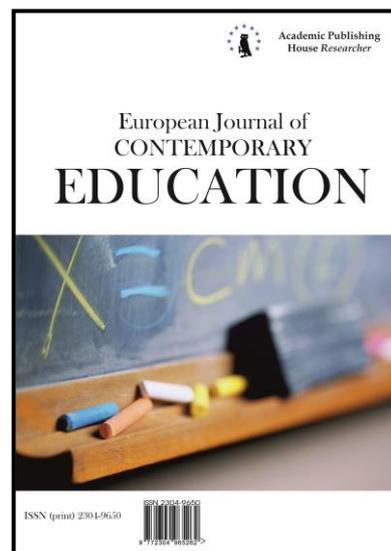




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## Using Methods and Means of the Augmented Reality Technology When Training Future Teachers of the Digital School

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### Abstract

The problem which is studied is due to the need to solve the contradiction between the needs of society for the quality of training future teachers of the digital school regarding to formation of skills related to innovative technologies, communicative competences, the ability to work in the information environment and insufficient elaboration of the methodological base for training graduates that satisfies this requirements.

The purpose of the study is to theoretically substantiate and experimentally verify the need to apply methods and means of the augmented reality technology when training future teachers of the digital school.

The research methodology is the analysis and generalization of scientific works on the problems and prospects of using the augmented reality (AR) technology in the university, formation of the professional competence of the future teacher of the digital school. Mind Mapping 3D, Google Lens, augmented reality browsers, WallaMe service are used as software implementation tools. The experiment is presented using the example of assessing changes in levels of skills that make up the essence of the professional competence of the future teacher of the digital school.

Research results. The authors clarified the potential of the augmented reality technology, the advantages and disadvantages in terms of development professional competences of future specialists (training program 44.03.05 Pedagogical education (two training program specializations). The options for using the AR technology to improve the quality of education, formation of digital literacy and development of personal qualities are identified. Specific materials on the use of methods, means of the augmented reality technology are proposed on the example of

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the discipline “Theory and methods of teaching computer science”. The assessment of the impact of AR services on the quality of mastering fundamental scientific theories by students, the level of solving professionally-oriented tasks is carried out.

In the conclusion, findings confirming that the use of methods and means of the augmented reality technology helps to improve the quality of training of future teachers of the digital school are formulated.

**Keywords:** professional competence, information literacy, personal qualities, communication, educational space, quality of education.

## **1. Introduction**

### **1.1. The relevance of the problem**

The future digital school teacher in the context of modern requirements for the quality of higher education, for the level of formation of digital skills for successful professional activity, should have such universal qualities as information literacy, creativity, communication, the ability to work in the virtual educational space, readiness for changes, and creation of something new. Formation of relevant skills within the framework of university education is complicated by a number of software, technical and methodological problems (Soboleva et al., 2018). The solution of these difficulties is of particular importance for training students of pedagogical training programs (Kalyanova, 2019). In the educational organization of higher education the teacher of the future learns to correlate the task, a means of action (a technique, a rule, an algorithm) and new knowledge that students, in future under his/her guidance, can acquire (Vázquez-Cano et al., 2020). In addition, it is important for a teacher to be a creator, a researcher in order to successfully fulfill duties.

Formation of the noted competences and the required personal qualities of the student of the pedagogical training program occurs mainly due to development of a variety of innovative technologies, means that activate knowledge and activity in the digital environment. In other words, the range of possible tools of the professional-teacher, his/her “portfolio”, is expanding. However, the question of the expediency of using these tools, the choice of the most effective one, corresponding to both the capabilities of the teacher and the individual needs of the student is still open.

Thus, as T.A. Kulikova, N.A. Poddubnaya note, intensive development of digital technologies forms a qualitatively new educational space of the university and requires taking into account the influence of innovative methods and means on formation of professional competences of students of pedagogical training programs (Kulikova, Poddubnaya, 2020).

At the same time, augmented reality (AR), as an innovative technology in the context of the digitalization of society, strives to become widespread in education and become a technology of social significance (Obdalova, Odegova, 2018). This follows from the passport of the federal project of the national program "Digital Economy", one of the goals of which is formation of a network of digital transformation centers of universities and development of students in accordance with personal trajectories using innovative technologies (Pasport natsional'noi...). The information educational space, as noted by M.V. Voronina, Z.O. Tretyakova, E.G. Krivonozhkina, S.I. Buslaev, G.G. Sidorenko, in the context of challenges of the future and professional training of the graduate in-demand, is focused on ensuring that students can immediately check their theoretical knowledge in the course of active practical, experimental activities (Voronina et al., 2019). Virtual classrooms and three-dimensional laboratories appear, where, according to D.B. Padilla, E. Vázquez-Cano, M.B. Morales Cevallos, E.L. Meneses, high-quality visualization of simulated objects and phenomena is required (Padilla et al., 2019). For example, after receiving theoretical information on geometry, students begin to build a three-dimensional virtual model, become participants of a knight's campaign or tournament, decrypt symbols of the Templars in ancient castles. In addition, a network of guided virtual excursions is developing, in the role of which robots and 3D objects are (Obdalova, Odegova, 2018).

In this regard the maximum didactic possibilities, as noted by P. Piriyaawong, are provided by the augmented reality technology (Piriyaawong, 2020). Indeed, the education system, as revealed in the work of A. Vidal-Balea, O. Blanco-Novoa, P. Fraga-Lamas, M. Vilar-Montesinos, T.M. Fernández-Caramés, gets unique chances to make a relatively safe historical journey through time and space, to realize a chemical experience, to make a dive, a cosmic discovery, etc. (Vidal-Balea et al., 2020). Augmented reality tools are actively used in the field of

health care and sports, in mathematical disciplines, in the work of cultural institutions (Geng, Yamada, 2020). In addition, the prospects for visualizing processes based on fundamental theoretical data, enhancing cognition, and supporting implementation of principles of visibility and understanding are expanding (Sarkar et al., 2020).

