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INTERACTION IN AN EDUCATIONAL ENVIRONMENT WITH VIRTUAL AND AUGMENTED REALITY

Abstract. The article is devoted to the problem and features of the use of virtual and augmented reality at general school. The integration of virtual reality (VR) and augmented reality (AR) in educational environment has opened up new possibilities for engaging and immersive learning experiences. This paper aims to explore the features of participants' interaction within an educational context using VR and AR technologies. To achieve the purpose of our study and also to clarify the problem of determining the features of interaction models of participants in the educational process of a general education institution using virtual and augmented reality we used the following methods: systematic and comparative analysis of pedagogical, psychological, philosophical and sociological works, methodological and specialized literature; analysis of the pedagogical experience of using virtual and augmented reality in general school; synthesis and generalization to formulate the main points of the study; interpretation of the research results. A research study was conducted in a general educational institution, where an educational project using virtual and augmented reality was developed and implemented. The purpose of the project was to investigate the issues surrounding the interaction among participants in the educational process when utilizing these technologies. The results of the questionnaire showed the following: the participants' interaction in the educational process with the use of VR needs improvement, methodological recommendations and research on the organization of this environment for various purposes, such as, for example, students' research of new educational material, performance of laboratory work, joint work of students on research, instructions for the teacher's activities in working with students in VR, etc.; the participants’ interaction in the educational process with the use of AR is best understood by teachers and students, they use both ready-made AR technologies and personally created ones. We concluded that the use of virtual and augmented reality technologies in the educational process provides a wealth of teaching and learning resources that can enhance the learning experience and free participants from limitations in time and space. However, the effective organization of interaction between participants in the educational process using VR and AR requires careful consideration of educational space and pedagogical and methodological recommendations.

Keywords: augmented reality; virtual reality; participants' interaction; educational environment; immersive learning.

1. INTRODUCTION

Since the beginning of the 21st century, the continuous development of science and technology has allowed information and communication technologies (ICT) to penetrate many aspects of social life. It affects the way people live and think. The products of the development process in human society, particularly education, require the support of information and communication technologies (ICT) for scientists and teachers to explore new ways of teaching.The development of ICT has led to significant changes in traditional educational concepts, educational models, and even the education system itself. Gradually, attention is shifting towards education that does not conform to traditional concepts and liberates participants in the learning process from limitations in time and space, providing a wealth of resources for teaching and learning [1].

When introducing these technologies into educational programs that have a distance equivalent [2], it is necessary to analyze the interaction of participants in the educational process in VR and AR.

The problem statement. The integration of AR and VR in the educational environment has the potential to revolutionize the way participants interact in institutions of general education. Here are some models of participants' interaction that can be implemented using AR and VR:

1. Collaborative Learning Model: AR and VR can facilitate collaborative learning by creating immersive and interactive virtual environments where students can work together on projects and assignments. Participants can interact with virtual objects, explore simulations, and solve problems collectively, regardless of their physical location [3].
2. Experiential Learning Model: AR and VR can provide students with realistic and engaging experiences that enhance their learning. Participants can virtually visit historical sites, explore distant locations, or simulate scientific experiments. These immersive experiences allow students to interact with the environment, manipulate objects, and gather data, promoting active and experiential learning [4].
3. Personalized Learning Model: AR and VR can be used to tailor educational experiences to individual students' needs and preferences. Participants can access customized content, adaptive assessments, and interactive simulations that adapt to their learning pace and style. This personalized approach fosters engagement and motivation, as students can explore topics at their own pace and receive immediate feedback [5].
4. Virtual Field Trips Model: AR and VR enable virtual field trips, allowing participants to visit museums, landmarks, or cultural sites without leaving the classroom. Students can explore these locations in a virtual environment, interacting with artifacts, observing details, and listening to guided tours. Virtual field trips enhance students' understanding and cultural awareness, even in subjects traditionally limited to textbooks [6].
5. Professional Development Model: AR and VR tools can support the professional development of teachers and staff in educational institutions. Participants can engage in virtual workshops, simulated classrooms, and training scenarios to enhance their teaching skills, explore new pedagogical approaches, and practice classroom management techniques. This model allows educators to learn and collaborate in a risk-free environment [7].
6. Virtual Laboratories Model: AR and VR simulations can replicate laboratory environments, providing participants with hands-on experiences in science and engineering disciplines. Students can conduct experiments, manipulate virtual equipment, and analyze data within a safe and cost-effective virtual setting. This model promotes scientific inquiry, critical thinking, and problem-solving skills [8].

