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# Transforming education for the STEM era

## Трансформація освіти для STEM епохи

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**Abstract**

The article explores the essence of STEM education and the STEM-oriented approach in the modern information and educational environment. It highlights key components and aspects of the STEM education environment, emphasizing effective organizational forms for implementing a STEM-oriented approach. The study provides recommendations for transforming the information and educational environment in higher education institutions to ensure the effective implementation of STEM. It analyzes international projects supporting STEM education and reveals key principles for transforming the educational environment. The research also demonstrates the necessity of specialized equipment for this transformation. An experimental study was conducted to analyze the readiness of future specialists in natural sciences and mathematics to utilize STEM technologies in their professional activities. The results showed that the experimental group, exposed to a

**Анотація**

У статті досліджується сутність STEM-освіти та STEM-орієнтованого підходу в сучасному інформаційно-освітньому середовищі. Висвітлено ключові компоненти та аспекти STEM-освітнього середовища, наголошено на ефективних організаційних формах реалізації STEM-орієнтованого підходу. У дослідженні подано рекомендації щодо трансформації інформаційно-освітнього середовища у ВНЗ для забезпечення ефективного впровадження STEM. Стаття аналізує міжнародні проекти підтримки STEM-освіти та розкриває ключові принципи трансформації освітнього середовища. Дослідження також демонструє необхідність спеціалізованого обладнання для цієї трансформації. Проведено експериментальне дослідження з метою аналізу готовності майбутніх фахівців природничо-математичного профілю до використання STEM-технологій у професійній діяльності. Результати показали, що

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transformed educational environment, demonstrated significantly improved readiness compared to the control group. The study highlights the importance of transforming the information and educational environment in higher education to facilitate the effective application of STEM technologies in future specialists' professional activities.

**Keywords:** information and educational environment, STEM-oriented approach, STEM technologies, STEM education, virtual space.

експериментальна група, яка зазнала впливу трансформованого освітнього середовища, продемонструвала значно кращу готовність порівняно з контрольною групою. На завершення дослідження підкреслено важливість трансформації інформаційно-освітнього середовища вищої освіти для ефективного застосування STEM-технологій у професійній діяльності майбутніх спеціалістів.

**Ключові слова:** інформаційно-освітнє середовище, STEM-орієнтований підхід, STEM технології, STEM-освіта, віртуальний простір.

## Introduction

Nowadays, in higher education, we observe changes in priorities, the emergence of new technologies and fields of knowledge (nano- and biotechnology, information and communication technologies), deepening of scientific research, which significantly depends on the rapid development of the information society. The growing demand for specialists in high-tech industries and innovative processes of socio-economic development, who are capable of engineering activities, and scientific complex activities, contribute to the development and formation of pedagogical innovation of the 21st century – the educational direction of STEM (Polikhun et al., 2019). Therefore, in the educational process of a higher school, it becomes important to focus teachers on the development of a sense of entrepreneurship and initiative in students, on a competence approach, on the formation of students of higher education in the ability to turn ideas into life through innovation, creativity, the development of creative thinking, etc.

In this regard, society puts forward requirements for the quality and new content of the training of future specialists, the modern stage of human development conditions the search for ways, ways, and methods of improving the educational process to increase the competitiveness of graduates. It is the STEM education system that is one of the directions of the innovative development of the educational field, which creates a person who carries out labor innovation activities with a high degree of technological and interdisciplinary, i.e., the STEM education system satisfies society's demand for a STEM specialist. Therefore, STEM education becomes the basis of training specialists of a new generation of specialists, formation of the latest competencies of citizens capable of using and developing the latest technologies, assimilation of a large amount of knowledge, and education is on the path of constant innovative development: research is conducted, centers are opened, methodological recommendations are developed, concepts related to STEM education are being developed. However, despite the active discussion in the academic community, the issue of implementing the ideas of integrated learning in the context of STEM education requires more thorough study and is quite complex. The transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in the professional training of future specialists will contribute to the formation of the ability to carry out labor innovation activities with a high degree of technological and interdisciplinary (Kryvylova & Zhigir, 2022).

Interesting data on updating global trends in STEM education (Hom & Dobrijevic, 2022) talk about its demand in the labor market: the need for 600,000 workers in STEM specialties in the USA; in Great Britain, the need for specialists is 100,000 workers in STEM specialties, in Germany – 210,000 specialists in STEM specialties (Fonariuk, 2021).

Also, as practice shows, future specialists after receiving diplomas are often not ready to implement an information and educational environment in the context of ensuring the effective implementation of a STEM-oriented approach in professional activities and do not have a clear understanding of the technology of STEM education (Tkachuk & Stetsenko, 2022).

All these important positions and the economic investments of countries in the development of STEM education (billions of dollars) speak of the relevance of research into a STEM-oriented approach to education, which requires the scientific exploration of practitioners and scientists, methods and forms of its implementation to highlight the content and essence of STEM education in informal and formal educational systems.

The pedagogical problem of STEM technologies acquires a new qualitative sound in connection with the challenges of the information society, such as the rapid impact of technologies on all spheres of life of a modern person; increasing the level of society's requirements for the technological awareness of every person, regardless of his profession; demand on the labor market for specialists; changing educational needs of the generation of today's students, which could be solved by integrating STEM technologies into the educational process.