Qualitative formation of professional competence (mastery of pedagogical technologies, solving professional problems, control of work activity), as it is emphasized by K.V. Cherkasov, N.S. Chistyakova, V.V. Chernov, is difficult to reconstruct in an educational institution (Cherkasov et al., 2017). However, the use of augmented reality methods and means when training future teachers makes it possible to model interaction in the information educational environment at a qualitatively new level.

At the same time, this digital technology, with all its undoubted advantages and positive impact on scientific and technical development and the didactic process, contains additional educational risks in the spectrum of its tools. As E.M. Bonsignore rightly notes, it is impossible to deny the influence of information interaction in the virtual augmented environment on the psychological formation of the individual (Bonsignore, 2016). Trolling, outing and fraping are all new ways to negatively influence the consciousness of the personality. Each of these psychological phenomena, according to A. S. Williams, F. R. Ortega, requires additional studies in science and the pedagogical theory (Williams, Ortega, 2020). For example, as F.K.M. Arif, N.Z. Zubir, M. Mohamad, M.M. Yunus point out, the constant appeal to modern technologies and their inclusion in the educational process can lead to oversaturation: students get used to everything interactive, and they become uninterested in traditional teaching aids (Arif, 2019).

As other organizational and pedagogical difficulties M. Fan, A.N. Antle, J.L. Warren point out: balance and feasibility of using innovative technologies to support cognitive activity when solving practice-oriented tasks, project management, and organization of teamwork are important (Fan et al., 2020).

Thus, there is the problem of determining the influence of the AR technology on the quality of training future teachers, on formation of digital literacy, on motivation and cognitive interest, on the quality of mastering the fundamental scientific theory by students, and on professional self-development. The solution to this problem involves an additional study of the potential of the augmented reality technology, taking into account all components of the professional competence of the future teacher of the digital school, the norms and requirements for his/her labor activity.

The hypothesis of the research is the inclusion of students of pedagogical training programs in the cognitive activity, supported by methods and means of the augmented reality technology, contributes to formation of qualities and competences that determine their future professional activity in the digital environment.

### **1.2. Research goals and objectives**

The purpose of the study was determined from the need to apply methods and means of the augmented reality technology to improve the quality of training future teachers of the digital school.

Research objectives:

- to reveal the essence of the phenomenon of "augmented reality" in the context of new challenges to the higher education system and requirements for the professional activity of the teacher;
- analyze the experience of using augmented reality resources in training and select applications that match the research goals best;
- to identify advantages and disadvantages of augmented reality both from the standpoint of formation of the professional competence of the future teacher of the digital school, and from the standpoint of development of personal qualities;
- describe the use of the augmented reality technology when training future teachers of the digital school by the example of work with the specific application;
- experimentally confirm effectiveness of the proposed educational and cognitive activity for formation of qualities and competences of the teacher, which determine his/her future professional activity in the digital environment.

## **2. Relevance**

### **2.1. Analysis of Russian scientific and pedagogical literature**

The use of the augmented reality technology in the cognitive activity of students is an important direction in development of the didactic system (Cherkasov et al., 2017). K.V. Cherkasov, N.S. Chistyakova, V.V. Chernov note that global digital transformation has a significant impact on the needs of society, business, government regarding professions in demand in the future. However, in practice, schools and universities often train graduates without using innovative technologies and trends of the world education.

As A.V. Ivanova notes, scientists are actively studying problems of identifying pedagogical conditions that ensure effectiveness of formation of professional competences and personal qualities of future specialists for teaching various disciplines (Ivanova, 2018).

The peculiarities of training specialists in demand for successful fulfillment of their professional duties in the digital environment were studied by M. Rummyantsev, I. Rudov. They reasonably state that there has not been a period in development of modern education comparable to the current changes in terms of rates and quality characteristics (Rummyantsev, Rudov, 2016).

E.V. Soboleva, E.G. Galimova, Z.A. Maydangalieva, K.K. Batchayeva conducted an experimental study of interaction of students in the information environment, its structure and role for formation of results of developmental learning (Soboleva et al., 2018). The authors study the following problems: what forms of cooperation and information interaction are most consistent with the content of the cognitive activity to acquire new knowledge; what the role of cooperation with peers in formation of modes of action (i.e. skills) is. They formulated new difficulties that teachers face when organizing such cognitive activity in the digital environment. Based on the results, a conclusion about effectiveness of interaction in the virtual educational environment to improve the quality of teaching and learning was made.

L.M. Kalyanova, based on the content of the current standards, believes that it is necessary to focus not only on the transfer of knowledge, but also on the acquisition of digital skills when training (Kalyanova, 2019). According to the conclusions of O.A. Obdalova, O.V. Odegova, the most important thing is to organize practice for the active use of knowledge and skills in practice by means of digital technologies within the framework of the system-activity approach demanded by the modern school (Obdalova, Odegova, 2018). Appropriate technologies (in particular, the augmented reality technology) are especially important when training students of pedagogical training programs.

L.M. Kalyanova concludes that specialists demanded by society must be able to solve non-standard tasks, situational practice-oriented tasks in the virtual, augmented world. At the same time, the desire to be successful (positive goals) is, in her opinion, the driving force in cognition (Kalyanova, 2019). The key feature of professionally oriented teaching of students of pedagogical training programs is integration of the motivational sphere of the person of labor (professional values, professional aspirations and motives, professional goal-setting, etc.) and the operational sphere (professional identity, professional abilities, learning, techniques and technologies as components of professional skill and creativity, etc.).

V.V. Kotenko believes that in order to achieve competences necessary/demanded by society, students should be involved in cognitive activities to solve practice-oriented and professional tasks in virtual educational spaces (Kotenko, 2020).

A.L. Zhuravlev, T.A. Nestik determine that the main tasks of training the modern graduate should be development of the ability to solve unfamiliar problems using digital technologies, quickly navigate large amounts of information, and make decisions in situations of uncertainty (Zhuravlev, Nestik, 2019).