It is important to note that the implementation of AR and VR in educational institutions may require appropriate infrastructure, technological support, and training for both teachers and students. However, these models offer great potential for enhancing participant' interaction and improving learning outcomes in a general education setting.

Analysis of recent studies and publications. Ukrainian researchers have explored the use of augmented and virtual realities in education, including the development of a conceptual model for the use of AR in the educational process (Litvinova S.G., Burov O.Yu., Semerikov

S.O., 2020 [9]); the determination of principles and approaches for using VR and AR technologies in research-based learning and their impact on the intellectual and psychophysiological development of students (Hrybiuk O.O., 2022 [10]); the analysis of students' readiness in general secondary education institutions to use virtual reality in the educational process (Lytvynova S.H., 2022 [11]); the development of educational content for a club on "Creating Augmented Reality" for informal student learning in a distance format (Slobodyanyk O.V., 2023 [12]); and the exploration of the possibilities of using augmented reality technologies in the teaching of physics in general education institutions (Sokolyuk O.M., Slobodyanyk O.V., 2022 [13]), etc.

Foreign researchers are actively conducting investigations in this direction. Indeed, the phenomenon, current state, possibilities, and challenges of using VR and AR technologies in the educational process have been studied by:

Doak D.G., Denyer G.S., Gerrard J.A., Mackay J.P., Allison J.R. Peppy, who researched the creation of a virtual reality educational environment for the development of medical science (Doak D.G., Denyer G.S., Gerrard J.A., Mackay J.P., Allison J.R. Peppy, 2020 [14]); Yuen S., Yaoyuneyong G., Johnson E., who addressed the issues of enhancing education quality through the application of augmented reality (Yuen S., Yaoyuneyong G., & Johnson E., 2011 [15]); Kuhail M.A., ElSayary A., Farooq S., Alghamdi A., who explored the creation and utilization of immersive educational environments (Kuhail M.A., ElSayary A., Farooq S., Alghamdi A., 2022 [16]); Díaz, J.E.M., who studied the development of virtual reality as a digital tool to support the learning of students and faculty in the Faculty of Systems Engineering at the University of Cundinamarca, with the aim of implementing and demonstrating its educational potential as an academic resource that motivates students in their studies and encourages teachers to develop new digital skills (Díaz J.E.M., 2020 [17]), Mukasheva M., Kornilov I., Beisembayev G., Soroko N., Sarsimbayeva S. & Omirzakova A. (Manargul Mukasheva, Iurii Kornilov, Gani Beisembayev, Nataliia Soroko, Saule Sarsimbayeva & Aisara Omirzakova, 2023 [18]), who researched the context structure as an approach to the study of the virtual reality learning environment, etc.

The research goal is to determine the features of interaction models of participants in the educational process of a general education institution using virtual and augmented reality.

2. THE THEORETICAL BACKGROUNDS

AR and VR are two of the most innovative technological achievements in the modern world, and their potential for enhancing education is immense. The use of AR and VR in education has been growing in recent years and offers numerous opportunities for effective learning technology utilization (Tan et al., 2022 [19]). AR and VR introduce students to an exciting digital experience that traditional teaching methods cannot replicate (Phakamach et al., 2022 [20]), enabling them to engage with complex materials beyond lectures and textbooks (Sun et al., 2022 [21]), while simultaneously allowing educators to tailor content to individual learning styles (Childs et al., 2021 [22]). These technologies not only create a more immersive learning experience but also provide educators with the potential to simulate educational environments through virtual excursions without physical travel consequences (Seydametova et al., 2021 [23]). Furthermore, the use of AR and VR can bridge the gap between traditional classroom learning and real-world experiences, offering tangible benefits for students' professional development.

It is important to note that the implementation of AR and VR in educational institutions may require appropriate infrastructure, technological support, and training for both teachers and students. However, these models offer great potential for enhancing participant' interaction and improving learning outcomes in a general education setting.

