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

Anna V. Iatsyshyn[1[0000-0001-8011-5956]], Valeriia O. Kovach[2,3[0000-0002-1014-8979]], Yevhen O. Romanenko[3[0000-0003-2285-0543]], Iryna I. Deinega[3[0000-0001-8712-250X]], Andrii V. Iatsyshyn[1,4,5[0000-0001-5508-7017]], Oleksandr O. Popov[3,4,5[0000-0002-5065-3822]], Yulii G. Kutsan[5[0000-0002-0361-3190]], Volodymyr O. Artemchuk[5[0000-0001-8819-4564]], Oleksandr Yu. Burov[1[0000-0003-0733-1120]] and Svitlana H. Lytvynova[1[0000-0002-5450-6635]]

[1] Institute of Information Technologies and Learning Tools of the NAES of Ukraine, 9, M. Berlynskoho Str., Kyiv, 04060, Ukraine
[2] National Aviation University, 1, Cosmonaut Komarov Ave., Kyiv, 03058, Ukraine
[3] Interregional Academy of Personnel Management, 2, Frometivska Str., Kyiv, 03039, Ukraine
[4] Institute of Environmental Geochemistry of the NAS of Ukraine, 34a, Palladin Ave., Kyiv, 03680, Ukraine
[5] Pukhov Institute for Modelling in Energy Engineering of the NAS of Ukraine, 15, General Naumova Str., Kyiv, 03164, Ukraine
anna13.00.10@gmail.com

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

Copyright © 2020 for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

CEUR-WS.org/Vol-2547/paper14.pdf

pedagogical expediency of augmented reality technologies application for training of specialists of different specialties; systematic conduction of number of national and international events on dissemination and application of augmented reality technology. It is confirmed that application of augmented reality technologies is appropriate for training of future specialists of new technological era.

Keywords: augmented reality, digitalization, professionals training.

1 Introduction

1.1 The problem statement

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

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

1.2 Literature review

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

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

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

1.3 The aim of the research

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

2 Research results

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

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

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

In the work [9] it is emphasized that AR technology has significant potential for implementation, in particular in educational process. Visualization of teaching materials during the classes provides an opportunity to increase level of communication

with students, enhance their activity and promotes better learning of material. In these circumstances, there is a need for comprehensive study of opportunities available for introduction of AR technologies in higher education institutions in Ukraine.

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

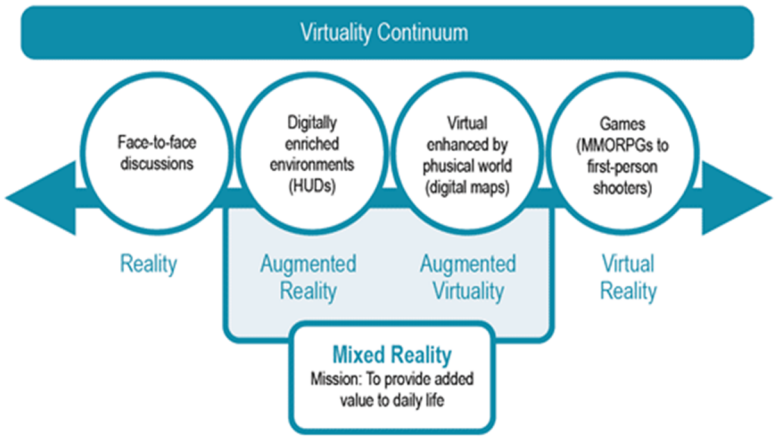

Fig. 1. Scheme of AR environment [29]

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

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

Government documents [6] state that it is important now to encourage businesses and citizens to consume and use information and digital technologies, i.e. to make

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

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

2.1 Experience of AR technologies application in education

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

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

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

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

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

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

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

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

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

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

level of achievement and more positive attitude towards the course than in the control group; the students were pleased and wanted to continue using AR applications in the future.