Insufficient theoretical and practical study of the outlined problem, its social importance, as well as the presence of several contradictions in modern higher education led to the choice of the topic of the article. The development of STEM technologies in the quality training of future specialists is currently an urgent issue of theory and teaching methods in the educational process. Based on this, we considered the following questions in the article:

1. The essence of STEM education, the STEM-oriented approach in the modern informational and educational environment, and the main components, and key aspects of the STEM education environment.
2. Recommendations for the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in higher education institutions.
3. International projects to support and organize STEM education.
4. The main principles of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach.
5. Availability of special equipment in the process of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach.

**Literature Review**

Scientists have analyzed the content of key concepts fundamental to understanding the essence of the new STEM educational direction. O. Stryzhak, I. Slipukhina, N. Polikhun, & I. Chernetckiy (2017) proved the relevance of the STEM approach in education and showed the significant shortcomings of the education system that do not sufficiently satisfy the requirements of the modern labor market. The scientists grouped the main definitions of STEM education, defined tasks, goals, content, and structure, showed the expected results of the development and implementation of STEM education, and proved its correspondence to the conceptual foundations of the development of the educational paradigm of society.

The starting points for the implementation of the STEM-oriented approach to the teaching of mathematics were revealed by O. Fonariuk (2021), which is defined as the process of forming several personal qualities of future specialists, characterized in the study of mathematics by a combination of practical orientation and interdisciplinarity, which determines the success of a specialist in the labor market (systemic thinking, critical thinking, the ability to work in a team, the ability to learn throughout life, the ability to solve complex problems, etc.).

L. Svitelska (2022) analyzes an innovative approach to the organization of the education process-oriented, with the help of STEM technologies, to the formation of scientific and technical competence. The researcher revealed the advantages of STEM education and showed the essence of STEM education, which consists of a combination of practice-oriented interdisciplinary approaches to the study of modern tools, methods of technical, technological, and scientific research, and individual subjects. STEM technologies are considered a means of developing the creative thinking of the acquirer of educational space, to reveal the creative potential of the student. In the implementation of practice-oriented, holistic teaching of science subjects, ways of implementing STEM education in the modern educational field are proposed, and the possibilities of an integrated interdisciplinary STEM approach are discussed.

N. Polikhun, K. Postova, I. Slipukhina, H. Onopchenko, & O. Onopchenko (2019) outline the features and determine the practical and theoretical aspects of the introduction of STEM education. Models of integration of informal and formal education for gifted students are proposed, which in the future can become the basis of transformational processes for education. The peculiarities of the educational STEM environment are revealed, emphasis is placed on the use of engineering design and the scientific method in the construction of STEM educational activities, the application of STEM projects is demonstrated on specific examples, and methodical approaches to the organization of STEM projects are proposed. Research is aimed at forming a deep understanding of the latest trends in education, which are designed to prepare the new generation for the requirements of the modern economy.

The research of N. Soroko (2020) is devoted to the problems of using cloud services for the organization of STEM education. With the help of information and communication technologies, foreign experience in solving educational issues regarding the implementation of a STEM-oriented approach at all levels of education is considered; the main problems that arise during this process are highlighted. STEM education is recognized as one of the urgent directions of education reform and its development, which is evidenced by the significant demand for STEM specialists in the global labor market.

T. Gumennykova, P. Ilchenko, O. Bazyl, A. Ilchenko, & O. Vydrych, (2022) aims to analyze the educational trends of the year 2022 and determine whether they are relevant in the future, whether they are a response to the challenges of the present. Also, attention is paid to the method of SWOT analysis, with the help of which the strengths and vulnerabilities of distance learning are identified. The results analyze the future of distance education, in particular, special attention is paid to the experience of implementing hybrid education as a likely promising direction of further learning.

Y. Zavalevskyi, O. Khokhlina, S. Gorbenko, O. Fliarkovska, & O. Chupryna, (2023) in their approach encourage students' independent creativity and prepare them for contemporary work environments. STEM education is positioned as a tool to develop key competencies like multicultural understanding, linguistic skills, and adaptability. This innovative educational method emphasizes the real-world application of scientific, mathematical, technical, and engineering knowledge. The research methodology combines theoretical analysis with practical evaluation. Key findings underscore the significance of independent research, interdisciplinary integration, and skill development in a blended learning environment. A notable outcome emphasizes empowering students to craft scalable business models, such as startups, vital for success in today's world.

O. Marrero-Sánchez, & A. Vergara-Romero, (2023) emphasize that technological evolution demands the development of digital skills that allow us to face problems and situations in this environment. Society has experienced an essential technological revolution in recent decades, generating significant repercussions in the educational field, especially in higher education.

It has been proven that "to ensure the effective implementation of the STEM-oriented approach in the educational process of a comprehensive educational institution at all levels of education, there is the use of information and communication technologies, in particular, cloud services".

The analysis of scientific research makes it possible to conclude that the scientists grouped the main definitions of STEM education, defined tasks, goals, content, structure, showed the expected results of the development and implementation of STEM education, proved its correspondence to the conceptual foundations of the development of the educational paradigm of society, revealed the content of skills and competencies that are most in demand in the 21st century, the role of interdisciplinary and competency-based approaches in shaping the content of STEM education is shown, the role of cognitive technologies in the organization of the student's cognitive activity, the role of problem-oriented learning, the organizational forms of informal learning are considered and analyzed (world cafe, workshop of the future , open space, learning by example), on the basis of communicative methods of informal education, the experience of implementing a STEM-oriented approach to education in institutions of higher education is described, models of integration of informal and formal education are proposed for gifted learners, who in the future can become the basis of transformational education for education processes.

At the same time, the issue of implementing ideas for the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach remains relevant.

