Chapter IV. PROBLEMS OF EDUCATION AND UPBRINGING OF CHILDREN IN EDUCATIONAL INSTITUTIONS OF MOUNTAIN REGIONS

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STEM EDUCATION IN THE PROFESSIONAL TRAINING OF FUTURE TEACHER EDUCATORS AS A SUBJECT OF SCIENTIFIC DISCOURSE

Abstract. The article analyzes STEM education in the professional training of future teachers as a subject of contemporary scientific discourse. The essence of STEM education is revealed as an integrative educational approach that combines natural sciences, technology, engineering, and mathematics with the aim of forming the professional competencies of a new generation of teachers. The views of domestic and foreign scholars on the role of STEM education in the modernization of teacher education in response to the challenges of digitalization, innovative development, and labor market demands are summarized.

Emphasis is placed on the interdisciplinary nature of STEM education and its potential to develop critical thinking, research skills, creativity, and the ability to solve complex problems among future teachers. Scientific approaches to the implementation of STEM-oriented methodologies in the system of professional pedagogical education are analyzed, including project-based learning, problem-based learning, and the use of digital technologies. Particular attention is paid to the relationship between STEM education and social and emotional learning as a factor in creating a safe and supportive educational environment in the process of training future teachers.

It is determined that STEM education serves not only as a tool for integrating academic disciplines but also as an important means of forming the professional identity of teachers who are ready for innovative activity and continuous professional development. The article concludes that further scientific reflection on STEM education as a strategic direction for the development of professional training of future teachers in the context of global educational trends is necessary. At the same time, the analysis of scientific sources indicates that the issue of STEM education in the professional training of future teachers of natural science disciplines requires further generalization in the context of contemporary educational reforms and the requirements for pedagogical activity. The purpose of the article is to provide a theoretical understanding of STEM education in the professional training of future teachers as a subject of contemporary scientific discourse and to determine its role in the preparation of natural science teachers under conditions of educational reforms and societal transformations.

The objectives of the study are to analyze the approaches of domestic and foreign scholars to the interpretation of STEM education, to reveal the essence of the concept of “STEM education” in the context of professional teacher training, to determine the role of STEM education in the formation of professional competencies of future natural science teachers, and to outline the significance of STEM education in the implementation of modern educational reforms.

Keywords: STEM education, professional training, scientific discourse, integration, natural science teachers, innovations.

STEM-ОСВІТА У ПРОФЕСІЙНІЙ ПІДГОТОВЦІ МАЙБУТНІХ ПЕДАГОГІВ ЯК ПРЕДМЕТ НАУКОВОГО ДИСКУРСУ

Анотація. У статті здійснено аналіз STEM-освіти в професійній підготовці майбутніх педагогів як предмета сучасного наукового дискурсу. Розкрито сутність поняття STEM-освіти як інтегративного освітнього підходу, що поєднує

природничі науки, технології, інженерію та математику з метою формування професійних компетентностей учителів нового покоління. Узагальнено погляди вітчизняних і зарубіжних дослідників щодо ролі STEM-освіти у модернізації педагогічної освіти відповідно до викликів цифровізації, інноваційного розвитку та потреб ринку праці. Акцентовано увагу на міждисциплінарному характері STEM-освіти, її потенціалі для розвитку критичного мислення, дослідницьких умінь, креативності та здатності до розв'язання комплексних проблем у діяльності майбутніх педагогів. Проаналізовано наукові підходи до впровадження STEM-орієнтованих методик у систему професійної педагогічної освіти, зокрема проєктну діяльність, проблемно-орієнтоване навчання та використання цифрових технологій. Окрему увагу приділено взаємозв'язку STEM-освіти та інноваційного навчання як чинника створення безпечного й підтримувального освітнього середовища у процесі підготовки майбутніх учителів. Визначено, що STEM-освіта виступає не лише інструментом інтеграції навчальних дисциплін, а й важливим засобом формування професійної ідентичності педагога, готового до інноваційної діяльності та безперервного професійного розвитку. Зроблено висновок про доцільність подальшого наукового осмислення STEM-освіти як стратегічного напряму розвитку професійної підготовки майбутніх педагогів у контексті глобальних освітніх трансформацій. Водночас аналіз наукових джерел засвідчує, що проблема STEM-освіти у професійній підготовці майбутніх учителів природничих дисциплін потребує подальшого узагальнення в контексті сучасних освітніх реформ та вимог до педагогічної діяльності.