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

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

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

The team of authors [60] emphasized that it is advisable to use integrated approach during professional training of future informatics teachers to develop interactive teaching materials. In this approach, design is performed using standard objects. It is performed in visual design environment with provision of standard objects with new

properties and creation new ones. At the current stage of digital development, it is advisable to share the Unity environment for visual design [21], Visual Studio or similar programming environments, as well as virtual (Google VR or similar) and augmented (Vuforia or similar) platforms. Integrated approach is implemented within optional course "Development of virtual and augmented reality software" for future computer science teachers, which consists of two content modules: "Development of virtual reality tools" and "Development of augmented reality tools".

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

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

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

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

2.2 Examples of AR technologies application in various fields

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

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

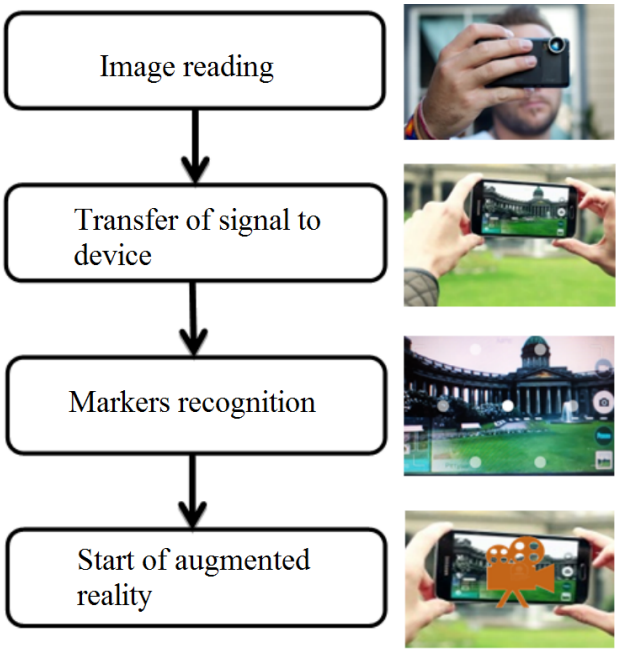

Fig. 2. Application algorithm of augmented reality technologies [26]

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

point camera at the right place and result will appear on the screen. It could be text, animation, a 3D object, or something else [53].

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

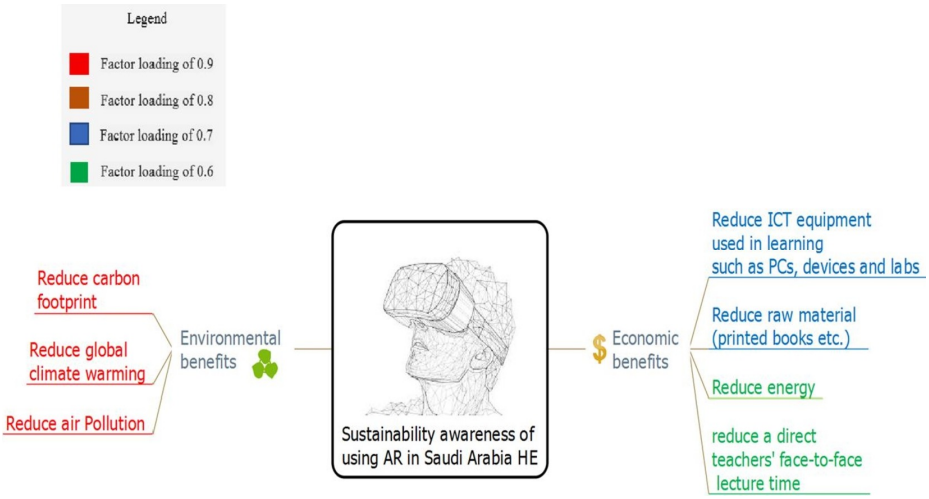

Fig. 3. Factors related to sustainability awareness of using AR in Saudi Arabian HE [1]

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

NASA contractors use Microsoft AR HoloLens augmented reality goggles for quick and correct assemble of Orion spacecraft items. Lockheed Martin (an aerospace engineer) uses the Microsoft HoloLens AR glasses to assist in assembly of cockpit capsule. It saves considerable time, since there is no need to read thousands of pages of

paperwork for preparation and production. Engineering personnel began using AR equipment daily to perform their current job responsibilities. Experts can see holographic models of spacecraft layout that are designed for engineering design with the help of special Scope AR software. Virtual parts models and marking schemes visually overlap with already assembled parts of the design [64].