The use of AR and VR in education is still relatively new, and there is much more potential for its application in various aspects of the learning experience. Below are some further ideas for how AR and VR can enhance participants' interaction in education:

- Language learning: AR and VR can be used to create immersive language learning experiences, such as virtual language exchanges with native speakers, interactive scenarios for practicing everyday conversation, and cultural immersion experiences;
- Soft skills development: AR and VR can be used to simulate real-life situations where students can practice and develop their soft skills, such as communication, collaboration, leadership, and problem-solving;
- Special needs education: AR and VR can be used to support students with special needs, such as visual or hearing impairments, by providing interactive and accessible learning experiences;
- Distance learning: AR and VR can be used to create interactive and engaging distance learning experiences, connecting students and teachers in virtual environments that replicate real classroom settings;
- Career exploration: AR and VR can be used to provide students with immersive and interactive career exploration experiences, allowing them to explore different career paths, visit work environments, and interact with professionals in various fields;
- Assessment and evaluation: AR and VR can be used to create innovative and adaptive assessment and evaluation tools, such as interactive simulations, immersive scenarios, and personalized feedback systems;
- Gamification: AR and VR can be used to gamify learning experiences, creating interactive and engaging games that promote learning and retention of knowledge.

3. RESEARCH METHODS

Research methods include:

1) the systematic analysis of pedagogical, methodological and specialized literature regarding the utilization of virtual and augmented reality in educational environments across various fields of study;

2) examination of pedagogical experiences involving the use of virtual and augmented reality in the implementation of educational projects by teachers in general education institutions to identify the specifics of participants' interaction in the educational process using virtual and augmented reality;

3) synthesis and generalization to determine the fundamental characteristics of participants' interaction in the educational environment of a general education institution using virtual and augmented reality;

4) analysis of research results through surveys conducted with teachers after the implementation of educational projects involving virtual and augmented reality to assess the effectiveness of participants' interaction within the educational environment utilizing virtual and augmented reality.

4. THE RESULTS AND DISCUSSION

The development of information and communication technologies, including virtual and augmented reality, has indeed brought about significant changes in traditional educational concepts, models, and systems. These technologies have the potential to transform the educational landscape by providing new opportunities for teaching and learning that are not bound by traditional limitations of time and space. By analyzing pedagogical and methodological literature, as well as domestic and foreign experiences, the main features of models of participants’ interaction in the educational process using virtual and augmented reality can be identified.

A model of participants’ interaction in the educational process of a general education institution using virtual and augmented reality typically includes the following blocks:

Teacher's activity: the teacher plays a crucial role in organizing participants’ interaction in the educational process using virtual and augmented reality. Teachers are responsible for designing and implementing activities that facilitate effective use of these technologies, ensuring access to appropriate resources, and guiding students' learning experiences.

Interaction between students and the teacher: AR and VR enable new forms of interaction between students and the teacher. The teacher can provide guidance, feedback, and support remotely, and students can engage in discussions, ask questions, and seek clarification.

Types of Participants' Interaction: various types of participants’ interaction can occur in the educational process using virtual and augmented reality. This can include collaborative projects, simulations, virtual field trips, virtual laboratories, and more. These interactions can enhance student engagement, critical thinking, and problem-solving skills.

Diagnostics of interaction effectiveness: evaluating the effectiveness of participants’ interaction in an educational project with virtual and augmented reality is crucial. Assessment methods can be adapted to measure learning outcomes, engagement levels, and the impact of these technologies on student achievement.

When implementing virtual reality, it is important to consider the spatial aspects of the environment. The VR space should be optimized to provide maximum coverage relative to the center of the classroom or learning environment, ensuring that participants have sufficient room to move and interact within the virtual space.

The existing research suggests that there is room for improvement in participants’ interaction in the educational process using virtual reality. Methodological recommendations and further research are needed to explore various purposes, such as students' exploration of new educational material, laboratory work, collaborative research, and providing guidance to teachers on working with students in virtual reality. On the other hand, participants in the educational process, including both teachers and students, have a better understanding of interaction using augmented reality. They utilize both pre-existing augmented reality technologies and create their own applications for educational purposes.

Overall, the integration of virtual and augmented reality technologies in the educational process opens up new possibilities for participants’ interaction, allowing for immersive and engaging learning experiences beyond the traditional boundaries of time and space.

The use of virtual reality (VR) can be effective for learning in various disciplines, including:

Natural Sciences: Complex concepts in physics, chemistry, and biology can become more understandable through visualizations and interactive experiments in virtual reality (for example, Google Earth VR, which enables students to explore the planet in a virtual environment, incorporating geographical and geological concepts; The Body VR, which allows the study of internal anatomy and organ functions in a three-dimensional virtual environment.).

Medicine: VR can assist future medical professionals in studying anatomy, conducting surgical simulations, and engaging in exercises for rehabilitation (for example, Osso VR, which is a platform for practicing surgical procedures in an immersive environment; Medicalholodeck – simulations of surgical interventions, analysis of organ structures, and disease diagnostics.).