Despite the significant interest of scientists in the use of STEM technologies both theoretically and practically the insufficient researched problem, which manifests itself in the lack of a unified understanding of the essence of this process, to the application of STEM technologies.

The urgency of solving the outlined problem is enhanced by the aggravation of several contradictions that characterize modern higher education, in particular:

- Between social requirements for saturation of the educational process modern technologies and unpreparedness of the education system for quick correction value guidelines of the average teacher for their use;
- Between the fragmentation and separation of the study of individual disciplines in professional training and the integrity and integration of scientific knowledge through the practice of STEM education;
- Between the need to study and take into account the individual characteristics and preferences of education seekers and the traditionally depersonalized methods, forms, and means of their teaching.

*The purpose of the research* is the theoretical substantiation of the possibility of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach.

**Methodology**

The research was conducted using both theoretical and empirical research methods: synthesis and analysis in order to clarify the categories of STEM education and basic concepts; comparative conceptual analysis with the aim of comparing STEM-oriented approaches and traditional approaches, materials of scientific and practical conferences, scientific, psychological, methodological, pedagogical literature on the problem of research, innovative pedagogical experience; highlighting the regularities of the investigated problem and formulating conclusions; systemic and structural synthesis and analysis to draw conclusions and prove the importance of STEM education on a global scale; empirical methods (included observation, direct observation, indirect observation) for researching the activities of STEM education centers, surveys that allowed to systematize and generalize statistical and analytical material; an experiment to identify the real state of readiness of future specialists in the field of natural sciences and mathematics to use STEM technologies in their future professional activities; mathematical: mathematical analysis, data processing; statistical: for statistical processing, summarization of results.

During the study, an analysis of the formation of the readiness of future specialists in the field of natural sciences and mathematics to use STEM technologies in their future professional activities was carried out. Indicators were divided into three main components: cognitive, activity, and value-motivational.

The indicators contained in each of the components were divided into two blocks:

- Indicators related to the formation of pedagogical competencies – these are pedagogical indicators;
- Indicators related to the formation of research, engineering, and technical competencies are technological indicators.

When assessing the level of readiness of future specialists to use STEM technologies in their future professional activities, appropriate questionnaires were used for both teachers and students who teach the disciplines of the natural-mathematical cycle.

A group of experts (teachers) was created to evaluate criteria and indicators to find out the level of readiness of future specialists to use STEM technologies in their future professional activities. The results of control measures and the current performance of students were also used.

The results of the diagnostic section and surveys conducted among students indicate the relevance of the research topic, which made it possible to draw the following conclusions:

- Students actively use digital technologies;
- Most students have clearly expressed characteristics of representatives of the Net generation;
- The level of skills and knowledge in the field of technology and project activity is insufficient for training students of higher education in the application of STEM technologies;
- Aspects of the purposeful formation of reflection skills and increase of students' motivation to study require special attention.

Taking into account the general results of the study of the formation of readiness of future specialists to use STEM technologies in their future professional activities, two groups of respondents were distinguished: an experimental group and a control group.

The experimental and control groups were chosen so that the indicators of the formation of the studied components, which were obtained during the preliminary study of the general population, corresponded to the greatest extent to the average indicators.

The obtained statistical data were analyzed for homogeneity using the Pearson test. Research at the ascertainment stage of the experiment allows us to say that at this stage of the experiment, there was no statistically significant difference between the experimental and control groups for any structural component of the readiness of future specialists to use STEM technologies in their future professional activities. At the control stage of checking the readiness of future specialists to use STEM technologies in their professional future activities in the control and experimental groups, we can see statistically significant differences between the levels of readiness of future specialists to use STEM technologies in their professional future activities of the experimental and control groups.

The obtained results of the experimental study proved that the readiness of future specialists to use STEM technologies in their future professional activities was formed more effectively in the experimental group than in the control group. Therefore, we see the importance of the transformation of the information and educational environment into a higher school in the context of ensuring the effective implementation of a STEM-oriented approach for the effective application of STEM technologies in the future professional activities of specialists.

The experiment was conducted at the Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine. The conduct of the experiment is permitted by the scientific councils of the Academy in order not to violate ethical considerations in institutions of higher education.

## Results and Discussion

### The essence of STEM education, the STEM-oriented approach in the modern informational and educational environment, and the main components, and key aspects of the STEM education environment.

In a broad context, STEM education is a pedagogical technology for the development and formation of creative qualities and mental, and cognitive qualities of students of educational space, the level of which determines the competitiveness of an individual in the modern labor market.

In the organization of the educational process, the STEM approach makes it possible to combine innovative and research activities, creativity, to cover the sphere of creative potential, to create horizontal connections between fields of knowledge, and to connect society with the surrounding world **(**Polikhun et al., 2019).

The STEM-oriented approach to education is implemented today in educational and higher education institutions, in particular. Based on a STEM-oriented educational environment, STEM technology provides for an innovative organization of the educational process, characterized by an interdisciplinary approach, and integration into the project and educational activities of students. The basis of the ideas of such innovative STEM education is the assertion that it is important to master academic disciplines comprehensively to form a complete picture of the world and in combination and close integration. Current STEAM areas are audio, web, video design, industrial and interior design, architecture, animation, beauty and fashion industry, industrial aesthetics, etc. (Tkachuk & Stetsenko, 2022).

In European countries at all levels of education, for the successful promotion of a STEM-oriented approach within the framework of the European Union (EU) initiative in Genious, the STEM Alliance was created, in which Microsoft is involved to promote the use of ICT (Debry & Gras-Velazquez, 2016). At the same time, considerable attention is focused on the adaptation and creation of cloud services to the needs of STEM education.