A.V. Ivanova describes the first attempts to create interactive devices that allow interacting with the simulated reality (Ivanova, 2018). K.V. Cherkasov, N.S. Chistyakova, V.V. Chernov give examples of the use of the augmented reality technology in various types of human activities. The possibility of using this technology in the educational environment for the purpose of visual modeling of educational materials supplementing it with visual information was shown (Cherkasov et al., 2017). At the same time, students develop spatial representations, imagination, and three-dimensional design skills. Scientists prove that appropriate methods and means allow optimizing labor costs and time resources for transmission, assimilation of fundamental theoretical facts, and catalyzing the process of cognition.

T.A. Kulikova, N.A. Poddubnaya formulate the problem of the need to form readiness of the future teacher to use virtual and augmented reality technologies in the context of digitalization of education. The relevance of the problem under the study comes from the social order and the requirements of the digital economy (Kulikova, Poddubnaya, 2020). The authors proposed a general technology for forming readiness of the future teacher to use virtual and augmented reality applications. However, now there are only general recommendations for this technology. An integrated methodological system for specific AR services and applications is not presented.

M.V. Voronina, Z.O. Tretyakova, E.G. Krivonozhkina, S.I. Buslaev, G.G. Sidorenko have the other solution of the problem of using the augmented reality technology in education (Voronina et al., 2019). They consider particular issues of the active use of AR applications for design activities in the course of descriptive geometry, engineering and computer graphics. As a conclusion, the scientists point to the lack of scientifically based and proven materials for teaching students using AR.

## **2.2. Analysis of foreign studies**

P. Piriyaawong justifies that the ongoing process of digitalization of education makes special requirements for improving the methodological system of the higher educational institution and supporting formation of professional competences (Piriyaawong, 2020). As vectors for development of the digital educational environment, maximally focused on supporting formation of professional competences of the competitive and in-demand graduate, foreign researchers distinguish: improving the quality of education, formation of the mobile personality capable of adapting to rapidly changing realities of the surrounding world, including software-technical sphere (Vázquez-Cano et al., 2020). In the arsenal of mentors, as described in detail by P. Sarkar, K. Kadam, J.S. Pillai, there are not only interactive resources, gaming educational platforms, cloud services, but also augmented and virtual reality technologies (Sarkar et al., 2020). At the same time, the use of appropriate software in the digital educational space of the university, according to A.S. Williams, F.R. Ortega, changes not only the forms of presentation and processing of information, but also the very way, style of interaction between participants of the information process (Williams, Ortega, 2020).

New means of the augmented and virtual reality, as the researchers argue, can and should be used to develop the communicative qualities of the person (Radkowski et al., 2015).

This means that development of the information environment of educational institutions should imply the use of new developments in the field of digital technologies, such as VR Thrills: Roller Coaster 360 (Cardboard Game), VR Space, Second Life, PhysicsPlayground, etc. (Raisamo et al., 2019). Their use, according to N. Nguyen, T. Muilu, A. Dirin, A. Alamäki, contributes to solving the problems of supporting motivation and involvement of students, enhancing cognition, inclusion in collaboration and monitoring attendance (Nguyen et al., 2018).

F. Marcel emphasizes that formation of professional competence necessarily includes development of communicative qualities of the person by means of modern information technologies (Marcel, 2019). The latter circumstance is especially relevant for studying at university. As J. Martín-Gutiérrez, CE Mora, B. Añorbe-Díaz, A. González-Marrero justify, the process of mastering professional skills in the digital educational environment of the university can be optimized by using augmented reality applications along with traditional learning technologies (Martín-Gutiérrez et al., 2017). For students, the educational process can often be a tedious routine. Having set the goal of training the graduate who best suits challenges of the future, educators-innovators first of all try to instill in the student love for the future work activity, a desire to master it at a high professional level (Marín-Díaz et al., 2020). In this context, the use of modern technologies, and this is proved by S. Lu, Y. Liu, M. Lin, F. Lu, allows diversifying the didactic process with non-standard activities and elements of the game, which captivates the student, concentrates attention on learning (Lu et al., 2019). If students understand the need to study one or another fundamental scientific theory, they can motivate themselves to study its laws and facts (Bacca et al., 2019). Augmented reality in learning can be viewed as an element of surprise pedagogy. From the teaching practice of E. Abad-Segura, we can note that augmented reality allows organizing the study of theoretical material in a fascinating way, which is rather "boring" for a student: rules, formulas, geometric constructions (Abad-Segura, 2020).

T. Liao analyzed various means of the augmented reality (Liao, 2020). F. Marcel singles out exactly those that have the didactic potential for university studies (Marcel, 2019).

At the moment, researches on the problems and prospects of introducing VR and AR into professional training of specialists are carried (Vázquez-Cano et al., 2020). In particular, many of them note that at present, higher education institutions use AR and VR mainly training natural sciences (Vidal-Balea et al., 2020).

In order to warn teachers who are actively seeking to enrich their software and hardware arsenal, M. Fan, A.N. Antle, J.L. Warren draw attention to psychological factors and risks of using new digital tools in terms of supporting personality development (Fan et al., 2020). Indeed, along with the undoubted didactic potential, information technologies for teaching, upbringing, and personal development, the impending danger that the digital school teacher should see and understand should be highlighted. The active immersion of the student in the space of computer games, the value of the rating in virtual interaction can become a more powerful argument for the student's personality than the advice of teachers, parents, friends from the real world (Arif, 2019).

The analysis of the literature makes it possible to reasonably assert that the teacher of the digital school should have a clear understanding of the need to adapt used rules of ensuring information security into new digital technologies including those based on augmented reality. So, despite the wide range of didactic possibilities of the augmented reality technology for teaching, there are a number of objective factors that should be taken into account when choosing appropriate methods and tools (Martín-Gutiérrez et al., 2017). In addition, students should be passionate about the very process of cognition, preparation for the future professional activity, and not only about the external emotional attractiveness of innovative technologies (Bacca et al., 2019).

