

CONTENT OF TECHNOLOGICAL EDUCATION IN THE ERA OF SCIENTIFIC AND TECHNOLOGICAL PROGRESS AND ITS DEVELOPMENT BASED ON THE STEM APPROACH

B. B. Imanov

Associate Professor, Candidate of Pedagogical Sciences (PhD)
Termez State Pedagogical Institute

Abstract:

This article provides a scientific and theoretical analysis of the renewal of the content of technological education in the era of scientific and technological progress and its priority tasks based on the STEM approach. The deep integration of digital technologies into human life and production processes, along with radical changes in the innovation-driven economy and the labor market, substantiates the significance of technological education in training competitive professionals. The article considers the STEM approach as an effective means of updating the content of technological education on an integrative, practice-oriented, and competency-based foundation. Furthermore, the tasks of STEM-based technological education aimed at developing students' technical thinking, engineering mindset, problem-solving abilities, creativity, and innovation skills are highlighted. The results of the study have practical value for updating technological education curricula, improving educational technologies, and strengthening the integration of education with production.

Keywords: Technological education, scientific and technological progress, STEM approach, integrative education, technical thinking, engineering competencies, innovation.

Introduction

In the 21st century, the rapid development of scientific and technological progress, digital technologies, artificial intelligence, robotics, automation, and the widespread implementation of cyber-physical systems are exerting a profound influence on all spheres of society, particularly on the education system. Under these conditions, revising the content of technological education, aligning it with contemporary achievements in science and technology, and improving it in accordance with labor market demands has become one of the most pressing issues in pedagogical research.

In global educational practice, the STEM approach (Science, Technology, Engineering, and Mathematics) is widely recognized as an effective pedagogical model for the advancement of technological education. This approach promotes the integrated acquisition of scientific, technological, engineering, and mathematical knowledge, encourages problem-solving through practical tasks, and fosters project-based and design-oriented activities. From this perspective, developing the content of technological education based on the STEM approach is a key factor in enhancing the quality of education and in cultivating students' technical thinking, creative problem-solving skills, and readiness for innovative activity.

Literature Review

In the contemporary context of accelerated scientific and technological progress, revising the education system—particularly the content of technological education—and improving it on the basis of innovative approaches has become one of the most pressing scientific issues. In this process, the content structure of technological education, teaching methods, and resultant competencies are increasingly being analyzed in close connection with the STEM approach (Science, Technology, Engineering, Mathematics).

Foreign researchers regard STEM education as a key factor in enhancing the quality of human capital under conditions of scientific and technological advancement. In particular, the works of Bybee, R. W. *STEM Education: Innovation and Reform* (Arlington: NSTA Press, 2013); Sanders, M. *STEM, STEM Education, STEMmania* (Virginia: Virginia Tech Press, 2009); and Honey, M., Pearson, G., Schweingruber, H. *STEM Integration in K–12 Education: Status, Prospects, and an Agenda for Research* (Washington, DC: National Academies Press, 2014) emphasize that the STEM approach serves to develop students' engineering thinking, creativity, and innovative abilities through interdisciplinary integration, problem-based learning, and project-based activities. These studies substantiate the linkage of technological education content with real production processes as a fundamental didactic principle of STEM education.

Scholars such as Polat, E. S. *Modern Pedagogical and Information Technologies in the Education System* (Moscow: Akademiya, 2015); Lednev, V. S. *Content of Education* (Moscow: Vysshaya Shkola, 1989); and Klarin, M. V. *Innovative Models of Learning in Contemporary Education* (Moscow: Pedagogika, 2016) highlight the necessity of ensuring the unity of theoretical knowledge and practical activity in technological education, as well as the formation of learners' conceptual understanding of machines, structures, and technological processes. Their works also provide a scientific rationale for interdisciplinary links, practical tasks, and project-based learning elements within the STEM approach.

In the studies of Uzbek researchers, it is emphasized that the content of technological education should be developed in harmony with national education standards, labor market requirements, and national values. Several studies focus on developing students' technical thinking through activities such as metal and wood processing, technical modeling, and design-based construction. At the same time, the possibilities of improving the content of technological education on the basis of a competency-based approach through the implementation of STEM education have been scientifically substantiated.