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

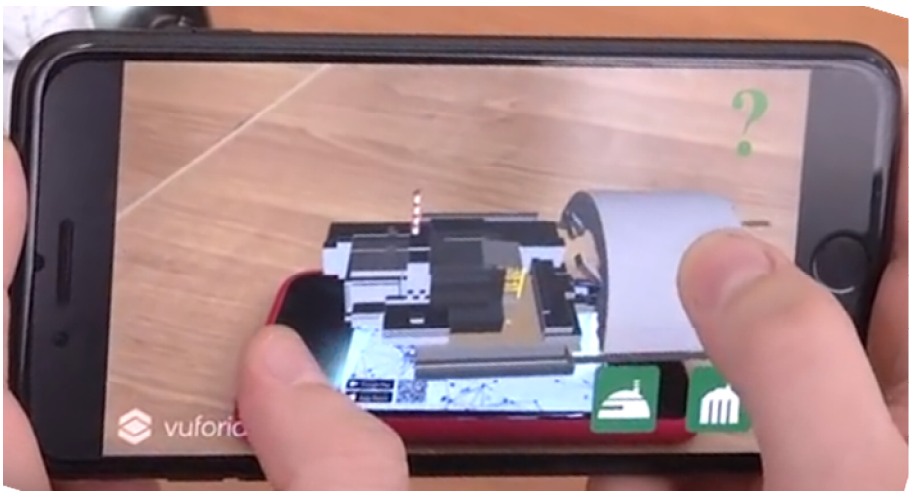

Fig. 4. Example of the application (Chornobyl NPP ARCH AR) operation on smartphone

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

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

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

2.3 Promotion measures for AR technologies

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

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

language; will be able to create 3D models of game characters and true 3D worlds; will understand principles of computer software development and the key elements of the game; will master stages of computer game development: genre, engine choice, game design, production, testing, release; will be able to use professional platform to create Unity 3D games [42].

6. There was a master class on programming of augmented reality of football training of students in format of "Meet and Code" initiative of the EU Code Week at the Institute of Computer Systems of the Odessa National Polytechnic University in Odessa in October 2018 [28].
7. In 2018 the Google launched a free course on Coursera. In this course you can acquire basic knowledge of AR technologies. Coursera is technological company operating in the field of education; founded by Stanford University professors Andrew Ng and Daphne Koller in April 2012.

