the user at this stage of work with the system.

In the framework of the conducted research Pavlo I. Fedoruk stated that by using adaptive and intellectual technologies, the educational system allows taking into account the student's abilities, his/her previous knowledge, skills [9].

In particular, Svitlana H. Lytvynova considered the design of a cloud-oriented environment in a general secondary education institution [19] that has the features of an adaptive system; Pavlo I. Fedoruk studied the methodology of organizing the process of individualized learning using an adaptive system of distance learning and knowledge control; Yurii V. Tryus considered pedagogical mentoring as an element of adaptive management in the system of preparation of future teachers [40].

Mariya P. Shyshkina in [36] considered the possibility of combining cloud technologies and adaptive systems while emphasizing that several models of cloud services can be used simultaneously: SaaS and PaaS. Mykola V. Pikulyak (2016) [34] proposed to build an adaptive training module in the distance education system based on the script method. The proposed idea is based on scenario examples as a separate special rule (software solution) that binds quanta (units of material).

Gary Natriello outline even more complex learning environments when discussing the possibilities of transformative VR games [26]. They rely on four types of meaningful engagement as a way to think about adaptive educational technologies that can support transactive engagement with adaptive systems. They compare the four types of content interaction as:

1. Procedural training,
2. Conceptual training or understanding how the tools work,
3. Consistent training or learning about the impact of their actions on the contexts developed,
4. Reflects the impact of their actions on the developed context.

In the study of National Academy of Education [25] the content of the concept of adaptive technologies examined, the potential of their use in education analyzed, the infrastructure required for successful implementation is characterized, etc.

Luis de-la-Fuente-Valentín, Aurora Carrasco, Kinga Konya and Daniel Burgos reveal predictions about what technologies will be used shortly in education [7]. The latest forecasts are the introduction of new concepts such as 3D printing [14], the Internet of Things [13], learning analytics [31], massive open online courses [32] and AR [38].

Lisa Balme in [2] presents the results of a survey of teachers on their experience in using adaptive technologies working with students with disabilities, their vision of the benefits of these technologies, and the obstacles to implementation, and more.

Philip Kerr describes the basic concepts, the use of adaptive technologies in English language learning, teacher training, and development opportunities are presented [17].

Moses Basitere and Eunice Ivala consider the effectiveness of the use of the adaptive Wiley Plus ORION training platform in the study of physics has been analyzed, the results of testing using the adaptive test and the standard blank (paper) test have been compared in [3].

Rosliza Hasan, Faieza Abdul Aziz, Hesham Ahmed Abdul Mutaleb and Zakaria Umar in [12] used many mobile technologies – from simple recording devices and audience response systems to VR/AR apps for tablets. The paper presents an architecture built to organize existing digital interactive web content for learning through the concept of modules, submodules, and essentials.

Yigal Rosen, Ilia Rushkin, Rob Rubin, Liberty Munson, Andrew Ang, Gregory Weber, Glenn Lopez and Dustin Tingley in [35] describes the results of an experiment on implementing adaptive functionality in a mass open online course (MOOC) based on edX. The advantages and disadvantages of this technology that need refinement are indicated.

Hayatunnufus Ahmad, Norziha Megat Mohd Zainuddin and Rasimah Che Mohd Yusoff considered the use of AR technology to better memorize Quran for students with hearing impairments. The research is aimed at developing an integrated mobile application that can facilitate the memorization of the Quran among hearing-impaired students [1].

Arwen H. DeCostanza, Amar R. Marathe, Addison Bohannon, A. William Evans, Edward T. Palazzolo, Jason S. Metcalfe and Kaleb McDowell in [6] suggest the development of the mechanisms to increase team effectiveness, in particular military teams, for heterogeneous teams using technologies focused on improving teamwork through individualized information, processes and activities for each team member. In particular, scientists have explored the use of VR/AR technology.

Synaptic Global Learning, in collaboration with the Center for Innovation and Excellence in eLearning at the University of Massachusetts (USA), developed the world's first adaptive MOOC in computational molecular dynamics, called aMOOC, based on Amazon Web Services cloud architecture [3].

The mobile technologies have been used to support the learning process in research of Yevhenii O. Modlo et al. – from audience response systems to virtual reality and augmented reality applications for mobile Internet devices [20; 21; 22; 23; 24]. The paper [1] presents an architecture built to organize existing digital interactive web content for learning through the concept of modules, submodules and essentials, among which are separate widgets.

Thus, adaptive learning technologies are based on the use of the most relevant and up-to-date student data, and collaborative teams are formed instantly on the request of teachers. This leads to the development of adaptive hypermedia systems and personalization of learning experiences and the creation of a personal learning environment in higher education. Collective and cooperative learning is no exception. Researchers look at a variety of strategies for group tasks within a similar environment, dividing students into groups, exploring the creation of dynamic groups and different models of group work in a pre-planned scenario, leading to improved learning [26].

Most research in the field of adaptive learning environments have been concerned to creating customized solutions designed to digitize a specific part of the curriculum used by teachers [33]. Such approaches lead to limited use of the system, typically requiring a significant amount of work and resources to be expanded with new techniques such as adaptive, collaborative and cooperative learning, unless they initially focus on their direct support. This is mainly because the introduction of support for new techniques in existing, advanced learning technologies usually means significant changes to existing databases of training systems.

Therefore, cloud-oriented approaches are a promising way of developing adaptive educational systems. Flexible and open, they are more focused on improving the learning environment, the introduction of new components, supplying computing power based on user needs, customization of personal information processing and information needs of the user.

Despite numerous partial studies of special issues of adaptive learning systems and AR technologies application, the methods of these technologies' educational use remain relevant and poorly understood subject matter.

Particularly relevant is the problem of developing theoretical and methodological foundations for the use of adaptive cloud-based systems in combination with AR technologies. This is the key to the training of competent ICT professionals, highly qualified teaching staff for modern education.

The purpose of this research is to consider the state of the art and the approach for adaptive cloud-based systems design and to develop the recommendations for educators on using adaptive technologies and augmented reality in personalized learning implementation.

3 The personification of learning as a leading global educational trend

Turning to the theory of adaptive systems, the task is to build a controller that will affect a specific object and over time will (under any circumstances) achieve the goal. The system consisting of the object parameters and the specified controller will be called adaptive [10]. The time to reach the goal is called the time of adaptation.

Due to [8] the inherent adaptability of the service can be manifested in one or more aspects: content, evaluation, and sequence (fig. 1).

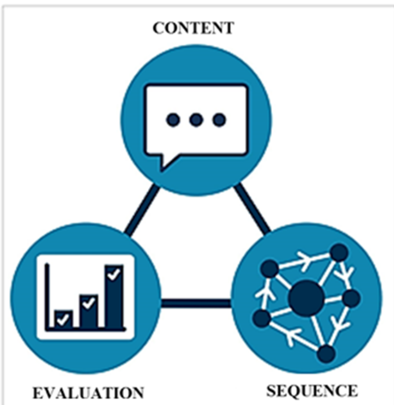

Fig. 1. Aspects of service adaptability [8].

Services with adaptive content allow you to determine what kind of educational material the student doesn't understand. The system “splits” each training block into parts, and the student can move to the next content unit only after successfully mastering the previous ones. If you have problems with a specific content block, the system monitors and prompts you to re-go through the content on that topic. At the same time, the educator can track the progress of each student: at what pace he/she is completing tasks, and so on. An example of a platform with adaptive content is CK-12 [5]. This is a free English language resource with educational materials in most school subjects. The typical content of a training block in CK-12 is video, textual examples, interactive assignments (PLIX), simulations [5].

Adaptive assessment services are designed in such a way that each question/task depends on how the student handled the previous one: if successful, the following question/task offered is more complex, if unsuccessful, then simpler. Such services can be created as part of certain applications, platforms (ST Math, Smart Sparrow, etc.), and separately (Typeform, Quizalize, etc.) [28]. Adaptive tests can be selected and applied depending on didactic goals – as a means of ongoing, thematic and/or final assessment, monitoring. For example, MAP Growth service is recommended to be used for periodic assessment of various subject matters (a "long" test every few months, and MAP Skills is recommended to be used more frequently since it allows you to determine what difficulties a student has when mastering the material and to properly adjust the learning process [28]. An important advantage of monitoring using adaptive tests is the ability to obtain detailed statistics for each student at different intervals – from months to years, and accordingly, build an individual learning trajectory (alone or with the help of an educator) [28].

Adaptive sequence services collect and analyze user data continuously. While the student is working on tasks, the program analyzes the answers and sequentially selects the next content of the corresponding complexity. In general, such programs can take into account different indicators: the correctness of the answers to the questions, the number of attempts, the time spent, the use of additional resources, personal interests (for example, which resources the student prefers), and sometimes mood [8]. The development of such services is the most time consuming since they allow us to build and adjust the individual educational trajectory of each student in real-time. The adaptive sequence goes through three steps: data collection, data analysis, adaptation of the material flow to the needs of each student [8]. The adaptive sequence is applied by Knewton (https://www.knewton.com/).

Sometimes developers of adaptive services apply several adaptive aspects. For example, the Precalculus online course combines adaptive assessment and adaptive sequencing (ALEKS service). Smart Sparrow platform has adaptive content and sequence (https://www.smartsparrow.com/what-is-adaptive-learning/), etc.

The world's leading companies and institutions are investing in advanced digital technologies, such as mobile communications, online social media, big data analytics systems, "intelligent" devices that control connected objects and sensors, and more. Hybrid cloud solutions emerge as a promising direction for technological development and implementation of the latest educational systems [36].

The development of adaptive educational systems, mostly with elements of artificial intelligence, requires the processing of large amounts of knowledge obtained from students. Due to cloud services that implement high-speed computing, the possibility of dynamic adaptation to the achieved level of knowledge, experience, skills of the learner is achieved. Therefore, with the use of hybrid cloud solutions, educational systems are becoming more adaptable, based on the integration of different types of services and their integration into teacher education into a single environment [36].

In this regard, a number of important trends can be identified that characterize the promising avenues for the development and use of modern learning personification technologies:

- The personification of learning that is achieved on the basis of "intellectualization" of all links of educational systems, their further integration in the educational process and the learning environment;
- The development of adaptive cloud-oriented platforms, their further unification, universalization, the formation of common standards for the development and implementation of individual modules, subsystems and training systems with elements of artificial intelligence;
- The growing role of the Big Data approach for collecting and analytics on learning outcomes and individual student progress;
- The development of information and analytical tools of the educational and scientific environment in the direction of their greater "intellectualization", use of advanced methods of semantic and syntactic analysis of data and texts in the process of searching for necessary information, processing of requests provided in natural language, use of elements of AR when working with text;
- The increasing saturation of the learning environment with a variety of intelligent devices, remote controls, robots, peripheral equipment, etc. that can be managed on a single platform, over the network (Internet of Things);
- The development and implementation of systems of educational and scientific cooperation in virtual teams with the use of augmented (virtual) agents, including technologies of individualization and enhanced collaboration between people and agents;
- The increasing role of computer literacy and technological culture for all participants in the learning process for the successful development and implementation of a new generation of artificial intelligence (AI) learning tools.

We anticipate advances in science and technology focused on personalized, adaptive technologies to improve teamwork, leading to new opportunities that revolutionize the way we train both individuals and teams to improve group collaboration. We also anticipate that this shift in focus to more basic and comprehensive incorporation of intelligent and adaptive technologies within the organization will lead to a change in critical knowledge, skills, and competences across different workplaces. Further, we expect that the study of shared mental models, such as transactive memory systems [6], will lead to the development of fully integrated human-agent (VR/AR) hybrid teams requiring new training using new techniques.

Some researchers consider assistive technologies as a separate subset of adaptive technologies. In a general sense, these are technologies which application provides support for specific activities for persons with special needs (SEN). Assistive technologies (ASTs) represent a wide range of tools, strategies, and services that meet an individual's individual needs, capabilities, and tasks, and include an assessment of an individual's needs with SEN, a functional assessment of the environment in which he/she resides, and selection, design, setting up, adapting, applying, maintaining, repairing and/or replacing services, coordinating them with educational and rehabilitation plans and programs for the comprehensive development and support of "education for all".

As a matter of fact, ASTs in educational systems are featured in adaptive technologies due to the ability to customize these systems to the needs of a wider range of users, e.g. persons with SEN. As a result of the pedagogically expedient implementation of the ASTs in the educational process gives students the opportunity to perform educational tasks with a greater degree of independence, with less effort.

Here are some examples:

- For students with visual impairments: Access Note, Aipoly Vision, VoiceOver, JAWS screen reader, the built-in Narrator system reader, NVDA reader, etc.;
- For students with hearing impairment: Fakih, AR-Book, ELRA, Vuforia
- For students with autism spectrum disorder: Expressionist, iCommunicate, Look2Learn, Proloquo2Go, etc.;
- For students with dyslexia and reading challenges: Audible, Learning Ally, Kami, Augmented Ally, Speechify, etc.