In the article by R. J. Ishmukhamedov, *Teaching Technologies in Technological Education Based on the Competency-Based Approach* (Tashkent: Journal of Science and Technology Development, 2018), issues related to organizing the content of technological education on a competency-based basis are discussed. In the study by N. Yu. Yuldashev, *Innovative Pedagogical Technologies in Modern Education and Their Impact on Education Quality* (Tashkent: Journal of Pedagogical Education, 2019), the role of modern pedagogical technologies in improving the quality of education is analyzed. The author demonstrates that organizing technological education on the basis of innovative approaches contributes to enhancing students' activity and independent thinking skills. In the article by Sh. M. Mirsoliqov, *Methodology for Developing Technical Creativity in Technological Education* (Tashkent:

Public Education Journal, 2016), methods for developing technical creativity in the technological education process are presented, and the importance of practical classes and project work in shaping students' engineering thinking is scientifically justified. In D. T. Rakhimov's article, Pedagogical Conditions for Forming Professional Competencies Based on STEM Education (Tashkent: Journal of Innovative Educational Technologies, 2021), pedagogical mechanisms for developing professional competencies through STEM education are analyzed, with a focus on interdisciplinary integration and practical tasks as means of training competitive specialists. Additionally, in B. Imanov's article published in an international scientific-theoretical conference (2025), titled The Role of STEM-Based Experiments in Developing the Ability to Scientifically Predict Natural Phenomena, strategies for integrating STEM experiments into the educational process to develop students' research abilities aimed at predicting the nature and essence of natural phenomena observed in everyday life are examined.

The analysis of the literature indicates that although the issue of developing the content of technological education based on the STEM approach has been addressed in numerous studies, most of them focus primarily on general didactic principles or integration within individual disciplines. However, comprehensive research linking the content of technological education with trends in scientific and technological development, digital technologies, and production innovations in an integrated manner remains insufficiently systematized.

Analysis and Results

Technological education is a type of education aimed at developing students' knowledge, skills, and competencies related to modern technologies, production processes, and practical labor activities, particularly for those studying in technical fields. It represents a modernized form of traditional polytechnic education. Its scientific and methodological foundations are based on the integration of theoretical knowledge with practical application. Unlike other forms of education, technological education has an integrative character; that is, in solving defined goals and tasks it relies on close connections with physics, mathematics, informatics, ecology, and engineering sciences. This, in turn, develops students' ability to find solutions to problems through technical and creative thinking while mastering both the theoretical and practical aspects of technological education.

From a scientific and methodological perspective, technological education is analyzed on the basis of the following key characteristics. First, its **integrative nature**, which is reflected in the formation of knowledge, skills, and competencies through interdisciplinary connections with physics, mathematics, informatics, engineering, and ecology. Second, its **focus on the development of creative activity**, aimed at fostering students' innovative thinking, creative approaches, and ability to make independent decisions. Third, its **socio-economic orientation**, which is defined by its focus on training highly qualified and competitive specialists capable of meeting consumer and labor market needs.

In the higher education system, the content of technological education consists of a set of knowledge, skills, and professional competencies defined in curricula developed in accordance with state educational standards. This content includes the following structural components:

1. **System of technical knowledge** – knowledge about construction materials, devices, machines, and mechanisms.
2. **Knowledge of technological processes** – methods of processing metallic and non-metallic materials, design and construction principles, energy sources, fundamentals of automation, and robotics.
3. **Creative and research activities** – development of skills in constructive thinking, modeling, experimentation, and creation of innovative solutions.
4. **Labor culture and professional ethics** – formation of teamwork skills, compliance with safety regulations, ecological culture, and a responsible professional attitude.
5. **Integration of digital technologies** – skills in using automated systems, 3D modeling, and elements of digital fabrication.

In modern education, the tasks of technological education are far broader than the traditional approach of merely “providing professional skills.” These tasks are implemented on the basis of the following principles: **integrativity**, ensuring the unity of natural sciences, mathematics, and engineering knowledge; **practice-oriented learning**, through the use of project-based, problem-based, and challenge-based learning technologies; **iterativity**, based on the “prototype–test–improve” cycle; **critical and creative thinking**, involving the development of multiple alternative solutions to a single problem; **inclusivity and gender equality**, creating individualized learning trajectories aligned with students’ abilities and interests; and **sustainability**, focusing on reducing environmental impact and using resource-efficient technologies.