Thus, in most of the studies analyzed, researchers note: incorrect assessment and lack of understanding of possibilities of using augmented reality in education; incorrect concept of ergonomic characteristics of modern virtual and augmented reality hardware in education; poor elaboration of the psychological and pedagogical base for design, implementation and use of AR teaching aids.

Due to the fact that formation of the professional competence of the highly qualified and competitive specialist is a priority of the modern educational space, there is an objective need to study the didactic potential of the augmented reality technology, taking into account the peculiarities of professionally oriented training of the future teacher of the digital school.

### **3. Materials and methods**

#### **3.1. Theoretical and empirical methods**

To obtain theoretical generalizations, the analysis of scientific works on the problems of using the augmented reality technology in education and professional training of highly qualified specialists was used.

The main research methods were the system-activity, communicative and competence approaches. The system of the activity is considered in the environment of virtual communication, supported by means of augmented reality: use of digital service tools to provide learning material by the teacher; use of functionalities of the technology in the cognitive activity by students; organization of interaction between teachers and students (Prikaz Mintruda...).

The communicative approach, as a research method, allows: to determine the directions and intensity of communication of the participants in the didactic process, used by means of the augmented reality technology; to describe conditions for implementation of information interaction in the space of augmented reality.

The analysis of the provisions of the standard for the professional activity of the teacher, the requirements for the results of mastering training programs 44.03.05 Pedagogical education (two training program specializations) made it possible to determine the competences and personality qualities, formation of which is the most important, taking into account challenges of the time and employers' requests for the quality of higher education.

A special group is made up of empirical methods (observation, analysis of the results of work with an AR resource) to obtain up-to-date information on changes in the level of skills that form the basis of the professional competence. A special entrance and final testing was developed and carried out, including questions on the topics of the school subject Computer Science (25 questions), on the methodology of teaching Computer Science (25 questions) and on work with the condition of the problem (25 questions). The students of the experimental group used Google

Lens, augmented reality browsers, online fitting rooms, and the WallaMe service as software tools to present the results of the cognitive activity.

Statistical processing of the research results was performed using the Pearson  $\chi^2$  (chi-square) test.

### **3.2. The research base**

Assessment of effectiveness of using methods and means of the augmented reality technology for training future teachers of the digital school and formation of skills that form the basis of their professional activities was carried out during the pedagogical experiment.

The research was conducted on the basis of Vyatka State University within the framework of teaching the discipline "Theory and Methods of Teaching Computer Science". 74 fourth-year students (60 % of girls and 40 % of boys, which is due to the specifics of the pedagogical training program) took part in it. The training program is 44.03.05 Pedagogical education (two training program specializations). The average age of the respondents was 22 years.

The sample was not random. To fulfill the rules of probabilistic selection, one and the same teacher was in charge of practical activities of all students. This teacher also formulated systems of educational tasks, directed information interaction in the process of solving professional and practice-oriented tasks by students. Working with digital resources (in particular, augmented reality services) was performed in the same classrooms, on the same hardware and software. The materials for the test were developed by the authors in accordance with the current higher education standard in the field of training.

### **3.3. Stages of research**

The research was carried out in three stages.

At the first stage of the experiment, general assessment of the existing level of theoretical knowledge and scientific terms in the field of training was carried out. The level of skills that form the basis of the teacher's professional competence was determined. As part of the entrance control event, students were asked to do testing on the topics of the school subject Computer Science (25 questions), on the methodology of teaching Computer Science (25 questions) and on working with the condition of the problem (25 questions). A total of 75 tasks were of the following types: correlate meanings, fill in the missing word, remove unnecessary words, choose the correct statement.

For the correct and complete solution of each task, the student received 2 points. Total was 150 points. With the help of the results of the entrance testing, we managed to collect the required initial data about the students. Then the participants were divided: 37 in the experimental group and 37 in the control group. The division was made in such a way as to guarantee that in each group there are students having the same skills and personality traits, which form the basis of the professional competence of the future teacher of the digital school, and their equal distribution.

Skills of working with digital technologies were also tested. The results of the cognitive activity were presented using LearningApps, interactive worksheets, cloud services, Learnis, etc.

The second stage of the research was devoted to determining the directions of the educational and cognitive activity, firstly, supported by methods and means of the augmented reality technology; secondly, working as effectively as possible for the conscious active development of fundamental scientific theory for the training program, for formation of digital literacy, for professional self-development. The relevant activities were accompanied by work in virtual educational spaces, using mobile applications, augmented reality browsers and QR codes.

The third stage of the study covered the experienced training and using methods and means of the augmented reality technology for formation of the professional competence of future teachers of the digital school.

## **4. Results**

### **4.1. Clarification of the essence of basic concepts**

By Augmented Reality (AR) we mean an environment with direct or indirect addition of the physical space with digital information in real time through computer devices (tablets, smartphones, gadgets and software for them). Summarizing the analyzed experience, we conclude that:

1. Augmented reality is the inclusion of audio and video components in the real world through computer simulation.
2. Augmented reality allows replacing a flat image in teaching materials with a 3D model.

3. Augmented reality integrates new data directly into the real physical space.

Examples of augmented reality: a parallel facial color line showing the location of the object; arrows indicating the distance from the place to the object; the "drawn" flight path of the object; mixing of real and fictional objects in computer virtual worlds, etc. By means of augmented reality you can read information about the environment. For example, using QR codes information about a point of interest (historical information, photos and audio guides) can be received.

The following advantages that realize the educational potential of the augmented reality technology for training future teachers of the digital school should be noted: enrichment of the didactic process with the help of multimedia information; adaptation to the specific learning needs of each student; supporting the opportunity to prepare communicative practical activity through immediacy and interactive nature of technology; supporting learning in practice, solving tasks and situations of professional communication; assistance in transforming the role of teachers and trainees; opportunities for learning outside the classroom.