Architecture and Design: Students can create and explore virtual models of buildings and spaces, enhancing skills in architectural design and creativity (for example, SketchUp Viewer allows creating and exploring virtual models of buildings and design; Gravity Sketch – a tool for crafting three-dimensional designs and models in a virtual space).

History and Cultural Studies: Virtual reality can recreate historical events, places, and cultural landmarks, aiding students in better understanding of history and culture (for example, Mona Lisa “Beyond the Glass”, which allows exploring and immersing into the virtual reality of the Mona Lisa painting; TimeLooper – Virtual tours to historical events and places).

Linguistics: VR can establish immersive language learning environments where students practice language skills in virtual real-world scenarios (for example, VRChat – a platform for communication and language practice with other users in virtual worlds).

Geography: Students can explore geography by transforming abstract concepts into tangible objects and locations in virtual reality (for example, Google Expeditions, which allows teachers to send students on virtual trips to geographic locations).

Psychology: Virtual reality can facilitate research into psychological states, phobias, and the development of therapeutic techniques (for example, Psious – a virtual simulator for the treatment of phobias and psychological conditions).

Art: Virtual reality opens avenues for creating interactive art projects and exploring new possibilities for artistic expression (for example, Tilt Brush – a creative platform where users can create 3D artwork).

Technical Sciences: Students can delve into engineering principles, developing virtual prototypes and simulations (for example, AutoCAD VR – Create and explore 3D models of virtual prototypes).

Ecology and Environmental Conservation: Virtual reality can aid in studying natural ecosystems and their interaction with humans (for example, EcoSim VR – an Ecosystem simulation to study human interactions and impacts on nature).

It is crucial to consider the specificity of each discipline and adequately prepare for the utilization of VR in the educational process.

Examples of AR applications and their use in education across various disciplines:

Natural Sciences:

Augment - AR Classroom: Augmented reality for studying natural objects and phenomena, such as planets or tectonic plates; Elements 4D: Virtual experiments with chemical elements and compounds.

Medicine: Anatomy 4D: Augmented reality for studying human anatomy, displaying internal organs and their functions.

Architecture and Design: MagicPlan – AR for creating three-dimensional room plans.

History and Cultural Studies: Wallame – Creating virtual exhibitions and informational markers in real-world locations.

Linguistics: Google Translate – using a smartphone camera for real-time translation of writings and texts.

Geography: Landmrk – creating augmented reality landmarks and locations.

Psychology: VirtualSpeech – practicing public speaking and communication skills in a virtual environment.

Art: Artivive – adding augmented reality to art pieces to create interactive explorations.

Technical Sciences: DAQRI – using augmented reality for education and diagnostics in the field of engineering.

Ecology and Environmental Conservation: Junaio – AR for displaying environmental data and information about ecosystems.

These applications demonstrate how augmented reality can enhance learning across diverse disciplines, incorporating visual and interactive elements into the educational process for students.

One of the educational projects offered by us to Specialized school of the city of Kyiv No. 181, named after Ivan Kudria, with in-depth study of foreign languages, was "Face Masks and the environment" (Table 1), during which students have to use AR and VR . The main idea was to make students conscious of the damage caused to the environment by the large amount of face masks discarded by people during Covid-19 pandemic and to make them research the principle behind biodegradable objects. In addition, the main goal of the project is to form STE(A)M skills in students [24].

Table 1

The plan of the project "Face Masks and the environment"

Name of activity	**Procedure**	**Time**
1st Lesson		
Brainstorming and discussion	Why and when do people have to wear masks? Was it the same in the past? When did masks appear first? What was their purpose? How has this item evolved in history?	15 min (discussion) 20 min (students' presentations)
Discussion and preparation for the next lesson	Is it possible to create a face mask that balances air permeability with effective filtration, ensuring a good fit and attractive design, without posing environmental hazards or risks to human health, and without causing allergic reactions? You can offer drawings of models with the help of programs, for example: GeoGebra Math Apps (https://www.geogebra.org); GeoGebra AR (https://www.geogebra.org/m/bcdafv8s), CoSpaces, Metaverse, Blippar, ARBook, BookVAR, Mozabook. Group presentation and demonstration of the used model.	60 min (students work out of school)
2nd Lesson		
STEM Subject 1	**Maths**	
Activity	Students make their research upon statistics from the use of masks and develop their own statistics after the warming-up of the preparation survey.	60 min (students work out of school) 20 min (students' presentations)

