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Augmented reality in higher school as a tool for implementation of STEM education

Доповнена реальність у вищій школі як засіб реалізації STEM-освіти

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Abstract

The article provides a meaningful definition of the concepts of STEM technology, STEM education, STEM approach, and STEM training; the meaning and main ways of using elements of augmented and virtual reality for higher education as a means of implementing STEM education are revealed. The purpose of the article is to show the importance and necessity of using elements of augmented reality in higher education as a means of implementing STEM education. As a result, an experimental study was conducted to clarify the state of development and the use of modern innovative technologies in education, clarifying the question – of to what extent modern technologies can effectively organize distance learning, and STEM education in higher education when using elements of augmented reality, which are provided to messengers preference of educators, which

Анотація

У статті подано змістовне визначення понять STEM технології, STEM-освіта, STEM-підхід та STEM навчання; розкрито значення та основні способи використання елементів доповненої та віртуальної реальності для вищої школіи як засобу реалізації STEM-освіти. Мета статті – показати важливість і необхідність використання елементів доповненої реальності у вищій освіті як засобу впровадження STEM-освіти. У результаті проведене експериментальне дослідження з метою з'ясування стану розвитку та використання сучасних інноваційних технологій в освіті, з'ясування питання – наскільки сучасні технології можуть дозволити ефективно організувати дистанційне навчання, STEM-навчання у вищій школі при використанні елементів доповненої реальності, яким месенджерам надають перевагу освітяни, які

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platforms are used by teachers in working with students of higher education during quarantine, etc. The conclusions summarize the most effective modern technologies for preparing and conducting practical online classes in higher education as a means of implementing STEM education and highlight the most important condition for creating a STEM environment in higher education.

Keywords: elements of augmented reality, higher school, STEM education, students of higher education, modern innovative technologies in education.

платформи використовують викладачі у роботі із здобувачами вищої освіти під час карантину, тощо. У висновках узагальнено найдієвіші сучасні технології підготовки та проведення практичних онлайн-занять у вищій школі як засобу реалізації STEM-освіти та виокремлено найважливішу умову створення STEM-середовища у вищій школі.

Ключові слова: елементи доповненої реальності, вища школа, STEM-освіта, здобувачі вищої освіти, сучасні інноваційні технології в освіті.

Introduction

The growing demand for competent specialists in high-tech industries who can creatively approach complex professional scientific activities and the innovative latest processes of socio-economic development of society contributed to the development and formation of the pedagogical innovation of the 21st century – the educational direction of STEM education, the implementation of which began in 2009 in the USA on at the state level from the "Educate to Innovate" program. Throughout the world, the ideas of the STEM approach in the field of education are supported by many educational systems in different countries (Polikhun et al., 2019).

In the field of education, one of the main factors of innovative activity, one of the priorities of the renewal of education is the strengthening of the role in the training of STEM-education specialists, which is an integral part of the state policy of any country to increase the development of human capital, the level of competitiveness of specialists who can implement qualitatively state innovations through continuous work in the field of education, own professional development and the national economy, which meets the needs of society and the demands of the economy (Drokina, 2023).

The use of modern technologies is one of the main principles of the development of STEM education. Augmented and virtual reality technology, artificial intelligence, virtual assistants, 3D printers, holograms, etc., are the technologies of the future, which now cover the educational sector, and are increasingly becoming the subject of scientific research. In the last century, these technologies were used in special scientific laboratories and were considered science fiction, but today they gradually fill all spheres of human life (Honcharova, 2021). Nowadays, virtual reality devices have become more common and available, and the task of pedagogy and science has become the search for ways to effectively use this technology. Therefore, the use of elements of augmented reality in higher education as a means of implementing STEM education is relevant, timely, and necessary, which is what our research is aimed at.