Метою статті є теоретичне осмислення STEM-освіти у професійній підготовці майбутніх педагогів як предмета сучасного наукового дискурсу та визначення її ролі у підготовці вчителя природничих дисциплін в умовах освітніх реформ та суспільних трансформацій.

Завдання дослідження: проаналізувати підходи вітчизняних і зарубіжних учених до трактування STEM-освіти, розкрити сутність поняття «STEM-освіта» у контексті професійної педагогічної підготовки, визначити роль STEM-освіти у формуванні професійних компетентностей майбутніх учителів природничих дисциплін, окреслити значення STEM-освіти в умовах реалізації сучасних освітніх реформ.

Ключові слова: STEM-освіта, професійна підготовка, науковий дискурс, інтеграція, учителі природничих дисциплін, інновації.

INTRODUCTION

The problem formulation. Transformational processes in education driven by globalization, digitalization, the development of knowledge-intensive technologies, and the reform of national education systems highlight the need to train a new type of teacher one capable of interdisciplinary integration, innovative activity, research-oriented thinking, and the use of modern educational technologies.

In this context, STEM education occupies a special place as a strategic direction for the development of Ukraine's education system. At the present stage, it is characterized by increased attention to the integration of science, technology, engineering, and mathematics as key drivers of innovation.

Among global educational transformations, STEM education is also viewed as a strategic direction for modernizing educational content and technologizing the professional training of teaching staff. Of particular relevance is the issue of implementing STEM education in the training of future teachers of natural sciences, who in their professional activities must ensure that school students develop an appropriate level of scientific thinking, research skills, technological literacy, and readiness to solve complex interdisciplinary problems.

Under the conditions of implementing the reforms of the New Ukrainian School, the competence-based approach, the digitalization of education, and orientation toward the European educational space, the requirements for the professional training of natural science teachers are increasing. Under these circumstances, teachers must be not only carriers of subject-specific competencies but also facilitators of learning, capable of integrating STEM education, project-based research methods, and innovative educational practices into the educational activities of institutions. In this regard, STEM education emerges as a subject of active scientific discourse that requires theoretical comprehension and generalization of scientific approaches.

An analysis of scientific sources (N. Byrka, S. Halata, N. Hushchyna, R. Koller) provides grounds for identifying the relevance of STEM education as an object of scientific reflection, determined by a number of global and national factors: the digitalization of society, the innovative development of the economy, changes in the labor market structure, the need to develop 21st-century competencies, and the modernization of the education system. In this context, STEM education acts as an effective strategy that responds to current educational transformations, contributes to updating the traditional subject-based model of learning, and facilitates the transition to interdisciplinary, practice-oriented, and competence-based approaches to organizing the educational process.

Analysis of recent research and publications. In Ukrainian and international scientific discourse, STEM education is considered not only an educational innovation but also a paradigmatic learning model that integrates scientific knowledge, technological tools, engineering thinking, and mathematical modeling with a focus on real-life and professional tasks. In the professional training of future natural science teachers, STEM education acquires the status of a pedagogical technology that determines the content, methods, forms, and learning outcomes.

The theoretical and methodological foundations of STEM education are presented in the works of domestic and foreign scholars. In the international academic space, the theoretical and methodological principles of STEM education have been studied by J. Bybee, R. Sanders, M. Honey, G. Pearson, E. Breiner, N. Stohlmann, S. Moore, and C. Roehrig, who emphasize the interdisciplinary nature of STEM, its focus on solving real problems of science and society, and the development of applied 21st-century competencies. Issues of teacher professional training in the STEM context are addressed in the studies of D. Capraro, R. Capraro, J. Falk, and L. Darling-Hammond,

which emphasize the importance of practice-oriented learning and pedagogical innovation. Various aspects of STEM education are widely represented in the works of Ukrainian scholars such as O. Barna, O. Buturlina, D. Vasylieva, O. Voronkin, N. Honcharova, O. Dziuba, V. Zhukova, S. Kyrylenko, O. Kuzmenko, O. Lozova, N. Morze, N. Polikhun, V. Khmurenko, and others. Researchers O. Trehub and Yu. Skibchyk analyze the peculiarities of applying STEM education in the training of future teachers of vocational education. In Ukrainian pedagogical science, various aspects of STEM education are studied by V. Kremen, O. Spirin, N. Morze, S. Semerikov, I. Slipukhina, and O. Patrykeieva, who reveal the potential of the STEM approach for modernizing natural and mathematical education, forming key and subject competencies, and developing the digital and engineering culture of future teachers.