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

3 Conclusions and prospects for further research

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

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

2. Difficulties in AR technologies application:

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

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

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

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

References

1. Alahmari, M., Issa, T., Issa, T., Nau, S.Z.: Faculty awareness of the economic and environmental benefits of augmented reality for sustainability in Saudi Arabian universities. Journal of Cleaner Production **226**, 259–269 (2019). doi:10.1016/j.jclepro.2019.04.090
2. AREdu 2019: 2nd International Workshop on Augmented Reality in Education. http://aredu.ccjournals.eu/aredu2019 (2019). Accessed 28 Nov 2019
3. Arici, F., Yildirim, P., Caliklar, Ş., Yilmaz, R.M.: Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. Computers & Education **142**, 103647 (2019). doi:10.1016/j.compedu.2019.103647
4. Blinov, I.V., Parus, Ye.V., Ivanov, H.A. Imitation modeling of the balancing electricity market functioning taking into account system constraints on the parameters of the IPS of Ukraine mode. Tekhnichna elektrodynamika 6, 72–79 (2017). doi:10.15407/techned2017.06.072
5. Butov R.A., Grigor'ev I.S.: Tehnologii virtual'noj i dopolnennoj real'nosti dlja obrazovanija (Virtual and augmented reality technologies for education). Pro_DOD **1**(13), 18–29. http://prodod.moscow/archives/6428 (2018). Accessed 31 Jan 2020
6. Cabinet of Ministers of Ukraine: Pro skhvalennia Kontseptsii rozvytku tsyfrovoi ekonomiky ta suspilstva Ukrainy na 2018-2020 roky ta zatverdzhennia planu zakhodiv shchodo yii realizatsii (On approval of the Concept of the development of the digital economy and society of Ukraine for 2018-2020). https://zakon.rada.gov.ua/laws/show/67-2018-%D1%80 (2018). Accessed 1 October 2019
7. Chemeris, A., Lazorenko, D., Sushko, S.: Influence of software optimization on energy consumption of embedded systems. In: Kharchenko, V., Kondratenko, Y., Kacprzyk, J. (eds.) Green IT Engineering: Components, Networks and Systems Implementation. Studies in Systems, Decision and Control, vol. 105, pp. 111–133. Springer, Cham (2017). doi:10.1007/978-3-319-55595-9_6
8. Chornobylska arka onlain: u merezhu zapustyly dodatok dlia stalkeriv (Chornobyl Arch online: Stalker application launched online). https://znaj.ua/society/175005-chornobilska-arka-onlayn-u-merezhu-zapustili-dodatok-dlya-stalkeriv (2018). Accessed 5 October 2019
9. Chubukova, O.Yu., Ponomarenko, I.V.: Innovatsiini tekhnolohii dopovnenoi realnosti dlia vykladannia dystsyplin u vyshchykh navchalnykh zakladakh Ukrainy (Augmented reality technology use for study of disciplines in ukraine's higher education institutions). Problemy innovatsiino-investytsiinoho rozvytku 16, 20–27 (2018)
10. Dmitriev, A.V.: Cifrovizacija transportno-logisticheskih uslug na osnove primenenija tehnologii dopolnennoj real'nosti (Digitalization of transport and logistics services based on

the application of augmented reality technology). Bulletin of South Ural State University, Series "Economics and Management" **12**(2), 169–178 (2018). doi:10.14529/em180220
11. Garzón, J., Acevedo, J.: Meta-analysis of the impact of Augmented Reality on students' learning gains. Educational Research Review **27**, 244–260 (2019). doi:10.1016/j.edurev.2019.04.001
12. Gurieiev, V., Sanginova, O.: Simulation and study of modes for full-scale mode simulator for Ukrainian energy systems. In: Proceedings of the 2nd International Conference on Intelligent Energy and Power Systems (IEPS'2016), Kyiv, Ukraine, 7-11 June 2016, pp. 1–4. IEEE (2016). doi:10.1109/IEPS.2016.7521848
13. Holovatyi, M.: The state and society: The conceptual foundations and social interaction in the context of formation and functioning of states. Economic Annals-XXI 9–10, 4–8 (2015)
14. Honcharova, N.: Tekhnolohiia dopovnenoi realnosti v pidruchnykakh novoho pokolinnia (Technology of augmented reality in textbooks of new generation. Problemy suchasnoho pidruchnyka 22, 46–56 (2019). doi:10.32405/2411-1309-2019-22-46-56
15. Hruntova, T.V., Yechkalo, Yu.V., Striuk, A.M., Pikilnyak, A.V.: Augmented Reality Tools in Physics Training at Higher Technical Educational Institutions. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 33–40. http://ceur-ws.org/Vol-2257/paper04.pdf (2018). Accessed 30 Nov 2018
16. Iatsyshyn, A.V., Popov, O.O., Artemchuk, V.O., Kovach, V.O., Zinovieva, I.S.: Automated and information decision support systems for environmental safety. Information Technologies and Learning Tools **72**(4), 286–305 (2019). doi:10.33407/itlt.v72i4.2993
17. Iatsyshyn, A.V., Popov, O.O., Kovach, V.O., Artemchuk, V.O.: The methodology of future specialists teaching in ecology using methods and means of environmental monitoring of the atmosphere's surface layer. Information Technologies and Learning Tools **66**(4), 217–230 (2018). doi:10.33407/itlt.v66i4.2233
18. Iatsyshyn, Anna V., Kovach, V.O., Romanenko, Ye.O., Iatsyshyn, Andrii V.: Cloud services application ways for preparation of future PhD. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 197–216. http://ceur-ws.org/Vol-2433/paper12.pdf (2019). Accessed 10 Sep 2019
19. Ibáñez, M.-B., Delgado-Kloos, C.: Augmented reality for STEM learning: A systematic review. Computers & Education **123**, 109–123 (2018). doi:10.1016/j.compedu.2018.05.002
20. Kahtanova, Ju.F., Bestybaeva, K.I.: Tehnologija dopolnennoj real'nosti v obrazovanii (Technology of augmented reality in education). Pedagogicheskoe masterstvo i pedagogicheskie tehnologii 2(8), 289–291 (2016)
21. Katsko, O.O., Moiseienko, N.V.: Development computer games on the Unity game engine for research of elements of the cognitive thinking in the playing process. In: Kiv, A.E., Semerikov, S.O., Soloviev, V.N., Striuk, A.M. (eds.) Proceedings of the 1st Student Workshop on Computer Science & Software Engineering (CS&SE@SW 2018), Kryvyi Rih, Ukraine, November 30, 2018. CEUR Workshop Proceedings **2292**, 151–155. http://ceur-ws.org/Vol-2292/paper17.pdf (2018). Accessed 31 Dec 2018
22. Klimova, A., Bilyatdinova, A., Karsakov, A.: Existing Teaching Practices in Augmented Reality. Procedia Computer Science **136**, 5–15 (2018). doi:10.1016/j.procs.2018.08.232
23. Kulikova, Ja.V., Matokhina, A.V., Shcherbakova, N.L.: Obzor bibliotek komp'juternogo zrenija dlja proektirovanija komponentov dopolnennoj real'nosti v uchebnom processe (Review of OCR libraries for augmented reality components in education). Nauka vchera, segodnja, zavtra 6(40), 27–32 (2017)