The advantages of STEM education are:

1. Integrated training. STEM combines a project-based and interdisciplinary approach that is currently recognized as the best by teachers around the world.
2. Application of acquired knowledge in real life. STEM demonstrates how children can use the information they receive in life. Students will study not just abstract data, they will study a concrete project, and then they will create their own project of a certain product.
3. Development of critical thinking. Schoolchildren should learn to navigate independently even in difficult situations and solve problems without outside help, based on the experience gained, analogies, and generalizations.
4. Confidence in one's own capabilities. The practical implementation of an idea provides moral satisfaction and increases the child's self-esteem.
5. Work in a team. Schoolchildren work together, express their ideas and proposals, discuss, justify their positions, and come to certain conclusions together
6. Increasing interest in technical disciplines. Students will see that being an engineer or a mathematician is not boring at all, but rather fun and interesting.

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7. Innovativeness. This is a special approach that allows you to study and apply technologies and sciences at the same time.
8. The direct path from education to career. Shortly, the demand for specialists in such specialties as chemical engineers, computer systems analysts, robotics engineers, nuclear medicine engineers, architects of underwater structures, etc. is expected to increase.
9. Preparation for rapid technical development. One of the main tasks of modern education is to create conditions for the comprehensive development of schoolchildren, taking into account the capabilities of everyone, then STEM education is an ideal option.

STEM education is aimed at maintaining a constant interest and encouraging students to pursue a career and their own research in a certain field. In the article, we highlighted the main aspects of this problem: a meaningful definition of STEM technology, STEM education, STEM approach, and STEM learning; the importance of using elements of augmented and virtual reality in higher education as a means of implementing STEM education; the main ways of using augmented reality in higher education as a means of implementing STEM education; modern technologies for preparing and conducting practical online classes in higher education as a means of implementing STEM education; the most important condition for creating a STEM environment in higher education; the use of elements of augmented reality in higher education as a means of implementing basic competencies in the formation of a STEM specialist.

Literature review

With the transition to new indicators of the quality of maritime education, by which competencies are recognized, the problems of strengthening the practical orientation of professional education, organizing productive independent work, and using modern digital technologies in the educational process. In the system of higher education, the search for new directed professional practice-oriented forms of education has begun, the purpose of which is to effectively ensure the formation of professional competencies of future maritime specialists on principles of electronic, blended learning, continuous education, use of simulation technologies, simulators of augmented, mixed and virtual reality, etc.

The essence, structure, and significance of the competence approach in the system of modern maritime education, and the peculiarities of the formation of professional competencies in future shipmasters are highlighted in the works of many scientists.

Modern works of scientists are aimed at using the latest technologies in the field of education. Thus, with the aim of quality training of future teachers of STEM disciplines, M. Mintii (2023) improved the content of the professional training of specialists and theoretically substantiated the identified pedagogical conditions of preparation for the application of augmented reality technologies in the professional activity of future teachers of STEM disciplines. A. Drokina (2023) will prove that immersive technologies are a powerful tool for the implementation of STEM education, in particular augmented reality technologies, which make the educational process interactive and exciting, and the use of augmented reality technologies contributes to the intensive search for knowledge in students of education and the formation of cognitive interest in learning and provides the possibility of an effective means of introducing STEM education by future specialists, already during practice, involving them in scientific and technical creativity, stimulating their curiosity.

Dulce-Salcedo, O. V., Maldonado, D., & Sanchez, F. (2022). analyzes the relationship between being exposed to female STEM teachers during secondary education and female graduates' enrollment in tertiary STEM programs.

Buitrago, L. M., Laverde, G. M., Amaya, L. Y., & Hernández, . S. I. (2022). emphasize on the results of the reflection shows that: a. in addition to computational thinking, STEM strategies allow the development of 21st-century skills, b. students with disabilities respond in an assertive and motivated way, c. Peer work enriches own and collective learning, d. the greater the number of teachers linked, the more coverage the project reaches.

Bascopé, M., & Reiss, K. (2021) analyze STEM projects conducted in eight schools with children from 4 to 10 years old in southern Chile. The main purpose of the study was to describe and analyze how these projects can affect students' and educators' attitudes and create community capacities to tackle local socioecological challenges.

Macías, W., Rodríguez, K., Arosemena-Burbano, F., & Zhangallimbay, D. (2023) show that the purpose of this study was to

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evaluate whether the variables that reside in the consumer's mind, such as brand awareness, associations, and evaluation of choice determinants, are significant in explaining the intention to enroll and recommend a higher education institution.