It is important to ensure that ASTs are accessible to vulnerable sections of the population. So, according to the World Health Organization, in low-income and middle-income countries, only 5-15% of people who require ASTs have access to them [41]. The availability of ASTs is greatly enhanced by the inclusion of VR/AR technologies. In this case, the user can use both single service and a range of services, depending on the needs and tasks.

Among the benefits for the students are the following:

- Involvement in the educational process and responsibility for one's own learning;
- Increased motivation and satisfaction with achievements;
- Positive attitude to the educational process, easier to perceive complex and abstract concepts;
- Development of practical skills;
- The use of different senses to receive and understand information.

4 Development and use of augmented reality technologies based on hybrid cloud solutions

The main difference between the new generation educational systems from the previous stages of the development of AI and computer-aided learning tools is a higher level of adaptability. It is achieved both through the use of more powerful and integrated student models and learning with AI elements, and the organization of a more flexible and open learning environment, in particular through hybrid cloud solutions, providing access to personalized services both individually and collectively [12].

By the *adaptive cloud-based learning system* the cloud-based system that has the property to be adjusted automatically by its parameters to the different individual characteristics and educational needs of the learning process participants is meant.

In order to implement the computer-procedural functions of this system, a virtualized computer-technological (corporate or hybrid) infrastructure should be purposefully created.

Thus, the most important characteristics of adaptive cloud-oriented educational systems, through which these systems have significant potential for use in pedagogical higher education systems, in particular pedagogical systems, include:

- availability of virtualized or hybrid ICT infrastructure;
- personalization of services;
- openness to modification and improvement;
- accessibility (use of open access, open data);
- the flexibility of algorithms for evaluating material complexity, student knowledge, readiness for learning, etc.;
- providing personalized assistance in the learning process;
- possibility of automatic adjustment on necessary parameters in real-time;
- systematic structure and functions.

VR training and assessment can have a progressive impact on productive learning [12]. VR systems are characterized as a human and computer environment in which users are integrated, ready to see, act, and collaborate with the three-dimensional world [12].

VR/AR has some learning benefits that are limited by traditional learning. For example, VR is ideal for dangerous workouts to avoid risk, allows you to present objects from different perspectives that are inaccessible under real conditions, allows you to visualize virtual equipment, allows you to use dynamic learning, gives students a sense of control as they can repeat the learning material as many times as they need and learn new topics at their own pace. A 3D interactive animation environment that attracts more attention than photography for students plays a positive role in learning. Besides, VR/AR can save time and money in the training of professionals, as they do not require the purchase of additional devices and provide training anywhere, anytime [12].

Starting and operating flexible manufacturing systems is extremely challenging because of the large number of output parameters. As tasks change over time, operators have no real way to learn or prepare to routinely solve their tasks. VR systems can fundamentally assist in operation and maintenance. Using VR, an administrator can get results online, and current directions can be guided by performing tasks that have never been done by downloading interactive media streams that could include motion, playback, the grouping of videos in real life, or their mixed set, from the so-called innovative multimedia base or even from a real-world framework (situation models). For example, a maintenance strategy is developed through an activity that demonstrates the development of the assembly and disassembly of the part, and the student controls the entire procedure [12].

The current problem is that all students who use VR have a shared training schedule that is not customized individually. However, each student learns at his/her own pace and focuses on specific parts of the task. Usually, given the end goal, adjusting or reworking the curriculum requires the human impact that is extremely large and painstaking. Computerization can stay out of this human influence [12].

Future reunions of VR/AR people and agents are giving rise to the idea of greater diversity and change in team and team members as you complete the training task. In particular, the anticipated benefits of these complex teams include combining the exact skills and skills required for a particular mission. Therefore, the ability to quickly bring together diverse teams of people and agents to work effectively in a group is needed. For example, with a long-term, ongoing knowledge of the strengths, status, and behavior of existing team members, and an individualized, adaptive agent may be responsible for working with team members to quickly assimilate individuals within the team, understanding the changing roles and responsibilities of team members, and facilitating shared understanding tasks and situations in the team [6]. VR/AR can offer a team during logical training, continuous monitoring of cognitive states, and communication to provide personalized, adaptive instruction when a team member seems to have misunderstandings or is out of sync with the group. That is, whether it is VR or AR, they contribute to the development of group work skills and their organization, interaction in a team.

5 Current research developments

From 2018 at the Institute of Information Technologies and Learning Tools of the National Academy of Educational Sciences of Ukraine (Ukraine), a planned scientific study “Adaptive cloud-based system of secondary school teachers’ training and professional development” (2018-2020) is held.

In 2019 the results of the different aspects of the study were tested at 28 scientific and practical events: 6 conferences (4 international ones); 17 workshops (1 international). The problematic issues of scientific research were discussed and presented for the scientific and pedagogical community by organizing and conducting by the authors a series of training sessions, seminars, webinars for scientific and pedagogical staff, and graduate students.

In 2018 the V4+ Academic Research Consortium Integrating Databases, Robotics and Language Technologies was established, which aimed to address regional issues related to EU ICT research priorities: Partner search for Horizon 2020, building up digital platforms of the future, language barriers, technology-enhanced learning, scientific-cultural heritage, and know-how to exchange.

The main result of the V4+ACARDC project was the creation of a complex system of IT support consisting of the technological network infrastructure, educational software WPadV4 and a didactics methodology on how to create educational packages and associated learning materials and multi-lingual support. A cloud-based platform was used for sustainable information support of the project life cycle according to the jointly determined aims and information technological integration of the project management. The platform proved to be suitable to meet these needs and to perform smoothly and intuitively.

The functional model of the WPadV4 system was demonstrated and analysed in the previous publication [4].

The adaptive content management was supported by the research tool WPadV4, which was used to process available data in a sustainable model. Thus, all the data collected in the course of the research were findable, accessible, interoperable, and for all partners. This was to provide the openness and flexibility of the research collaboration processes.

The learning platform was considered as the set of the cloud-based tools to support different learning and research activities. Within the unite platform a lot of different tools may be integrated providing more opportunities to realize adaptive learning.

The question of choosing and integrating services, exploring their various components (adaptive technologies and VR/AR), as well as supporting open education and science systems, combining intelligent technologies and network services presents a prospect for further research that needs careful study.

As now the hybrid cloud-based solutions are at demand there is an important issue for further research is to consider and build different configurations in view of the basic principles and approach. The experimental design was based on several available services for the different components of the general model that was outlined. Still, the set of services is not still exhaustive in any case.

6 Recommendations and suggestions

With individualized, adaptive technologies and systems, VR/AR we can truly represent the revolutionary capacity for lifelong learning that can be incorporated into future concepts of uniting people and agents of virtual or augmented reality.

Combining adaptive cloud-oriented systems, VR/AR technologies and modern pedagogical techniques will be an effective solution to the problem, which will contribute to the adaptability of the education system to the individual characteristics of training pedagogical and scientific-pedagogical staff. The use of information technology, at this stage of educational development, is better focused on combining adaptive technologies with VR/AR technologies. These technologies are effective modern tools to personalize learning.

Adaptive VR can make learning more efficient and effective. AR learning can be improved by using adaptive, information-oriented models for adaptation and computerization of learning.

Conducting training and practice sessions in realistic learning environments or environments reminiscent of the future workplace increases the likelihood that professional competencies will help to increase productivity in the future, in the work process. There is already some experience in using realistic learning environments and modeling to work effectively with a team. Recent technological advances, including the proliferation and cost-effectiveness of VR/AR systems, combined with artificial intelligence to extend the experience, create the potential for large-scale implementation of the learning process in a realistic environment.

An important component of adaptive cloud-based learning systems is assistive technology. Developers and users of ASTs should follow the recommendations:

- Development/selection of ASTs according to the needs of a specific user group. ASTs should be compatible with tasks, emotional needs of users, their lifestyle, etc.;
- Support for the policy of providing vulnerable groups with access to the ASTs (point and strategic sponsorship support);
- Ensuring ease of use (availability of ASTs instruction manual that is accessible and understandable to any user who does not have) proper technical training;
- Involvement of users in the design of the ASTs - at different stages of development and testing.

Some ASTs include AR systems, which are particularly effective to support the Augmented Reality Operational hearing process [1].

Among the areas of adaptive cloud-based systems use for teachers training there are such as:

- To organize educational communication in a personalized mode, with the use of telecommunication tools, for example, the components of the public and the corporate cloud of the educational institution, as well as communication services and scientific and educational information networks;
- To support of individual and group forms of learning activities (classroom and extra-classroom) using the services of a scientific-educational cloud of an educational institution based on Microsoft Office 365, G Suite for Education, FaceTime, Google Duo, Meet and other;
- To use computer-based adaptive systems and platforms that were tested in different educational and socio-cultural environments and are now widely used in the world educational space: curriculum platforms (Alta, Cerego, Fishtree, Fulcrum Labs, LearnSmart, RedBird Advanced Learning, Smart Sparrow, Socrative); adaptive learning management systems, creation of training courses (Neo LMS, Open Learning Initiative (OLI)); adaptive testing systems (Typeform, Quizalize); adaptive adult learning platforms (Elevate) and more;
- To include cloud services of open science, in particular, services of European research infrastructures, in the composition of facilities and services of forming adaptive cloud-oriented systems in a pedagogical university; scientific and educational networks; cloud data collection, submission, and processing services; as well as the services of the European Open Science Cloud;
- To use adaptive content management tools based on a public cloud, for example, WPadV4 tool;
- To implement the methodology for supporting the adaptive knowledge-based processes of creation and use of e-learning resources and other kinds of services;
- To include the components of the corporate and public clouds of the educational institution (databases and data collections, adaptive content management systems, cloud-based office software applications, specialized software training tools, language processing tools, educational robots, and others) as well as services of publicly available information systems (scientific-educational information networks and infrastructures, cloud-based educational, scientific services) into teachers training;

- To provide visibility by constructing different interpretations of mathematical models, visualization of mathematical abstractions, etc. via AR tools;
- To provide accessibility through the use of a shared interface for access to environmental assets and reliable open source software; increasing temporal and spatial mobility;
- To form a unified learning environment, the content of which is developed in the learning process.

7 Conclusions

The main difference between the new generation educational systems from the previous stages of the development of computer-aided learning tools is a higher level of adaptability. It is achieved both through the use of more powerful and integrated student models and learning with artificial intelligence elements, and the organization of a more flexible and open learning environment, in particular through hybrid cloud solutions, providing access to personalized services both individually and collectively.

The development of adaptive educational systems, mostly with elements of artificial intelligence, requires the processing of large amounts of knowledge obtained from students. Due to cloud services that implement high-speed computing, the possibility of dynamic adaptation to the achieved level of knowledge, experience, skills of the learner is achieved. Therefore, with the use of hybrid cloud solutions, educational systems are becoming more adaptable, based on the integration of different types of services and their integration into teacher education into a single environment.

An important component of the adaptive cloud-based learning systems is assistive technology that cover a wide range of tools, strategies and services that meet the individual needs, capabilities and tasks of the individual, as well as the selection, design, setup, adapting, implementing, maintaining, repairing and / or replacing services, coordinating them with educational and rehabilitation plans and programs for comprehensive development of each individual.

Today a promising educational trend is to introduce teaching methods that will combine the adaptive technologies with VR/AR. Integration of adaptive cloud-oriented systems, the augmented reality technologies and the modern pedagogical techniques will be an effective solution to the problem of the adaptability of the education system to the individual features of educators' training, and will allow to achieve better personalization of the educational process. This issue needs further thorough research.

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Using a virtual digital board to organize student's cooperative learning

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Abstract. The article substantiates the importance of using a virtual digital board to organize student's cooperative learning in the conditions of distance education, incl. social distance (for the quarantine period 2020). The main advantages of using a virtual digital board are outlined and their functions for the organization of cooperative education are compared. An analysis of the benefits of using virtual digital boards and a survey of experts made it possible to identify the most popular virtual digital boards: Wiki-Wall, Glogster, PadLet, Linoit, Twidla, Trello, Realtimeboard (Miro), Rizzoma. The comparison of the functions of virtual digital boards outlines their ability to organize students' cooperative learning. The structure of the module E-Learning "Creating education content with tools of virtual digital board Padlet" is presented in the system LMS Moodle. The results of the experiment are presented, which show the effectiveness of the use of instruments of the virtual digital board to organize student's cooperative learning. Perspectives of researches in developing methods of using a virtual digital board by students of natural-mathematical specialties are determined.

Keywords: visualization, virtual digital board, digital technologies, LMS Moodle, cooperative learning.

