Application of VR/AR Technologies in Secondary General Education. Problems and Prospects

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Abstract

The article is devoted to the recent problem of using virtual and augmented reality technologies in secondary general education. The article provides a theoretical analysis of VR /AR technologies, reveals the essence of the basic concepts that determine the content of the article, the meaning and purpose of the technologies under consideration, analyses the experience of foreign and Russian studies on this topic, which allow revealing the advantages of using VR/AR technologies in the educational process.

Based on the examples of the existing pedagogical experience in the use of these technologies (the presence of developed VR/AR applications, the organization of teaching using these applications), the article shows the prospects for further research in the direction of "Neurotechnology, virtual and augmented reality technologies", experimentally confirming the effectiveness of using it in the educational process in general education organizations, as well as the experience of using VR/AR technologies for teaching students in the field of «Teacher training» in the educational organization of higher education (Belgorod State National Research University, Russia), and presents the prospects for such technologies in the context of using educational equipment in the educational process of the university.

Keywords 1

Virtual reality, augmented reality, educational process, information technology.

1. Introduction

The problems of using virtual and augmented reality technologies in education cause heightened scientific and practical interest, which is reflected in the works of foreign and Russian authors on this topic (H. Kaufmann, M. Papp, V.N. Taran, P.S. Bazhina, A.V. Dementieva, A.F. Ivanko, M.B. Burtseva, etc.) [1; 2]. The use of virtual and augmented reality technologies in the educational process was studied by the following Russian and foreign scientists: T.G. Vezirov, N. Kononova, I. Oblasova, A. Pletuhina, N. Shiryaeva, G.A. Semenova, M. Lee, S.A. Lee, M. Jeong, H. Oh et al. [3; 4; 5; 6; 7].

To study and predict the possible future of Russian education and education on a global scale, on September 1, 2020, a national project «Digital Educational Environment» (DEE) was launched in the system of school education (general and vocational) in some regions. This project is aimed at the development of school education and is part of the «Education 2030» project, the main tasks of which are: preparing children for the responsible career development that «does not yet exist» and technologies that «have not yet been invented»; the solution of problems which «now are impossible to predict». These tasks are planned to be solved in the context of «designing a learning environment that can effectively support the development of students' competencies» [8; 9; 10; 11]. Following the challenges of the time, the Head of the Government of the Russian Federation M.V. Mishustin has signed order No. 3345-r of December 15, 2020, on the allocation of 1 billion rubles for the implementation of digital technologies in education: monetary funds should be spent on the purchase of educational content:

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digital notes on all general education subjects, interactive teaching materials (didactic games, educational tests, virtual laboratories, multimedia cards, etc.).

2. The Purpose

Acknowledging the theoretical and scientific significance of the conducted research, we note that at the moment the virtual and augmented reality technologies are rapidly developing and have great prospects in education. This is especially relevant during the pandemic and lockdowns.

The purpose of this article is to study and analyze the possibilities of using VR/AR technologies and the benefits of their use in the educational process.

3. Presentation of the Main Material

Currently, the use of virtual and augmented reality in education is gaining more and more popularity and distribution. This is primarily because these technologies make it possible to bring teaching to a fundamentally new qualitative level, and also help students to assimilate information better, arouse their interest in the studied material. Students gradually, but strictly and at play study courses' complex topics and learn to apply theoretical material practically. In general education organizations, educational organizations of secondary vocational education and higher education, traditional types and forms of education are being replaced by more innovative ones: active and interactive [12; 13]. So, at present, educational organizations widely use technologies of virtual and augmented reality: textbooks with augmented reality, full-fledged training modules in virtual reality, and also full-fledged virtual simulators [9, 14, 15].