Laurens-Arredondo, L.A. (2022) evaluates the use of m-learning in university students for STEM learning, in times of pandemic, through the use of a mobile application, which was used by students to determine kinematic variables.

The research of N. V. Horbachenko (2021) showed the need for virtual reality in education to increase its level through immersion and integration with academic disciplines. S. Semerikov, S. Lytvynova & M. Mintii (2020) also analyzed the experience of using augmented reality technology in the educational space; conducted an overview of augmented and virtual reality tools, and showed the expediency of sharing the Unity environment, the Visual Studio programming environment, for visual design, augmented (Vuforia or other) and virtual (Google VR or other) reality platforms related to STEM disciplines. Valuable is the research of S. Lytvynova (2022), who in the field of education identified the key directions of VR research, described the main components characterizing virtual reality (immersion, involvement, interaction) that are characteristic of this technology, in particular: features of conducting practical and laboratory work, which in it is impossible to carry out traditional learning conditions, the development of multisensory learning, the development of the spatial imagination of students of higher education, the improvement of the quality of STEM education. O. Pinchuk & L. Luparenko (2022) revealed ways of practical application of augmented and virtual reality technologies in production, corporate training, and business. In particular, the scientists showed the features of the application of augmented reality technology in the educational process: the application of Khan's generalized model of electronic education; based on augmented reality technology – educational digital content; augmented reality technologies and game activity; with the support of augmented reality technology – a review of educational mobile applications.

So, summing up the use of information and communication technologies in the modern educational process, we can say that an important trend is the use of virtual reality technologies.

Modern works of scientists are aimed at using the latest technologies in the field of education. Thus, the content of the professional training of specialists has been improved and the pedagogical conditions of training for the application of augmented reality technologies in the professional activity of future teachers of STEM disciplines have been theoretically substantiated; the possibilities of applying augmented reality applications during distance learning in the educational process are described, the possibilities of virtual reality applications are highlighted to form the necessary skills for a career in STEM professions.

As a result of the analysis of practical experience, in the preparation of future teachers for the use of Augmented Reality in higher education as a means of implementing STEM education several contradictions between:

- the need for higher education institutions for teachers who are ready to use Augmented Reality in higher education, and the insufficient level of development of the theoretical and methodological aspects of the application of these innovations;
- the need to intensify the process of using Augmented Reality in higher education and the lack of theoretically grounded pedagogical conditions for its implementation;
- the need for methodical support of the process of using Augmented Reality in higher education and the unsatisfactory state of program content and organizational-methodological support in the practice of higher education institutions;
- the presence of the potential means of using Augmented Reality in higher education and the insufficient level of provision of pedagogical conditions.

The relevance and significance of the problem, the lack of its theoretical and methodical treatment, the need to find practical mechanisms for the use of Augmented Reality in higher education, and the possibility of resolving these contradictions determined the choice of the topic of our article.

The purpose of the article is to show the importance and necessity of using elements of augmented reality in higher education as a means of implementing STEM education.

Methodology

The systematic method was singled out by the general scientific method, which we applied for

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a comprehensive study of the features of the use of augmented reality elements in higher education as a means of implementing STEM education.

Theoretical methods were used: comparative-historical – to evaluate the historical-social prerequisites for the formation of a system of using elements of augmented reality in higher education as a means of implementing STEM education; structural – to identify the factors of qualitative changes in the use of elements of augmented reality as a means of implementing STEM education in the conditions of graduate education; classification and systematization of data – to analyze the structure and content of elements of augmented reality in higher education as a means of implementing STEM education; empirical – conducting research and experimental work; analysis of the results of educational activities of higher education applicants and teaching activities; surveys, questionnaires of respondents; expert assessment; observing the activities of teachers and students regarding the use of elements of augmented reality in higher education as a means of implementing STEM education; statistical – processing of experimental data obtained for the purpose of quantitative and qualitative analysis of experimental research results.

We conducted a study in 2022-2023 to find out: the state of development and use of modern innovative technologies in education, to what extent modern technologies can effectively organize distance learning, in particular STEM-learning in higher education using elements of augmented reality, which messengers educators prefer, which platforms are used by teachers in working with students of higher education during quarantine, etc.