1 Introduction

The rapid spread of the COVID-2019 pandemic in the early 2020s [12] has become a kind of global challenge for the entire educational environment, in particular for higher education [2]. The forced transition to distance learning during quarantine has outlined a number of pressing issues at all levels: macro-levels (Ministry of Education and Science of Ukraine – development of national strategy and tactics of realization educational process in conditions of forced quarantine), mezo-level (higher education institution – the choice of structure and forms of education, focusing on the educational-professional (scientific) program, curriculum, level of preparation of students, their emotional state, available technical capabilities, etc.), micro-levels (teacher – ensuring implementation of the educational process, the realization of its quality control). It is clear that in such a situation, it is the teacher of the higher institutions is the one who has a heavy responsibility for the process and results of the professional training of students.

In the context of social distance (during quarantine) teachers, even e-learning opponents, have made massive use of digital technologies. However, the practice has shown that for most of them the ability to use digital technologies is extremely limited. Typically, during quarantine time teachers used the free open system Moodle learning management system [10], and various programs for video-conferencing (Google Meet, Skype, Webex, MS Teams, Zoom). An insufficient level of development of the digital competence [11] of several teachers showed their weak ability to bring distance learning to the usual classroom lesson as much as possible. We attribute the current situation to a limited ability of teachers to use such digital technologies that can effectively simulate full-time education. As an example, the need to use a regular board as a classic technical tool in the educational process. This digital interpretation is represented by virtual digital (interactive) boards (Whiteboard), which as virtualization tools allow users to conveniently make different markings in much the same way as on a regular board or flipchart.

2 Analysis of previous results

There have been a number of studies recently outlining various aspects of using whiteboard in the educational process. So, Christine E. King described the directions for using whiteboard within computer-aided design courses [5]. Wisam Zaqoot and Lih-Bin Oh discovered the possibilities of Whiteboard in the process of Teaching design thinking [14]. Adherence to the principle of accessibility of education for all people with disabilities has encouraged Caron Y. Inouye, Christine L. Bae and Kathryn N. Hayes to highlight the methodological principles of using whiteboard in the organization of inclusive education [3]. Besides, Karina J. Wilkie explored the process of organizing math teaching using whiteboard in inclusive educational space [13]. General theoretical-methodological principles of using whiteboard in the process of teaching physics are presented by Colleen Megowan-Romanowicz [9]. Noteworthy principles prepared by Marek Kowalkiewicz for working with Whiteboard “IdeaWall” in a process of realization “brainstorm” [6]. Dmytro L. Desyatov [1], Svitlana H. Lytvynova and Oleksandr Yu. Burov [8] revealed the essence and advantages of using a virtual digital board as a means of organizing students’ cooperative activities. Nataliia A. Khmil and Iryna V. Morkvian reviewed virtual digital boards and highlighted their considerable didactical potential [4]. Taking into account the results of the conducted research, the problem of organizing students’ cooperative education with the use of a virtual digital board requires further investigation.

3 Research methodology

The purpose of the article – is to substantiate and experimentally test the possibilities of using the virtual digital board tools to organize student’s cooperative education.

In the process of research the following methods were used: analysis of scientific-pedagogical literature on highlighting the theoretical foundations of the use of digital technologies in the educational process; analysis of online resources, methodological literature on a generalization of opportunities of virtual digital boards; studying and generalization of pedagogical experience on the use of virtual digital boards in the educational process; a pedagogical experiment to prove the effectiveness of using virtual digital board tools to organize student's cooperative education.

Work on the material of the article was conducted within the framework of the scientific topic 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", state registration number 0116U004625.

4 Results and discussion

Analysis of scientific sources allows us to say that modern scientists use similar terms: virtual digital board, virtual electronic whiteboard, interactive whiteboard, virtual interactive whiteboard, and others. In our opinion, these definitions are essentially more common than different. In our work, we do not aim to define the differences between these terms, therefore, we propose to use a common definition – a virtual digital board.

Virtual digital boards have been successfully used in the educational process for over 20 years. The experience of the authors of the article suggests that a virtual digital board – is a convenient instrument for cooperative student's learning, that allows people, even at a distance from one another, to combine text, images, videos, audios, etc. in one interactive format.

According to Mariya P. Leshchenko and Inga I. Kapustyan, the strategy of such education is a popular model of partnership. In co-operation during training, tasks should be shared between the members of the working group, who are united to achieve the goal, and each is responsible for part of the problem identified. The focus is not on the individual performance of a task, but on the development of cooperation within the group [7]. In other words, cooperative education appears not as a form of education, but a special method of organizing educational activities in a group, the basis of which is the positive interdependence between individuals in the course of an educational task and the result of such educational activities become a joint effort created by the end product [1].

Today, there are dozens of resources available on the Internet to create virtual digital boards, including: WikiWall, Tutorsbox, Glogster, Dabbleboard, Twiddla, Scribblar, Padlet, Educreations, Popplet, Realtimeboard (Miro), Twiddla, etc.

They are quite similar in the instrumental set, but each has its specific properties, that can be applied at different stages of the lesson and for different purposes. Using a digital virtual online board can be a very convenient tool in organizing cooperative learning, in creating different types of projects, because classroom projects are a popular and important component of the modern educational process.

In terms of efficiency of use in the educational process, we highlight some advantages of virtual digital boards. First, the virtual board can be posted on social networks (Facebook, Twitter, etc.) that students actively use daily, saved as an electronic document in PDF, CSV, JPG, etc., and sent via email, embed in your page or blog, and use its mobile version and create a QR code. Second, various objects can be added to the virtual digital board. This allows students to work with their projects at any time of the day; to collaborate in a familiar environment for today's youth; ensure simultaneous processing (filling, editing) of the project irrespective of geographical location and social distance (introduction of quarantine/state of emergency in the region, etc.).

Besides, the experience of the authors of the article on the organization of the educational process with the help of virtual digital boards shows that virtual boards act as an effective means of realization of various forms of conducting classes (web competitions, interactive games, quizzes), allow to organize student surveys and carry out reflection, expand opportunities research work of students, consulting.

It should be noted that the use of virtual digital boards in the educational process promotes the formation of students' ability to work independently with different sources of information, allow to immediately see the result and evaluation of their work through the ability to respond quickly to the participants of one board or giving access to their board.

Virtual digital boards provide a great opportunity to visualize information while working in groups, even when away from each other, but under the control of a teacher who acts as an administrator, coordinator. It regulates remotely, adjusts the flow of information. The administrator is notified of changes to the board. After the necessary information is collected, students, together with the teacher, begin to systematize the information and draw up a single project. Figure 1 demonstrates several variants of boards in services Wikiwall, Realtimeboard (Miro) and Linoit.

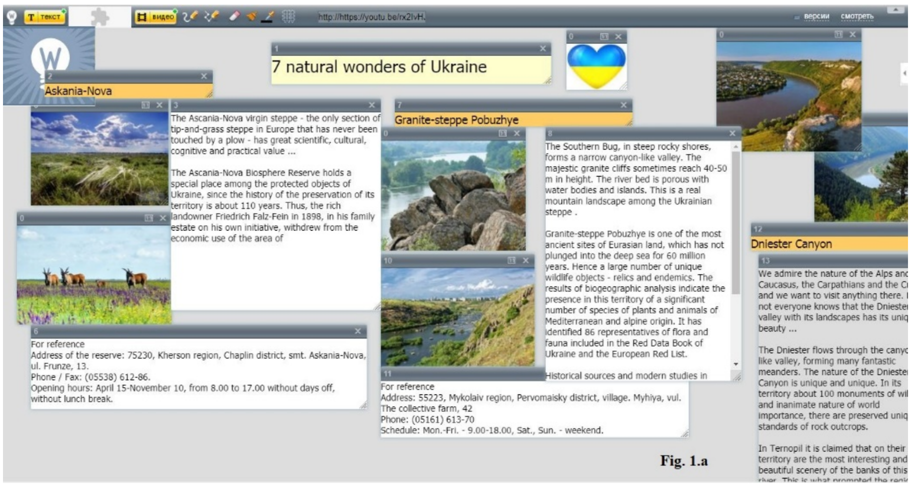

Fig. 1.a

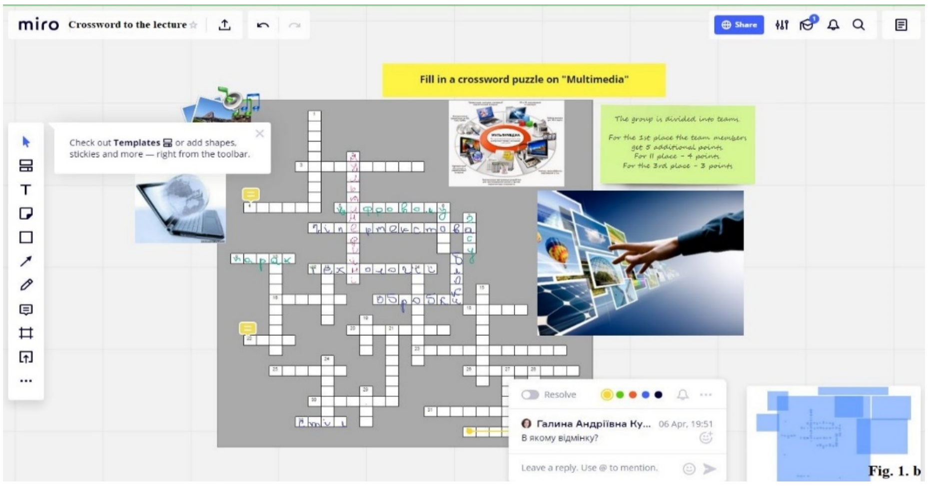

Fig. 1. Board options in services Wikiwall (a), Realtimeboard (Miro) (b), Linoit (c).

Let's focus on another important advantage of using virtual digital boards. It is sometimes quite difficult for a teacher to identify and evaluate each student's contribution to the final product as a result of collaborative learning. It is the digital technologies that allow recording the individual contribution of each student, which permits to realize the principle of cooperative learning – individual responsibility of each person for their activity.

In order to find out the real state of the use of virtual digital boards in the educational process, we surveyed teaching staff during September, October 2018. In total, 14 experts from the Department of Computer Science and Mathematics, and the Department of Information and Cyber Security at the Borys Grinchenko Kyiv University, who are involved in teaching computer science and experience in application virtual digital boards, participated in the study. The survey found that the most popular tools used by teachers in the educational process are the following: WikiWall, Glogster, PadLet, Linoit, Twidla, Trello, Realtimeboard, Rizzoma. Summarizing the answers of the respondents, it can be argued that these tools are the most adapted for the organization of educational activities with various content for better visualization of the material. This allowed us to systematically summarize the main features of digital virtual boards, so we provide a comparative table of their advantages and disadvantages to provide visualization of the training material (table 1).

Table 1. Comparative table of functions of digital virtual boards.

Opportunities	**WikiWall**	**Glogster**	**PadLet**	**Linoit**	**Twidla**	**Trello**	**Miro**	**Rizzoma**
Collaboration on one board	+	+	+	+	+	+	+	+
Communication on the board via chat	–	–	–	+	+	–	–	+
Placing text, illustrations, videos on the desktop	+	+	+	+	+	+	+	+
To build in documents, widgets and html-code	+	+	+	+	+	+	+	+
Saving a board/wall on computer as a picture	–	–	+	–	–	–	–	–
Common browsing websites in online	–	–	–	–	+	+	–	–
Organize a discussion for each marked object	+	–	–	+	–	–	+	+
Consistency with other web-services	+	+	+	+	+	+	+	+
Collaboration (registered & unregistered participants)	+	–	–	+	+	+	+	+
Free registration and use	–	–	+	–	+	+	+	+
Support for Cyrillic in posts	+	–	+	–	–	+	+	+

Next, we give a detailed description of the virtual digital board's capabilities.

- Collaboration on one board. Denies communication among students and facilitates discussion when organizing cooperative, in particular, project activities in terms of distance education.
- Communication on the board via chat. A separate chat gives a chance to discuss problem issues with a concrete user or organize a separate chat for a project group.
- Placing text, illustrations, videos on the desktop; To build in documents, widgets, and html-code. Facilitates exchange of information among participants/users for better visualization of training information when organizing a lecture/practical classes.
- Saving work on a computer as a picture.
- Consistency with other web-services (posting board on your blog, site, social network page; creating a QR-code for the board). Improves the communicative component of education and the ability to disseminate your work to other Internet users. When organizing cooperative education or project activities assists the approbation of produced materials.
- Collaboration with the board for both registered and unregistered participants. It simplifies the step of registering on the resource, but comments or entries on the board will be added as an anonymous note.

- Support for Cyrillic in posts. An important feature of the service for those who do not speak a good foreign language. Working with the non-Ukrainian language interface helps to develop users' linguistic competence.