According to state educational standards, the content of technological education in higher education institutions encompasses a comprehensive system of knowledge, practical skills, and professional competencies. It is aimed at forming students’ technological thinking, ensuring readiness for professional activity, and preparing competitive specialists who meet labor market demands. Its main components include:

1. **System of technical knowledge** – scientifically grounded knowledge about construction materials, technical devices, machines, and mechanisms, including their structure, operating principles, and functional capabilities.
2. **Knowledge of technological processes** – technologies for mechanical, physical, and chemical processing of metallic and non-metallic materials, principles of design and engineering, energy sources, automation of production processes, and elements of robotics.
3. **Creative and research activities** – development of competencies related to constructive and technical thinking, modeling, experimental research, generation of innovative ideas, and their practical implementation.
4. **Labor culture and professional ethics** – effective teamwork, strict adherence to labor protection and safety rules, development of environmental awareness, and understanding of professional responsibility and social duty.
5. **Integration of digital technologies** – use of automated and digital control systems, 3D modeling, digital fabrication tools, and effective application of information and communication technologies in production processes.

In the modern higher education system, technological education is interpreted not merely as a means of providing practical skills, but as a comprehensive pedagogical system aimed at developing students' intellectual, creative, and innovative potential. It seeks to equip students not only with practical competencies but also with universal skills aligned with the requirements of modern production, the digital economy, and innovative environments.

These tasks are implemented on the basis of key scientific and pedagogical principles: integrativity, ensuring interdisciplinary links among natural sciences, mathematics, and engineering; practice-oriented learning, establishing unity between theory and practice through project-based, problem-based, and challenge-based learning; iterativity, organizing continuous improvement through the "prototype-test-improve" cycle; development of critical and creative thinking, enabling analysis of problems and generation of multiple alternative solutions; inclusivity and gender equality, taking into account individual abilities, interests, and educational needs of each student; and sustainability-oriented development, integrating resource-efficient and environmentally safe technologies into the educational process.

A technological education system organized on the basis of these principles serves as an effective mechanism for training highly competent, innovative, and competitive specialists who meet the demands of modern production. As a result, students systematically develop technical and engineering competencies (such as analyzing constructions, performing calculations, and modeling), technological and digital competencies, as well as creative, innovative, and socially active competencies.

The modern model of technological education is also aimed at developing students' personal and socio-psychological qualities, fostering creativity, initiative, and responsibility, and educating an active, responsible individual. Within this framework, technological education is closely integrated with the STEM (Science, Technology, Engineering, Mathematics) concept. This approach activates the "know-do-create" chain through interdisciplinary integration. While traditional education often separates theory from real-life contexts, the STEM approach ensures the formation of practical engineering competencies such as design, prototyping, experimentation, and testing.

The rapid development of digital technologies, robotics, sensor systems, and 3D printing necessitates continuous updating of educational content. Essentially, technological education prepares individuals for conscious and purposeful interaction with the material world, emphasizing not only reproductive learning but also the transformation of knowledge into practical and creative activity. In this process, technical and design activities, technological processes, labor culture, safety requirements, rational use of resources, and principles of sustainable development are integrally addressed.

The content of technological education comprises the following main components: the **theoretical component**, including materials science, fundamentals of constructions, principles of mechanism operation, energy transformation processes, automation and control systems, and basics of algorithmization;

the **practical component**, focused on hands-on activities related to modern technologies and production processes, design, and prototyping skills;

and the **innovative-competency component**, encompassing problem-solving, development of constructive and engineering thinking, and the ability to generate creative and innovative solutions.

From this perspective, technological education emerges not only as a knowledge-oriented field, but as a modern pedagogical system that prepares students for professional and practical activity, ensuring the integration of science, education, and production.

Conclusion

In the context of the rapid development of scientific and technological progress, the need to improve the content of technological education in accordance with modern requirements is becoming increasingly significant. The advancement of digital technologies, automation, and robotics necessitates the organization of technological education through a STEM-based approach grounded in interdisciplinary integration.

The results of the study demonstrate that the STEM approach is effective in ensuring the integration of theory and practice in technological education, as well as in developing students' technical and creative thinking and their competencies in solving practical problems. A STEM-oriented educational process contributes to the formation of competitive specialists equipped with modern professional training and skills relevant to contemporary industry and technology.

Therefore, developing the content of technological education based on the STEM approach is a key factor in enhancing the quality of education and in preparing specialists who meet the demands of the labor market and the challenges of scientific and technological development.

Recommendations

1. To improve the content of technological education in line with current trends in scientific and technological progress.
2. To develop and implement interdisciplinary, STEM-based learning modules and project-oriented tasks within the educational process.
3. To increase the proportion of teaching methods focused on practical and innovative activities in technological education.
4. To design and implement systematic mechanisms for developing STEM and digital pedagogical competencies among technological education teachers.
5. To establish STEM-based laboratories and учебно-practical (educational-practical) material and technical facilities at all levels of the education system.

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