Respondents were scientists, teachers of higher education institutions, administrators of educational institutions, and methodologists.

The survey of respondents was carried out by online filling in Google forms, anonymously.

The total volume of the sample is 62 subjects. When forming the sample, the criteria of meaningfulness, representativeness, and equivalence were taken into account. The sample was formed by random selection using the technical procedure for calculating the selection step.

The implementation of the pedagogical experiment was carried out in three stages: preparatory, main, and final.

At the preparatory stage, the purpose and tasks of the research were determined, the experimental plan was developed, methods of measurement and processing of results were selected, control and experimental groups were selected, and their homogeneity was checked.

At the main stage, an experiment was conducted. At the final stage, the results of the experiment were analyzed, their reliability was confirmed, and conclusions were drawn about the pedagogical effect of the experiment.

The reliability and validity of the obtained results, and the objectivity of their assessment were ensured by the methodological soundness of the initial positions and the qualitative mechanism for evaluating the quality under study, the use of a complex of complementary research methods, and the involvement of a group of respondents from a higher educational institution in the analysis of its results.

To assess the homogeneity of experimental and control data, statistical processing was performed using MS Excel and SPSS (Statistical Package for Social Science).

Research relies heavily on the accuracy and reliability of the data. In research work, the quality of data collection and analysis not only adds weight to the research but also contributes to the formation of sound conclusions, which is the key to academic success.

The following digital data collection tools were useful in the study:

- Google Forms - a simple tool for creating surveys that allows you to collect data from respondents, create different types of questions, and collect answers in spreadsheets.
- SurveyMonkey - a modern survey tool that offers a wide range of customization options and analytical tools for analyzing the collected data.
- JSTOR, Google Scholar, and other academic search engines provide access to scholarly articles, books, and other academic resources that may be useful for literature review and theoretical data collection.
- Zotero or Mendeley - bibliography management programs that help organize research materials, store references, and format bibliographies and citations according to different citation styles.

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- Microsoft Excel or Google Sheets - spreadsheets are useful for organizing and analyzing collected data when working with quantitative data.
- SPSS, R, or Python for more advanced data analysis, statistical analysis, and processing of volumes of data.

The results of the experimental study confirmed the applicability, optimality, and effectiveness of the proposed pedagogical conditions for the formation of an environmental culture of an ecologist in the process of professional training.

Results and discussion

A meaningful definition of STEM technology, STEM education, STEM approach, and STEM learning.

STEM education is defined as the educational activity of the subjects of the pedagogical process aimed at improving or forming relevant competencies in higher education seekers. The concept of "STEM technology" is interpreted as modern technological and instrumental-technical means that ensure the mastery of higher education students with scientific research, primary engineering-technological skills, and knowledge, as well as the formation of the values of STEM education in them (Valko, 2020). The origin of the abbreviation STEM from Science, Mathematics, Engineering, Technology (science, engineering, technology, mathematics). New versions of this concept based on STEM have also appeared, the most common of which are: STEAM (technology, science, art, engineering, mathematics), STREAM (robotics, technology, science, engineering, mathematics, art) (Drokina, 2023).

In STEM education, the approach is based on the construction of individual didactic elements, and educational disciplines on an interdisciplinary basis (according to certain topics – integrated learning, not individual disciplines) with the use of the latest innovative educational technologies: social, cognitive and knowledge transfer (Stryzhak et al., 2017).

Immersive technologies are effective means of implementing modern STEM education (eng. immersive – to immerse) – various types of mixing of augmented, virtual, and real reality or technology of partial or full immersion in the virtual world. Immersive technologies are also called augmented reality technologies. They provide the effect of partial or full presence in an alternative space and change the experience in completely different areas intended for the user. These technologies combine Augmented Reality (AR) and Virtual Reality (VR) or partial or full immersion in the virtual world.

The importance of using elements of augmented and virtual reality in higher education as a means of implementing STEM education.