Alliance experts Maïté Debry, & Dr. Agueda Gras-Velazquez (2016) believe that the use of ICT will allow:

- Will increase the motivation to study STEM disciplines and increase the interest in STEM education among students of all levels;
- It will allow to attract education seekers to interactive, active, joint learning;
- Will provide an opportunity for education seekers to choose technologies, tools, and resources for team learning, self-learning, self-assessment, and evaluation of educational activities.

For such activities, the most common tools are cloud services, which facilitate the joint work of students and teachers and facilitate the worldwide interaction of subjects of the educational process (Soroko, 2018).

Let's highlight the main components of the STEM education environment. They are:

- Aimed at solving practical real-world tasks, the interdisciplinary principles of education that exist in the conditions of practice-oriented education within and outside the STEM disciplines, lack of academic knowledge;
- Modern educational tools, including construction robots, are important in education (LEGO Mindstorms, LEGO, Cubelets, MakeBlock, LittleBits, etc.), which allow you to familiarize yourself with the basics of electronics, robotics, programming, mechanics in a playful way, create with various sensors for interaction with the environment and navigation complex structures and implement them in practice, put forward your own ideas, microprocessors and programming, digital measuring complexes, remote and network tools of project management and cooperation, which provide for quality education for students of different age groups the principle of equal access;
- Elective courses, integrated training programs that focus on the formation of competencies (representatives of industry and business, educators, etc. should be involved in the creation of creative content);
- Zones of activity in the audience: zones of creativity and research, interaction and development, presentation zone, etc.;
- Emphasis on team, project, and group work of educational space acquirers;
- Cooperation between educational teams, the attraction of resources between external participants: academic research institutions, institutions of higher education, enterprises, research laboratories, nature centers, museums, public organizations, business structures, etc.;
- The dominant organizational forms are hackathons, integrated classes, projects, cases, quests, festivals of engineering projects, excursions, competitions, thematic days, scientific exhibitions, etc.;
- Active interaction with colleagues;
- Systematic monitoring of results.

To ensure the implementation of a STEM-oriented approach and proper educational and methodological support of the student during his studies, the development of elective courses, and appropriate integrated educational programs focused on the formation of the necessary competencies for the further professional determination of a specialist is of particular importance.

Festivals, hackathons, integrated classes, projects, excursions, quests, contests, thematic days, scientific exhibitions, etc. are effective organizational forms of applying the STEM-oriented approach to education. The development of creative content to support the educational process should be carried out not only by specialists in a certain field of knowledge and educators but also by representatives of business and industry (Leleka et al., 2023).

The focus of the STEM-oriented approach to education is a real problem that needs to be solved in the process of interdisciplinary education, the organization of a competency-oriented, integrated educational process, or a practical task. Therefore, classes must necessarily have signs of problem-based learning, and then it is possible to apply a STEM-oriented approach to learning, which is based on the setting of tasks with real practical content, the solution of which involves the predominant use of inductive research methods, interdisciplinary interaction, team activities, etc. The productivity of education increases significantly under the condition of coherence and systematic interaction of students and teachers who jointly implement a STEM-oriented approach in education.

The STEM-oriented approach assumes a spatial and subject component of the modern educational environment, its completely different essence. A modern educational environment is a physical-spatial environment, a social, material-technological environment that is innovative, accessible, open, businessoriented, inclusive, developmental, value-oriented, and motivating, which includes in its content intelligent design, innovative technologies, programs, and means of training that contribute to the lifelong acquisition of professional education competencies by future specialists.

In the process of education, the transition to the systematic introduction of ICT is ensured with the implementation of a STEM-oriented approach in all types of educational activities, the use of electronic textbooks, the creation of online platforms with methodical and educational materials for students and teachers, smart complexes, content libraries, new IT technologies, social professional networks, multimedia learning tools.

Let's name the key aspects of the educational process of the STEM approach:

- Building the educational process on real technical and technological, socially significant, and economic problems;
- Construction of educational programs and curricula on an interdisciplinary basis;
- Integration into a single paradigm of natural sciences methodology and content, modern technologies (engineering design, information technologies, mathematical tools, etc.);
- Application of social technologies, cognitive technologies, and knowledge transfer;
- By certain topics, and not individual disciplines of the application of integrated education;
- Emphasis on the comprehensive formation of the student's engineering and scientific thinking.
- Formation using the STEM approach of "soft" skills defined in Framework P21;
- Aspects of STEM, as processes of external influence on the individual – social (preparation for further employment and lifelong learning by the requirements of the 21st century) and personal (acquiring practical authentic experience of innovative activity) (Polikhun et al., 2019).

Recommendations for the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in higher education institutions.

We will consider the recommended strategies for the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in higher education institutions **(**Leleka et al., 2023):

- Start with an explanation of the goal, the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in higher education institutions should be based on objectivity;
- Demonstration of graphs at the beginning of solving problems, tasks, etc. by students of higher education, since it is the visualization that contributes more than the read text to the quick perception of the material; presentation of data using charts and graphs using presentations and graphic editors;
- The use of ICT to ensure the interactivity of the educational process of the higher school for the use and creation of virtual laboratories, search and presentation of educational resources; creation of educational electronic games, blogs, software, etc.;
- Providing students with an educational space of abstract and concrete concepts after explaining the purpose, which is carried out by using examples from real life to understand the connections with abstract concepts;
- Training of future professionals to use and evaluate technologies, in particular, ICT for self-learning and training;
- Involvement of students in interactive educational work during study and in professional work;
- Focusing not on group work during higher education, but on teamwork;
- Training in business etiquette that meets the needs of entrepreneurship and business;
- Focusing on a student-centric rather than a teacher-centric approach;
- Promoting the development of the educational environment of the higher school, in which the main values are independent and creative thinking;
- Involve students in educational projects, mega brain, and technical support to develop their leadership abilities.