Learning products	**Economic analysis, data analysis and reporting for designer and creation masks**	
3rd Lesson		
STEM Subject 2	**Technology and Ecology**	
Activity	– Make an example of augmented reality "face and mask" using any of the platforms such as: ARCore Augmented Images (https://codelabs.developers.google.com/codelabs/augimg-intro?utm_source=google-io&utm_medium=organic&utm_campaign=io21-learninglab#0); Blippar (https://blipps.blippar.com/; Metaverse (https://studio.gometa.io/)); – Make an example of virtual reality "face and mask" using any of the platforms such as: CoSpaces; Metaverse; – Create a Mind map "types of face masks"; "materials for face masks"; "ecology and use of face masks" (https://miro.com)	50 minute lesson
Learning products	This review aims to address the mentioned environmental toll by discussing materials options for more eco-friendly face masks, and analyzing additional functionalities, such as antibacterial, antiviral, and self-disinfection characteristics. Using biodegradable precursors along with such multifunctional properties may be a new approach for controlling the pandemic while caring for our planet and people. The present review focuses on the general filtration mechanisms, manufacturing technologies used to make face mask media, characterization of different surgical face mask structures, biodegradable materials that have been used, desired added functionalities, and the future demands for such effective biodegradable multifunctional face masks. [25]	
4th Lesson		
STEM Subject 3	**Biology**	
Activity	Students should create a medical mask and combine it with art. Explain the choice of material and pattern or other decorations, highlight the benefits of the mask because of its biological characteristics, which are positive for humans, namely, it may be anti-allergic properties, adaptation to the respiratory system, etc.	60 min (students work out of school)

Learning products	*Students should create a medical mask and combine it with art.* *Students should consider the following.* These materials have been used in manufacturing personal protection equipment (PPE) since the beginning of the 20th century. These materials have proven to be capable of withstanding high temperatures during autoclaving without any changes in the structure. Masks are fabricated via melt blowing technique, during which the charges are imparted to the material creating a quasi-permanent electric field providing an adequate filtration of particulate matters (PM) by electrostatic force. The filtration efficiency of the membrane depends upon the structure (pore size, fibre organisation), the charge of the fibres, fibre thickness and diameter, packing density, etc., of the material. It has been concluded that fibres with small diameter and a large surface area that forms small voids when compared to long fibres, leads to increased filtering efficiency. Several studies have been conducted to theoretically explain the process of filtration through electrostatic attraction and impaction by the fibrous medium. An early study concluded that electret filters (non-woven fibres) hold high filtration efficiency with low air resistance and large dust holding capacity when compared to conventional fibrous filters. The filtration works based on electrostatic forces of attraction between the masks matrix and the aerosol particles and depends on the dielectric property of the material. Hence, polymeric materials with high electrical resistance and stability, such as polypropylene, polyethylene, polyacrylonitrile, etc., are the best choices for masks and respirators. However, the hydrophilicity of these polymer surfaces needs to be improved for effective trapping and filtration of aqueous particles. *Surgical masks are modified using a fibrous filtration unit functionalised with sodium chloride (NaCl)*	
5th Lesson		
Non-STEM subject 1	**History**	
Activity	Students read some texts and watch videos about the evolution of masks from their origins up to now.	60 min (students work out of school). 15 min (students' presentations)

Learning products	Virtual exhibition of medical masks - website (graphic designer that combines text and visual); vocabulary or glossary for the project topic with visualization by using CoSpaces, Metaverse, Blippar, ARBook, BookVAR, Mozabook etc.	
6th Lesson		
Non-STEM subject 2	**English**	
Activity	Students watch the following videos and answer some questions offered by the teacher. Group debate will be carried out. "The History of Medical Face Masks", Youtube: https://www.youtube.com/watch?v=7BVHF1H2IFg "The Science behind face masks", Youtube: https://www.youtube.com/watch?v=0V6qupC8B6s	50 minute lesson
Learning products	Students must write a for-and-against essay about the topic: *"The Use of Face Masks during the Pandemic".*	
7th Lesson		
Non-STEM subject 3	**Art**	
Activity	Students must design their own face mask thinking about everything they have learnt about the environment, disposal and biodegradable materials. When they finish, they share the results with their classmates. Students are asked to launch a campaign (prezi/genially/canva/youtube video) to help people become aware of this environmental problem and promote right behaviour.	50 minute lesson + 50 minute lesson (students' presentations)
Learning products	*Production of a mask with a 3d printer and digital presentation.*	

The organization and assessment are also important for the implementation of an educational project.