Problems limiting the use of methods and means of the augmented reality technology for training future teachers of the digital school are the following: the lack of holistic educational programs on the use of AR and VR in education. Most of them are used when teaching natural sciences (biology, medicine). The high cost of developing training materials and equipment for demonstrating AR should be noted. The average retail price of a set of augmented reality devices reaches 40-50 thousand rubles. At the same time, it is possible to demonstrate educational materials in augmented reality mode on laptops, tablets and other devices. In addition, there are costs associated with the retraining of specialists, as well as changes in the training programs for future teachers of educational institutions.

It is necessary to highlight the negative factors of the impact of augmented reality:

- distracting character. For example, a large amount of various information in the field of vision of the student overloads the perception and the nervous system;

- threats of data theft. On the one hand, the use of programs that implement augmented reality increases the speed of information processing and activates the interaction of network users. On the other hand, information transmitted over the network reveals details of the IP address, location, device type, user access rights, etc. Augmented reality must gain access to some personal data – geolocation, purchase history, financial details, so if an attacker uses such a channel, the consequences will be immediate;

- not every student or teacher can afford the means that implement the augmented reality technology.

Further, the essence of the concept of "professional competence of the future teacher of the digital school" was made more specific in the context of enriching the educational environment with the augmented reality technology.

A high level of the professional competence of the future digital school teacher: correctly applies scientific terminology; independently analyzes the research object based on deep knowledge; knows theories, concepts, functional capabilities of the software environment and gives them a critical assessment; shows in work elements of scientific knowledge, creativity, independence; clearly identifies the goals and objectives of the activity; logically, consistently and reasonably defend point of view and choice of the environment functionality; selects information sources that are adequate to the goals of the project, taking into account the maximum efficiency of communication; proposes and implements the method for verifying the accuracy of information; competently, correctly and comprehensively answers all additional questions; does not make mistakes in the technical presentation of the results; knows how to present and defend work in a team.

The average level of the professional competence of the future digital school teacher: knows scientific terminology; owns the functionality of the software environment, but does not use it effectively in all situations; knows main theories, concepts, but cannot always give them a critical assessment; in most of work shows elements of scientific knowledge; adheres to the goals and objectives of professional activity; cannot always defend decision with arguments; demonstrates skills of creative independent thinking; extracts information from one or more sources and organizes it; interprets information in the context of work; competently, logically correctly answers most of the additional questions; makes one or two non-critical errors in the technical presentation of the results; not in all cases can present and defend work in a team.

The low level of the professional competence of the future teacher of the digital school: shows an insufficiently complete volume of concepts, knowledge from the field of computer science, cybernetics, etc.; uses terminology, but cannot always answer additional questions about the research object; does not know how to navigate theories, concepts and functionality of the software environment; makes meaningful mistakes when working with educational material; cannot reason decisions; does not understand the lack of information or uses the proposed method to obtain information from one source; makes a simple conclusions when researching, but does not cope with tasks for making a series of conclusions; when reporting the results makes technical mistakes; refuses to present and defend work in a team.

#### **4.2. Educational and cognitive activities on using methods and means of the augmented reality technology when training future teachers of the digital school**

To achieve the goal of this study it was proposed to expand the traditional training methods of the theory and methodology of teaching computer science using capabilities of augmented reality applications, that is, the inclusion of the student in the process of independent interaction with visually vivid and three-dimensionally presented models.

In the holistic methodological system for training future teachers of the digital school, we single out the following components: the goals of studying the AR technology, place in the course, motivational component, content, software, methods and control.

The objectives of studying the technology of augmented reality within the framework of the course "Theory and methods of teaching Computer Science" are defined as follows:

1. To form an idea of the augmented reality technology as a technology for achieving new educational results, which determines a high level of professional training of the future teacher and functions and direction of his/her labor activity.
2. To form an idea of the complex of software and hardware for development of interactive digital content.
3. To teach to reasonably choose software tools for solving professional/practice-oriented tasks of the future professional activity in the digital school;
4. To study the basic functionalities and learn how to apply them in the course of practical activities.

The motivational component is determined based on the specifics of the educational topic of the school subject Computer Science, the study of which is supported by the appropriate AR-technology software tool. For example, when studying the topic "Device and architecture of the computer" in the lessons of computer disciplines. As a motivation, the following option can be offered: the use of 3D objects of augmented reality instead of real parts, each student has the opportunity to get acquainted with a separate computer device, to get an idea of its technological structure and functional capabilities.

The place in the course and the content are also determined by the characteristics of the study of the topic in the school computer science course. For example, the topic "Computer structure and architecture" is studied concentrically (propaedeutic level, in basic school (core of the course) and deepening lines).

Propedeutical level: safety rules at the computer, understanding of the main blocks of the computer, information processes.

The core of the course: the study of input-output devices, processor, memory; trunk-modular principle of operation.

Deepening lines: representation of information in computer memory, number systems, etc.

Software tools: Google Lens, Mind Mapping 3D, QR code generation apps, augmented reality browsers, online fitting rooms, WallaMe app.

Methods: modeling, project method, demonstration, laboratory work (frontal and independent; according to instructions and in commenting mode); excursion; work with simulators.

At the stage of control, a prerequisite is the solution of a system of educational practice-oriented tasks corresponding to fields of the future labor activity. For example:

1. To offer software tools that support work with smart cards in augmented reality (at least three).
2. To analyze and reasonably select an AR application for building a map "Device and computer architecture".

3. To design problematic learning situations for future professional activities in which the use of such a card will contribute to the educational goals of the digital school.

The following were used as the augmented reality software for teaching in the experimental group:

1. IigSpace. With this application you can turn each model, zoom in, disassemble it into parts. Such activities allowed students to consider in detail the main blocks, device and architecture of computers.