Note also that these services have many features that are interesting for students of particular specialties, such as formula editor, patterns of geometric shapes, etc.

Therefore, the opportunities defined are a compelling an argument for purposeful student learning in the context of using virtual digital boards for cooperative training, especially in the case of failure to complete a full-time study (for example, during the quarantine period of 2020).

To accomplish the outlined task, we developed an e-learning module in the LMS Moodle system on "Creating educational content with tools of virtual digital board Padlet", which contained small group method-related tasks (that is, it contained a task aimed at developing cooperative learning). The module has been added to courses in LMS Moodle within the framework of information science for students of the following specialties: "International Law" (discipline "Information-analytical Studies: Modern Information Systems and Technologies"), "International Information" (discipline "International Information: ICT in International information"), "English Philology" (discipline "Information Technologies in Foreign Languages: Modern Information Technologies in Foreign Languages "), "Eastern Philology" (discipline "Information Technologies in Eastern Languages"). "Creating educational content with tools of virtual digital board Padlet" module is designed as universal for computer science courses taught to enhance students' digital competence.

Padlet virtual board service is chosen by us as an easy-to-use, popular among our experts – teachers at KUBG. Besides, as shown in table 1, this tool contains a significant amount of functionality.

The module "Creating educational content with tools of virtual digital board Padlet" contains the following components:

- lectures (1. The history of development and general characteristics of cloud service; 2. An online analog of the wall for notes – is the Padlet service; 3. Advantages and disadvantages; 4. Using the Padlet in professional activity and presentation of a given topic);
- practical work (20 detailed tasks for mastering the skills of work in the service);
- video manual (step-by-step instructions for completing the most practical tasks);
- glossary (dictionary of terms);
- knowledge tests.

In fig. 2 shows a copy of the screen element of the training course "Creating educational content with tools of virtual digital board Padlet" in LMS Moodle.

Here are examples of using a virtual digital board Padlet at different stages of training within the ELC in the LMS Moodle system.

Fig. 3 presents a fragment of the results of students' work during the discussion of the material as part of the lecture on "Social network services". The purpose of the task was to organize students into groups and discuss the types of social networking services, their opportunities, and directions of use in future professional activity. All members of groups had the opportunity to add, comment on relevant entries, put likes/dislikes. We believe that when organizing such a reflexive approach, students are highlighted in collaborative and communication skills.

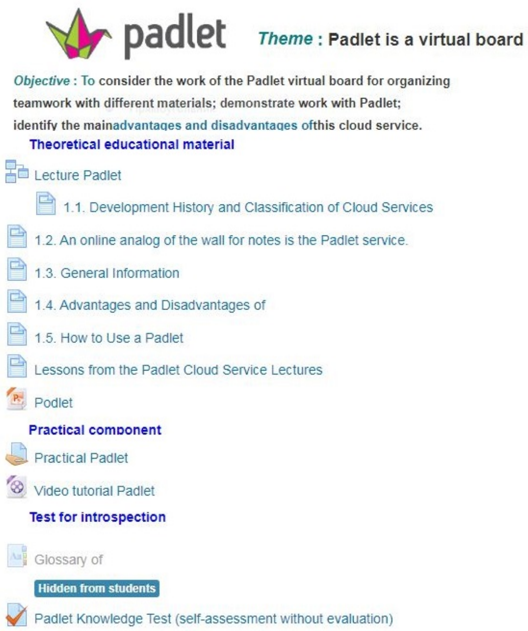

Fig. 2. The element of the training course “Creating educational content with tools of virtual digital board Padlet” in LMS Moodle.

Fig. 3. An example of using a virtual board in the course of a lecture on “Social network services”.

In fig. 4 a teacher’s board is submitted, which presents the tasks for the practical work, evaluation criteria, etc. Besides, there are student’s comments, links to other boards created. With such a visual observation organization, users can view, discuss, and comment on other students’ boards, which helps communicate to users both in separately organized groups in project work and in general when organizing cooperative learning.

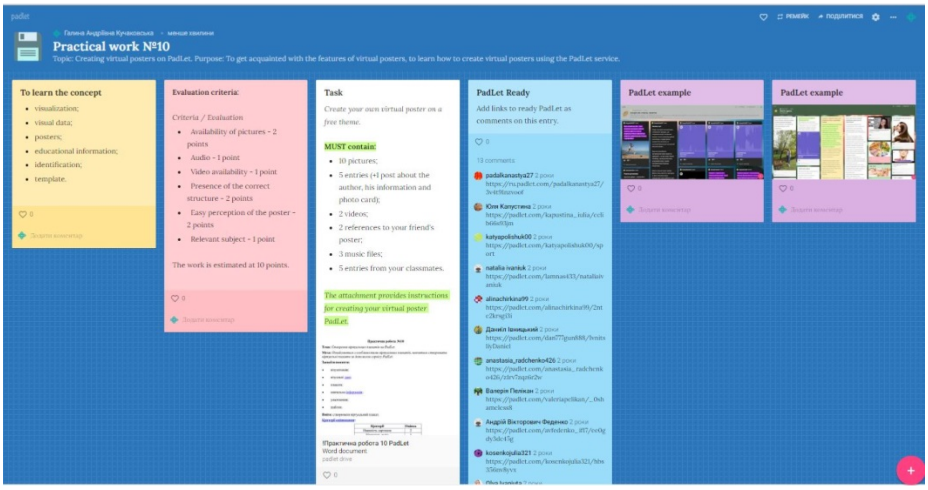

Fig. 4. An example of using a virtual board in the process of organizing a practical lesson.

Students of the above specialties of KUBG were involved in the implementation of the forming experiment (conducted during February – December 2019). The experiment aimed to determine the effectiveness of using a virtual digital board for the organization of student’s cooperative learning. The experiment was conducted over two academic semesters, depending on the curricula governing the study of computer science in different specialties at the university. The total number of students was 164 persons, of which – the control group (80 persons), the experimental group (84 persons). All students studied the element of the training course “Creating educational content with tools of virtual digital board Padlet”.

For the students in the control group, we used the standard tasks to develop skills to work with virtual digital boards, for example:

1. Register and create your digital board (wall), give access to the digital board to your small group of researchers (hereinafter SGR).
2. Add your files from your desktop or computer folders, drag photos to your wall.
3. Add a portrait and change the wallpaper.
4. Change file location to Grid.
5. Click on the plus icon in the right column to start a new wall.
6. Click on any item to zoom in and make it easier to view.
7. Post your wall on any social network.
8. Set up privacy and more.

For the students of the experimental group, in addition to the standard tasks, we have developed our tasks aimed at implementing cooperative learning (in small groups). To accomplish each task effectively, it was necessary to share responsibilities among the group members. Each student was responsible for solving part of a common problem. In addition, it was important to establish effective collaboration between team members to achieve the desired result.

Here is an example of a problem. Add a file or advertisement to a virtual digital board containing a specific problem (for example organizing of student distant learning: motivation and incentives). Discuss (for example, using SWOT analysis, identifying strengths, weaknesses, opportunities, and threats). As a result of the discussion, make the appropriate decisions as a result of the small group discussion.

To evaluate the effectiveness of using a virtual digital board for the organization of student cooperative learning, a test was developed and conducted that contained 10 tasks that required the presence of cooperative activities skills. So, students had to solve problems regarding the effective organization of work in small groups, systematization of knowledge, reflection, etc.

Test results for students in the control and experimental groups, we obtained data. The statistical hypothesis was tested using the Student's *t*-test. Obtained that $t_{emp} = 4.78 > t_{cr} = 2.6380$ at the level of statistical significance α=0.01, therefore, we can argue that the use of virtual digital board tools is effective for organizing cooperative student learning.

5 Conclusions

The importance of realization of cooperative student's education in the process of professional training is proved in the article, including in the conditions of social distance (for example, during quarantine time). To maximize the approximation of distance learning to full-time form, the importance of using a virtual digital board, which simulates the work of a regular board as a classic technical medium is outlined.

An analysis of the benefits of using virtual digital boards and a survey of experts made it possible to identify the most popular virtual digital boards: WikiWall, Glogster, PadLet, Linoit, Twidla, Trello, Realtimeboard, Rizzoma. The comparison of the functions of virtual digital boards outlines their ability to organize students' cooperative learning.

The ELC module "Creating educational content with tools of virtual digital board Padlet" has been developed, containing the following components: lectures, practical work, video-manual, glossary, knowledge test. A pedagogical experiment was conducted to test the possibilities of using a virtual digital board for organizing cooperative student learning. For students of the experimental group, tasks aimed at implementing cooperative learning (in small groups) were introduced. Statistical processing of the study results (Student's t-test) allowed us to establish that the use of virtual digital board tools is an effective means of organizing cooperative student learning.

The perspectives for further research are seen in the development of methods of using virtual digital boards by students of natural-mathematical specialties.

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Distance learning as innovation technology of school geographical education

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Abstract. The article substantiates the necessity of using innovative technologies in the process of studying and teaching geographical disciplines at secondary schools. Particular attention is paid to distance learning as a pedagogical innovation, its theoretical aspects and the ways of its introduction into the educational process. The relevance of using distance learning at the New Ukrainian School is proved. Its advantages and disadvantages are revealed. The examples of some forms of distance learning that will contribute to geographical competence development according to European requirements are provided. The article particularly focuses on the Massive Open Online Courses, modern websites, virtual portals of individual teachers, LearningApps.org portal, and Moodle.

Keywords: pedagogical innovation capability, distance learning, mass open online courses, Moodle.

1 Introduction

1.1 The problem statement

Today's young people live in a media environment where the use of computers, Internet resources and mobile devices is part of their daily lives, they are, in the words of Alexander Kuleshov, "digitally born" [18], and this cannot be ignored. Students seemed ready for distance learning, but forced distance learning during quarantine was a challenge for all participants in the learning process: students, teachers and parents. It was very difficult to organize quality education using digital technologies, motivate students, give advice on overcoming technical problems. Global quarantine has made its unexpected adjustments and forced everyone to urgently learn digital tools and new pedagogical approaches and methods [11].

The urgency of the problem of our study can be presented in the form of a contradiction between the social requirements for the proper organization of distance learning and the state of readiness for it as individual participants in the educational process and the domestic education system as a whole.

1.2 Theoretical background

Distance learning has become the characteristic innovation of the last decade, which is sometimes understood by the scientists as a way of learning process implementation which involves using modern telecommunication and innovative technologies that make studying in distance without personal teacher-student contacts possible [1]; organizational form of educational process in the specially created educational environment using modern information and communication technologies [2].

Not denying the definitions, given by the scientists, taking into account the specific character of geography, let's understand distance learning as the individual process of gaining knowledge, abilities, skills and the ways of the personal cognitive activity, occurring mainly at the mediated interaction of the participants of the training process, being distant from one another, in the specialized environment, functioning on the basis of modern psychological-pedagogical and information-pedagogical technologies, in the presented publication.

The different aspects of distance learning were revealed by Aleksandr A. Andreev [1], Borje Holmberg [13], Mihail P. Karpenko [15], Desmond Keegan [17], Michael Moore [31], Vasilii I. Soldatkin [1], Charles Wedemeyer [50], and others. Pedagogical works which raise issues of theory and practice of distance learning cover the following topics of scientific research: scientific support for distance learning, problems and areas of research (Valerii Yu. Bykov [6; 7], Volodymyr M. Kukharenko [24], Yukhym I. Mashbyts [28], Natalya V. Rashevska [41], Serhiy O. Semerikov [30; 33], Andrii M. Striuk [46], Bohdan I. Shunevych [43], Nina H. Syrotenko [5], Yurii V. Tryus [48], Myroslav I. Zhaldak [53]), organizational and pedagogical conditions of distance learning, approaches to their realization (Hennadiy M. Kravtsov [23], Svitlana V. Shokaliuk [42], Vasyl V. Yahupov [51]); development and use of multimedia and computers for teaching different subjects, for instance, foreign languages (Svitlana M. Amelina [47], Olha V. Chorna [9], Vita A. Hamaniuk [16], Iryna S. Mintii [49]) and music (Liudmyla H. Havrilova [12]); marketing of distance learning (Larysa M. Petrenko [36]).

1.3 The objective of the article

The objective of the article is to reveal the meaning of distance learning, to characterize its specific forms and to demonstrate the features of their application in school geographic education.

2 Results and discussion

A retrospective analysis of scientific research suggests that the origins of distance learning as a means of education date back to the 19^{th} century, when the University of London offered “correspondence training”. The educational institution, in parallel with full-time education, introduced such forms of education that were carried out at a distance from the educational institution. The term “distance learning” was officially recognized in 1982 [17]. Distance education began to become more widespread in the 1990s in countries such as the United Kingdom, the United States and France. In Ukraine, such education began to be introduced and developed only at the end of the 20^{th} century and mainly in the higher education system.

