QUALITY OF LIFE IN THE GLOBAL UNCERTAINTY DIMENSIONS

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Quality of Life
in the Global Uncertainty Dimensions

Monograph

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2.7. Analysis of the current state of preparation of future teachers for STEM-oriented professional activities

Relevance of the Study. A country's success in scientific and technological development directly depends on the quality of teacher training, particularly on educators capable of fostering in schoolchildren an interest in exploring the world through the lens of science, technology, engineering, and mathematics. The teacher plays a key role in stimulating the intellectual and creative potential of children and youth, awakening their curiosity toward research activities, engineering design, and the use of modern technologies to solve applied problems. An effective tool for such educational renewal is STEM education.

STEM (Science, Technology, Engineering, and Mathematics) represents a modern didactic approach based on the integration of interdisciplinary practices and problem-based learning methods in the teaching of natural and mathematical sciences. With the development of educational innovations, the component Arts was added to this model, forming the STEAM approach, which aims to include creative and artistic disciplines within the framework of scientific and technical education. These areas include industrial design, architecture, and industrial aesthetics, among others. In the European educational discourse, a broader interpretation of STEAM has emerged, viewing it as a combination of all educational fields (A – *All*), emphasizing the importance of a comprehensive integration of scientific, technical, humanitarian, and artistic components in educational programs.

STEM education functions not only as a field of study but also as a pedagogical technology focused on developing transversal skills such as problem-solving, critical and systems thinking, creativity, cognitive flexibility, teamwork, as well as managerial and innovative abilities. This approach enables students to think in the context of real-world challenges and to create solutions that combine scientific knowledge, engineering reasoning, and technological tools.

Thus, the ability to integrate the STEM approach into the educational process determines whether the next generation will be ready not only to consume existing knowledge but also to create innovations. In this context, the integration of STEM disciplines into teacher education programs becomes a key condition for developing the competencies necessary for implementing STEM-oriented pedagogical activities.

In our view, the implementation of the STEM approach should not be limited to teachers of science and mathematics. Contemporary educational practice demonstrates that teachers of humanities can also effectively contribute to the formation of STEM competencies among students by integrating elements of research and technological activities into their subjects.

The aim of this study is to analyze the presence and nature of STEM components in educational programs of both humanitarian and non-humanitarian fields offered by Ukrainian higher education institutions (HEIs).

The methodological framework of the research is based on contemporary pedagogical theories that emphasize systemic, competence-based, and interdisciplinary approaches to teacher education. The study employs a qualitative content analysis of educational programs from various Ukrainian HEIs in order to identify the presence and specifics of STEM integration within the structure of future teacher training.

The study analyzed over thirty educational programs at the first (bachelor's) and second (master's) levels in the field of *Education* (according to the Resolutions of the Cabinet of Ministers of Ukraine No. 1021 of August 30, 2024, and No. 266 of April 29, 2015), as well as several programs in the humanities and natural-mathematical sciences profiles that include teacher training components. The empirical base consisted of open educational resources: official university websites, electronic repositories of educational documentation, public curricula, and course descriptions.

To process the data, content analysis was used, involving the examination of program structures, learning outcomes, course content, and methods of implementing interdisciplinary connections. A comparative analysis allowed for identifying the specific features of integrating STEM disciplines into pedagogical, humanitarian, and science-oriented programs, as well as differences between the bachelor's and master's levels.

The criteria for determining the presence of STEM components included:

1. Availability of courses or modules aimed at developing digital literacy, technological culture, analytical and critical thinking.

2. Reflection of STEM approaches in the program learning outcomes (emphasis on research, project-based, and practice-oriented activities).

3. Interdisciplinary nature of course content (integration of scientific, technical, and humanitarian fields).

4. Inclusion of practical or research-based project work focused on solving applied scientific problems.

The findings are presented to identify trends in the integration of STEM disciplines into teacher education and to develop recommendations for further modernization of educational programs.