The selected recommendations are important for the implementation and organization of STEM education in educational institutions and indicate the important role of ICT and cloud services in education.

**International projects to support and organize STEM education.**

To use cloud services to support and organize STEM education, it is necessary to establish international projects. Let's single out the main ones:

– Global Learning and Observations to Benefit the Environment, GLOBE; official website: https://www.globe.gov/;
– Group-Based Cloud Computing for STEM Education Project, GbCC; official website: https://www.gbccstem.com/;
– School on the Cloud; official site: http://www.schoolonthecloud.net/ and others.

Thus, the GLOBE project is an international scientific and educational program that provides students of the public all over the world with the opportunity to participate in the educational and scientific process, data collection, and contribute to the understanding of the system of the global environment and the Earth within the framework of natural and mathematical disciplines. The project cloud provides data exchange between registered participants and is an infrastructure that enables collaborative work on scientific research of students from different countries, which is offered within educational institutions of higher education, etc.

Three levels make up the operational structure of the GLOBE program:

– Primary Activities;
– Support Infrastructure;
– Underpinning Operations.

The main operations supporting the GLOBE project include management systems, the task of which is to provide adequate overview, evaluation of services, monitoring, maximizing the effectiveness of all activities, and ensuring continuous improvement.

The GbCC project is aimed at the use of cloud services and is aimed at implementing a research approach to the creation and study of materials and technologies that support learning within STEM education and generative learning. consider the goals that GbCC sites have:

– Observation in the educational field of experimental sites to support the organization of STEM education with the effective use of cloud services;
– Dissemination of approaches for teacher certification for the preparation of STEM education;
– Motivational training within STEM fields/professions;
– Raising the level of students' awareness of STEM content;
– Development of disciplinary skills, practices, and skills;
– Formation of young people in the framework of the STEM fields of Computational thinking to improve the generalization and analysis of the material that is presented on the project site, which is understood as the processing of data with the help of ICT;
– Promoting the formation of communication skills, and critical thinking, necessary for entering the STEM environment.

Within the framework of the GbCC project, the following necessary tasks are being researched:

– Based on geo-information technologies and systems of modeling and processing of geospatial data, which are analyzed and substantiated by students in educational projects;
– Distribution of research materials of quantitative and qualitative data, results of technological measures on the nature and intensity of use of innovative technologies.
– Through the expansion and integration of leading computing tools, the development of a group-optimized device-independent architecture, including a modeling language based on NetLogo web agents, using NSF-funded cloud services, is carried out.

School on the Cloud project (Koutsopoulos, 2015), exists within the framework of the lifelong learning program, financed with the support of the European Commission. The project network will unite 18

European countries; 57 partners; national authorities, schools, universities, non-governmental organizations, research centers, associations, companies, and adult education providers.

Cloud services of Apple, Google, Microsoft, SAM Labs, etc. are offered within the project.

In all the described projects, a special role is played by Cloud-based Distributed Network Simulation Environment and Cloud-based Simulations for students to conduct scientific research in STEM fields, such as NetLogo, Google Maps, HubNet, etc.

Cloud services help the reporting industry to solve problems related to the balance between practice and the content of the curriculum, between student interests and student attendance, between the effective use of ICT in the educational process and their rapid development, etc. (Soroko, 2018).

**The main principles of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach.**

Let's highlight the main principles of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach:

- Integrability – the unification of topics, programs, training courses, and tasks for versatile research of objects and phenomena; giving priority to teaching methods and organizational forms built on joint activity, communication, and student activity;
- Connection with life – designing and modeling the tasks set by the educational process based on the awareness of resources, real cases, and the experience of the students of the educational process regarding the methods and content of solving educational tasks;
- Systematicity – a systematic combination of technologies, science;
- Technology – the use of information and communication technologies, computer programs, and specialized tools for finding ways to solve the educational situation and its analysis;
- Adaptability – attention to the development of adaptive abilities of students by changes in society and social demands; the change to the information society of the educational paradigm of the industrial society requires a reorientation of the educational material given the expected educational competencies of the students;
- Informality – determines in the learning process the need to create an informal educational environment that takes into account the interests and actual needs of the student, attention to the individual, the peculiarities of his communication and thinking; to solve educational tasks, providing the opportunity to stimulate creativity, teamwork, independent choice of learning method, personal responsibility for learning results (Fonariuk, 2021);
- Constant updating of the content of education, taking into account the development of technologies, scientific achievements, and the requirements of the labor market;
- Taking into account the individual and age characteristics of the students, their abilities and interests, and special educational needs, which plays a significant role in the integrative approach to the implementation of STEM education, ensures thorough, consistent, high-quality teaching;
- Productive motivation of education seekers to the invention, project activity, and implementation of scientific and research activity;
- Encouraging the development and formation of "flexible skills" among students (presentations, communication, group work); use of problem-based and developmental learning technologies.
- Interdisciplinary principle – provides practice-oriented training to the scientific and educational system and an interdisciplinary approach in STEM education to eliminate the gap between the practical implementation of skills and theoretical knowledge of a person.