24. Kyrylenko, O.V., Blinov, I.V., Parus, Y.V., Ivanov, H.A.: Simulation model of day ahead market with implicit consideration of power systems network constraints. Tekhnichna elektrodynamika **5**, 60–67 (2019). doi:10.15407/techned2019.05.060
25. Lavrentieva, O.O., Arkhypov, I.O., Kuchma, O.I., Uchitel, A.D.: Use of simulators together with virtual and augmented reality in the system of welders' vocational training: past, present, and future. In: Kiv, A.E., Shyskina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)
26. Leshko, K.V., Rykova, L.L.: Augmented reality as a tool in creative development of future education professionals. New Computer Technology **17**, 76–81 (2019)
27. Lvov, M.S., Popova, H.V.: Simulation technologies of virtual reality usage in the training of future ship navigators. In: Kiv, A.E., Shyskina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)
28. Maister-klas iz prohramuvannia virtualno-dopovnenoi realnosti | Odeskyi natsionalnyi politekhnichnyi universytet (Virtual/Augmented Reality Programming Master Class | Odessa National Polytechnic University). https://opu.ua/news/1715 (2018). Accessed 25 Oct 2019
29. Milgram, P., Kishino, F.: A taxonomy of mixed reality visual displays. IEICE Transactionson Information Systems. **E77-D**(12), 1321–1329 (1994)
30. Mintii, I.S., Soloviev, V.N.: Augmented Reality: Ukrainian Present Business and Future Education. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 227–231. http://ceur-ws.org/Vol-2257/paper22.pdf (2018). Accessed 30 Nov 2018
31. Modlo, Ye.O., Semerikov, S.O., Bondarevskyi, S.L., Tolmachev, S.T., Markova, O.M., Nechypurenko, P.P.: Methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)
32. Mokhor, V., Gonchar, S., Dybach, O.: Methods for the Total Risk Assessment of Cybersecurity of Critical Infrastructure Facilities. Nuclear and Radiation Safety **2**(82), 4–8 (2019). doi:10.32918/nrs.2019.2(82).01
33. Morkun, V., Semerikov, S., Hryshchenko, S., Slovak, K.: Environmental Geo-information Technologies as a Tool of Pre-service Mining Engineer's Training for Sustainable Development of Mining Industry. In: Ermolayev, V., Bassiliades, N., Fill, H.-G., Yakovyna, V., Mayr, H.C., Kharchenko, V., Peschanenko, V., Shyshkina, M., Nikitchenko, M., Spivakovsky, A. (eds.) 13th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer (ICTERI, 2017), Kyiv, Ukraine, 15-18 May 2017. CEUR Workshop Proceedings **1844**, 303–310. http://ceur-ws.org/Vol-1844/10000303.pdf (2017). Accessed 21 Mar 2019
34. Nechypurenko, P.P., Selivanova, T.V., Chernova, M.S.: Using the Cloud-Oriented Virtual Chemical Laboratory VLab in Teaching the Solution of Experimental Problems in Chemistry of 9th Grade Students. In: Ermolayev, V., Mallet, F., Yakovyna, V., Kharchenko, V., Kobets, V., Korniłowicz, A., Kravtsov, H., Nikitchenko, M., Semerikov, S., Spivakovsky, A. (eds.) Proceedings of the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer (ICTERI, 2019), Kherson, Ukraine, June 12-15 2019, vol. II:

Workshops. CEUR Workshop Proceedings **2393**, 968–983. http://ceur-ws.org/Vol-2393/paper_329.pdf (2019). Accessed 30 Jun 2019

35. Nechypurenko, P.P., Stoliarenko, V.G., Starova, T.V., Selivanova, T.V., Markova, O.M., Modlo, Ye.O., Shmeltser, E.O.: Development and implementation of educational resources in chemistry with elements of augmented reality. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)
36. Orlova, E.Ju., Karpova, I.V.: Ispol'zovanie tehnologij dopolnennoj i virtual'noj real'nosti v prepodavanii v tehnicheskom vuze (Using Augmented and Virtual Reality Technologies in Teaching at a Technical University). Metodicheskie voprosy prepodavanija infokommunikacij v vysshej shkole 7(2), 40–43 (2018)
37. Pinchuk, O.P., Sokolyuk, O.M., Burov, O.Yu., Shyshkina, M.P.: Digital transformation of learning environment: aspect of cognitive activity of students. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 90–101. http://ceur-ws.org/Vol-2433/paper05.pdf (2019). Accessed 10 Sep 2019
38. Popel, M.V., Shyshkina, M.P.: The Cloud Technologies and Augmented Reality: the Prospects of Use. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 232–236. http://ceur-ws.org/Vol-2257/paper23.pdf (2018). Accessed 30 Nov 2018
39. Popov, O., Iatsyshyn, A., Kovach, V., Artemchuk, V., Taraduda, D., Sobyna, V., Sokolov, D., Dement, M., Yatsyshyn, T.: Conceptual Approaches for Development of Informational and Analytical Expert System for Assessing the NPP impact on the Environment. Nuclear and Radiation Safety **3**(79), 56–65 (2018). doi:10.32918/nrs.2018.3(79).09
40. Popov, O., Yatsyshyn, A.: Mathematical Tools to Assess Soil Contamination by Deposition of Technogenic Emissions. In: Dent, D., Dmytruk, Y. (eds.) Soil Science Working for a Living: Applications of soil science to present-day problems, pp. 127–137. Springer, Cham (2017). doi:10.1007/978-3-319-45417-7_11
41. Popov, O., Iatsyshyn A., Kovach, V., Artemchuk, V., Taraduda, D., Sobyna, V., Sokolov, D., Dement, M., Yatsyshyn, T., Matvieieva, I.: Analysis of Possible Causes of NPP Emergencies to Minimize Risk of Their Occurrence. Nuclear and Radiation Safety **1**(81), 75–80 (2019). doi:10.32918/nrs.2019.1(81).13
42. Prohramuvannia na Unity 3D ta dopovnena realnist - IT Future (Unity 3D programming and augmented reality - IT Future). http://www.itfuture.com.ua/unity3d (2019). Accessed 28 Nov 2019
43. PwC: US Blogs directory. http://usblogs.pwc.com (2019). Accessed 25 Oct 2019
44. Quandt, M., Knoke, B., Gorldt, C., Freitag, M., Thoben, K.-D.: General Requirements for Industrial Augmented Reality Applications. Procedia CIRP **72**, 1130–1135 (2018). doi:10.1016/j.procir.2018.03.061
45. Rashevska, N.V., Soloviev, V.N.: Augmented Reality and the Prospects for Applying Its in the Training of Future Engineers. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 192–197. http://ceur-ws.org/Vol-2257/paper18.pdf (2018). Accessed 30 Nov 2018
46. Romanenko, Y.O.: Internet as a means of communication and its influence on public policy formation. Actual Problems of Economics **175**(1), 429–434 (2016)