Augmented reality (AR) is the projection of various digital information on electronic devices. Unlike virtual reality, augmented reality does not create a whole artificial world, but allows you to supplement the real world with virtual objects: video, graphic images, text information, etc. Augmented reality can be implemented using applications for smartphones, tablets, augmented reality glasses, stationary screens, and other devices [5; 6; 14; 16]. Augmented reality allows you to provide visibility to the learning process. Modern AR textbooks do not just convey certain facts but immerse a person in the subject area, bring objects to life and/or help to study material using animation. So, using a smartphone and/or tablet camera, the user can see a virtual 3D object with animation or video, which can be controlled in real space, viewed from different angles, rotated, and moved (Fig. 1).

These actions help develop spatial thinking, make learning more interesting and exciting, and also improve the quality of the information received. Analysis of studies by foreign and Russian authors on this topic (P.S. Bazhina, T.G. Vezirov, A.V. Dementieva, H. Kaufmann, M. Papp, G.A. Semenova, V.N. Taran, etc.) allows us to conclude the practical significance, respectively, the great prospects of using augmented reality technologies in education [1, 4, 5, 6].

Figure 1: An example of augmented reality technology

Virtual reality (VR) is the surrounding world, artificially created using technical tools. A person perceives it through the senses and sensations (Fig. 2).

Figure 2: An example of virtual reality technology

Virtual and augmented reality technologies in the educational sphere have proven themselves well in the study of various academic subjects and disciplines. So, in physics, when studying the most complex topics (for example, «Magnetic field», «Electromagnetic induction», etc.), it is recommended to conduct experiments, which, in turn, can be transferred to virtual reality, thereby captivating, increasing the cognitive interest of students. Also, these technologies are relevant in the study of the following disciplines: «Environment», «Biology», «Geography», «Chemistry», etc. (Fig. 3).

Figure 3: Fragment of VR-lessons in the chemistry

The ability to combine visual and audial information allows one to create a complete immersion in the virtual environment. Students can study dangerous chemical/physical phenomena in detail, conduct laboratory work using virtual equipment. Teaching using virtual and augmented reality technologies are based on immersive technologies, as a kind of method that uses a simulated (artificial) environment, while using which students can immerse themselves in the learning process, which improves the quality of e-learning. Below you can see the advantages of using VR/AR technologies in education:

1. Visibility. Using 3D graphics or virtual space, it becomes possible to examine objects and processes in more detail, for example, physical and chemical processes, human structure, cell structure, traveling across countries, etc. These technologies allow demonstrating the process with any degree of detail (Fig. 4).

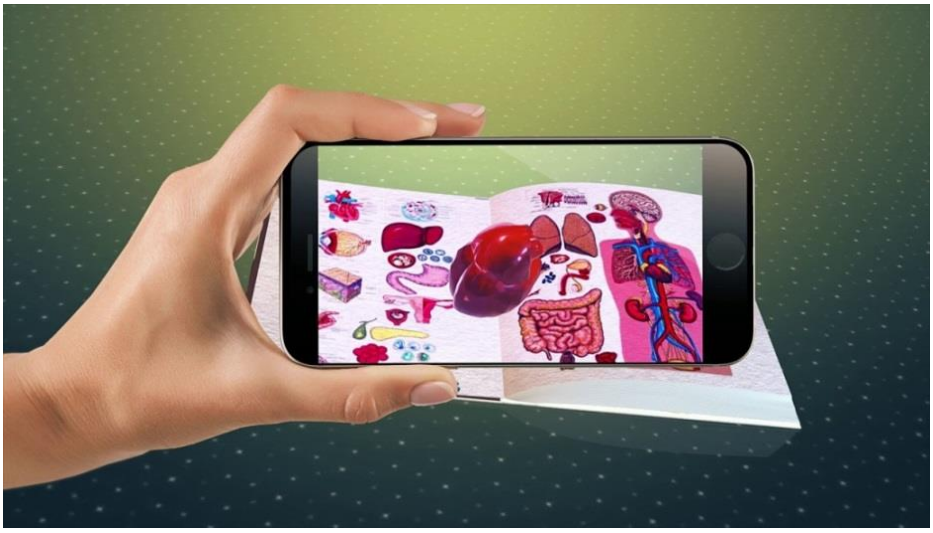

Figure 4: Fragment of the lesson «Human Anatomy» in augmented reality

2. Involvement. In virtual and augmented reality, students solve complex educational problems in a more fun and understandable form for them – at play; conduct experiments, influence the course of the experiment independently. While using virtual and augmented reality technologies in class, one has the opportunity to visit the place of a historical event, go on a trip across countries, etc. (Fig. 5).