Distance learning has revealed itself as the most efficient system of the 21^{st} century educational process in different educational institutions. The main objective of distance learning is to develop learners’ creative and intellectual skills by means of the open and free use of all educational resources and programs.

As noted above, distance learning gains more and more popularity in our state nowadays, due to the development of the information technologies, the change of the attitude to the traditional education and also due to the announcement of the quarantine, connected with the pandemic of COVID-19. The task arose before the teaching staff, which required the urgent solvation on conditions of the quarantine: the organization of distance learning.

A little bit before, distance learning remained extremely urgent, due to the situation in the AR of the Crimea and also in the Donetsk and Lugansk special districts. Young residents of the temporarily occupied territories had not had the access to Ukrainian education for a long time and, consequently, had not had the opportunity to go to Ukrainian higher educational institutions. Therefore, in September 2016, the E-school educational portal was created where students can choose one of the five basic Ukrainian schools in Donetsk region and gain free distance education. In addition, the MES website has a list of schools from all over Ukraine where distance education can be obtained.

There were three schools in general in our state, concentrated only at distance learning, before the announcement of the quarantine: Optima Education Center (Kyiv); Distance school ANGSTREM (Kharkiv); Center for Distance Education Source (Kyiv). These schools require tuition fee. Despite functioning only few years, they are successful at implementing world distance education standards [19].

Let’s characterize a distance learning geography. The basic elements of the distance learning system are the sets of educational and methodological materials from different disciplines (geography included), presented in the following forms: distance courses, interactive learning resources, set of online lessons and teaching fragments, virtual learning environments, electronic libraries, electronic circuit simulators, electronic periodicals, electronic systems for monitoring and assessing learning results, computer simulation tools, computer demonstrations.

The development of such sets is supposed to be done on the basis of the content of the State Educational Standards of each subject, and the volume and content of the sets should be sufficient or excessive for educational process, considering the students who have different basic education, different learning styles and skills.

An analysis of the experience of using distance learning in the study of geography made it possible to single out the following forms of classes that are most often used:

- chat sessions – training sessions that are conducted using chat technologies. Chat sessions involve synchronous interaction what means that all participants have instant access to the chat. Many distant educational establishments operate chat-schools where teacher-student interaction is organized by means of chat rooms [38];
- web-classes – distant lessons, conferences, seminars, business games, and other forms of telecommunication and Internet training;
- video lessons are an integral part of distance learning. Digital files can be stored on an individual electronic device or on a web server. Typically, a record of teaching process is broadcast on the screen. It is considered effective for distance learning to use dynamic video aids: movie clips, animations, spreadsheets. The advantage of this form of material presentation is the opportunity for a student to regulate the course of the lesson individually, to review previous stages and difficult moments;
- web-forums – the form of dealing with a particular topic or issue by means of posts that remain on one of the sites with the relevant program installed on it. Web forums are distinguished from chat sessions by longer (multi-day) work and the asynchronous nature of teacher-student interaction;
- distant conference as a class can take several forms, therefore, the following types are distinguished: video conference, audio conference computer conference, and teleconference. Teleconference is usually carried out on the basis of mailing lists using e-mail [19];
- individual work (investigative, creative) based on a certain plan, schedule or scenario;
- individual projects;
- trainings, master-classes, workshops;
- assessment (tests, keys to tests);
- consultations.

The specific educational need of a modern subject teacher is to create a virtual portal and integrate it into the single information space. This Interactive Geographer’s Office was created on Iryna V. Makhanko’s site [27]. The distance course “The Last Terra Incognita of Our Planet” is designed for students’ individual studying, comprehension, knowledge enlargement and self-evalution of all geographical courses. For example, in the course “Geography of continents and oceans” in the part “South America is a mysterious lost world”, the motto of which is: “A person cannot truly improve themselves unless they help others to develop”, C. Dickens, the course developer singled out different sections with hyperlinks to the information and tasks, among which are: “Case for creative students”, “Co-operative tables to the topic”, “Teacher’s Web consultation”, “Collective opinion: voting”, “Collective diary of the explorer”, “Advanced tasks, materials for self-study”, “Topic assessment: online testing”.

The author of the site has offered other rubrics to study the topic “Empire of Cold Incognita”: “Program and explanations for the course”, “Interactive map”, “Nature of

Antarctica", "Cartographic simulator", "Video excursion to the course", "Teacher's Web consultation", "Geographical workshop", "Scaffolding schemes for classes", "Test yourself", "Questions for self-control", "Topics of research works", "Useful links", "Course test – online testing".

The course algorithm is easy to use. The content of the rubrics is accessible, scientific, systematic, visually enriched.

The use of elements of automated learning, Internet portals enables teachers to increase the students' cognitive interest in self-study of geographical content.

Geography teachers using innovative teaching methods understand the simplicity and effectiveness of modern educational tools such as LearningApps.org [25].

Registration to this portal is required for both teachers and students. To work on the tasks at individual pace and to have this process controlled, the users may apply a special program. To use it, they need to connect their computers to a local Internet network.

On the portal home page, there is a video with brief instructions of how to work with the portal; there are several windows with the examples of exercises for different subjects and of different levels; the following sections are attached: "What is LearningApps.org", "Show help". Also, on this page there are sections with the access to other windows with additional information: "About LearningApps.org", "About us", "Agreements / Terms", the icon for registration, review of exercises, designing exercises, a search window – "Exercise view".

The LearningApps.org has the following characteristics:

- the option to create individually all kinds of puzzles, crosswords, matching tasks, games of cartographic format, classifications, simple ordering, quizzes, etc.;
- easy and comfortable use, interface is simple for navigation;
- comfortable language choice, Ukrainian included;
- the choice of the task level: from the pre-school to postgraduate levels;
- the opportunity to do the tasks presented at the portal for enhancing knowledge;
- transferring the content of the exercises to registered users, including teachers and students, either simultaneously to all students' workplaces, or selectively to some of them. It gives the opportunity to consult students during the creation of certain exercises, to check the level of the acquired knowledge and skills, to view the results of the done exercises;
- the option to register under both teacher's and student's profile with the opportunity of organizing classes with the aligned conversations [45].

LearningApps.org is a service to support learning and teaching processes through small interactive modules. These modules can be used either directly as training resources or for independent work.

You can create your account under the title "Create an account" providing the required data: login (phone number), e-mail, password. Registered users can design their own exercises. To do this, select the section "Creating exercises" on the home page. The suggested rubrics are: "Matching", "Classification", "Ordering", "Long text answer", "Parts of a picture", "Multiple choice", "Fill in the gaps", "Exercise collection", "Audio- and video collection", "First million", "Puzzle", "Crossword", "Find the word", "Where is it?", "Guess the word", "Jumps", "Pairs".

The further preview or completion of the creating exercises online is possible. It is advisable to use them at the stage of testing, generalization and systematization or application of the acquired knowledge and skills, or at the stage of their direct formation and acquisition. It is also possible to suggest designing similar exercises for students as homework.

In the modern world, blogs and other types of websites are used to communicate and interact with the participants of the educational process. Such browsers as Mozilla Firefox, Opera, Google Chrome, Safari make it possible [37].

Blog (English origin) is a modern web-site with the continuously added posts as the main content that contain texts, images, presentations, films etc. For authors, blogs provide an opportunity to create materials, share important information and experience, conduct online testing, organize team work, etc. For users, blogs are examples of creative tasks, participation in projects, competitions, means for posting photos, notes, creative works and for communication to discuss common issues and, what is more, it is an opportunity for self-education [39].

Blogs and websites play an important role in the educational process for teaching and studying geographical disciplines serving as a source of information published on the site and used to organize distance learning; monitoring; work and task discussion.

The example of Geography distance learning can be Olena Chuiko's (Geography teacher) blog (https://geovsviti.blogspot.com/). Its content consist of the following rubrics: the main (geographical events, nationally patriotic education, recommendations); author's portfolio; photos (made by the author concerning the local area and learning activities), methodological materials (textbooks, manuals, geographical problems); visual aids (posters, maps to various geography courses and topics), presentations (on various geographical topics), lessons (the information is presented using various visual, practical, multimedia materials), practical techniques (activities like "Jigsaw", "STEM-lesson", "Flash-cards", etc.); contests, videos (on the topics "How to create a blog", "Travelers", "Ukraine", "Countries of the world", "Continents", "Oceans", "Famous buildings"). The author demonstrates the ways of implementing the experience into the practice.

"Geography for the curious" is a personal blog of Geography and Economics teacher of Pereyaslav-Khmelnitsky gymnasium Olga Chemeris [8]. The analysis of the section "About me" proves the author to be an enthusiastic teacher using modern technologies and innovative training tools.

A number of Internet sites, including "Theory of Geography" (https://sites.google.com/site/teoriageografiie/), "Geographic. Geographical Portal" (http://geografica.net.ua), Popular Geography (http://www.geosite.com.ru/), "World of Mysteries and Wonders" (http://chudesa-sveta.narod.ru /) are advised to be used for Geography distance learning.

The world tendency is that YouTube channel is rapidly gaining popularity among users and now it is the third most popular web-site after Google and Facebook [9; 37]. Plenty of interesting and useful geographical presentations are available on the channel "Geography presentations". The playlists can demonstrate online presentations on any topic including “Environment”, “Geography of Ukraine”, “Industry”, “Interesting facts”, “World geography”, “Bodies of Water”, “Cartography”, “Continents and Oceans” etc. The channel represents itself as a video resource for those interested in the present situation and provides students with the opportunities to do learning activities independently in order to obtain additional sources of information during distance learning.

One of the forms of an educational material set for Geography distance learning is Massive Open Online Courses (MOOC) – (substantial, massive, accessible, public, open distant online courses) – they are online courses with large-scale interactive and information participation and open Internet access [35].

The point of such courses is to provide the opportunity to use an interactive online forum which, in turn, helps to organize a union of teachers and students, as a supplement to traditional geography teaching methods such as: working with atlas maps; analyzing statistical and text tables, charts, graphs; work with a textbook, explanation and various types of conversations.

Currently, mass online courses are one of the most widely used elements of distance learning that is rapidly developing in the global education system. There are a number of widely popular mass online courses that attract broad audience and active users. The following courses are extremely popular: Coursera, EdX, Udacity. On the basis of Taras Shevchenko National University of Kyiv, mass open online courses – “Online University” – were developed in 2014. The interactive online educational project EdEra which continuously develops online resources and accessible educational content was launched [14].

Plenty of various free learning management systems are available today: Acollab, ATutor, Claroline, Colloquia, DodeboLMS, Dokeos, ELEDGE, Ganesha, ILIAS, LAMS, LON-CAPA, LRN, MOODLE, OLAT, OpenACS, OpenCartable, OpenLMS, SAKAI, The Manhattan Virtual Classroom. However, Google Classroom and Moodle are the most popular and massively used systems [20; 29].

Google Classroom is the online educational interactive tool, with the help of which you may create the educational environment, enriched by information, where the text editor Docs, the cloud storage Drive, Gmail and other addendums are combined (YouTube, Sheets, Slides, Forms, etc.) [3]. On conditions of the interactive online cooperation, Google Classroom gives you the opportunity to realize the efficient interaction of the training subjects in the real-time mode by the creation of the task for each definite class with the hyper-inclination to the multimedia content; the editing and commenting on the state of the tasks’ fulfillment by the pupils; the integration of the individual tasks into the topical modules; the publication of the announcement, question, the information digests, etc.; the control’s realization over the fulfillment of the individual tasks by pupils; the setting of the fulfillment terms for each task; the commenting on the reviewed multimedia content, suggested for the tasks; the evaluation of the pupils' educational achievements; the copying of the training achievements into the Google tables for the creation of the statistical reports, the visual monitoring of training’s quality. The experience of the distance learning’s organization at the study of geographical disciplines has been presented in details in the previous publications [3; 4].

The Moodle platform is equally popular among the teaching staff learning environment, also called the Learning Management System (LMS), the Course Management System (CMS), the Virtual Learning Environment, or just a learning platform that provides teachers, students and administrators with a very broad set of tools for computerized learning, including distance learning. It is the most advanced and widespread system in Ukraine and in the world used for this purpose. At the moment, Moodle continues to progress at a much faster pace than its competitors. At schools where the system is used, teachers (Geography teachers included), students, and parents are all connected to it.

Moodle system enables the users to implement the following communication mechanisms: perceptional (responsible for each other's perception); interactive (responsible for arranging interaction); communicative (responsible for sharing information).