The use of elements of augmented reality in higher education as a means of implementing STEM education allows combining various types of digital data (video, text, graphics) with objects of the real environment displayed on the screen of gadgets, which provides opportunities for creating an effective innovative educational space. Speaking about the importance and considering the essence of MixedReality, it can be argued that it is a way of embedding non-existent virtual objects into our usual environment, a complex combination of augmented reality and virtual (Oleksiuk & Oleksiuk, 2021). Nowadays, immersive technologies are not systematically implemented in educational practice, but they are only at the stage of selection, design, the approbation of the user environment, and the development of methods for using such an environment (Lytvynova, 2023).

The main ways of using augmented reality in higher education as a means of implementing STEM education.

Let's highlight the main methods of using augmented reality for training students of higher education:

- material visualization;
- interactive activities;
- maximum productivity and efficiency;
- teamwork;
- method of cooperation;
- transparent and fair monitoring of results (Aleksov & Didyk, 2023).

We believe that this classification is the most productive in higher education. It is she who reveals the possibilities of implementing AR in the educational process of higher education students.

The diverse spectrum of AR technologies that exist today requires the future specialist not only to practice their skills well but also to master the methods of their application well in their professional activities.

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In any form of STEM education (project, class, quest, hackathon, etc.), the use of augmented reality technologies contributes to the successful implementation of new professional roles by a modern specialist. With this approach, the mentor's role is completely changed to a mentor, facilitator, innovator, and tutor, and higher education students turn into innovators and researchers. A teacher who observes the progress of scientific research introduces innovations into the educational intellectual activity of pupils, inspires and supports them through pedagogical interaction, identifies educational requests, stimulates them to conclusions, helps eliminate shortcomings, and understands their cause.

During STEM classes, students implement a wide variety of ideas, generating them, based on the available materials and the set goal – plan their activities. The features of this approach optimize the educational process as much as possible, allowing the teacher to successfully solve educational tasks of a professional orientation.

STEM projects, which involve integrated research activities of students of higher education: contribute to the critical evaluation of the obtained results, the search for ways to solve problems, the formation of a scientific worldview in students, and the provision of a favorable psychological-pedagogical atmosphere for collective discussions. Students of higher education learn to interact in a team, actively express their opinions, and are not afraid to present their results. The creation of a STEM project involves innovation and multi-subjects since students of higher education comprehensively apply knowledge of engineering, mathematics, etc., using digital technologies (Drokina, 2023).

Modern technologies for preparing and conducting practical online classes in higher education as a means of implementing STEM education.

Let's consider the most important modern technologies for conducting and preparing practical online classes.

Automated, remote access laboratory workshops using network technologies: synthesis of virtual reality, multimedia technologies, and presentations. The value of laboratory practicums is the ability to simulate the work of stand-alone unique equipment of real operating factories, the ability to organize the practical part of the educational process online, to get rid of the insufficient material base of educational institutions, as problems of individual villages, regions, problems of institutions where there are no large manufacturing enterprises (Plakhotnik et al., 2023).

Smart Virtual Classroom – technology enables the teacher to display drawings, text, presentations, and graphics, create a joint educational product, use the electronic notebook of a student of higher education, monitor knowledge, etc. on an interactive whiteboard.

Game-based learning technology – provides continuous learning that uses the principles of game organization, simulates a real situation, and provides an opportunity to establish a connection between real life and the theoretical material of classes.

Organizing classes in the virtual classroom and creating a program requires the use of modern means of the educational process (Shetelya et al., 2023).

Let's consider some of them.

Web Whiteboard – a white web board that facilitates the creation of graphic content in a team, the organization of "brainstorming", provides an opportunity for several participants to draw diagrams at the same time, and can connect remote participants.

Trello is an online manager that is convenient and greatly simplifies the organization of joint work in a group; provides an opportunity to monitor compliance with the calendar schedule, create tasks by project, comment, attach files, highlight priority tasks with the desired color, create projects and add as many participants as you like.

Breakout rooms are virtual rooms for the organization of simultaneous studies in small groups of higher education seekers. The resource uses modern information and communication technologies for joint work with text and video material.

For education, Google services include an ad-free and free set of tools for teachers and students to effectively and successfully interact, learn, and teach.

Google Google Docs – internet services – text editors that provide an opportunity to make marks on the downloaded image, build a diagram, and quickly draw a block diagram

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without leaving the browser. Based on these tables, charts are created that interact with other Google services and are stored in the Google Cloud.