To solve practical problems in the education and practical activity of a specialist, the use of a transdisciplinary approach to education is based on the practical application of technical, scientific, mathematical, and engineering knowledge with the aim of further use of skills and knowledge in professional activities (Kuchai et al., 2017).

So, the leading idea of the STEM-oriented approach is to provide the educational process with the principle of interdisciplinarity to learning with the ability to construct innovative content of courses according to the interdisciplinary principle, disciplines, educational subjects, thanks to which there is a combination of

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technology, scientific method, and design.

**Availability of special equipment in the process of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach**

A STEM-oriented approach to education requires the availability of special equipment, and not only the introduction of new methodological approaches. To implement professional tasks at various stages of training, it is necessary to use educational robot designers: LEGO Mindstorms EV3, LEGO, LittleBits, Cubelets, Makeblock, etc., which in a game form allows you to get acquainted with the basics of programming, mechanics, electronics, robotics, implement on put forward their own ideas in practice, creating complex designs with various sensors, for example, for interaction with the environment and navigation, etc.

When implementing a STEM-oriented approach, educational and practical STEM centers, and high-tech STEM laboratories are created, and simulation centers, start-ups, and educational-production clusters are established as coalitions in the educational process.

In the process of educational and methodical interdisciplinary activities and a comprehensive scientific education system, a STEM-oriented approach to education is implemented through a network of STEM centers and STEM laboratories.

STEM centers and high-tech STEM laboratories are successfully operating in the educational space of almost all countries of the world.

Educational and practical STEM centers and high-tech STEM laboratories, coalitions are an integral part of STEM education; the defining goal of such educational organizations is to contribute to the development of the global workforce in the 21st century. They are created based on scientific laboratories, institutions of general education, higher education, extracurricular educational institutions, specially organized educational spaces with training programs, appropriate material and technical base, scientists, representatives of business structures, specialists, teachers, consultants, etc.).

The competencies of educational and practical STEM centers and high-tech STEM laboratories and coalitions include:

- Establishment of cooperation and dynamic partnership relations between schools, universities, and other institutions of higher education and representatives of industry and business for the implementation of modern initiatives in STEM education;
- Coordination of the activities of symposia, conferences, international schools in the field of STEM education and round tables, the latest learning technologies to discuss important new events in state policy and the impact of global innovative STEM educational programs with the participation of practitioners and leaders of world education in these events, conducting thematic discussions, etc;
- Management and initiation of the activities of educational pilot programs that allow working in different cultural environments and learning to solve problems of global importance, gaining authentic experience in the field of science, technology, and engineering (for example, in mastering 3D-printing, in astronomical observations, in international geographical expeditions to create artifacts of the future, etc.);
- Systematic training, preparation for the relevant activities of teachers, management, consultations, and support for the implementation of STEM programs.

Virtual centers of STEM education deserve special attention, their goal is knowledge transfer and design with the involvement of social and cognitive technologies. Educators of all levels can join international research projects, and participate in virtual and real educational research with the help of such network resources, including ICE Cubes Service, BioTalent, Edu-Arctic, etc. (Polikhun et al., 2019).

STEM laboratories can be equipped with institutions of general secondary education, and higher education, as well as institutions of professional (vocational-technical) and professional higher education to provide a person with a full education to engage in research-experimental, educational-research, design, search, and invention activities applicants of higher education by educational programs, educational standards with the use of design technologies in the educational process.

The implementation of a STEM-oriented approach in educational institutions of all levels of education requires the use of special laboratory, technological, and educational equipment. These are 3D visualization tools, 3D printers and scanners, augmented reality tools, and other things that can make the educational process higher quality and provide future specialists with the necessary equipment. Education seekers, focusing on practical abilities, can master teamwork skills, and develop creative potential, willpower, and flexibility (Kryvylova & Zhigir, 2022).

To ensure the effective implementation of a STEM-oriented approach, STEM centers, and high-tech STEM laboratories in the educational space at all levels of education use ICT, in particular cloud services.

Let's consider the main problems that arise during this process:

- Development of information and communication competence of teachers to ensure continuous improvement of the STEM education environment with the help of cloud services and the use of ICT;
- Creation of informal and formal online courses in the field of STEM with the help of ICT and the involvement of students, specialists, and teachers in them;
- For the organization of the educational process of STEM education – selection of the necessary ICT, etc.

The solution to the problems is:

- Participation in educational projects of educational institutions, to promote the development of the skills and abilities of teachers to use ICT, in particular cloud services, in their professional activities, by the world's priority areas of the education industry.
- The organization and creation of open mass online courses for teachers, which provide an opportunity for all those who wish to develop their skills and abilities, and acquire certain knowledge, regardless of their teaching experience and qualifications, when teaching a subject with the help of ICT (Hura et al., 2023).

Let's emphasize the importance of the hardware and software module with software, which is the most important condition for creating a STEM environment.

In today's educational process, modern technological devices (iPhone, iPad, etc.) are increasingly used, which provide remote work with online resources through the use of applications using wireless technology (Epson, Android, Projection, etc.). These devices enable the organization of the educational process to conveniently and easily obtain all the advantages of using modern technologies (seminars, video conferences, presentations, remote classes, control of learning results, etc.). The advantage is the computer-mediated way of interaction, which has become popular with the emergence of such social networks as Facebook, media sites Flickr, MySpace, YouTube, and commercial sites eBay. Such Internet projects, which are widely known, have common characteristics: service-oriented design, open APIs, and the possibility of remote hosting of media files and data.