Figure 5: Viewing historical events in virtual reality

3. Security. With the help of virtual technologies, students have the opportunity to study phenomena that threaten life and health, conduct complex operations, experiment, and much more without any risks (Fig. 6). Regardless of the complexity of the scenario, the student will not harm himself or other people.

Figure 6: Training on simulators in the virtual reality

4. Efficiency. The research on the implementation of VR/AR technologies in the educational segment has its history. So, in 2019, the specialists of Modul Lab company, engaged in the development of virtual and augmented reality solutions, together with the NTI Center for Neurotechnologies and VR/AR on the base of the Far Eastern Federal University, conducted an intensive physics course in five schools and colleges in the cities of Moscow and Vladivostok [15]. More than 60 students took part in the experiment. A course of VR lessons on the topic «Magnetism» (9^{th} grade) was specifically developed for the research (Fig. 7).

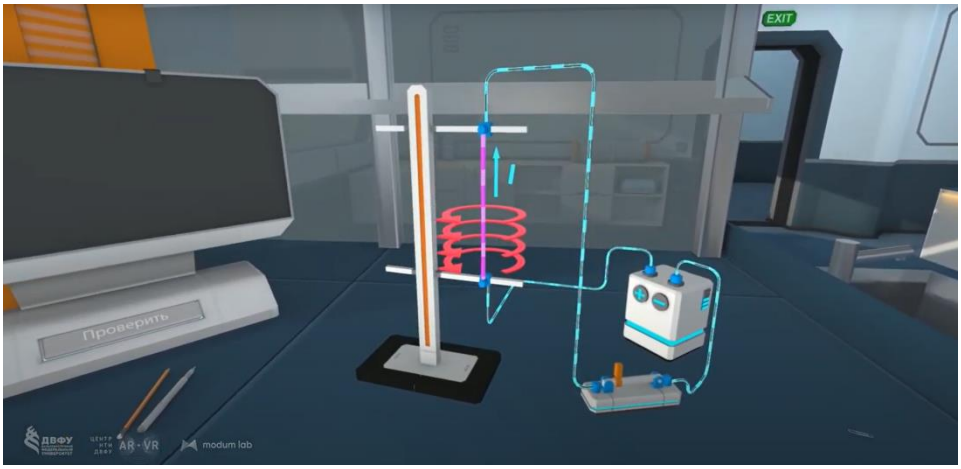

Figure 7: Fragment of a VR lesson on the topic «Magnetism»

In the research, the main group of students took an intensive course in a blended learning format, alternating virtual sessions with classroom discussion after being divided into groups of ten. After completing VR training, the average final score on the test among the students of the main group increased by 28.8%, while the score of the students from the control group (in this group, VR/AR technologies were not used) did not change. Previously, a similar study on the use of VR in the study of fundamental disciplines was conducted at the University of Warwick in the UK [14]. This study, there was organized a comparative analysis of the use of virtual reality technologies, paper textbooks, and video tutorials. According to the test results, the quality of learning the material when using VR devices has increased by 28.5%, video - by 16.1%, printed textbooks - by 24.9%. Confidence on a scale from 1 to 5 as a result of using a VR device has increased by 1.18 points, after training by video - by 0.71 points, after studying a textbook - by 1.12 points. In addition, VR has significantly increased the number of positive emotions among students, and video tools reduced them. The level of involvement in VR training was significantly higher.