2. Google Lens. This application scans everything that the smartphone camera is aimed at. With the help of it, students travel along oval bus lines.

3. Mind Mapping 3D. This application is for creating three-dimensional mind maps that contain links to various educational resources: web pages and file attachments. During training students used tools to visualize concepts, thoughts and ideas; share the structure of Word documents, images, files, presentations on the big screen using Chromecast; collected resources for the project, organized links, and quotes.

On the topic "Device and architecture of the computer" the resulting mental map included the main blocks (input devices, output devices and the system unit). Through discussion and teamwork examples of I/O devices were identified. An independent study included the task to clarify/concretize what elements the system unit consists of, their functionality and purpose. It was proposed to add historical timing for additional assessment.

4. The augmented reality browser Layer, which allows you to "see through walls" and show the selected points of interest, regardless of whether they are in the line of sight. Students adjusted the degree of "range" of the layer in its settings, for example, by introducing a limit of 1 kilometer instead of 5. The number of objects became smaller. In another case, on the contrary, it was necessary to show that there are already enough of them now so that one could experiment with all this augmented reality.

5. Online fitting rooms to show the use of the digital technology in everyday life. For example, the Ecco website, which supports the goal of finding the perfect shoes for the user online. To do this, the students downloaded the Ecco Fitting Room application to their smartphones and followed a short video instruction. The leg scan process takes only a few minutes. After that, the application creates a visual 3D model of the leg, taking into account the fullness, the height of the rise and other measurements. The app is available on IOS and Android and supports family sharing, i.e. it can be used by up to 6 people at a time.

6. WallaMe application. For example, quests and games were held repeatedly, which consisted of looking for answers on the wall using this mobile application. In order to create own "wall of augmented reality", the following steps must be performed: open the camera by clicking on the "+" icon; take a photo; perform one of the possible actions: insert a ready-made image, draw own picture or write a text; confirm the performed action; open the message so that everyone can see it.

During the game an additional reality was "superimposed" on the walls, which contained images and symbols that the students were looking for and deciphering. Thus, the playful nature of the study contributed to the memorization of new words, the resolution of communication situations, the activation of cognition.

7. The HP Reveal platform was used to create a variety of visual aids to make class activities more interesting and fun. The tools of the environment supported the study of complex theoretical facts. On the topic "Device and architecture of the computer", when doing homework, future teachers created fragments of lessons. When pointing the smartphone camera at the task, the other participants in the experiment started a video lesson in which the speaker explains the material or the principle of the solution. When studying occupational health and safety, tags were placed in a classroom corner, a laboratory, when scanning them other participants could get acquainted with the rules of working at the computer.

The study of scientific terms was facilitated by working with a dictionary on the wall. On the stand in the classroom labels or concepts, the definitions for which can be seen (heard) on the smartphone screen were placed. Students could independently record a video in which they explained the meanings of terms for classmates. Those, in turn, using the application viewed them on the screen of their gadget.

The developed materials are aimed at users who are just starting to include elements of augmented reality in the educational process. As part of the course “Theory and Methods of Teaching Computer Science”, students studied historical facts, basic terms, examples of applications for augmented reality. As the main advantages of the proposed option for using augmented reality technology for training of future teachers of the digital school, we note: the ability to organize concentric references to topics, structuredness and filling in accordance with the school curriculum, practice-orientedness of the system of educational tasks, feedback, access to all methodological developments.

### **4.3. Experimental assessment**

#### **4.3.1. The ascertaining stage of the experiment**

At the first stage of the experiment, to assess the input conditions, materials of specially organized testing were used, taking into account the priorities of the digital society, the requirements of the standard for the teacher labor activity. In total, the control event contained 75 tasks: 25 on the course Computer Science, 25 on the course Methods of Teaching Computer Science, 25 on working with the condition of the professional/practice-oriented task. For the correct and complete solution of each task, the student received 2 points.

Here is an example of a task on the Theory and Methodology of Teaching Computer Science: “Choose the correct statement characterizing the essence of innovative technology: Yandex.Disk is the world's first service for unlimited subscription to virtual reality applications, including educational; using Maya, any user can create virtual reality without professional programming knowledge; AR function in Search allows you to view and interact with 3D objects directly from Search and place them in their own space, which gives a sense of scale and detail; HTML – allows you to design 3D models for engineering graphics”.

An example of a task on the school subject Computer Science: “Match the type of hardware and its definition.

The first list: Personal computer; Mobile phone; Smart-TV; PlayStation.

The second list: a device for receiving and displaying graphics, sound; an electronic device designed and built for video games; an electronic device intended to be operated by one user; a tool designed to work in the networks of mobile operators”.

An example of a task for working with the task condition: the task is “Selection of array elements by criterion (recalculate, output, add)”. Select from the list of tasks those that do not correspond to this type: find the sum of grades for the term, determine the number of unsatisfactory grades, and calculate the arithmetic mean for the subject.

Thus, for completing the control event the students could score 150 points. The marks were set as follows: “excellent”, if students scored 140 points or more; “good” if the number of points scored was in the range from 101 to 139 points; “satisfactory” for the interval from 76 to 100. In all other cases, the student got “unsatisfactory”. The mark “excellent” corresponded to the high level of the professional competence of the future teacher of the digital school, “good” and “satisfactory” – to average, in other cases the level was defined as low.

As a result of the entry control event, almost the same initial level of preparedness of the students-participants in the pedagogical experiment was revealed. We can consider them as a total sample of 74 people. Thus, the experimental (37 students) and control (37 students) groups were formed. Characterizing the sample, we note that 60 % of girls and 40 % of boys are in the experimental group.

#### **4.3.2. Forming stage of the experiment**

At the forming stage of the experiment norms and requirements of the current standard for the labor activity of the teacher in the digital school were analyzed. The provisions of the current state federal educational standards determine that within the framework of professional competences the student must be able to advise and use fundamental knowledge in the field of computer science in professional activities; have skills related to information and communication technologies, formed by communicative competence, the ability to work in a team ([Prikaz Mintruda...](#)). The labor activity of the digital school teacher is characterized by: work planning; flexibility of mind, the ability to look at the object of knowledge from different angles; persistence; openness of perception to the search for new solutions; ability to comprehend, critical assessment of the results.