47. Romanenko, Y.O.: Place and role of communication in public policy. Actual Problems of Economics **176**(2), 25–31 (2016)
48. Sahin, D., Yilmaz, R.M.: The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. Computers & Education **144**, 103710 (2020). doi:10.1016/j.compedu.2019.103710
49. Sailors Use Augmented Reality to Train for Combat. https://www.photonics.com/Articles/Sailors_Use_Augmented_Reality_to_Train_for_Combat/a64948 (2018). Accessed 29 Jan 2020
50. Scaravetti, D., Doroszewski, D.: Augmented Reality experiment in higher education, for complex system appropriation in mechanical design. Procedia CIRP **84**, 197–202 (2019). doi:10.1016/j.procir.2019.04.284
51. Sensorama Academy. http://sensoramalab.com/en/academy (2018). Accessed 31 Jan 2020
52. Shapovalov, V.B., Atamas, A.I., Bilyk, Zh.I., Shapovalov, Ye.B., Uchitel, A.D.: Structuring Augmented Reality Information on the stemua.science. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 75–86. http://ceur-ws.org/Vol-2257/paper09.pdf (2018). Accessed 30 Nov 2018
53. Shcho take dopovnena realnist i chym vona vidrizniaietsia vid virtualnoi realnosti? (What is augmented reality and how is it different from virtual reality?). https://blog.comfy.ua/ua/shho-take-dopovnena-realnist-i-chim-vona-vidriznyaehtsya-vid-virtualnoyi-realnosti (2018). Accessed 5 October 2019
54. Shkitsa, L.E., Yatsyshyn, T.M., Popov, A.A., Artemchuk, V.A.: Prognozirovanie rasprostranenija zagrjaznjajushhih veshhestv v atmosfere na territorii burovoj ustanovki (The development of mathematical tools for ecological safe of atmosfere on the drilling well area). Neftjanoe hozjajstvo 11, 136–140 (2013)
55. Shyshkina, M.P., Marienko, M.V.: Augmented reality as a tool for open science platform by research collaboration in virtual teams. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)
56. Sorko, S.R., Brunnhofer, M.: Potentials of Augmented Reality in Training. Procedia Manufacturing **31**, 85–90 (2019). doi:10.1016/j.promfg.2019.03.014
57. Spirin, O.M., Iatsyshyn, A.V.: Dosvid pidhotovky naukovykh kadriv z informatsiino-komunikatsiinykh tekhnolohii v osviti (do 15-richchia Instytutu informatsiinykh tekhnolohii i zasobiv navchannia NAPN Ukrainy) (Experience of academic staff training on information and communication technologies in education (dedicated to the 15th anniversary of the Institute of Information Technologies and Learning Tools of NAPS of Ukraine)). Kompiuter u shkoli ta simi 2, 3–8 (2014)
58. Spirin, O.M., Nosenko, Yu.H., Iatsyshyn, A.V.: Current Requirements and Contents of Training of Qualified Scientists on Information and Communication Technologies in Education. Information Technologies and Learning Tools **56**(6), 219–239 (2016). doi:10.33407/itlt.v56i6.1526
59. Spirin, O.M., Nosenko, Yu.H., Yatsyshyn, A.V.: Pidhotovka naukovykh kadriv vyshchoi kvalifikatsii z informatsiino-komunikatsiinykh tekhnolohii v osviti (Training of highqualified scientists on information and communication technologies in education). Naukovyi chasopys NPU im. M. P. Drahomanova, Seriia 2: Kompiuterno-oriientovani systemy navchannia 19(26), 25–34 (2017)
60. Syrovatskyi, O.V., Semerikov, S.O., Modlo, Ye.O., Yechkalo, Yu.V., Zelinska, S.O.: Augmented reality software design for educational purposes. In: Kiv, A.E., Semerikov, S.O., Soloviev, V.N., Striuk, A.M. (eds.) Proceedings of the 1st Student Workshop on