4. Results

Large-scale research was conducted from October 2020 to May 2021 by NTI Center for Neurotechnologies and VR/AR based on the Far Eastern Federal University [15]. During the experiment, there were tested such educational software of virtual and augmented reality as in Physics. Magnetism; VARVARA; VR Space; Virtual Museum of Russian Style; VR Chemistry Lab; VR-«Fundamentals of health and safety», etc. To determine the effectiveness of the use of virtual and augmented reality technologies, there were involved the representatives of educational organizations from many regions, such as Primorsky Krai; Nizhny Novgorod, Sverdlovsk, Samara, Irkutsk, Omsk regions; the Republic of Dagestan, as well as teachers teaching in children's technoparks «Quantorium» and in non-governmental educational organizations. In total, 1095 educational organizations took part in the experiment [15]. In the course of the research, there were developed 23 educational software products (applications), which were classified according to the disciplinary principle: chemistry, physics, biology, foreign language, fundamentals of health and safety, computer science and technology, mathematics, history, complementary education, interdisciplinary programs, and inclusive education. The testing was carried out in 3 stages.

At the first stage of the experiment (August-September 2020), there was conducted a large-scale sociological survey with the support of the Ministry of Education of the Russian Federation. During the survey, there were assessed the equipment of educational organizations with VR equipment and the attitude of teachers to technology in general. At the second (September-December 2020) and third (January-May 2021) stages of approbation, the organizations took part in the experiment that tested educational software and methodological materials for it, and also involved development companies that corrected the shortcomings of their software, identified during testing. In May 2021, at the final

stage of work, the FEFU NTI Center, based on the analysis of feedback forms from teachers participating in the approbation program, obtained the following results (Table 1).

Table 1

Application benefits

№	Advantages	Number of participants
1	Helpful	186
2	Methodologically literate	84
3	Convenient to use	148
4	Liked by the students	206
5	Has pedagogical experience	144
6	Others	13

To the question: Did you like the app? 98% of the respondents answered positively. As it can be seen from the table, among the main advantages of the tested programs we can also name the following additional advantages: positive attitude of students, usefulness, and ease of use. In addition, according to educators, the applications have pedagogical potential and are methodologically literate. Among other advantages of the software, there were also noted the following: the development of new educational skills among students; gamification; the expediency of immersion in the information and educational environment to consolidate practical skills; visualization of processes, visibility (more detailed than video or image); new opportunities for additional education; more effective memorization; novelty, innovativeness; benefit in consolidating and testing knowledge; increased cognitive interest of students in the subject and increased learning motivation [8; 15].

In addition to the advantages of using the applications, the disadvantages were also mentioned (Table 2).

Table 2

Negative experience of using apps

№	Disadvantages	Number of participants
1	Complicates the teaching process	28
2	Methodologically impractical	6
3	Inconvenient to use	15
4	Disliked by the students	5
5	Has no pedagogical potential	1
6	No disadvantages	170
7	Others	55

Some teachers decided that certain applications were complicating the learning process (28 respondents), were inconvenient to use (15), were methodologically impractical (5): teachers noted that the students did not like the applications. Among other disadvantages, there were mentioned the following: the non-obvious expediency of using virtual reality technology («helmets are not needed»); the lack of content - teachers wanted more content, assignments, tests, scripts, objects in libraries, etc.; some technical difficulties (the app loads slowly, «freezes», there is no optimization, does not fit all devices); the unsatisfactory graphics; the need to improve pedagogical design; the lack of introductory lesson/instruction for students who «put on a helmet» for the first time; the application is fee-paying. Insufficient equipment (one helmet per class) and poor Internet connection at school were also noted. However, these problems are not related to software shortcomings and 98% of teachers would like to use the applications in their classes in the future. Thus, we can conclude that the effectiveness of training with the use of virtual and augmented reality is significantly higher compared to the use of the classical format.