To implement these requirements, support labor functions, the following types of tasks were used: situational-motivational (encourage the search for new knowledge); support tasks (set the direction for development of the plot, conditions); borderline (serve as a basis for further research, connect the points of the trajectory of the student's development from "existing knowledge to new knowledge"). The solution of all presented tasks corresponds to the specifics of future professional activities.

Then the control group studied the course "Theory and Methodology of Teaching Computer Science" using traditional methods and software (presentations, teaching materials, audio recordings, etc.). Mind maps were created using Xmind, quests were implemented using the Learnis environment, and sticker boards were used to memorize terms. Results of the cognitive activity were also discussed in the group.

For the experimental group, methods and means of the augmented reality technology were used. Thus, students of pedagogical training programs were actively involved in cognition, experiment and information interaction. Some of the educational solutions based on AR applications are presented by them at international conferences (for example, the X International Conference-Competition "Innovative Information and Pedagogical Technologies in the IT Education System" and noted by experts.

#### **4.3. 3. Control stage of the experiment**

At the control stage of the experiment, a repeated measurement was carried out – testing consisted 75 tasks, for each of which 2 points were given. The quality of training and the level of formation of the professional competence of the future teacher of the digital school was determined according to the criteria described earlier.

Examples of the final control testing tasks.

The question on the theory and methodology of teaching computer science: "From the list of scientists who have contributed to the informatization of education, cross out the names of those who are not the author of school textbooks on computer science and ICT. The list: A.P. Ershov, A.G. Gein, V.G. Zhitomirsky, I.V. Robert, A.G. Asmolov, K.K. Kolin, A.A. Kuznetsov".

The question on the school subject Computer Science: "Compare the object of the real world with its possible information models.

Object: Construction company, Cat, Saturn, Country house, Clinic patient, Flower, Chemical element, Kirov.

The information model: Verbal description of the plant, House plan, Review on the official website, Animal photo, Mendeleev's table, Globe, City map, Medical card".

The question on working with the condition of the task. When completing the task, the student received 11 points. From the proposed formulations of the tasks, choose the one that can lead to such a result.

1. How much information is contained in the message: "PlayStation".
2. Wanting to help friends, the student carefully whispers the answer to his neighbor: "Chlorine". The last student wrote "Bor" in the reply. Only the first student received a point for this answer. How and how many times has information been distorted?
3. Create a program that generates a character string consisting of N stars ( $5 \leq N \leq 25$ ).

The statistical analysis of the reliability of the results of the pedagogical experiment was carried out using the  $\chi^2$  (chi-square) Pearson test.

Let us formulate the hypothesis:

H<sub>0</sub>: the level of skills that form the basis of the professional competence of the future teacher of the digital school, after the inclusion of the methods and means of augmented reality in the educational and cognitive activity of students, remained unchanged.

H<sub>1</sub>: the level of skills that form the basis of the professional competence of the future digital school teacher has increased.

The results of the measuring activity before and after the experiment for the students of the control and experimental groups are presented in [Table 1](#).

**Table 1.** The results of the test

Level	The number of tested (people)			
	Experimental group (37 students)		Control group (37 students)	
	Before	After	Before	After
High	3	10	3	5
Average	16	23	17	18
Low	18	4	17	14

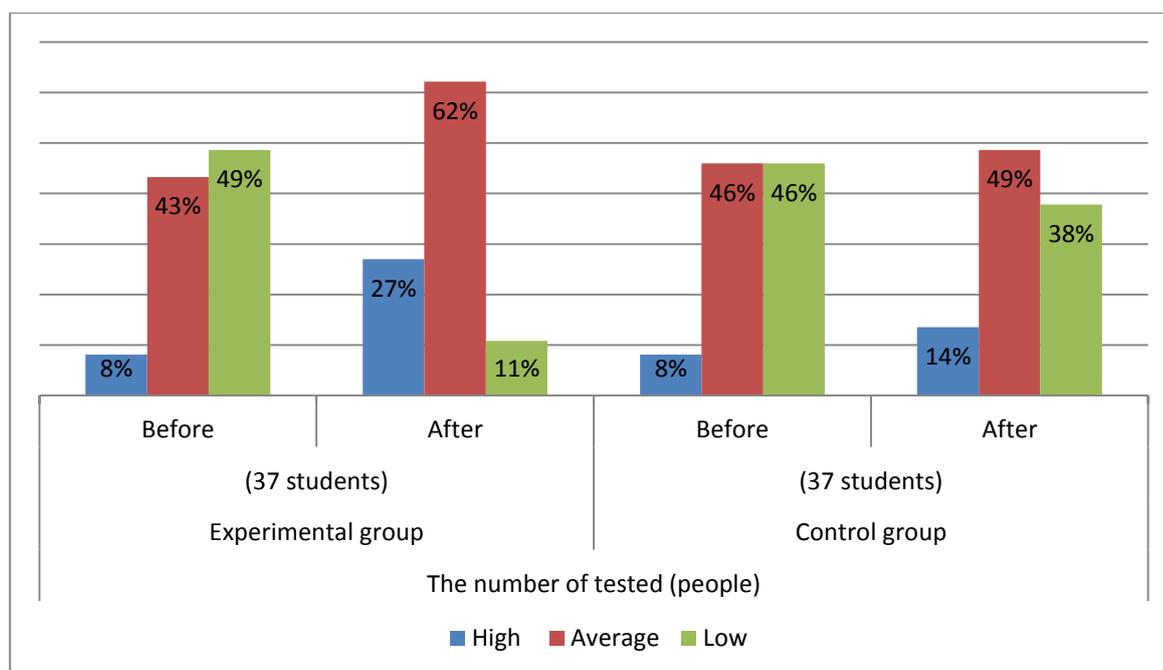
We calculate the value of the criterion statistics before ( $\chi^2_{obs.1}$ ) and ( $\chi^2_{obs.2}$ ) the experiment using the online resource <http://medstatistic.ru/calculators/calchit.html>. Let's choose the significance level  $\alpha = 0,05$ . In this case,  $c = 3$ , which means that the number of degrees of freedom  $\nu = c - 1 = 2$ . According to the distribution tables  $\chi^2$  for  $\nu = 2$  and  $\alpha = 0,05$ , the critical value of the statistics is 5,99. Thus, we obtain:  $\chi^2_{obs.1} < \chi^2_{crit}$  ( $0,06 < 5,99$ ), and  $\chi^2_{obs.2} > \chi^2_{crit}$  ( $7,83 > 5,99$ ). Consequently,  $H_0$  is rejected and hypothesis  $H_1$  is accepted. In other words, the use of the augmented reality technology when training future teachers of the digital school contributes to an increase in the quality of education and formation of personality traits that form the basis of professional competence.