At the same time, the analysis of scientific sources indicates that the problem of STEM education in the professional training of future natural science teachers requires further generalization in the context of modern educational reforms and contemporary requirements for pedagogical activity.

THE PURPOSE OF THE RESEARCH

The purpose of the article is the theoretical comprehension of STEM education in the professional training of future teachers as an object of contemporary scientific discourse and the determination of its role in training natural science teachers under conditions of educational reforms and societal transformations.

The objectives of the study are to analyze the approaches of Ukrainian and foreign scholars to the interpretation of STEM education; to reveal the essence of the concept of “STEM education” in the context of professional pedagogical training; to determine the role of STEM education in the formation of professional competencies of future natural science teachers; and to outline the significance of STEM education in the implementation of modern educational reforms.

RESEARCH METHODS

The research methods include theoretical analysis and synthesis of scientific sources, comparison, generalization, systematization of pedagogical approaches, and interpretation of research findings in the field of STEM education.

RESULTS OF THE RESEARCH

Issues of a country’s STEM development are at the center of attention of many international organizations and educational institutions worldwide. Accordingly, high-quality STEM education of citizens is an integral component of the national educational strategies of leading highly developed countries. In this context, the views of O. Yurova, O. Yevtushenko, and I. Savchenko are noteworthy, as they point out that “modern education systems and labor markets face global challenges associated with dynamic changes in the professional sphere. New professions are emerging, and the range of specialties in existing industries is expanding. This is especially true for professions related to science, technology, engineering, and mathematics (STEM)” (Yurova, O., Yevtushenko, O., & Savchenko, I., 2019).

According to current regulatory documents (Order of the Cabinet of Ministers of Ukraine “On Approval of the Concept for the Development of Natural and Mathematical Education (STEM Education)” (2020) and “On Approval of the Action Plan for the Implementation of the Concept for the Development of Natural and Mathematical Education (STEM Education) until 2027” (2021)), “STEM education is considered one of the priorities for the development of the education sector, a component of state policy aimed at increasing the competitiveness of the national economy and developing human capital, and a key factor of innovation in education that meets economic demands and societal needs” (Order of the Cabinet of Ministers of Ukraine, 2020; 2021).

STEM education is based on transdisciplinary approaches to curriculum design at various levels, individual didactic elements, the study of phenomena and processes of the surrounding world, and the solution of problem-oriented tasks. The application of the leading principle of STEM education—integration—“makes it possible to modernize methodological foundations, educational content, the scope of learning material, technologize the learning process, and form qualitatively new learning competencies among learners. It also contributes to higher-quality training of future specialists for successful employment and further professional growth, which requires diverse and technically more complex skills, including the application of mathematical knowledge and scientific concepts” (Yurova, O., Yevtushenko, O., & Savchenko, I., 2019).

In contemporary research, STEM education is viewed as an integrated educational paradigm that combines natural sciences (Science), technology (Technology), engineering (Engineering), and mathematics (Mathematics) with the aim of forming a holistic scientific and technological worldview and developing research, project-based, and critical skills.

The acronym “STEM” stands for Science, Technology, Engineering, and Mathematics. It should be noted that these disciplines occupy leading positions not only in education but also in the economy and energy sectors. As researchers V. Miziuk and H. Novak note, “global practice includes analogous forms of such integration: STEAM, STREM, STREAM, STEMLE, iSTEM, eSTEM, METALS, MINT, GEMS, etc. They denote combinations of core disciplines with various fields (Logic, Law, Gender studies, Ecology, etc.)” (Miziuk & Novak, 2023).