Research Results. Today, Ukraine has established a fairly robust regulatory and legal framework for the implementation of STEM education, including the following:

- Laws of Ukraine: *On Education, On Complete General Secondary Education*, *On Extracurricular Education*, *On Scientific and Scientific-Technical Activity*, *On Innovation Activity*, *On Culture*;
- The State Standard for Primary Education, approved by the Resolution of the Cabinet of Ministers of Ukraine dated February 21, 2018, No. 87;
- The State Standard for Basic Secondary Education, approved by the Resolution of the Cabinet of Ministers of Ukraine dated September 30, 2020, No. 898;

- *Strategy for the Development of the Innovation Sphere until 2030*, approved by the Order of the Cabinet of Ministers of Ukraine dated July 10, 2019, No. 526-r;
- *Strategy for the Development of Higher Education in Ukraine for 2022-2032*, approved by the Order of the Cabinet of Ministers of Ukraine dated February 23, 2022, No. 286-r;
- The Concept for Implementing State Policy in the Reform of General Secondary Education *"New Ukrainian School"* until 2029, approved by the Order of the Cabinet of Ministers of Ukraine dated December 14, 2016, No. 988-r;
- The Concept for the Development of Natural Science and Mathematics Education (STEM Education), approved by the Order of the Cabinet of Ministers of Ukraine dated August 5, 2020, No. 960-r;
- The Action Plan for Implementing the Concept for the Development of Natural Science and Mathematics Education (STEM Education) until 2027, approved by the Order of the Cabinet of Ministers of Ukraine dated January 13, 2021, No. 131-r;
- The Action Plan for Promoting Natural Sciences and Mathematics until 2025, approved by the Order of the Cabinet of Ministers of Ukraine dated April 14, 2021, No. 320-r;
- Regulations on the Procedure for Implementing Innovative Educational Activities, approved by the Order of the Ministry of Education and Science of Ukraine dated November 7, 2000, No. 522, registered with the Ministry of Justice of Ukraine on December 26, 2000, No. 946/5167 (as amended by the Order of the Ministry of Education and Science, Youth and Sports of Ukraine dated November 30, 2012, No. 1352);
- Order of the Ministry of Education and Science of Ukraine dated October 16, 2019, No. 1303 *"On Approval of the Standard for Specialized Education of a Scientific Orientation"*;

- Order of the Ministry of Education and Science of Ukraine dated August 29, 2024, No. 1225 *"On Approval of the Professional Standard 'Teacher of a General Secondary Education Institution"*;
- Order of the Ministry of Education and Science of Ukraine dated April 29, 2020, No. 574 *"On Approval of the Typical List of Teaching Aids and Equipment for Classrooms and STEM Laboratories"*, among others.

Thus, the established regulatory and legal foundation not only regulates processes in the field of STEM education but also defines strategic directions for its practical implementation. At this stage, the implementation aspect becomes crucial – ensuring mechanisms and allocating resources that support the integration of the STEM approach into Ukraine's educational space. Accordingly, in line with the Concept for the Development of Natural Science and Mathematics Education (STEM Education), scientific institutions and educational establishments in Ukraine focus on the following priority actions:

- The planned creation of a network of regional STEM centers to provide informational and methodological support for students' learning activities; each regional STEM center is expected to have working groups of developers, experts, and educational process moderators;
- Formation of a network-centric environment of STEM centers to support science-oriented education aimed at modernizing mathematics, natural sciences, and humanities education;
- Coordination of methodological and software-information resources for teaching;
- Organization of international, national, and regional conferences, seminars, webinars, and round tables for teachers, methodologists, moderators of STEM center educational processes, educational institutions at various levels, developers, and experts;

- Creation of virtual platforms for interdisciplinary laboratories to connect Ukrainian educational institutions to the STEM center network;
- Ensuring the availability of educational and methodological resources for effective implementation of STEM education in Ukraine (*Concept for the Development of Natural Science and Mathematics Education*, 2020).

Despite the presence of a robust regulatory and legal framework aimed at developing and promoting STEM education, its provisions are not yet consistently reflected in professional teacher training programs. Analyses of instructors' and students' perspectives indicate a significant gap between state initiatives and their implementation in teacher education (Mytsyk, et al., 2024; Nesterenko, et al., 2025; Petryk, et al., 2024), (Nesterenko, et al., 2024). As a result, future teachers do not acquire the necessary competencies for effective implementation of the STEM approach, which complicates the achievement of strategic goals of contemporary Ukrainian education related to cultivating a scientifically oriented and technologically competent generation.

This situation necessitates a more thorough analysis of the current state of teacher preparation for STEM-oriented professional activity, including examining pedagogical universities' curricula, determining the level of STEM integration in the learning content, and evaluating its alignment with the requirements of an innovative educational environment.

At *Berdyansk State Pedagogical University*, professional training of future teachers is carried out through 34 educational and professional programs at the first (bachelor's) level and 23 programs at the second (master's) level of higher education.