Assessment of the learning scenario will be both continuous and personalized:

- Initial assessment, namely, during the preparation session, a survey by using the tools of Google suite will provide information about the number of masks people see in different places;
- Formative evaluation, namely, during every subject lesson, different formative assessments will take place in the form of a survey, rubrics, quizzes, presentations, writings, etc. with the purpose of getting information about how students are developing their learning process;

– Final assessment will be carried out by students according to the rubrics prepared by teachers.

Student feedback: each student will be interviewed about the methodology supplied during the teaching process such as PBL, IBSE, the different activities performed, their feelings about the learning process using virtual and augmented reality and outcome and their general satisfaction with the final result of the learning scenario.

This learning scenario will provide us with valuable information about our students' development and learning achievements. Firstly, the initial survey will show the students' digital competence in using the tools of VR and AR. Next, several tests and rubrics will offer relevant information about the students' knowledge of the materials masks are made of as well as their life span, their competence dealing with the collection of data, the evidence of the impact of masks on the environment and the historical evolution of masks. Students' performance in English will offer a general overview of their linguistic competence level. Finally, the creation of their own masks in the Art class will show their creativity as a product of the whole thinking process.

To sum up, thanks to the fulfillment of this learning scenario, our students will be able to answer the real-life questions proposed at the beginning: How masks are harmful to our environment when disposed of and what their effects are; moreover, what makes materials resistant.

After the educational project and seminar "Using AR and VR in the educational process" in 2022, teachers were asked to answer a questionnaire about their attitude to the interaction of participants in educational projects with the use of AR and VR (48 teachers participated in the survey).

In the questionnaire, the respondents had to check "yes", "no", or "don't know" against the following statements (Table 2):

– Students' interaction in VR was successfully organized;
– I personally create VR for my lessons;
– I use ready-made virtual laboratories in class;
– During the interaction of the participants with the help of AR, the teacher provided instructions that were understandable for the students, which improved the learning results;
– Ready-made AR was used for student interaction in the group;
– Students independently created AR examples to present their project results;
– Students independently created VR examples to present their project results;
– There were problems with the organization of VR in the lesson;
– There were problems with the organization of AR in the lesson;
– Methodological recommendations are necessary for organizing the interaction of participants when using educational VR;
– Methodological recommendations are necessary for organizing the interaction of participants when using educational AR.

Table 2

The results of teachers' answers to the questionnaire

Suggested answers	Yes (%)/number of respondents	No (%)/number of respondents	Don't know (%)/number of respondents
Students' interaction in VR was successfully organized	41.67% / 20	58% / 28	-

I personally create VR for my lessons	2.08% / 1	98% / 47	-
I use ready-made virtual laboratories in class	41.67% / 20	58% / 28	-
During the interaction of the participants using AR, the teacher provided instructions that were understandable for the students, which improved the learning results	72.92% / 35	25%25%/ 12	2.08% / 1
Ready-made AR was used for student interaction in the group	37.5% / 18	63.5% / 30	-
Students independently created AR examples to present their project results	85.42% / 41	10.42% / 5	4.17% / 2
Students independently created VR examples to present their project results	4.17% / 2	95.83% / 46	-
There were problems with the organization of VR in the lesson	81.25% / 39	18.75% / 9	-
There were problems with the organization of AR in the lesson	14.58% / 7	85.42% / 41	-
Methodological recommendations are needed for organizing the interaction of participants when using educational VR	100% / 48	-	-
Methodological recommendations are necessary for organizing the interaction of participants when using educational AR	16.67% / 8	83.33% / 40	-

Looking at the statistics, several observations can be made:

Interaction of students in virtual reality (VR):

The majority of the respondents (41.67%) agreed that the interaction of students in VR was successfully organized.

A significant portion of the respondents (58%) reported being dissatisfied with the organization of interaction in VR.

Creation of VR for lessons:

Nearly all the respondents (98%) answered that they did not create VR for their lessons personally.

Use of ready-made virtual laboratories:

Approximately half of the respondents (41.67%) used ready-made virtual laboratories in their lessons.

The other half (58%) did not use ready-made virtual laboratories.

Interaction of participants through augmented reality (AR):

The majority of the respondents (72.92%) stated that providing clear instructions through AR improved learning outcomes. However, 25% of the respondents answered "no," indicating potential insufficiency in providing instructions through AR.

Creation of AR by students for project presentations:

A significant majority of the respondents (85.42%) created AR examples independently for presenting their project results.

Issues with organizing VR and AR in the classroom:

A significant majority of the respondents (81.25%) faced problems with organizing VR in the classroom. Some respondents (14.58%) also mentioned issues with AR.