Analyzing the experience of countries where STEM education is successfully implemented, it should be emphasized that several of its variants are actively introduced in the Ukrainian education system, namely:

STEM (Science, Technology, Engineering, Mathematics);

STEAM (Science, Technology, Engineering, Arts, Mathematics);

STREAM (Science, Technology, Reading, Engineering, Arts, Mathematics) (Office of the Chief Scientist, 2013).

STEM education develops in such key areas as educational robotics, information technologies, and project-based research activities.

These innovative educational formats not only enrich educational content but also significantly improve the quality of training of future specialists. The integration of scientific, technical, and creative (humanitarian) fields of knowledge makes the learning process more effective and valuable for both learners and educators.

STEM education is implemented through all forms of education: formal, non-formal, and informal (via various technological online platforms, simulation laboratories, technological spaces, and digital hubs), as well as through excursions, competitions, Olympiads, festivals, and techno-quests.

STEM education is a response to the challenges of modern "Society 4.0," driven by rapid developments in science, technology, digitalization, and the global labor market. The main problem addressed by STEM education is the mismatch between the traditional subject-fragmented learning system and the needs of modern education, which requires integrated thinking and the ability to apply interdisciplinary knowledge to practical life tasks.

Unlike traditional subject-based education, STEM education focuses on interdisciplinary integration, practical orientation, and solving real-world problems, thereby ensuring the connection between theory and practice and fostering innovative thinking. Researcher O. Trehub defines STEM education as "an interdisciplinary approach to learning that cultivates critical thinking, innovation, and technical competencies necessary for solving complex problems in various spheres of life" (Trehub, 2024).

The Concept for the Development of Natural and Mathematical Education defines STEM education as "a holistic system of natural and mathematical educational fields aimed at personal development through the formation of competencies, a scientific worldview, value orientations, and life values using a transdisciplinary approach to learning based on the practical application of scientific, mathematical, technical, and engineering knowledge to solve practical problems for further use in professional activities" (Concept for the Development of Natural and Mathematical Education, 2020). The theory of practice-oriented learning, which underlies the modern understanding of STEM education, is attributed to MIT professor Mitchel Resnick (Resnick, Lifelong Kindergarten: Cultivating Creativity Through Projects, 2017).

The organization of STEM learning is based on practice-oriented and interdisciplinary approaches, whereby learners apply knowledge from various fields to solve specific practical tasks. This approach forms engineering and technical competencies that include critical thinking, teamwork, and the ability to present and defend projects. In the educational process, the STEM approach is applied in the study of geography, biology, mathematics, physics, and robotics.

Today, STEM education integrates the educational process, professional activity, and career development into a holistic system. A vivid example of its implementation is the creation of the "Atlas of Future Professions," which outlines new professions that will emerge or be in demand in the near future. Most of these professions are based on engineering and technical competencies formed through STEM-based learning. According to the Institute for the Future (USA), by 2030, 85% of professions that today's students will work in have not yet been fully defined or even invented (Institute for the Future, 2024). In this context, STEM education is viewed not merely as a fashionable educational trend but as a new stage in the development of the global education system.

The implementation of educational innovations is carried out through the interconnection of formal, non-formal, and informal learning by developing specialized educational programs for different age groups and through extracurricular activities such as science camps, museums, excursions, STEM competitions, projects, and fairs (Morze, Strutynska, & Umryk, 2018).

Thus, STEM education is one of the priorities for today's labor market, placing increasing demands on the quality of training of qualified professionals—future natural science teachers. A successful specialist today is one who can work with information technologies, process large data sets, quickly find, analyze, and present information effectively. While knowledge can be acquired through learning activities, core competencies are formed through practical work and strong motivation.

Integrative STEM education involves approaches that examine learning interactions among multiple subject areas included in STEM education within social and ethical contexts of human activity. The mastery of technologies should not be detached from the study of basic humanities, social sciences, or arts, nor from adherence to academic integrity and ethical standards.

In the classical educational model, scientific disciplines are often taught in isolation, leading to fragmented knowledge acquisition and reduced motivation. In contrast, real scientific, technical, and engineering tasks are complex and cannot be effectively solved within a single discipline. This contradiction between educational content and societal needs constitutes the key problem that STEM education seeks to address.