## 5. Discussion

The sample of students was not probabilistic, since the experimental and control groups were formed in such a way as to guarantee the presence in each group of students having similar skills and personality traits, which form the basis of the professional competence of the future teacher of the digital school, and their identical distribution. For diagnostics, the results of the input control were taken into account. The selection of participants for the experiment and the sample size are justified by the specifics of the study: the study of the theory and methodology of teaching computer science, the use of augmented reality for educational purposes is included in the training program for a limited number of specialities. Throughout the experiment, practical activities for solving professionally oriented problems, supported by AR applications, were carried out by the same teacher, using the same software in special classrooms. The implementation took into account the basic didactic principles, the functionality of augmented reality tools.

As the practice has shown, currently there is an opportunity to work with ready-made developments and AR applications, which does not require any additional knowledge, time and funds to create them. Most of free applications have a simple and convenient interface that even a beginner can easily use (without any instructions). AR apps can be used to explore a variety of educational topics, intensifying the educational process. Additional conditions are being created for development of qualities and competences that are most in demand in the modern information society.

In general, the dynamics of values by the levels of the professional competence testifies to a qualitative improvement in the indicators of learning and formation of the monitored personality traits in the experimental group (see [Figure 1](#)).



**Fig. 1.** Dynamics of changes in the level

Performing the quantitative analysis of the above results, we can conclude that after the completion of the experiment, 27 % of the students in the experimental group had a high level of skills that form the basis of computational thinking, while initially this percentage was 8 %. The share of students, the level of computational thinking of whose was initially determined to be low, decreased qualitatively from 49 % to 11 %. It can be argued that most of these participants are those respondents who initially had an average level, i.e. made mistakes in solving tasks of the future labor activity.

The dynamics of changes in the control group is less significant. So, only for 14 % of students in the control group at the control stage of the experiment, the level of skills that form the basis of the professional competence of the future teacher of the digital school turned out to be high. This percentage was also originally 8 %. The share of students, the level of professional competence of whose was initially determined to be low, decreased qualitatively from 46 % to 38 %.

So, when preparing the future teacher for the digital school, the augmented reality technology can and should be used as an auxiliary tool to increase the visibility and interactivity of the subject being studied, to support the study and understanding of fundamental scientific theories in the course of solving professionally oriented tasks. However, one should understand and minimize negative factors of the impact of new digital means on personal development. Thus, the digital school teacher becomes a highly qualified specialist and maximally prepared for challenges of the future.

## 6. Conclusion

The study presents the solution to the problem caused by the need to resolve the contradiction between society requirements for the quality of training the future teacher of the digital school and the insufficiently developed methodological system for using the augmented reality technology when training graduates that meets these requirements.

The obtained results allowed us to draw the following conclusions regarding the assessment of the impact of the augmented reality technology on formation of students' professional competence.

1. The existing opportunity to work with ready-made developments and AR applications allows to effectively simulate virtual educational spaces without requiring the teacher to have special additional knowledge, time and funds to create them.

2. AR applications contribute to motivation, development of the cognitive interest, and improvement of the quality of professional training by increasing information flows of interaction

between participants in the didactic process. There is a transformation of the role of teachers and trainees.

3. The AR technology supports principles of visibility, accessibility, completeness and interactivity for formation of figurative thinking and spatial imagination (3D visualization, adaptation to the specific needs of each user).

4. The AR environment makes it possible to implement feedback mechanisms at a qualitatively different level, since augmented reality superimposes computer-generated visual, audio and tactile signals on the person's natural field of vision, auditory and tactile background, respectively. Navigational data, remote projection allow supporting epistemological processes.

5. The distracting nature of the AR technology. A large amount of information appears in the field of view of the student, which overloads the perception and the nervous system. In the course of the study, there are negative factors of influence on the psychological component of the student's personality (increased excitability, emotional burnout, headaches), increased risks of violation of confidentiality and data integrity. For many people augmented reality means were perceived as opportunities to manipulate another object, to realize aggression.

6. When using AR resources, new threats of data theft appear.

7. Not every student or teacher can afford means that implement the augmented reality technology.

The carried out experiment confirmed the undoubted advantages of the augmented reality technology for enhancing learning and improving the quality of training future teacher of the digital school.

As methodological recommendations for teachers planning to include this technology in the learning process we note: the need to regulate the use of AR resources; alternation of activities, traditional methods and teaching aids with innovative; inclusion of physical education and elements of neuro-gymnastics; instructing students on safe work with network and virtual resources. Thus, it is important not only to form the professional competence. It is necessary to teach students objective analytics and assessment of information coming to them from the AR space; analysis of possible threats arising from the use of the augmented reality technology.

The results of the research can be used in scientific and methodological work for development of didactic traditions in the field of forming the professional competence and also for development of digital literacy, information culture of the individual in general.

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