One of the most consistently STEM-oriented educational programs is the bachelor's program in specialty 014.09 "Secondary Education (Informatics)", implemented by the Faculty of Physical, Mathematical, Computer, and Technological Education. The structure of the program itself demonstrates its focus on developing integrated competence, related to solving complex specialized problems in the field of information and communication technologies and in teaching informatics in general secondary education institutions.

An analysis of the program's goals, focus, and structure reveals its clear orientation toward forming in future teachers the ability to combine pedagogical activity with technological thinking, an understanding of the functioning of the digital educational environment, and the use of modern teaching methods in informatics. A particularly valuable feature of this program is the explicit inclusion of STEM education in teacher training. Specifically, the program includes educational components directly related to STEM competency development, such as "STEM Education and Robotics" (5 ECTS credits) and "Production Internship (in Robotics and STEM Education Clubs)" (9 ECTS credits). The very presence of such components within the cycle of professional training is a positive indicator.

The content of the discipline *"STEM Education and Robotics"* reflects a focus on the practical application of theoretical knowledge – students learn to work with hardware and software tools, develop instructional models, and design methodologies for integrating elements of robotics into the educational process. The learning outcomes – such as the ability to solve practical problems based on the integration of knowledge about computer systems, select and apply modern digital tools, and organize systems for learning assessment – correspond directly to key characteristics of the STEM approach (interdisciplinarity, practical orientation, and inquiry-based learning).

An equally important component of the program is the production internship, aimed at applying knowledge in real educational environments. The internship in robotics and STEM clubs promotes not only methodological but also organizational and pedagogical competencies, including the ability to design educational projects, implement digital technologies, and foster students' creativity and technical imagination. Analysis of the learning outcomes shows an emphasis on developing skills in information search, analytical thinking, digital communication, and adherence to ethical and social norms in the use of technology.

It is important to emphasize that the structure of competencies and expected learning outcomes demonstrates a balanced combination of theoretical and practical components of training: future teachers not only acquire knowledge of digital technologies but also develop the ability to implement them.

At the same time, it is evident that while the STEM component is integrated, it remains fragmentary – represented by only one course and one internship – whereas most other educational components continue to focus primarily on classical informatics teaching methods. To foster systemic STEM-oriented thinking, it would be appropriate to strengthen interdisciplinary connections across all professional modules, integrating project-based learning, research methods, and digital simulations into core courses.

Thus, the educational and professional program "Secondary Education (Informatics)" demonstrates high potential for implementing STEM-oriented teacher training, as it already includes components that develop relevant competencies. However, further improvement of the program requires expanding its interdisciplinary content to ensure more comprehensive integration of STEM across all levels of professional training for future educators.

The educational and professional program "Primary Education" of the second (master's) level of higher education, implemented by the Faculty of Psychological, Pedagogical Education and Arts, has a distinctly humanitarian and pedagogical orientation. Its goal is to train a highly qualified primary school teacher who possesses innovative thinking, creativity, and readiness to operate within any educational reform framework, particularly that of the New Ukrainian School.

Tte educational and professional program combines traditional pedagogical approaches with a focus on the modern requirements of innovative education; however, an analysis of its structure shows that the STEM component is only partially represented – within the certificate program “Informatics and Its Teaching Technologies”, which has an elective status. This means that mastering the course *“STEM Education and the Basics of Robotics in Primary School”* is not mandatory for all master’s students. Such an organizational model, while allowing for individualized educational trajectories, limits the scope of STEM training to only those who voluntarily choose this elective.

The content analysis of this discipline reveals significant potential for developing in future teachers the competencies necessary for implementing the STEM approach in primary education through learning outcomes such as: “to create an innovative information and educational environment in primary school using STEM technologies,” and “to organize and manage the educational process with the use of innovative technologies.”

However, the fact that STEM-oriented preparation is implemented through only one elective discipline indicates a lack of systematic integration of the STEM approach into the professional training of future primary school teachers. Some students acquire basic knowledge of robotics and STEM principles, while others remain outside this innovative framework.

Nevertheless, the inclusion of *“STEM Education and the Basics of Robotics in Primary School”* in the master’s curriculum represents a significant step toward modernizing teacher education. Its content focuses on developing students’ creativity, digital literacy, and project-based learning skills. The set of general and professional competencies reflects a trend toward integrating pedagogical, technological, and research activities – fundamental for the development of STEM-thinking.