STEM education is an object of interdisciplinary scientific analysis, as it integrates knowledge, methods, and approaches from various fields, including:

- pedagogy (learning theory, didactics, educational technologies);
- psychology (cognitive development, motivation, critical and creative thinking);
- natural sciences (geography, natural science, physics, chemistry, biology);
- mathematics and computer science (modeling, algorithmic thinking, data analysis);
- engineering and technology (project activity, construction, design thinking, engineering);
- sociology and economics (labor market needs, innovative societal development).

Thus, it should be emphasized that STEM education is not reduced to the simple addition of several subjects but represents a holistic educational concept based on the integration of scientific knowledge and practical activity. This integration is reflected in an interdisciplinary approach, which in STEM education is substantiated from several perspectives.

First, the nature of contemporary problems of sustainable societal development is inherently interdisciplinary. Environmental crises, energy challenges, and the development of artificial intelligence and biotechnology require the simultaneous application of knowledge from various scientific fields.

Second, interdisciplinarity contributes to the formation of key competencies, including critical thinking, teamwork skills, the ability to analyze and synthesize information, creativity, and innovativeness.

Third, the integration of disciplines enhances the practical orientation of learning. Project-based and research activities in STEM education enable learners to see the real-world application of knowledge, which positively affects motivation and the quality of learning outcomes.

Fourth, the interdisciplinary approach corresponds to the requirements of the modern labor market, where not narrowly specialized knowledge but rather the ability to learn quickly, adapt, and work at the intersection of different educational fields is highly valued.

Therefore, STEM education as an object of interdisciplinary scientific analysis is a complex, multidimensional phenomenon that combines pedagogical, psychological, scientific, and socio-economic aspects. The interdisciplinary approach constitutes its methodological foundation, as it ensures the integrity of knowledge, the practical orientation of learning, and the preparation of individuals for effective activity in a modern technological society.

Global transformations driven by the development of digital technologies, automation, and the knowledge economy actualize the need to update the content and methods of education. In this context, STEM education is viewed as a strategic direction for the modernization of educational systems, aimed at developing learners' abilities for complex problem-solving, critical thinking, and innovative activity.

At the same time, scientific discourse indicates that STEM education cannot be adequately comprehended within the framework of a single field of knowledge, which necessitates its interdisciplinary analysis.

Analyzing the essence of the comprehensive interpretation of the concept of STEM education in contemporary scientific research, it should be noted that in scholarly literature STEM education is interpreted as "an integrated approach to learning that combines science, technology, engineering, and mathematics with the aim of forming applied and research competencies" (Honcharova, N., 2017).

According to the definition of the National Science Foundation (USA), "STEM education is an educational model that involves the integration of disciplines to solve real-world problems through inquiry, design, and experimentation" (National Science Foundation, 2022). In this context, R. Bybee emphasizes that STEM is not a collection of subjects but a pedagogical paradigm aimed at developing scientific and technological literacy and the ability to apply knowledge in new situations. UNESCO considers STEM education as "a tool for ensuring sustainable development, emphasizing its role in preparing human capital for an innovative economy" (Bybee, 2013). Interdisciplinarity is a defining characteristic of STEM education, manifested in the integration of methods, concepts, and research strategies from different scientific fields.

From a pedagogical perspective, STEM education is based on competency-based, activity-oriented, and constructivist approaches, emphasizing the active role of learners in the process of cognition (Froyd, Wankat, & Smith, 2012).

The psychological dimension of STEM is associated with "the study of cognitive processes, the development of critical and creative thinking, motivation for learning, and self-realization" (Hmelo-Silver, 2004).

The socio-economic aspect of STEM education is considered in the context of labor market needs and the innovative development of society. According to OECD analytical reports, the integration of STEM disciplines contributes to the development of 21st-century skills necessary for economic competitiveness and the achievement of sustainable development goals (OECD, 2019). The need for an interdisciplinary approach is primarily обусловлена the nature of modern scientific and technological problems, which are complex in character. As J. Klein notes, "interdisciplinarity is the response of science and education to the complexity of the real world, which cannot be adequately analyzed from the perspective of a single discipline" (Klein, 2010).

Within the context of STEM education, the interdisciplinary approach ensures:

- the integrity of scientific knowledge;
- the transfer of theoretical knowledge into practical activity;
- the formation of abilities for analysis, synthesis, and modeling;
- the development of engineering and systems thinking.