Its use as a means of distance learning has a number of advantages, namely: considerable motivational potential; confidentiality; higher levels of interactivity compared to classroom work; absence of "error fear"; opportunity for repeated material revision; modularity; dynamic access to information; accessibility; availability of a constant active help system; option of self-control; compliance with the principles of developmental learning; individualization; providing visibility and variability of information presenting.

Having analyzed the experience of the distance learning organization by the educational establishments, being promulgated on their web-sites, we tried to classify the means and the technologies of distance learning (table 1).

Table 1. Tools and technologies of distance learning, that gained widening on conditions of quarantine [40; 44].

Distance learning tools	Examples
LMS	CenturyTech, ClassDojo, Google Classroom, Moodle, Schoology
Videoconferencing	Zoom, Skype, Teams, Hangouts Meet, Lark, Dingtalk
Messengers	Viber, Telegram, WhatcApp
Social networks	Facebook, Instagram, Twitter, Pinterest, Reddit
Educational projects	To the Lesson. Vseosvita, EdPro
Teacher's blogs and the interactive rooms	O. Chuiko (https://geovsviti.blogspot.com/, I. Makhanko (https://mo-teachers-sc4.ucoz.com/), M. Maznytsya (https://mariwamazni4ka.wixsite.com/mysite), V. Kotsybynska (https://sites.google.com/view/kotsyubinskaya/)
Educational sites	"Theory of Geography" (https://sites.google.com/site/teoriageografiie/), Site "Geographics. Geographical Portal" (http://geografica.net.ua), Site "Popular Geography" (http://www.geosite.com.ru/), Site "World of Mysteries and Wonders" (http://chudesa-sveta.narod.ru/)
Electronic libraries	Electronic Library of Ukraine, UkrLib, Open Book, Library of Originals and Translations of the World Literature Compositions, Poetics, Portal, OpenLibrary, Pensilvania University Library, etc.
Online training contents	Byju's, Discovery Education, Khan Academy, KitKit School, LabXchange, Mindspark, OneCourse, Quizlet (link is external)

Distance learning has both the advantages and disadvantages (table 2).

Table 2. Advantages and disadvantages of distance learning on conditions of quarantine [10; 21; 22; 32].

Advantages	Disadvantages
— the ability to get knowledge anytime and anywhere; — the psychological stability and comfort of training. ability to work at a pace, being convenient for a pupil or a student, and the organization of the individual approach to everybody; — the possibility to control the educational process from the side of parents; — the availability of educational materials; — the interest of pupils and students in the use of new means and tools for learning; — the convenience for the teacher; — the possibility of educational process centralization.	— the access inability of pupils and students to high-quality Internet (especially in the rural area); — the absence of a single platform for the organization of distance learning; — the possibility of hacker invasion into the electronic database; — the insufficient amount of equipment (the age or the software correspondingly) in the families, where there are pupils and students, the high cost of equipment for the realization of distance learning; — the contents of distance learning may depend on the technological characteristics of the equipment used; — the absence of practical abilities and skills of application of both pupils and teachers; — the predominance of the external motivation of learning and the low readiness level of separate pupils and teachers for the work in a new environment; — the absence of some pupils' skills of the independent mastering of educational material; — the insufficient control over the pupils' mastering of the acquired knowledge. a great amount of time for the prepared works' checking by the teacher. the problem of estimation; — copyright problems in the use of educational materials; — distance education is not suitable for the development of the sociability; — the problem of the pupil's identification.

To overcome the problems, appeared at distance learning, we may offer the following ways of their solution [26; 32; 34; 52]:

- to provide an equal access to the high-quality Internet connection and to the technical means for the education getters and teachers;
- to elaborate the single standard for distance learning;
- the educational establishments should operate on one platform;
- to improve the qualification of teachers, dealing with the use of ICT-technologies;
- to increase the education getters' motivation to training;
- to renovate the modern educational programs;
- to elaborate the single standards for the estimation and control of the training achievements of the education getters;
- to renovate the material and technical base of educational establishments;
- to reduce the educational loading for the education getters at the expense of application of the new modern methods of training.

3 Conclusions

1. The introduction of innovative methods in natural sciences teaching allows to change radically the approaches to the educational process. The broad introduction of innovations is facilitated by the rapid development of information and communication technologies, which creates new educational opportunities. The use of computer technologies enhances the educational process, provides new ways of acquiring information, provides testing for new ideas and projects.
2. Distance learning is the individual process of gaining knowledge, abilities, skills and the ways of the personal cognitive activity, occurring mainly at the mediated interaction of the participants of the training process, being distant from one another, in the specialized environment, functioning on the basis of modern psychological-pedagogical and information-communication technologies. Distance learning is actively used as an innovative technique for the geographical competence.
3. On the basis of the content of the State Educational Standard for each subject (geography included), sets of educational and methodical materials are being developed and presented in the form of distant courses, interactive training resources, online lessons, electronic simulators, electronic periodicals, electronic systems of monitoring and assessment of educational results, etc. Distance learning via computer telecommunications has the following forms: chat, web-lessons, video-lessons, web -forums, distant conferences, individual project works; trainings, etc.
4. The most widely used means of distance learning nowadays are considered to be Massive Open Online Courses (Coursera, EdX, Udacity, EdEra, etc.), virtual web portals (LearningApps.org., Teachers of Geography Online), websites (Blogs, Google, Facebook, YouTube), Learning Management Systems (Acollab, ATutor, Claroline, Colloquia, Dokeos, ELEDGE, Ganesha, ILIAS, LAMS, LON-CAPA, LRN, Moodle, OLAT, OpenACS, OpenCartable, OpenLMS, SAKAI, The Manhattan Virtual Classroom) etc. The most advanced and widespread both in Ukraine and around the world is viewed to be the Moodle system, which enables users to implement all the basic mechanisms of communication.
5. Distance learning is characterized by a number of advantages: the chance to study at convenient time, anywhere and at individual pace; the opportunity to use information from multiple sources, media files, teachers' comments, article links, etc.; sparing time for extracurricular activities; encouragement to acquire skills to use modern information and communication technologies.
6. The problems with the wide application of distance learning in Ukrainian geographical educational process are caused mainly by insufficient school supply of modern technological aids, Internet, as well as methodological, psychological and pedagogical recommendations concerning distant learning, high requirements for a "virtual" teacher.
7. We see the perspectives of the further scientific searching in the elaboration of the model and the methods of the future Geography teachers' preparation to distance learning.

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The development of students' critical thinking in the context of information security

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Abstract. The problem of students' critical thinking development in the context of information security becomes important in international and national educational policies as a means of fostering active citizenship and in turn sustainable development. The purpose of the given research is to introduce theoretical substantiation and experimental approbation of students' critical thinking development in the context of information security. The skills of critical thinking help students to cope with the bulk of information they daily receive. However, there is still no conventional methodology for critical thinking development in university students. In our study we suggest possible ways to develop critical thinking in university students via introducing some special courses into the curriculum, and consider the results of the experimental study conducted on the basis of two Ukrainian leading universities. In order to improve the students' skills of critical thinking the author suggested implementing the special course "The specifics of students' critical thinking in the context of information security", and an optional distance course on optimization of students' critical thinking on the background of information and communication technologies. After the implementation of the suggested courses the indicators of students' critical thinking development showed positive changes and proved the efficiency of the special courses as well as the general hypothesis of the study.

Keywords: critical thinking development, information security.

1 Introduction

In the course of substantiating the terms of information security, let us mention the interpretation of the "critical thinking" concept. It is a type of human intellectual activity characterized by high level of perception, understanding, and objective approach to the surrounding information field.

We believe that the modern globalization processes and the rapid development of information technologies in the multicultural world have led to negative consequences for humanity, and also affect the mission of higher educational institutions. For that reason, these days the mission of modern universities is to develop the information culture of students in order that they could critically evaluate the events in the world and appropriately respond to them. Accordingly, a critically thinking student is able to adequately analyze information, verify its accuracy, data contradictions, select and evaluate arguments to prove.

It should be noted that "critical thinking" concept is quite common in both psycho-pedagogical periodicals, and technical publications. Moreover, there is no unique interpretation of "critical thinking" concept because it is multifaceted, so each researcher is focused on a particular aspect of the concept. An active study of this concept can be found in the context of foreign language learning. The explanation for this phenomenon is quite simple. Such strong interest of foreign language methodologists can be explained by the fact that the first scientific researches of this concept belong to foreign scientists and researchers. The definitions given by different authors have some differences and depend on their own approaches to the formation and development of critical thinking.

The researches of critical thinking began in the 1960s. Researchers made attempts to explain critical thinking via philosophical and psychological approaches. Richard Paul made attempt to give a definition for critical thinking. He argued that critical thinking included skills, such as spotting conclusions, examining premises, forming conclusions and diagnosing fallacies [16]. Consequently, he put forward the idea that critical thinking may be regarded as disciplined, self-directed thinking which exemplifies perfection of thinking appropriate to a particular mode or domain of thinking [16]. Tracy Bowell and Gary Kemp published a concise guide to critical thinking, where they introduced and discussed the main concepts related to critical thinking, gave examples and provided exercises and techniques of how to become a critical thinker [2]. Ian Wright regarded the problem of critical thinking in the context of the social world of the young learner [19], and Carol Ann Giancarlo, Stephen W. Blohm and Tim Urdan studied the issue of secondary students' disposition toward critical thinking [5]. Margaret Lloyd and Nan Bahr researched critical thinking in the context of higher education [13]. Emily R. Lai gives a literature review on critical thinking; she explores the ways in which critical thinking has been defined by researchers, investigates how critical thinking develops, learns how teachers can encourage the development of critical thinking skills in their students, and reviews best practices in assessing critical thinking skills [11]. Murat Karakoç (2016) regarded the significance of critical thinking ability in terms of education process and the importance of thinking critically for a student who attends any education programme [9]. However, the problem of students' critical thinking development in the context of information security has not been the subject for scientific discussion yet.

The purpose of the article is to introduce theoretical substantiation and experimental approbation of students' critical thinking development in the context of information security.

Mass media as intermediaries and repeaters of information play a decisive role in the perception and reproduction by consumers of information messages of the real picture of the world. The information of the mass media is the most massive and accessible, so it is able to manipulate public opinion and create a so-called "informational picture of the world", which does not always correspond to reality. In the context of information security of society, the media play an ambiguous role: depending on the semantic content of the message, the information in them can help protect national interests and national information space, or vice versa, lead to destructive processes within society [14].

FM radio stations remain an effective tools of informational influence, which, thanks to the combination with musical accompaniment, significantly increase the suggestiveness and uncritical perception of any information directed at Ukrainian youth.

Thus, there is a separation and development of a new direction of intersectional research, namely – *information and psychological security*, in connection with the further development of information technology, which will significantly solve the possibilities of the media, and the power of this government will increase even more [18]. In the context of our research, the problem of forming information and psychological security of student youth is an urgent and priority task, especially in the context of informational-hybrid war [17].

Scholars emphasize the influence of the mass media on the course of any social processes with the development of Internet technologies continues to grow and is transformed from passive to active [15]. At the present stage, it is impossible to fully protect the consciousness of student youth from the negative impact of media influence, so there must be other means of protection against such influence on the consciousness of youth.

Confirmation of the relevance of our work is the opinion of scientists who are among the priority measures to ensure information and psychological security – is the development of critical thinking of students, including personal ways of active and passive protection from dangerous information influences and instilling skills of technologically competent information production [18].

Information security is a state of protection of information needs of the individual, society and the government, which ensures their existence and progressive development, regardless of the presence of internal and external information threats [6]. Some scholars understand the concept of information security as a value dimension of the object of security, that is, when it comes to human information security – it is primarily human needs, the possibility of which is enshrined in the legal field through its rights and freedoms [21].

From the political and legal point of view, the threat to the information security of Ukrainian government remains the threat of enemy influence on the information infrastructure, information resources, society, consciousness and subconscious to impose its own system of values, views, interests and decisions in vital spheres of public and government activity. The information component of informational influence is a psychological war, the purpose of which is not the destruction of millions of people, but intimidation, demoralization, worldview, spiritual and moral, national mutilation of Ukrainians [8]. Undoubtedly, in the context of the educational process at the university is the formation of national consciousness and sustainable national values in student youth, so in this period, ensuring information and psychological security is a strategic task of higher education in Ukraine.

Speaking about the informational and psychological security of student youth, then there are interrelated categories that will provide information and psychological security. The antonymous term "informational security" is the concept of "informational danger". According to the logic of determining the content of antonymous concepts, we note that the means and mechanisms that cause information and psychological danger are means to be avoided or the definition of means and technologies that would counteract informational danger and ensure the formation of informational culture of student youth.

Such a tool is the category of "informational and psychological influence", which is understood as the impact on the consciousness of the individual and the population in order to make changes in their behavior and worldview. The basic methods of information and psychological influence are persuasion and suggestion.