At the same time, the absence of a cross-cutting STEM component integrated into the program’s core professional courses reduces its potential for systematically forming future teachers’ readiness to implement STEM education in primary school. This approach currently corresponds more to a facultative rather than a strategic model of STEM integration. To enhance the effectiveness of training, it would be advisable to expand STEM content through interdisciplinary modules, joint courses in pedagogy, psychology, and science education methodology, as well as to create opportunities for practical application of STEM technologies during teaching practice.

Thus, the educational and professional program *"Primary Education"* demonstrates a positive trend in preparing future teachers for STEM-oriented professional activity; however, its implementation remains limited, due to the elective nature of the course and insufficient integration of STEM ideas into the overall program structure.

An overall analysis shows that among all the educational and professional programs at Berdyansk State Pedagogical University, only two *"Secondary Education (Informatics)"* and *"Primary Education"* include courses directly dedicated to STEM education. Even in these cases, the STEM component remains fragmentary, represented by individual subjects rather than by a consistent integration throughout the curriculum. This level of implementation does not yet ensure systematic preparation of teachers for the realization of the STEM approach in school education.

At Ternopil Volodymyr Hnatiuk National Pedagogical University, professional training is carried out across ten faculties that cover a wide range of specialties in pedagogical, natural-mathematical, humanitarian, and artistic fields. In total, the university offers 75 educational and professional programs at the bachelor's level and 63 programs at the master's level of higher education.

At the Faculty of Physics and Mathematics (Department of Computer Science and Methods of Its Teaching), future specialists are trained in educational programs that include STEM disciplines at both the first (bachelor's) and second (master's) levels of higher education. Let us consider each of them in more detail.

First of all, the bachelor's educational and professional program "Secondary Education (Computer Science, Mathematics, Fundamentals of STEM Education)" stands out for its integrated approach to developing dual subject competence and incorporating the STEM approach into the training of future computer science teachers. The program combines in-depth theoretical preparation in computer science and mathematics with a practical focus on the use of technology in school education. It emphasizes interdisciplinarity, which is reflected in the integration of natural and mathematical content with methodological and technological aspects of teaching.

The STEM component of the educational and professional program is implemented through two key educational courses: "Methods of Teaching Computer Science and STEM Education" and "Project and Technological Practice in STEM Education", each worth 6 ECTS credits. The first course combines methodological training with elements of technological and research thinking. Its content focuses on developing the ability of future teachers to model the educational process according to the STEM approach, design learning projects, apply innovative digital learning tools, and integrate computer science and mathematics in teaching practice. The program learning outcomes demonstrate a strong link between theoretical mathematical training and its practical application in a STEM context – through the use of algorithmic thinking, systems analysis, programming knowledge, and physical principles for creating educational projects and technical models.

The Project and Technological Practice, in turn, ensures the development of skills to implement the STEM approach in a real educational environment. Its content aims to foster leadership, innovation, and research competencies, as well as the ability to work with cloud technologies, design information systems, and organize learning through practical activity and experimentation. Particular attention is paid to the ability of future teachers to implement integrated teaching, apply interdisciplinary links, and lead STEM clubs or laboratories.

Overall, the educational and professional program is characterized by a high degree of practical orientation and technological intensity. It prepares students not only to teach computer science and mathematics but also to design and manage

STEM projects. At the same time, the STEM component is concentrated within two disciplines and does not fully cover other professional modules. Therefore, despite its potential, the program requires further structural optimization to ensure that STEM becomes the core of the entire educational trajectory.

The second educational and professional program, “Secondary Education (Computer Science, Mathematics, STEM Education)” at the master’s level, is designed to prepare computer science and mathematics teachers with advanced IT training and a research focus. Its declared goal – to enable graduates to analyze and synthesize complex systems and conduct scientific research using modern information technologies and methodologies – aligns well with the master’s level and the digital competence framework.

The STEM block includes two courses: “Methods of Teaching Computer Science and STEM Technologies” (6 ECTS credits) and “Project and Technological Practice in STEM Education” (3 ECTS credits). The first course provides a methodological foundation (combining ICT, mathematics, and pedagogy; designing innovative educational environments; inclusion), while the second ensures the acquisition of practical skills in a real educational context. As can be seen, STEM is integrated across a total of 9 ECTS credits, with only 3 credits allocated to practice – insufficient for the sustainable development of engineering and design skills in master’s-level teachers capable of effectively implementing the STEM approach. Computer science and mathematics methodology dominate, while interdisciplinary courses are absent.