Google services are separate web applications that are interconnected by a repository of all information and a single account, but a browser and an Internet connection are required to access the information.

Google Sites is a simple site builder, available for games to test knowledge, publishing test materials, provides informational material for laboratory work, classes, etc.

Google Forms is an online service that provides various quizzes and surveys, feedback, creation of tests, and questionnaires. The user configures the questionnaire with the required fields, sends a link to it to the participants of the educational process, and receives, based on the answers received, access to statistics. The forms are designed with images and videos to your own taste. A Google table is automatically created when creating a form, in which the results of filling out the form are stored and accumulated. The table serves as a convenient storage and processing of the collected data.

Google Disk is necessary for creating backup copies of your files in the cloud storage and accessing them both from a computer and mobile devices.

Google Mars is an important service for geographers.

Google Alerts is a service for notification and detection of content changes.

Google Body is a visualization of an anatomical 3D model of the human body.

Among the educational community of higher education institutions, Google services are also in demand:

Google Calendar – an online calendar;
Gmail – free e-mail;
Google Docs – online office;
Google Sites – free hosting that uses wiki technology;
YouTube – video hosting;
Google Translate is a translator.

All the Google services mentioned above provide tools for students of higher education and teachers of an educational institution, which are necessary for joint work and effective communication. Scientific and research virtual sites ensure the creation of a STEM environment in a higher education institution, network interaction of subjects, and mutual learning (Polikhun et al., 2019).

In the educational process of higher school, today, modern technological devices iPhone, iPad, etc. are increasingly used, which provide remote work with online resources through the use of applications Epson, Android, Projection, etc., using wireless technology. These devices make it possible to conveniently and easily receive all the advantages of using modern technologies in the organization of the educational process: seminars, video conferences, presentations, remote classes, control of learning results, etc. Computer-mediated interaction is an advantage. It became popular when the following social networks appeared: Facebook, MySpace, media sites YouTube, Flickr, commercial sites eBay. These Internet projects are well-known and have the following common characteristics: service-oriented design, open APIs, and the possibility of remote hosting of media files and data.

In higher education, devices with the support of virtual and augmented reality (VR/AR) are increasingly popular, which assist in simulating comfortable conditions for acquiring knowledge, while creating with the effect of involvement an innovative environment that the student of higher education perceives through the senses (mobile VR/AR-enabled and software applications, virtual helmets, etc.).

The most important condition for creating a STEM environment in higher education.

A hardware module with software is the most important condition for creating a STEM environment. It consists of:

- software for automating the activities of various services (personnel accounting, accounting of subjects of the information environment, library automation, performance monitoring, etc.);
- general purpose software (spreadsheets, graphic and text editors, etc.);
- information resources of the educational institution (multimedia educational developments, educational and methodical data banks, website, unified databases, document storage, etc.);
- software and methodological support (electronic guides, developmental and

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educational computer programs, multimedia encyclopedias, etc.) (Polikhun et al., 2019).

The use of elements of augmented reality in higher education as a means of implementing basic competencies in the formation of a STEM specialist.

The main signs of the formation of digital competence are the ability to manage information, protect data, content, and digital identities; program, access, use, evaluate, filter, create, and distribute digital content; to effectively work with artificial intelligence, devices, programs, and robots.

With a projection on the educational STEM environment, we highlight the main characteristics of a specialist's competence: update and distribution of digital content; critical thinking; combination of methods of activity, classification; and creativity in use.

Working with digital technologies and their content requires a higher education student to have a safe, ethical, responsible approach to the use of innovative tools; and a critical and reflective, open, inquisitive, and perspective attitude towards their development. Therefore, the main competencies in the formation of a STEM specialist are goals; business; creativity; communication; promotional activity; IT (ability); development of interests; self-controlling orientation; awareness of needs; epistemological, informational, knowledge orientation; critical thinking; distribution of digital content, its updating; creativity in use, combination of methods of activity.