In addition, the integration of disciplines in STEM education correlates with the ideas of education for sustainable development, where knowledge is viewed as a tool for social and technological change (UNESCO, 2017).

STEM education is an interdisciplinary educational phenomenon that integrates pedagogical, psychological, scientific, and socio-economic aspects. Its analysis requires the use of an interdisciplinary methodology capable of reflecting the complexity and multidimensionality of this phenomenon. The interdisciplinary approach in STEM education functions not only as a didactic principle but also as a strategic condition for training specialists capable of innovative activity in a modern technological society.

Thus, STEM education is a complex systemic phenomenon that cannot be fully studied within the framework of a single scientific paradigm. In the professional training of future teachers, STEM education functions not only as a content component but also as a methodological foundation for organizing the educational process, involving the use of project-based, research-oriented, digital, and engineering learning technologies. As A. Ihnatusha notes, "during the implementation of STEM education in Ukraine, the main emphasis is placed on practical tasks and problem-solving close to real-life situations. This motivates learners to seek solutions not only through mastering theoretical material but also through conducting practical experiments and organizing applied testing" (Ihnatusha, A., 2018).

In its modern understanding, STEM education represents the organization of learning interaction through practice-oriented activity, challenging the traditional didactic principle of progression from theory to practice. In STEM education, the process is reversed: learners first reflect, design projects, experiment, and work on inventions. Based on the experience and practical skills acquired, they then master theoretical principles and gain new knowledge. The analysis of literature shows that STEM education presupposes a blended learning environment in which learners become aware of how to optimally apply acquired knowledge in practical activities.

Thus, the analysis of theoretical literature provides grounds to assert that STEM education is a progressive direction in educational interaction that combines interdisciplinary and applied approaches. This integration helps learners acquire more knowledge and expands and deepens interdisciplinary connections. By integrating disparate natural science and humanities disciplines into a unified whole, future teachers learn to understand and more deeply comprehend a holistic picture of the world.

It should also be emphasized that STEM education contains its own resources. Macro-resources of STEM education include specially designed educational and technological environments equipped with the necessary technological tools (laboratories, studios, technoparks). Micro-resources of STEM education may include various phenomena of material and spiritual culture that contain educational potential for the development of technological and innovative thinking. The blended STEM learning environment makes it possible to design forms and learning technologies with an emphasis on project-based and research activities of future natural science teachers.

Therefore, the focus of modern pedagogical science on the essence of STEM education and the implementation of innovative technologies in teacher training programs can become an effective step toward optimizing the preparation of modern teaching staff for the rapidly changing educational services market under the conditions of the Fourth Industrial Revolution. The introduction of innovative STEM technologies into the educational process and educational-professional programs for training future specialists in the natural sciences within formal, informal, and non-formal education in modern higher education institutions can ensure, through the integration of interdisciplinary and applied approaches, the solution of not only general pedagogical problems related to the development of innovative and technological thinking and the formation of core "4C" skills of the 21st century, but also promote learners' involvement in scientific and research activities.

CONCLUSIONS AND PROSPECTS OF FURTHER RESEARCH

The generalization of the results of the theoretical analysis allows for the following conclusions.

STEM education is a complex interdisciplinary phenomenon formed at the intersection of pedagogy, natural sciences, technologies, and professional education, and it constitutes an object of active scientific discourse.

In scientific research, STEM education is conceptualized through integrative, competency-based, activity-oriented, technological, and professionally oriented approaches, which complement one another and form a holistic understanding of its essence. In the professional training of future natural science teachers, STEM education has a system-forming significance, as it ensures the integration of learning content, the activation of cognitive activity, and the formation of readiness for innovative pedagogical practice.

STEM education contributes to the formation of professional competencies in future teachers necessary for implementing the ideas of the New Ukrainian School, including the ability for interdisciplinary integration, project-based activity, the use of digital technologies, and formative assessment.

The theoretical comprehension of STEM education as an object of scientific discourse creates a methodological foundation for further research into the organizational and didactic conditions for preparing future teachers to apply STEM technologies in professional activity, which determines the prospects for subsequent studies on the outlined problem.

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