Hence, there is a clear need to enhance the “cross-cutting” nature of STEM by incorporating project-based and research modules into core courses on teaching methodology in computer science and mathematics; to increase the volume of practical training (with real STEM cases, interdisciplinary projects, and maker challenges); and to refine learning outcomes and align them with measurable performance indicators (project portfolios, prototypes, digital products). This would significantly strengthen the quality of master's-level teacher education in accordance with current educational priorities.

The Ukrainian State University of Science and Technology provides training for future specialists in 41 educational and professional programs at the first (bachelor's) level of higher education and 38 programs at the second (master's) level of higher education.

At the Faculty of Computer Technologies and Systems (Department of Physics and Applied Mathematics), students are trained under the bachelor's program "STEM Education" within the specialty 014 Secondary Education (by subject specializations), subject specialization 014.08 Secondary Education (Physics and Astronomy), in the field of knowledge 01 Education/Pedagogy.

The program declares a priority in preparing teachers of the natural and mathematical profile capable of integrating physics, mathematics, and computer science within the logic of STEM / STEAM education. Its structure includes fundamental training in three subject areas, a psychological and pedagogical block, and practice-oriented modules. It also provides for interdisciplinary research, project-based learning, and innovative forms of education.

The core of the STEM component lies in two professional disciplines: "Fundamentals of STEM Education" (8 ECTS credits) and "STEM Practice" (6 ECTS credits). The first course develops the methodological and instrumental foundation (integration of physics, mathematics, and computer science; modeling; use of information and communication technologies), while the second provides an opportunity to apply the acquired competencies in real educational settings (project tasks, computer experiments, organization of extracurricular activities).

The strengths of the program include a significant scope of both the core discipline and the practicum (8 and 6 credits, respectively), as well as its focus on real-life cases (extracurricular formats, clubs, projects). Under these conditions, the program has better potential to prepare teachers capable of organizing interdisciplinary learning and leading STEM-related activities.

However, these are still only two courses totaling 14 credits out of 240 in the entire bachelor's curriculum. In many other subject and methodological disciplines, integrative approaches are not clearly defined. Furthermore, the declared STEAM orientation is not sufficiently supported by explicitly articulated artistic or design components.

At the Kryvyi Rih State Pedagogical University, among 49 bachelor's and 37 master's educational programs, several are closest to implementing the objectives of the Concept of Natural-Mathematical (STEM) Education.

First of all, at the Faculty of Physics and Mathematics (Departments of Physics and Methods of Its Teaching; Informatics and Applied Mathematics), students are trained under the bachelor's program "Physics and Astronomy. Mathematics." It focuses on preparing teachers capable of organizing and conducting the educational process in physics, astronomy, and mathematics, solving complex specialized tasks. The STEM component is represented by a single professional discipline – "STEM Practices in Education" (3 ECTS credits) – aimed at the integrated application of theories and methods from different subject specializations (declared as an integrative competence).

The list of program learning outcomes partially correlates with STEM education goals, for example, knowledge of modern educational and information-digital technologies in teaching methodology and the ability to organize student projects and activities. However, this is insufficient, as many competencies remain general, and the mechanisms of cross-curricular integration are not concretely defined.

A similar situation is observed in the bachelor's educational and professional program "Informatics. Programming", which also includes only one professional discipline supporting the development of integrative competencies and preparing graduates to implement STEM approaches in educational institutions. This course, “STEM Practices in Education” (4 ECTS credits), connects subject-specific computer science training, methodology of teaching informatics, and the practical implementation of technologies in the school environment.

On the one hand, strengthened IT-oriented professional preparation potentially enables the formation of modern teachers capable of creating and maintaining a digital educational environment and initiating school projects with programming components. On the other hand, the STEM content is limited to a single 4-credit course, which is insufficient for full-fledged, science-and-technology-oriented learning, as STEM education extends beyond digital technologies alone.

At the Faculty of Pedagogical Education (Department of Technological and Vocational Education), future professionals are trained at the bachelor’s level under the unique educational and professional program “Technologies. STEM Education. Robotics” (specialty 014.10 Secondary Education (Technologies)) and at the master’s level under the program “Technologies”.

The main focus of this educational and professional program is general education within the specialty 014.10 Secondary Education (Technologies), which prepares teachers for general secondary schools, specialized education (technologies), and instructors for institutions of professional pre-higher education. The program integrates psychological-pedagogical, methodological, and project-based preparation of future technology teachers, taking into account current innovation-oriented requirements and the use of STEM technologies in education.