The implementation of the STEM education model process in the educational process of a higher school using elements of augmented reality will allow students to develop such STEM competencies as the ability to:

- pose a problem;
- regarding the solution of certain problems, understand the possibility of other points of view;
- to formulate and determine the ways of solving the research task;
- apply knowledge in different situations;
- to develop interdisciplinary projects in the field of STEM education;
- originally solve the problem;
- to monitor and forecast needs that can be realized using STEM;
- apply thinking skills at a high level.
- teach using project method technology, case studies, etc. (Rakhmanina et al., 2022).

Key aspects of the STEM approach in higher education when using elements of augmented reality:

- integration into a single paradigm of the methodology and content of sciences, and modern technologies, in particular, engineering design, information, and mathematical tools;
- by certain topics, and not individual disciplines of the application of integrated education;
- designing programs and curricula on an interdisciplinary basis;
- application of social technologies and cognitive technologies, knowledge transfer;
- training on real technical and technological, socially significant, and economic problems;
- emphasis on the formation of complex engineering and scientific thinking.

The peculiarity and main components of the STEM educational environment. STEM education is based on the use of equipment and modern tools related to electrical engineering, computing, scientific research in the field of energy-saving technologies, energy, technical modeling, informatics, multimedia technologies, automation, robotics, telemechanics, intelligent systems, radio electronics, radio engineering, cosmonautics, aviation, aerospace engineering, etc. In the educational environment, innovations in STEM education relate to all its components – informational and technological, spatial and material, social and personal.

The main components of the STEM education environment are:

- elective courses, integrated training programs focused on the formation of competencies (educators and specialists from certain fields of knowledge must be involved in the creation of creative content, as well as representatives of business and industry);
- practice-oriented training within STEM disciplines and beyond them;
- interdisciplinary principles of education, which solve real practical tasks in conditions of shortage of academic knowledge;
- emphasis on team, project, and group work of students of higher education; dominant organizational forms are integrated classes, projects, quests, excursions, cases, thematic

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days, scientific exhibitions, competitions, hackathons, festivals of engineering projects, etc.;
- zones of activity in the audience: presentation zone, zones of development and interaction, research and creativity, etc.;
- modern teaching aids, containing educational robots-constructors (LEGO Mindstorms, LEGO, Cubelets, MakeBlock, LittleBits, etc.), which create learning in a game form, allow putting forward your own ideas, familiarize yourself with electronics, the basics of robotics, programming, mechanics, with using various sensors for navigation to create complex designs and implement them in practice, microprocessors and programming, digital measuring complexes, network and remote tools of project management and cooperation, which ensure the principle of equal access to quality education for students of higher education and their special needs;
- interaction with parents;
- cooperation and attraction of resources between external participants and educational teams: academic research institutions, institutions of higher education, research laboratories, centers, museums, business structures, enterprises, public organizations, etc.;
- systematic monitoring of the results of educational activities (Polikhun et al., 2019).

Experimental research aimed at clarifying the state of development and use of modern innovative technologies in education.

We conducted a study in 2022-2023 to find out: the state of development and use of modern innovative technologies in education, to what extent modern technologies can effectively organize distance learning, in particular STEM-learning in higher education using elements of augmented reality, which messengers educators prefer, which platforms are used by teachers in working with students of higher education during quarantine, etc.

Respondents were scientists, teachers of higher education institutions, administrators of educational institutions, and methodologists.

The survey of respondents was carried out by online filling in Google forms, anonymously.

The questionnaire questions were as follows.

1. "Do modern technologies in higher education, when using elements of augmented reality, make it possible to effectively organize STEM training and distance learning?" The respondents gave the following answers:

- "Yes" – 55.8%,
- "Partly" – 40.5%;
- "No" – 2.5%;
- "Difficult to answer" – 1.2%.

2. "Which platforms in quarantine do you prefer when communicating online with students of higher education?" Respondents' answers to questionnaire questions showed that most specialists use it in their work

- Zoom (65%);
- Google Meet (64%);
- Google Classroom (63.5%);
- Skype (10%);
- Cisco Webex (1.3%).

Therefore, specialists use Google Meet and Zoom services the most for conducting online meetings. Each of these services has its own disadvantages and advantages, so specialists choose one or the other, depending on goals, wishes, financial capabilities, preferences.