Persuasion is addressed to one's own critical perception of reality. It has its own algorithms of influence:

- the logic of persuasion must be accessible to the intelligence of the object of influence;
- persuasion must be based on facts known to the object;
- persuasive information should contain general suggestions;
- persuasion must consist of logically consistent theses;
- the reported facts must be appropriately emotionally colored.

Suggestion, on the other hand, is aimed at subjects who are uncritical of information. Features of suggestion are:

- purposefulness and planned application;
- specificity of the definition of the object of suggestion (selective influence on certain groups of the population, taking into account the main socio-psychological, national and other features of these groups);
- uncritical perception of information by the object of suggestion (suggestion is based on the effect of perception of transmitted information as instructions for action without its logical analysis);
- certainty, specificity of the initiated behavior (the object must be instructed to carry out its specific reactions and actions that meet the purpose of the impact).

In today's globalizing world, the first is the informational and psychological impact on the population, the second – economic and political (trade, gas, diplomatic) confrontation. And force operations, which are used in parallel, are aimed not so much at the conquest or retention of territory, as chaos, continuous conflict and the constant generation of provocations and staged military events for the zombie media [3].

The consequences of information effects are appeared in a number of effects, which are classified as follows:

- cognitive effects are appeared in changing the level of awareness, increasing the amount of knowledge (both in conscious and unconscious forms); formation of new cognitive schemes, ways of understanding reality, handling information;

- emotional effects are expressed in the change of emotional state, the appearance of some and the disappearance of other feelings, in changing the general emotional and psychological background of human existence, the emergence of impulses to active reflection, processing, transformation of information, the desire to obtain or create new, etc.;
- value effects are expressed in the formation of new or strengthening or weakening of existing interests, tastes, attitudes, evaluations, value orientations, guidelines about the world, individual objects, phenomena, about other people or themselves [12].

Thus, informational and psychological influence is directed to both individual and public consciousness by informational and psychological means, which causes a change of views, opinions, attitudes, values, motives, stereotypes of the individual in order to influence its activities (or inactivity) and behavior. Such influences involve the achievement of a certain reaction, behavior (activity or inactivity) of the individual, which meets a certain goal of informational and psychological influence.

Today, no drastic measures have been developed to counter informational attacks. This means that in the informational world success will be ensured through the increasing improvement of informational technologies [4]. Therefore, we believe that in the context of the current globalization situation in the world it is necessary to develop informational security technologies and develop informational and psychological technologies to prevent informational and psychological influences of the media by forming critical thinking of student youth.

Undoubtedly, the government must constantly improve the informational security system, taking care of the development of critical thinking of students, improving educational programs, carrying out educational and counter-advocacy activities in society and beyond. Therefore, we believe that the formation of critical thinking should take place at the student age, so in the educational process it is necessary to introduce technologies that contribute to the formation of informational and psychological security and national identity of student youth.

Despite the generally accepted concept of "critical thinking", there is still no conventional methodology for critical thinking development in university students, so we shall suggest and experimentally test the methods and technologies for its testing. Presently, it is essential to organize and summarize the accumulated experience of scientists as to this concept.

Scientists suggest several stages of students' critical thinking development. Particularly, in the first stage the students' attention is focused on the problem, and they get interested in the topic under discussion; the second stage involves setting the goal and task of the lesson, checking the previously learned educational material; the third stage provides practical mastering of the educational material, achievement of the goal set; the last stage (reflection) involves analysis of the lesson, advantages and disadvantages in the classroom activity, elimination of possible mistakes in future educational activity [10].

More frequently, critical thinking is regarded as a person's ability to think independently, to analyze information; the ability to realize mistakes or logical violations in partner's statements; give reasons for their thoughts, change them if they are wrong; the presence of a mental part of skepticism and doubt; striving to find optimal solutions; courage, commitment to principle, bravery in defending their position; open-mindedness to different views [20].

In the course of scientific research, many scholars try to identify the key factors for critical thinking development in university students. Consequently, researchers believe that the major requirement is that the information should not be fully provided to the students, teachers should create conflicting and problematic situations in certain disciplines, which will activate students' critical thinking. Such strategy motivates students to find new information that is not sufficient for their complacency. The specifics of the educational discipline can also influence the development and consolidation of skills which teach students to logically build the methodology of gaining scientific knowledge in their professional field.

In the course of professional training a teacher should demonstrate a tolerant attitude towards any student's position, since such a position is personal and most vulnerable for the further personal development of the student. A positive attitude towards dissidence from both the teacher and the students is the principal condition for students' critical thinking development.

The most important and fundamental factor is to provide students with the basic necessary methods for the development of critical thinking, that is, to acquaint students with the basic thinking operations that inspire critical thinking [7].

In our opinion, the background of critical thinking is the pedagogical educational activity of students and the development of such skills as: analysis, synthesis, evaluation, comparison, correlation, etc. Students have to set themselves a series of goals to overcome difficulties, develop an improved working plan and realize that they can enhance their professional competence by means of internal resources.

The scholars in the field of education have also participated in discussions about critical thinking. Benjamin Bloom and his associates are included in this category. Their taxonomy for information processing skills is one of the most widely cited sources for educational practitioners when it comes to teaching and assessing higher-order thinking skills. Bloom's taxonomy is hierarchical, with "comprehension" at the bottom and "evaluation" at the top. The three highest levels (analysis, synthesis, and evaluation) are frequently said to represent critical thinking [1].

The term "taxonomy" means the classification and organization of objects, based on natural interrelationship, which is used to describe the categories arranged in order of their increasing complexity. One of the main principles of taxonomy is that it should be an effective tool, both in learning and evaluating learning outcomes. Bloom's taxonomy is presented in table 1.

In the context of our research we are interested in the highest possible level of critical thinking development (4, 5, 6 levels in the table 1), namely: analysis, synthesis, evaluation of information received. Consequently, the fourth level (analysis of the information received) involves such students' activity as dividing information into related parts. The activity of the tutor/curator includes the following: he accompanies, teaches, helps to make attempts, and finds the sources of information.

Table 1. Bloom's taxonomy.

Thinking skills	***Definition***	***Curator or tutor activity***	***Students' activity***
Evaluation	Evaluation based on criteria	Evaluation based on criteria	Evaluate, assess, argue, give evidence, determine give preference; make choice, support, draw conclusions,
Synthesis	Combining information to create a new entity	Expands, evaluates, reflects, influences	Systematize, combine, connect, create, design, invent redistribute, modernize, suggest hypotheses
Analysis	Dividing information into related parts	Accompanies, teaches, assists, tries to find the sources of information	Analyze, arrange, systematize, compare, establish correlation organize, ask questions, relate, separate
Usage	Using of concepts, ideas in new situations	Observes, draws attention, promotes, helps, criticizes	Use, consume, calculate, demonstrate, give examples, interpret, relate, make a list, describe in general terms
Understanding	Understanding	Verifies, correlates, demonstrates	Discuss, recognize, retell, explain, make messages, demonstrate examples
Knowledge	Identification and retelling	Tells, shows, manages, points	Memorize, learn, master, recognize, remember, name; cite, identify, register, put to a certain category

As a result, students should adequately analyze, arrange, systematize, compare, establish correlation (between words, parts of a whole), contrast, distinguish, differentiate, separate parts, draw (conclusions), organize, ask questions, relate, and separate.

At the fifth level (synthesis) students should combine information to create a new entity. The activity of the curator in the course of thinking skills development is to expand, evaluate, reflect and influence the activities of students.

As a result, students must learn to systematize, combine, connect, create, design, invent, construct, generate (principles, rules), integrate, enlarge, elaborate, transform, modify, correct, arrange, work up, rearrange, redistribute, modernize, use instead of something, suggest hypotheses, etc.

The highest level (evaluation) gives the student an opportunity to determine the value based on criteria. In this case, the activity of the curator/tutor is accompanying, because he clarifies, concludes, admits, recognizes, agrees, leads to agreement as to one or another piece of information.

As a result students should evaluate, assess, argue, give evidence, determine (rate, significance, benefit, harm), give preference; make choice, support (requirements, standards, criteria), draw conclusions, persuade, make decisions, uphold, justify (actions, deeds, etc.), judge, attribute (class, rank), become arbitrators, anticipate, predict, distribute places, provide recommendations, corroborate evidence, argue for (something/somebody).

2 Methodology

To achieve the goal of the given study we have used such theoretical methods of research as analysis of philosophical, psychological and pedagogical literature on the problem of research in order to determine the conceptual and categorical apparatus and to consider the state of theoretical and practical elaboration of the problem of students' critical thinking development. Also, we have applied the following empirical methods: observation, interviews, questioning, testing to diagnose the level of students' critical thinking development; pedagogical experiment to test the effectiveness of the proposed educational conditions; statistical methods for processing the results of experimental work.

Students of two Ukrainian leading universities have participated in the pedagogical experiment. We have selected Luhansk Taras Shevchenko National University and Volodymyr Dahl East Ukrainian National University as two universities which relocated during the years of the information-hybrid war in Ukraine.

According to the first task of the second stage of the observational experiment, a total sample of 130 students was selected. The sample consisted of a total of 63 students of the specialty "Ukrainian language and literature and English language", "Biology", "Geography", "Music", "Physical education", "Physics", "Mathematics" and "Informatics" in control group and 67 people in experimental group.

The experimental study was conducted during 2016 and 2019. It covered several stages of scientific and pedagogical research.

The first stage (October 2016 – February 2017) – the study of psychological, pedagogical and methodological literature in terms of a particular problem; analysis of normative and methodical literature on the formation of critical thinking of students; defining the purpose, object, subject and general terms of the study. The hypothesis was formulated; the tasks and the program of scientific research were defined.

The second stage (2017 – 2018) – the main theoretical and methodological approaches to the research problem were established; criteria, indicators and levels of formation of students' critical thinking were substantiated and determined; developed a special questionnaire for students and experts-teachers-methodologists "The specifics of students' critical thinking in the context of information security" to study the initial and final state of the control and experimental group, as well as the required number of students; the duration of the experiment was chosen, and the real state of the level of formation of critical thinking of students of the control and experimental group was determined during the ascertaining stage of the experiment.

The third stage (2018 – 2019) – the formative stage of the experiment was carried out, which provided for a direct experiment to form critical thinking of students. At the same time, considerable attention was paid to testing the probability of our hypothesis, which involved determining the pedagogical conditions that affect the level of formation of critical thinking of students. At this stage, the special course "The specifics of students' critical thinking in the context of information security" was introduced. This course was developed on the basis of an optional distance course on optimization of students' critical thinking on the background of information and communication technologies.

The introduction of the pedagogical condition for the optimization of students' critical thinking on the background of information and communication technologies through the use of modern web technologies was carried out in order to provide purposeful guidance to the tutor of this process. This condition was aimed at forming students' critical thinking and providing counseling in the process of raising their awareness of the search, retrieval and critical analysis of certain information; to increase the ability of students to independently create and develop new knowledge based on the information obtained; on the development of the ability to information insight, the ability to design and build possible consequences based on the information obtained. To fulfill this condition, during the period of implementation of this condition, a special eight-week course was created on the Moodle platform for the formation of critical thinking of students who could join the project optional.

At the first stage of the project on the formation of students' critical thinking by means of web technologies was provided by information and cognitive web resources special course on the platform Moodle, which would contribute to the formation of skills of critical analysis and media literacy of students; secondly, it was necessary to involve and motivate students to participate in an experimental project on the formation of informational culture. In the second stage, the content of the special course was filled with web resources that were used in the experimental study.

Let us proceed directly to the detailed characteristics of each criterion of students' critical thinking development in the context of information security.

We have developed the criteria and indicators of students' critical thinking (table 2):

1. *motivational* (motivation to search, retrieve and critically analyze certain information; constant motivations to achieve success, self-fulfillment in professional activity);
2. *content-related* (basic knowledge about information resources, information systems, information technologies, informatization of society; the ability to independently create and develop new knowledge based on the information received);
3. *activity-based* (the ability to operate following the sequence of actions and complete awareness of the actions for critical analysis of new information; information insight, the ability to plan and predict possible consequences based on the information received);
4. *resultative* (self-assessment and self-reflection concerning the critical analysis of the information received; the ability to predict the result through critical thinking due to the information received).