This training is already structured as a continuous trajectory: the bachelor’s program, with a clear focus on STEM and robotics, and the master’s program “Technologies,” aimed at deepening project-engineering, methodological, and digital components. Its distinctive feature is the integration of psychological-pedagogical, methodological, and project-based preparation with the implementation of STEM technologies in educational institutions.

However, the STEM component in the master's educational and professional program is represented by only one course – "STEM Technologies in Technological Education" (3 ECTS credits), which forms the ability to organize practical and transformative activities, perceive and implement technological innovations, apply digital/computer-aided design, modeling, project management, and use STEM innovations in professional practice. Yet, cross-curricular integration of STEM into core methodological and specialized disciplines is not observed, nor are the program learning outcomes detailed enough to confirm graduates' readiness to organize laboratory or maker-style learning formats.

Thus, this bachelor's STEM-oriented technological training and master's project-engineering specialization form a coherent tandem, yet the overall scope and cross-cutting integration of STEM remain insufficient.

Conclusions. The synthesis of the obtained results shows that the integration of STEM into pedagogical educational and professional programs in Ukraine still has a predominantly point-based and fragmented character. The modernization goals declared in regulatory documents are being implemented unevenly in the practice of teacher training: in some programs, there are individual strong modules with clear logic; however, they function more as supplements rather than as a cross-cutting principle of curriculum design. As a result, STEM often becomes an "external add-on" rather than a constructive foundation for forming teachers' professional competencies.

A typical trend is the representation of STEM through a single course of 3-6 ECTS credits, and less frequently through two interconnected components (methods + practice) totaling 9-14 ECTS credits. Under such proportions, the share of STEM in the overall structure of the program is insufficient for stable acquisition of the necessary organizational skills. There is also a noticeable shift toward digital literacy and programming, which partially replaces the broader content of STEM (engineering design, material and technical aspects, experimentation and simulation, design thinking, data handling, and result validation).

Particular attention should be paid to how STEM is embedded in curricula: in most cases, relevant courses are mandatory, yet there are also models where STEM is offered as an elective or as part of a certificate program. In such configurations, coverage decreases significantly: some master's students complete their studies without basic STEM competencies, which prevents systematic implementation of the approach in school practice and creates institutional inequality in teacher training.

A comparison between levels of education reveals different risk profiles. In bachelor's programs, where two-component solutions with a strong practical focus (e.g., "Fundamentals of STEM" + "STEM Practice") are more common, better conditions are created for interdisciplinary tasks, extracurricular and lab work, and mini-projects. Conversely, in master's programs, STEM is usually represented by a single course with minimal practical content; methodological and research rhetoric dominates without sufficient scientific and technical training in real educational environments. As a result, master's students often demonstrate ideological readiness for innovation but lack a well-developed set of procedures, tools, and assessment criteria to lead full-scale STEM projects with pupils.

Summarizing the issue, it is important to highlight several key challenges: the formal inclusion of STEM (lack of cross-cutting integration into core subject and methodological courses, weak connection with final assessment); the substitution of STEM with IT components (narrowing it to digital tools and coding without the engineering and experimental dimension); insufficient practice, especially at the master's level; and the absence of thoughtful integration in humanities programs. Overcoming these limitations requires correction on two levels. At the program level, it is advisable to move from the "one course = STEM" model to a cross-cutting structure: at least three mandatory STEM modules at different stages of training with a significant practical share. STEM should be embedded into core disciplinary and methodological courses through mini-projects, digital labs, simulations, and maker tasks.

At the system level, coherent frameworks are needed. It is recommended to establish regulatory minimums for required STEM credits and the share of project-based/practical activities in teacher education programs of different levels; to ensure targeted funding for STEM infrastructure in universities (laboratories, robotics, microcontrollers, sensors, etc.) with guaranteed access for all students; and to launch professional development programs for university instructors in engineering design for education, digital experimentation, design thinking, and interdisciplinary supervision of student projects. Additionally, it is necessary to develop methodological packages with examples of integrated tasks, a national open repository of STEM cases, and to include STEM indicators in internal quality assurance systems, supported by grant and staffing incentives for effective implementation.

Thus, it can be stated that STEM integration today is largely insufficient in terms of systemic depth and practical orientation. To ensure that graduates are truly ready to implement STEM-oriented pedagogical activities, a transition is required from episodic courses to a structural, integrated, and practice-oriented model of teacher education across disciplines, supported by a coherent state and institutional policy.

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