Recently, devices with support for virtual and augmented reality (VR/AR) have become important and popular in education, which, by creating an environment with the effect of involvement, enable the acquisition of new knowledge, and simulation of comfortable conditions, which allows the student to perceive educational processes through the senses (with support for VR/AR mobile applications, virtual helmets with software, etc.).

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

- Information resources of an educational institution (document storage, educational and methodical data banks, unified databases, multimedia educational developments, websites, etc.).
- Software to automate the activities of various services (personnel accounting, library automation, accounting of information environment subjects, performance analysis, etc.);
- General purpose software (spreadsheets, graphic and text editors, etc.);
- Software and methodological support (electronic guides, educational and educational computer programs, multimedia encyclopedias, etc.) (Zabalza Navarro, & González Torres, 2023).

For the successful development of STEM education, thanks to its expanded functionality and for the interaction of the participants of the educational space, the local social networks of the educational institution are quite capable of creating pedagogically favorable conditions for the graduation of a highly qualified specialist. A special virtual space is created by virtual classes, where an innovative educational process is formed, which uses the Internet as an information channel. Virtual classrooms can provide access to scientific libraries, modern databases, and high-quality educational materials. This provides an opportunity not only to choose the optimal pace of learning the program, and to choose a convenient time for classes but also to communicate with curators and teachers using e-mail, web conferences, ISQ, Skype, etc., which makes training one of the most effective forms of working with students education in a virtual environment where access to electronic libraries is provided (Shetelya et al., 2023).

The creative space for the formation of a person's worldview provides a STEM-oriented approach to education, in which a person fully realizes his needs, and not only prepares for adult life. The entire transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach is built in such a way as to contribute to the formation of the individual as a designer and creator of his own life, humanization and harmonization of relations between students, teachers, family and educational institution, based on the idea of choosing a conscious personal life path of a person.

The introduction of the STEM education model into the educational process will provide an opportunity to form such STEM competencies in students as:

- The ability to pose a problem;
- Ability to apply acquired knowledge in different situations;
- The ability to formulate and determine ways to solve a research task;
- The ability to understand the possibility of other points of view on solving problems;
- The ability to apply high-level thinking skills;
- The ability to solve problems in an original way (Balyk & Shmyger, 2017).

**Experiment**

During the study, an analysis of the formation of the readiness of future specialists in the field of natural sciences and mathematics to use STEM technologies in their future professional activities was carried out. Indicators were divided into three main components: cognitive, activity, and value-motivational.

The indicators contained in each of the components were divided into two blocks:

- Indicators related to the formation of pedagogical competencies – these are pedagogical indicators;
- Indicators related to the formation of research, engineering, and technical competencies are technological indicators.

When assessing the level of readiness of future specialists to use STEM technologies in their future professional activities, appropriate questionnaires were used for both teachers and students who teach the disciplines of the natural-mathematical cycle.

A group of experts (teachers) was created to evaluate criteria and indicators to find out the level of readiness of future specialists to use STEM technologies in their future professional activities. The results of control measures and the current performance of students were also used.

The analysis results were evaluated on a three-level ordinal scale: (100-point scale):

- High level of assessment – range from 90 to 100 points;
- The average level of assessment – the range from 74 to 89 points;
- The initial level of assessment – the range from 60 to 73 points.

The results of the diagnostic section and surveys conducted among students indicate the relevance of the research topic, which made it possible to draw the following conclusions:

- Students actively use digital technologies;
- Most students have clearly expressed characteristics of representatives of the Net generation;
- The level of skills and knowledge in the field of technology and project activity is insufficient for training students of higher education in the application of STEM technologies;
- Aspects of the purposeful formation of reflection skills and increase of students' motivation to study require special attention.

The study showed the results that

- 12% of respondents have a high level of formation of components (knowledge, activity, value-motivational). These respondents have approximately the same level of assimilation of the components.
- 20% of respondents have an average level of formation of components (knowledge, activity, value-motivational). The smallest percentage among the components has a knowledge component.

If we take as a criterion of the effectiveness of the developed system the readiness of future specialists to use STEM technologies in their professional future activities and the achievement by future specialists of an average level or high level of readiness to use STEM technologies in their professional future activities, then 33% of the respondents of the general population satisfy this criterion. Given the urgent need for the use of the information and educational environment in education and professional activity in the context of ensuring the effective implementation of the STEM-oriented approach and given the modern requirements for the educational process in higher education institutions, this is a low indicator.

Taking into account the general results of the study of the readiness of future specialists to use STEM technologies in their future professional activities, two groups were distinguished among the respondents:

- Experimental Group – 102 people;
- Control Group – 108 people.

The experimental and control groups were chosen so that the indicators of the formation of the studied components, which were obtained during the preliminary study of the general population, corresponded to the greatest extent to the average indicators.

We observe close values of the composition of the components of the experimental and control groups at all levels of assessment. We say that both experimental and control groups are in the same conditions.

In the research in the experimental group, we used the most important organizational forms in the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in higher education for the effective use of STEM technologies in the future professional activities of specialists: hackathons, quests, excursions, projects, thematic days, integrated classes, competitions, festivals, scientific exhibitions, etc.

The experimental group used local and global information networks with specialized expert systems and various databases along with traditional sources of knowledge acquisition.

To conduct a scientific experiment, analyze and study phenomena, modeling, etc., and create an innovative environment of educational space using ICT, they created a virtual STEM laboratory, a science museum, etc.; singled out modern innovative forms of training organization, which allow to implement the STEM-oriented approach to training in the educational process for effective application in the future professional activity of STEM technology specialists.