In order to evaluate the effectiveness of the formation of students' critical thinking, we developed a self-assessment questionnaire for the teaching staff. Let us consider its contents. Questionnaire to identify basic knowledge about information resources, information systems, information technologies, informatization of society:

1. What do the "new opportunities of the 21st century" mean to you? How, in your opinion, the 21st century is radically different from the 20th? Why, in preparing students for life in the 21st century, should we teach them differently today? Think about these questions and write down your answers.
2. What qualities must a person have in the 21st century in order to be successful in professional activities, public and private life? Think for five minutes and write down your answers.
3. Learn about different approaches to identifying the most important human qualities of the 21stcentury. What is the similarity and what is the difference? Which of the following skills were not named in groups? Why do you think so? Write down your thoughts.
   a. Educators have long discussed what is more important: factual knowledge or practical and conceptual knowledge. Those who believe that factual knowledge is more important usually believe that there is a set of facts that can be memorized that will prepare students to become active participants in the social system. Others say that conceptual knowledge and practical experience are most important, and argue that knowledge alone is not enough. Moreover, they believe that knowledge is only valuable when it is useful, and that it is only useful when it is understood in conceptual terms and can be applied creatively and critically.
   b. No one doubts the importance of factual knowledge. People need to know a lot in order to be successful in their daily activities. However, the idea that there is a set of knowledge that will give students practical preparation for the future as changes in society accelerate is becoming less popular. The difficulty of describing such a set of wise ideas becomes clear when you begin to realize that 100% of what we know today is only 10-15% of the knowledge that will be relevant in 25 years. Moreover, this rapidly growing knowledge base will soon become more and more accessible to everyone.
   c. Now that electronic communication systems cover almost all countries of the world, the school and home are becoming a kind of information centers with access to world information.
   d. In order to operate successfully in a changing world, students must be able to sift through information and make decisions about what is important and what is not. They will have to understand how different pieces of information can be related to each other, learn to look at new ideas and knowledge in an appropriate context, make sense of new meetings, reject information that is irrelevant or incorrect. Students must learn to critically, creatively and productively evaluate the part of the information universe that they encounter.
   e. To manage information well, students will have to master practical thinking skills. This will enable them to efficiently sort information based on the idea; the selected information will lead to the correction of the idea and can be transformed into practical forms of behavior. In short, they will have to become critical thinkers. However, this does not happen automatically. Experience in reviewing,

processing and appropriating useful information and ideas should be accumulated. The critical review process should be systematic.

4. Which of the computer technologies, social services, graphic packages, technical means of training of the new generation known to you can be used for formation of the successful person skills?
5. Which of the computer technologies, social services, graphics packages, technical means of learning of the new generation known to you are available to you? What do you not wield, but would like to learn? Write down the most interesting ideas.
6. Are you ready to meet the new opportunities of the 21st century? Whereby.
7. Are you ready to take a new look at the subjects you have been taught?
8. Are you ready to rethink your way of thinking to help your students do the same? Why?
9. Are you ready to learn to think critically to pass on this desire and then the skills to your students?

Table 2. Criteria and indicators of students' critical thinking development in the context of information security.

Criteria	**Indicator**
Motivational	1) motivation to search, retrieve and critically analyze certain information; 2) constant motivations to achieve success, self-fulfillment in professional activity;
Content-related	3) basic knowledge about information resources, information systems, information technologies, informatization of society; 4) the ability to independently create and develop new knowledge based on the information received;
Activity-based	5) the ability to operate following the sequence of actions and complete awareness of the actions for critical analysis of new information; 6) information insight, the ability to plan and predict possible consequences based on the information received;
Resultative	7) self-assessment and self-reflection concerning the critical analysis of the information received; 8) the ability to predict the result through critical thinking due to the information received.

Questionnaire to identify skills in working with information data and the ability to independently develop new knowledge based on the information obtained:

1. Students today receive most of the information not in books, as it was before, but on the Internet. How do you think reading a book differs from reading from a monitor screen?
2. Are there any problems reading the book and reading from the monitor screen?
3. How does reading a book and reading from a monitor screen affect the perception and understanding of information?
4. Think about how the technology of developing critical thinking through reading and writing can be used when reading from electronic rather than paper media?

5. Read the proposed text. How do you see the prejudication and bias of the author? Why did you decide so?
6. How reliable can this source be? What is the criterion of reliability for you?
7. What is the point of view of the author of this material? Why do you think so? Is it possible to trace the logic of reasoning as the author comes to his conclusions and inferences?
8. How the author's position is strongly argued? Or does he invite you to take his judgments on faith? How did you come to this judgment?
9. How accurate is the information in this material? What did you do to make sure it was accurate?
10. Does the author give alternative points of view? How does he relate to the arguments of his opponents?

After the control stage of experiment, we came to the conclusion that motivational skills appeared to be the most developed in students. Their average rate in Control group (CG) is 33% and in Experimental group (EG) is 32%. Cognitive skills are less developed, their average rate in CG is 22% and in EG – 27%. We must admit that the data for this criterion in the experimental group is higher than in the control group. It indicates that the experimental group has a higher success rate than the control group. However, the success rate is not vital to critical thinking development, so it will not have a significant impact on the general indicator of critical thinking in the process of its development.

The indicator of students' activity skills is at the lowest level of development, as its average rate in CG is 10% and in EG – 16%. Resultative-reflexive skills are also underdeveloped in students, sufficient level of development is observed only in about a quarter of students and the average rate in CG is 27% and in EG – 26%.

The experimental stage dealt with the implementation of proposed special course "The specifics of students' critical thinking in the context of information security". The content of this course consisted of three modules such as:

Module 1. "Web resources for verifying information and data and its security".

Topic 1.1. Legal information (founders, signatories, date of registration, contact address and telephone number).

Topic 1.2. Public procurement system ProZorro.

Topic 1.3. How to find out about a website owner? Information about digital security; Industrial Portal (some victories against betrayals).

Module 2. "Leading Ukrainian media organizations in FB".

Topic 2.1. Media Detector – explores the entire media space of Ukraine (news, political (and not only) programs, talk-shows, movies, and TV shows), as well as a variety of text and video material on the site, results of social studies, etc.

Topic 2.2. The Ukrainian Press Academy is the first organization to develop and implement media literacy programs in education in Ukraine.

Topic 2.3. Stopfake – a project to refute the fakes of Russian propaganda "Without lies – a project to expose the lies of Ukrainian politicians and fact-checking". MEDIALAB is a brilliant project with accessible articles from practitioners and many tests. Independent Broadcasting Association - a lot of training in the management and marketing of television companies.

Module 3. "Critical information analysis projects, guides, and films".

Topic 3.1. Resources for information verification. "Information Security Recommendations on the Internet during the Conflict".

Topic 3.2. How to distinguish real news from lies, manipulations and half-truths. Instruction.

Topic 3.3. European truth – information concerning European integration, visa waiver, etc.

At the final stage, the results obtained during the ascertaining and forming stages of the experiment were analyzed and statistically processed. Tables and diagrams on the dynamics of the level of formation of critical thinking of students were compiled, and on the basis of the experiment general conclusions were formulated.

Comparing the average indicators of control and experimental groups (table 3), we can see that the level of students' critical thinking development is approximately equal in all criteria and indicators.

Table 3. Distribution of students control group and experimental group according to their level of critical thinking development according to each criterion before formative stage.

Criteria	Levels the number of people in %					
	Low		Average		High	
	CG	EG	CG	EG	CG	EG
1. Motivational	26	25	41	43	33	32
2. Content-related	32	25	46	48	22	27
3. Activity-based	34	34	56	50	10	16
4. Resultative	29	29	44	46	27	26

The analysis of the results of control stage experiment has led us to the conclusion that the level of critical thinking in students in the context of information security is insufficient. It should be taken into account when developing appropriate pedagogical conditions and modern methods for students' critical thinking development. The insufficiency of the level of students' critical thinking development in the context of information security is supported by several arguments. Students' professional training is mostly focused on knowledge acquisition, while their skills remain underdeveloped. Obviously, students are expected to independently find the ways to put their knowledge into practice through critical thinking, but teacher-trainers do not control how it really happens in practice.

3 Results

During the formative stage of the experiment in the course of achieving the goal set, we proposed to develop a curriculum for the course "The specifics of students' critical thinking in the context of information security"; to develop an optional distance course on optimization of students' critical thinking on the background of information and communication technologies.

After the implementation of the suggested course, we have obtained the following results presented in table 4.

Table 4. Distribution of students from control group according to their level of critical thinking development according to each criterion after formative stage.

Criteria	Levels the number of people in %					
	Low		Average		High	
Experiment stage	**Before**	**After**	**Before**	**After**	**Before**	**After**
1. Motivational	26	19	41	44	33	37
2. Content-related	32	26	46	39	22	35
3. Activity-based	34	23	56	39	10	38
4. Resultative	29	19	44	30	27	51

According to the results of final diagnostics of indicators and levels of critical thinking development in students from control and experimental groups, we have obtained the data, which proved the efficiency of the implementation of the special course "The specifics of students' critical thinking in the context of information security", as well as an optional distance course on optimization of students' critical thinking on the background of information and communication technologies. We have obtained the following results presented in table 5.

Table 5. Distribution of students from experimental group according to their level of critical thinking development according to each criterion after formative stage.

Criteria	Levels the number of people in %					
	Low		Average		High	
Experiment stage	**Before**	**After**	**Before**	**After**	**Before**	**After**
1. Motivational	25	11	43	33	32	56
2. Content-related	25	12	48	31	27	57
3. Activity-based	34	15	50	28	16	57
4. Resultative	29	6	46	29	26	65

General tendency of variability of indicators and levels of students' critical thinking is almost identical in dynamics. At the ascertaining stage of the experiment, the majority of students from CG (44%) showed an average level and thus all indicators in CG needed improvement. The data from two tables proves that in both groups there is a tendency for the predominant development of indicators of students' critical thinking in the context of information security. However, comparing the results obtained from control and experimental groups, we have noticed a certain difference. Thus, the experimental group's indicators are higher than those of the control group.

To compare the results of summative and formative assessment stages, we also used the Kolmogorov-Smirnov λ-criterion. The criterion allows to compare two empirical distributions and conclude whether they are consistent with each other. Here is a brief summary of the calculations applying this criterion.

The Kolmogorov-Smirnov λ-criterion is intended to compare two distributions: 1) empirical with theoretical, for example, uniform or normal; 2) one empirical distribution with another empirical distribution.

The criterion allows to find the point in which the sum of accumulated divergencies between two distributions is the largest and to assess the validity of this divergency.

If, in the χ^2 method, the frequencies of two distributions are compared separately according to each category, then under the Kolmogorov-Smirnov λ-criterion firstly the frequencies from the first category are compared, then the sums of the first and the second categories are compared, then the sums of the first, the second, and the third categories are compared, and so on. Thus, each time we match the frequencies accumulated in this category.

If the divergencies between the two distributions are significant, then at some point the difference in accumulated frequencies will become critical, and we shall be able to recognize the divergencies as statistically valid. Hypotheses to be verified are the following: H_0 – the divergencies between two distributions are unreliable; H_1 – the divergencies between two distributions are reliable.

The results of the λ-criterion calculations are given in the table 6. The analysis of table 6 shows that the empirical value of the λ_{emp} criterion at summative assessment stage is less than the critical value of 1.36 for all the criteria (corresponding values are 0.130, 0.955, 0.829, and 0.278), therefore, the differences between the distributions in control and experimental groups at summative assessment stage are statistically insignificant ($p > 0.05$).

Table 6. Comparison of the distributions in CG and EG according to their level of critical thinking development according to each criterion after formative stage by the Kolmogorov-Smirnov λ-criterion.

Criteria	The empirical value of the Kolmogorov-Smirnov λ-criterion when comparing the control and experimental groups at summative assessment stage	The empirical value of the Kolmogorov-Smirnov λ-criterion when comparing the control and experimental groups at formative assessment stage
Motivational	0.130	2.605
Content-related	0.955	2.990
Activity-based	0.829	26. 01
Resultative	0.278	1.906

As we can observe, the empirical value of the λ_{emp} criterion for all the criteria at formative assessment stage exceeds the critical value of 1.63 (corresponding values are 2.605; 2.990; 2.601; and 1.906); consequently, the differences between the distributions in control and experimental groups after the experiment are defined at the level of $p < 0.01$.

Consequently, the results of the processing of experimental data by mathematical statistics method prove the efficiency of the created pedagogical conditions for the students' critical thinking development in the context of information security.

4 Conclusions

Experimental and research work on students' critical thinking development in the context of information security, as well as analysis of the results obtained through the developed system of criteria, showed rather steady and positive dynamics of particular indicators and general level of critical thinking of students involved into experimental work. Consequently, the successful solution of the problem of students' critical thinking development at theoretical and practical levels has proved the general hypothesis of the study that the process of students' critical thinking development in the context of information security should be carried out via the introduction of the special course "The specifics of students' critical thinking in the context of information security", as well as an optional distance course on optimization of students' critical thinking on the background of information and communication technologies.

The given study does not cover all the aspects of the problem under discussion. Issues related to the development of critical thinking in the context of distance learning, searching the effective methods to correct the consequences of insufficient development of critical thinking in students require further study.

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