3. "Which messengers do you prefer in professional activities?". The answers to this question were interesting:

- Viber – 93%,
- Telegram – 58%,
- Messenger –39.5%,
- WhatsApp – used by 30% of respondents.

An example of conducting various remote activities, using elements of augmented reality in higher education among the STEM community is the permanent festival "STEM Education – Higher School" organized by institutions of higher education.

Each institution of higher education has the opportunity to share the experience of introducing elements of STEM education in the educational space and to present their projects, developments, and ideas.

We believe that, despite the obstacles in the use of modern technologies and elements of augmented reality in higher education as a means of implementing STEM education (a large amount of time spent on mastering new material,

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the lack of an appropriate method of using elements of augmented reality in higher education as a means of implementing STEM education, lack of technical support, etc.), educators manage to implement quality education.

Analysis of the challenges of implementing STEM education with augmented reality

With the development of STEM education and the strengthening of the practical component based on the use of digital technologies, the development of STEM centers and laboratories, and the improvement of the qualifications of teachers, the problem of continuous updating and development of methods of using the latest technologies and teaching aids, in particular digital ones such as augmented reality, remains relevant.

Augmented reality promotes creativity, critical thinking, data management, and analysis. The use of immersive technologies in a STEM-oriented environment contributes to the improvement of the quality of education, and the use of forms and methods implemented on the principles of active, purposeful learning - the assimilation of educational material and a greater understanding of the content of education.

Recommendations for teachers who want to implement the implementation of STEM education with augmented reality in their activities:

- development of scientific and methodical foundations for the implementation of STEM education;
- promoting the development of STEM education: analysis of the effectiveness of the process and the dynamics of development, ways to increase the efficiency of the implementation of innovations, identifying problems and forecasting future trends in the development of STEM education;
- organizing and conducting educational events aimed at popularizing STEM education, and career guidance work among young people;
- dissemination of experience and achievements in the field of STEM education through publications, and presentations during educational events of various levels;
- initiation, fundraising, and coordination of innovative educational projects;
- increasing the level of professional skills of scientific and pedagogical workers and presentation of pedagogical work experience, in particular, within the framework of a STEM school.

Specific examples of how elements of STEM education with augmented reality have been used to enhance student learning.

The educational process using STEM is a new education system. Students of education receive an individual task, compile a list of sources of information, obtain them, filter them for reliability, compare numbers and opinions, select the necessary ones, and start constructing new knowledge. Having received the result, they present it to society (the teacher), having earned a multi-vector assessment in the form of an index of their own personal achievements. According to this STEM methodology, the focus is on a practical task or problem of a research nature, which is significantly different from traditional tasks. Research tasks are formulated in such a way that students do not see an obvious answer, but find it on their own and justify it through trial and error. The task is formulated in the direction of: "investigate", "it's true that if..., then", "analyze"... There is a gradual increase in the independent activity of the students of education: from research works based on the program material, experimentation with topics that go beyond the boundaries of the program to conducting scientific research.

Conclusions

The concepts of STEM technology, STEM education, STEM approach, and STEM training are defined. The importance of using elements of augmented and virtual reality in higher education as a means of implementing STEM education is shown and the main methods of its use are prescribed. Modern technologies for preparing and conducting practical online classes in higher education as a means of implementing STEM education are proposed.

The key aspects of the STEM approach in higher education when using elements of augmented reality, features, and main components of the STEM educational environment are named.

We conducted an experimental study to find out: the state of development and use of modern innovative technologies in education, to what extent modern technologies can effectively organize distance learning, in

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particular STEM-learning in higher education when using elements of augmented reality, which messengers are preferred by educators, which platforms are used by teachers in working with students of higher education during quarantine, etc.

Experimental research aimed at clarifying the state of development and use of modern innovative technologies in education has been developed.

Recommendations have been developed for teachers who want to implement augmented reality in their work.

Therefore, the use of elements of augmented reality in higher education as a means of implementing STEM education is an effective tool of the educational space, which contains a huge potential for solving the tasks of the educational process. The perspective of the new educational space of the higher school is the mass introduction of augmented reality technologies in education, as well as the development of methodical and didactic materials for their effective use.

The issue of the organization of distance learning, which is relevant nowadays, needs further research.

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