To the forms of transformation of the informational and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach for the effective application of STEM technologies in the future professional activity of specialists, we in the experimental group include learning by example, open space, world cafe, workshop of the future. The use of network tools of interaction gave us the opportunity to participate in open specialized network communities and the opportunity to join international scientific and educational projects (Pakhomova, 2020).

To ensure the transformation of the information and educational environment in the context of ensuring the

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effective implementation of the STEM-oriented approach for the effective application of STEM technologies in the future professional activities of specialists, the development of appropriate optional courses and integrated curricula aimed at the formation of the necessary for further professional determination was of particular importance in the experimental group competencies.

The transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach for the effective use of STEM technologies in the future professional activities of specialists requires the introduction of special equipment, and not only new methodological approaches. At the stages of the research, the experimental group carried out the implementation of the specified tasks to promote the use of educational robots-designers (LEGO Mindstorms EV3, LEGO, LittleBits, Cubelets, Makeblock, etc.), which in a game form allow you to get acquainted with the basics of electronics, robotics, programming, mechanics, put forward your own ideas and implement them in practice, creating complex structures with various sensors, etc.

To transform the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach for the effective application of STEM technologies in the future professional activities of STEM specialists, the STEM center and the STEM laboratory were created to help establish dynamic partnership relations and cooperation in the implementation and development of the STEM-oriented approach between all interested in popularizing such innovative training. The STEM laboratory and the STEM center organized and initiated the coordination of innovative educational projects that enable students in the future to solve problems of general importance, work in various innovative environments, gain experience in the field of science, technology, and engineering, hold symposia, training, consultations, conferences, round tables, thematic discussions in the field of STEM education, developing individual educational STEM trajectories, designing an interdisciplinary plan, forming skills for a successful life in the 21st century, mastering methods of the invention, online cooperation with colleagues, using telecommunication technologies, etc. (Kuchai et al., 2022)

During the experiment, the level of formation of indicators of readiness of future specialists to use STEM technologies in their future professional activities was checked, both in the experimental and control groups. In the control group, the degree of formation of the components compared to the ascertainment experiment increased by 6%, from 33% to 39%.

In the experimental group, the degree of formation of the components increased by 30%, from 33% to 62%. These data testify to the effectiveness of the developed system in forming the readiness of future specialists to use STEM technologies in their future professional activities.

Statistical hypothesis testing criteria were used to establish the probability of the obtained results:

– About the significance of the differences (alternative hypothesis) of the characteristics of the experimental and control groups;
– About the absence of differences (null hypothesis).

The obtained statistical data were analyzed for homogeneity using the Pearson test. Research at the ascertainment stage of the experiment allows us to say that at this stage of the experiment, there was no statistically significant difference between the experimental and control groups for any structural component of the readiness of future specialists to use STEM technologies in their future professional activities. At the control stage of checking the readiness of future specialists to use STEM technologies in their professional future activities in the control and experimental groups, we can see statistically significant differences between the levels of readiness of future specialists to use STEM technologies in their professional future activities of the experimental and control groups.

The obtained results of the experimental study proved that the readiness of future specialists to use STEM technologies in their future professional activities was formed more effectively in the experimental group than in the control group. Therefore, we see the importance of the transformation of the information and educational environment into a higher school in the context of ensuring the effective implementation of a STEM-oriented approach for the effective application of STEM technologies in the future professional activities of specialists.

The conducted research provided an opportunity to ascertain the fulfillment of the assigned tasks. The obtained results made it possible to outline some directions for further research:

- Determination of ways of learning STEM technologies in the conditions of mixed and distance learning;
- Determining the effectiveness of STEM technologies using non-formal education;
- Determining the possibilities of using the components of the developed methodical system of preparation for teaching STEM technologies for future specialists and trainees of the system of professional development of pedagogical personnel.

**Conclusions**

The essence of STEM education, the STEM-oriented approach in the modern informational and educational environment, and the main components, and key aspects of the STEM education environment are considered. Effective organizational forms of applying the STEM-oriented approach to education are emphasized. The key aspects in the educational process of the STEM approach are named.

Recommendations for the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach in higher education institutions are provided.

International projects to support and organize STEM education are analyzed.

The main principles of the transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach are revealed.

The need for special equipment in the process of transformation of the information and educational environment in the context of ensuring the effective implementation of the STEM-oriented approach is proven. The importance of the hardware and software module with software is emphasized, which is the most important condition for creating a STEM environment and a special virtual space created by virtual classes, where an innovative educational process is formed.

The STEM competencies of students, which will make it possible to shape the implementation of the STEM education model in the education process, are considered.

During the study, an analysis of the formation of the readiness of future specialists in the field of natural sciences and mathematics to use STEM technologies in their future professional activities was carried out.

The obtained results of the experimental study proved that the readiness of future specialists to use STEM technologies in their future professional activities was formed more effectively in the experimental group than in the control group. Therefore, we see the importance of the transformation of the information and educational environment into a higher school in the context of ensuring the effective implementation of a STEM-oriented approach for the effective application of STEM technologies in the future professional activities of specialists.

We consider the use of cloud services for the organization of STEM education in higher education and the creation of a cloud-oriented STEM education environment as perspectives for the research.

The results of the research can be used for the development of flexible and variable work curricula and programs of disciplines, lecture courses, seminar classes and workshops, elective courses, and special courses in institutions of higher education, which prepare future specialists and can supplement the content of academic disciplines. The main points, results, and conclusions of the article can be used to develop provisions and standards for teaching STEM disciplines. It is advisable to use the research materials in the training of teachers at various educational and qualification levels and in the postgraduate education system.

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