Computer Science & Software Engineering (CS&SE@SW 2018), Kryvyi Rih, Ukraine, November 30, 2018. CEUR Workshop Proceedings **2292**, 193–225. http://ceur-ws.org/Vol-2292/paper20.pdf (2018). Accessed 21 Mar 2019

61. Tkachuk, V.V., Yechkalo, Yu.V., Markova, O.M.: Augmented reality in education of students with special educational needs. In: Semerikov, S.O., Shyshkina, M.P. (eds.) Proceedings of the 5th Workshop on Cloud Technologies in Education (CTE 2017), Kryvyi Rih, Ukraine, April 28, 2017. CEUR Workshop Proceedings **2168**, 66–71. http://ceur-ws.org/Vol-2168/paper9.pdf (2018). Accessed 21 Mar 2019
62. Unity XR: How to Build AR and VR Apps Specialization. https://www.coursera.org/specializations/unity-xr (2018). Accessed 29 Jan 2020
63. Vakaliuk, T.A., Kontsedailo, V.V., Antoniuk, D.S., Korotun, O.V., Mintii, I.S., Pikilnyak, A.V.: Using game simulator Software Inc in the Software Engineering education. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)
64. Winick, E.: NASA is using HoloLens AR headsets to build its new spacecraft faster https://www.technologyreview.com/s/612247/nasa-is-using-hololens-ar-headsets-to-build-its-new-spacecraft-faster (2018). Accessed 15 October 2019
65. Yechkalo, Yu.V., Tkachuk, V.V., Hruntova, T.V., Brovko, D.V., Tron, V.V.: Augmented Reality in Training Engineering Students: Teaching Techniques. In: Ermolayev, V., Mallet, F., Yakovyna, V., Kharchenko, V., Kobets, V., Korniłowicz, A., Kravtsov, H., Nikitchenko, M., Semerikov, S., Spivakovsky, A. (eds.) Proceedings of the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer (ICTERI, 2019), Kherson, Ukraine, June 12-15 2019, vol. II: Workshops. CEUR Workshop Proceedings **2393**, 952–959. http://ceur-ws.org/Vol-2393/paper_337.pdf (2019). Accessed 30 Jun 2019
66. Zaporozhets A., Eremenko V., Serhiienko R., Ivanov S.: Methods and Hardware for Diagnosing Thermal Power Equipment Based on Smart Grid Technology. In: Shakhovska N., Medykovskyy M. (eds.) Advances in Intelligent Systems and Computing III. CSIT 2018. Advances in Intelligent Systems and Computing, vol. 871, pp. 476–489. Springer, Cham (2019). doi:10.1007/978-3-030-01069-0_34
67. Zaporozhets A.O., Eremenko V.S., Serhiienko R.V., Ivanov S.A.: Development of an intelligent system for diagnosing the technical condition of the heat power equipment. In: 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), Lviv, Ukraine, September 11-14, 2018, pp. 48–51. IEEE (2018). doi:10.1109/STC-CSIT.2018.8526742
68. Zelinska, S.O., Azaryan, A.A., Azaryan, V.A.: Investigation of Opportunities of the Practical Application of the Augmented Reality Technologies in the Information and Educative Environment for Mining Engineers Training in the Higher Education Establishment. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 204–214. http://ceur-ws.org/Vol-2257/paper20.pdf (2018). Accessed 30 Nov 2018
69. Zinonos, N.O., Vihrova, E.V., Pikilnyak, A.V.: Prospects of Using the Augmented Reality for Training Foreign Students at the Preparatory Departments of Universities in Ukraine. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 87–92. http://ceur-ws.org/Vol-2257/paper10.pdf (2018). Accessed 30 Nov 2018

70. Zinovieva, I.S., Artemchuk, V.O., Iatsyshyn, A.V.: The use of open geoinformation systems in computer science education. Information Technologies and Learning Tools **68**(6), 87–99 (2018). doi:10.33407/itlt.v68i6.2567