Continuing the analysis, the following observations can be made:

The necessity of methodological recommendations:

All the respondents (100%) believed that methodological recommendations for organizing participants' interaction in educational VR are necessary.

Meanwhile, only 16.67% of the respondents answered that they required methodological recommendations for organizing participants' interaction in educational AR.

Table 3

Results of Excel calculations

Arguments	***Mean***	***Standard Deviation***
Interaction among students in VR was successfully organized	0.4167	0.239
Personally creating VR for lessons	0.0208	0.144
Using pre-made virtual laboratories during lessons	0.4167	0.239
When participants interacted through AR, teachers provided understandable instructions that improved learning outcomes	0.7292	0.447
Utilizing pre-made AR for student group interaction	0.375	0.488
Students independently created AR examples for presenting project results	0.8542	0.355
Students independently created VR examples for presenting project results	0.0417	0.202
Encountering problems with organizing VR during lessons	0.8125	0.393
Encountering problems with organizing AR during lessons	0.1458	0.355
Need for methodological recommendations regarding participant' interaction when using educational VR	1.0	0.0
Need for methodological recommendations regarding participant' interaction when using educational AR	0.1667	0.376

During calculations, the following formulas were used:

Mean (Average): Calculated by summing all values and dividing by the number of observations.

Standard Deviation: A measure of the dispersion of values from the mean. Formula: Standard Deviation = $\sqrt{(\Sigma(xi - Mean)^2) / n}$, where xi is each individual value, Mean is the mean value, Σ signifies summation, and n is the number of observations.

Overall, satisfaction and effectiveness levels vary in the use of virtual and augmented reality in education. Positive impacts are highlighted, especially with clear instructions. However, issues with organizing VR and AR in lessons are noted, emphasizing the need for methodological recommendations in using these technologies.

Many respondents acknowledge the positive impact of VR and AR on learning, particularly when clear instructions are provided. However, there are concerns regarding the organization of VR and AR in the classroom, as well as the need for methodological recommendations for using these technologies. This analysis can serve as a basis for further research and development of virtual and augmented reality in the education sector, aiming to improve the learning process and engage students in active interaction.

The results of the questionnaire showed the following:

- the participants' interaction in the educational process with the use of VR needs improvement, methodological recommendations and research on the organization of this environment for various purposes, such as, for example, students' research of new educational material, performance of laboratory work, joint work of students on research, instructions for the teacher's activities in working with students in VR, etc.;
- teachers and students best comprehend the interaction in the educational process when using AR; they use ready-made AR technologies, as well as personally created ones.

While analyzing the experiment results, we were able to identify the key factors contributing to successful student interaction in VR (Table 4) and AR environments (Tables 5).

Table 4

Factors of successful student interaction in VR

Factor	Factor Description
Quality of VR Environment	The quality of graphics, sound, and immersion in the VR environment plays a significant role in student interaction. The more realistic and engaging the environment is, the higher the likelihood that students will be interested and engaged [26]
Interpersonal Communication	Successful interaction in VR requires effective interpersonal communication. Audio and visual elements, such as voice chat and facial expressions, can help create more natural communication among students.
Collaborative Activities	VR can facilitate collaborative activities among students, such as interactive tasks, projects, or educational games that require joint efforts and promote interaction and cooperation
Feedback and Assessment	A feedback and assessment system can stimulate student interaction in VR. It creates competition, motivates students to achieve, and provides an opportunity for objective assessment of learning outcomes

Table 5

Factors of successful student interaction in AR

Factor	Factor Description
Quality of AR Environment	The quality of graphics, realism of visual effects, and their integration with the real environment are crucial for successful interaction. The more AR enables the integration of virtual objects into the real world, the greater the interaction and engagement of students [27].
Interpersonal Communication	Interactive AR can stimulate student interaction by allowing them to manipulate virtual objects in real-time. Interactive tasks, practical exercises, or the ability to interact with objects in the real environment promote active learning and material comprehension. Accessibility and Mobility AR technologies can be available on various devices such as smartphones or tablets, making them more mobile and accessible for students. This allows for AR sessions to be conducted anywhere and at any time
Collaborative Activities	Collaboration AR can facilitate collaborative activities among students, enabling them to solve tasks together, combine their AR objects, or exchange information in real-time while working on projects
Feedback and Assessment	A feedback and assessment system can stimulate student interaction with AR. It motivates students to achieve and provides an opportunity for objective assessment of their learning achievements.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Overall, both virtual reality and augmented reality offer many unique features for participants’ interaction in an educational environment. From immersive and interactive learning environments to personalized and inclusive learning experiences, these technologies have the potential to transform the way we teach and learn. As technology continues to evolve, it is likely that virtual and augmented reality will play an increasingly important role in the future of education.