To improve the information and technological competence of students - future teachers, Belgorod State National Research University has a certain experience in the use of VR/AR technologies. So, in 2021, at the Department of Informatics, Natural Sciences and Teaching Methods of the Faculty of

Mathematics and Natural Science Education of the Pedagogical Institute, as part of the final qualification work in the direction of preparation 44.04.01 «Teacher training», the master's program «Information Technologies in Education», there was organized research on the following topic: «Development of a game application with elements of augmented reality». A computer science game application with augmented reality elements was developed. Tasks were compiled on the following topics: «The structure of a personal computer», «Operations with binary numbers», «Measurement of information», «Coding of Information». This app was developed using the Unity IDE and the SDK Vuforia augmented reality platform. It was developed for educational purposes and, as shown by observation and testing of students, contributes to better assimilation of educational material [9; 13].

Taking into account the challenges of modern school education and the introduction of new approaches to the training of highly qualified specialists, since 2019 teachers of the Department of Informatics, Natural Sciences and Teaching Methods have been participating in the implementation of the project of the European Union program «Erasmus +» on the following topic: «Integrated Approach to the Training of STEM Teachers» (STEM) for 2019-2021. The project goal is the implementation of the best practices of the STEM approach to learning in the educational systems of Russia and Kazakhstan [9; 17; 18]. As an interdisciplinary approach to teaching, learning, and educating, STEM aims to develop «flexible skills» relevant to modern society: critical thinking, a creative approach to finding solutions to the problems of the modern world, communication, collaboration, and teamwork. Following the demands of the time, in 2020, there was opened a master's program called «Training of STEM teachers» at the Belgorod State National Research University. As a part of the project, the software and hardware complex Mobile virtual reality class EDUBLOCK Plus (VR-3) was purchased. The mobile virtual reality classroom EDUBLOCK Plus includes an autonomous virtual reality helmet HTC Vive Focus Plus (Fig. 8), which does not require a connection to a computer and the installation of base stations.

Figure 8: HTC Vive Focus Plus virtual reality helmet

The use of this equipment will allow future teachers, within the framework of interdisciplinary connections and project activities, to independently create VR applications, and to teach this to students in the future. As it was shown by the theoretical analysis of scientific and methodological literature, the own work experience when using VR/ R technologies in the educational process, attention should be paid to the following points:

1. When creating content for a discipline, it is necessary to develop lessons for each topic in the form of separate materials or a complete course, which requires large human and program resources. Currently, there is not enough groundwork in the field of virtual reality, a small amount of content has been developed for school lessons. The Russian education system lacks augmented reality textbooks and mobile applications that allow the implementation of AR technologies in learning places.

2. When developing educational applications using augmented reality, unfortunately, all the possibilities of virtual reality are not always used, which leads to insufficient performance of

educational and developmental functions. Therefore, it is important to make the content visual and involve learners in the educational process, for which it is necessary to create/use the right tools [2; 3].

3. The use of virtual and augmented reality opens up new opportunities in learning, however, the complexity of content development, the high cost of devices, and the high cost of final solutions limit its use in the educational process [4].

5. Conclusion

The implementation of virtual and augmented reality technologies into the educational process of the school is recent and prompt: it meets the modern challenges of society; contributes to solving the problems of developing the digital educational environment, increasing the motivation of students for educational activities and their involvement in the educational process; significantly improves the quality of teaching and learning. The use of these technologies in school is especially recent during studying the natural science disciplines: it allows students to conduct experiments at different levels of complexity without harm to health, improves the quality of learning of educational material, helps to increase students' self-confidence.

The solution of the issue of the implementation of virtual and augmented reality (VR/AR) technologies into secondary general education necessarily requires the full equipping of schools with modern digital equipment and the corresponding high-quality teacher training. The experience of using VR/AR technologies in the educational process of the Belgorod State National Research University has shown that the use of such technologies contributes to improving the quality of students' assimilation of educational material.

The analysis of scientific sources, research materials, the current situation on the educational services market, and work experience allows us to say that that virtual and augmented reality are modern and rapidly developing technologies that cannot yet completely replace the content, forms, and means of secondary general education, but today they can qualitatively complement them, optimize the educational process in educational organizations of different levels.

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