So, as a result of the conducted research, we can single out the following models.

Student-Teacher Interaction, which includes:

a. Facilitating personalized instruction and feedback in VR and AR environments.
b. Expanding the role of teachers as guides and facilitators in immersive learning experiences.
c. Leveraging VR and AR to foster active student engagement and collaborative learning.
d. Peer Interaction and Collaboration, which includes:
e. Promoting peer-to-peer learning and knowledge sharing through VR and AR simulations.
f. Encouraging cooperative problem-solving and teamwork in virtual and augmented environments.
g. Enhancing communication and social skills through collaborative projects using VR and AR.

Learner Autonomy and Personalized Learning, which encompasses:

a. Empowering students to take ownership of their learning in VR and AR settings.
b. Customizing educational experiences to meet individual learning styles and preferences.
c. Providing opportunities for self-paced learning and exploration in virtual and augmented realities.

Interface Design and User Experience, which includes:

a. Designing intuitive and user-friendly interfaces for seamless interaction in VR and AR.
b. Considering factors such as comfort, immersion, and accessibility in interface design.
c. Balancing realism and functionality to optimize user experience in educational applications.

Assessing Learning Outcomes, which includes:

a. Developing assessment methods suitable for evaluating learning in VR and AR environments.
b. Measuring cognitive, affective, and behavioral outcomes resulting from immersive experiences.
c. Exploring the potential of data analytics and learning analytics in assessing student performance.

In conclusion, the use of virtual and augmented reality technologies in the educational process provides a wealth of teaching and learning resources that can enhance the learning experience and free participants from limitations in time and space. However, the effective organization of interaction between participants in the educational process using VR and AR requires careful consideration of educational space and relevant pedagogical and methodological recommendations.

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ВЗАЄМОДІЯ В ОСВІТНЬОМУ СЕРЕДОВИЩІ З ВІРТУАЛЬНОЮ ТА ДОПОВНЕНОЮ РЕАЛЬНІСТЮ

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Анотація. Стаття присвячена проблемі та особливостям використання віртуальної та доповненої реальності в закладах загальної освіти. Інтеграція віртуальної реальності (VR) і доповненої реальності (AR) в освітнє середовище відкрила нові можливості для залучення та захоплюючого навчання учнів. Ця стаття спрямована на дослідження особливостей взаємодії учасників в освітньому контексті з використанням технологій VR та AR. Для досягнення мети нашого дослідження, а також з’ясування проблеми визначення особливостей моделей взаємодії учасників навчально-виховного процесу закладу загальної освіти з використанням віртуальної та доповненої реальності були використані методи: системного та порівняльного аналізу педагогічних, психологічних, філософських, соціологічних праць, методичної та спеціальної літератури; аналіз педагогічного досвіду використання віртуальної та доповненої реальності в закладі загальної освіти; синтез і узагальнення для формулювання основних положень дослідження; інтерпретація результатів дослідження. Дослідження проводилось у закладі загальної середньої освіти, де розроблено та реалізовано навчальний проєкт з використанням віртуальної та доповненої реальності. Метою проєкту було дослідження проблеми взаємодії учасників освітнього процесу при використанні цих технологій. Результати анкетування показали наступне: взаємодія учасників навчального процесу з використанням ВР потребує вдосконалення, методичних рекомендацій та досліджень щодо організації цього середовища для різних цілей, наприклад, дослідження учнями нових освітніх матеріалів, виконання лабораторних робіт, спільна робота учнів над дослідженням, вказівки щодо діяльності вчителя в роботі з учнями у ВР тощо; взаємодія учасників навчального процесу з використанням доповненої реальності надає можливості взаєморозуміння вчителів та учнів, крім цього, вони використовують як готові AR-технології, так і власноруч створені. Ми дійшли висновку, що віртуальна та доповнена реальності пропонують багато унікальних можливостей для взаємодії учасників освітнього середовища. Від захоплюючого та інтерактивного навчального середовища до персоналізованого та інклюзивного навчання - ці технології мають потенціал змінити спосіб та методи навчання. Оскільки технології продовжують розвиватися, цілком імовірно, що віртуальна та доповнена реальності відіграватимуть дедалі важливішу роль у майбутньому освіти.

Ключові слова: доповнена реальність; віртуальна реальність; взаємодія учасників; освітнє середовище; занурення в навчання.