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Stem Approach: A Key Tool for Transforming Kazakhstan's Education System

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Abstract. *The article is dedicated to the improvement of a new direction in the educational system – STEM education. It discusses the organization of the educational process based on STEM principles, defining the essence and content of STEM education, identifying problems, outlining main approaches to its development, and listing the advantages and disadvantages of STEM education, which include the combination of interdisciplinary practice-oriented approaches to the study of individual disciplines. An analysis of the application of STEM technologies and the project-based learning method is presented, which will facilitate the development of creative thinking and creative potential and create conditions for creative activity in future professional activities. The experience of implementing STEM education in Europe, Asia, and beyond is described, presenting the integration of modern educational technologies, including STEM, into the educational system of Kazakhstan. The article highlights the complexity and multifaceted nature of STEM education, which involves not only theoretical study but also practical application. Examples of STEM education directions are shown, aimed at forming subject-specific, cross-curricular, and basic competencies of school graduates based on an interdisciplinary approach.*

Keywords: *education system, STEM education, project-based learning method, interdisciplinary approach, modern educational technologies, integrated lesson.*

Introduction

The reform of Kazakhstan's education system and the introduction of modern educational technologies, including STEM education, should be viewed as a crucial condition for the intellectual, creative, and moral development of students. The incorporation of STEM education becomes a key word in the pedagogical process, a profound and essential concept of learning.

This process is accompanied by significant changes in pedagogical theory and practice of the educational process, involving adjustments in the content of learning technologies that must be adequate to contemporary possibilities and contribute to the harmonious entry of students into the digital society. Digital technologies and modern educational technologies, including STEM education, are intended to become an integral part of the holistic educational process, significantly increasing its effectiveness.

Significant changes in the economic, political, and spiritual life of the Republic of Kazakhstan lead to a reorientation in the structure of values and moral priorities. The education system cannot ignore this; new social conditions pose new pedagogical challenges. Among them, the primary task becomes the education of a school graduate ready to determine their place in the employment structure, capable of self-realization in a competitive labor market and real unemployment. Defining characteristics of a competitive personality become independence in decision-making, research and creative activity, personal responsibility for the results and consequences of one's activities, purposefulness, and efficiency in achieving a set goal with a morally valuable choice of means to achieve it.

In the education system, there are many teaching methods, different types of lessons, all aimed at a single goal – the assimilation of knowledge by students. The introduction of innovations, or as it is now fashionable to say, innovations, and their harmonious integration into the established lesson structure, is encouraged.

STEM education involves modeling life situations, using role-playing games, collectively solving issues based on the analysis of circumstances and situations, and the penetration of digital streams into consciousness, activating its activities. It is clear that the lesson structure with the introduction of STEM education will differ from the structure of a conventional lesson, which also requires professionalism and experience from the teacher. Learning in the context of STEM teaches critical thinking, increases general scientific literacy, and spawns a new generation of innovators and inventors.

Methods and Materials

Currently, there are many educational technologies that differ in goals, tasks, structure, methodology, group learning, educational and entertaining games, which are used not only in the educational process but also in other areas.

STEM is a teaching methodology at the core of which is the integrated study of science, technology, engineering, and mathematics as the most in-demand disciplines. STEM technologies in education imply not only theoretical study of the material but also its practical application.

Finland is one of the leaders in Europe in preparing STEM specialists. The country coordinates interaction between schools, universities, industry, and business, develops events for schoolchildren, and trains teachers.

In the USA, Malaysia, and Australia, state programs for the development of STEM education have been adopted. The key tasks include teacher training, increasing student engagement and interest, and ensuring the interaction of educational institutions with business and industry.

Students often do not understand why they need to learn a specific formula or theorem and how it will help them in life. Thanks to the implementation of STEM technologies in education, students around the world will begin to not only study theory but also test it on real projects. This will increase student interest and consolidate the knowledge gained. Also, with the help of elements of the STEM approach, educational courses and materials for interdisciplinary research and design in school and preschool educational institutions have begun to be actively created. The results of the STEM approach in higher education have been approved by the US government through educational standards, establishing STEM education as a basic teaching method in schools. Australia, Canada, and Singapore did this even earlier.

The term STEM (Science, Technology, Engineering, Math) was introduced in the early 2000s by the National Science Foundation in the USA to denote a new educational trend that was supposed to compensate for the shortage of technical specialists in the country. Since then, the development of STEM has become part of the US government policy and then spread around the world.

Today, STEM education is available in leading universities in the United Kingdom, Germany, Japan, Singapore, and other countries worldwide.

STEM education includes methodologies and training programs focused on deep applied learning in four fundamental directions of STEM.

Researchers V.N. Chemekova and D.A. Krylova understand STEM education as a modern educational phenomenon that means improving the quality of understanding by students of disciplines related to science, technology, engineering, and mathematics, the main goal of which is to prepare students for more effective application of acquired knowledge to solve professional tasks and problems and develop competencies in STEM [1]. In the work [2] of G.R. Rimskaia, it is highlighted that STEM education involves participation in active activities in the field of natural sciences, thereby ensuring the success of future specialists in the constantly improving world of information technologies. A. Tokpalinova believes that STEAM education is one of the breakthrough tools for transforming education, allowing the integration of innovative pedagogical technologies and methods into the educational process [3]. STEM education better prepares for real life, breaking down the wall between traditional classroom education and practical work on specific tasks, demonstrating how the scientific method studied can be applied in everyday life [4].

General questions of STEAM education as an innovative technology are considered in the works of T.I. Anisimova, O.V. Shatunova, F.M. Sabirova, A.V. Frolova [5-6]. According to many foreign researchers, STEAM education is based on the application of an interdisciplinary and applied approach (B.T.M. Wong, K.C. Li, and others; H. Nakata, K. Takamatsu, K. Bannaka, and others; X. Gu, D. Tong, P. Shi, and others) [7-9].

The STEAM approach retains the focus on project activity, practical orientation, and in-

terdisciplinarity but changes the arrangement of key disciplines.

The project method is from the field of didactics of specific methodologies if it is used within a certain subject. It is a set of techniques, operations for mastering a certain area of practical or theoretical knowledge, a certain activity. It is a way of cognition, a method of organizing the cognition process.

In the process of analyzing the pedagogical literature on the essence of the «project method» concept, it was shown that today scientists offer various definitions, so in the work of A.A. Krishtal, the project method is considered as a set of educational and cognitive techniques; a personally oriented method; a technology for organizing educational activities and a system of education based on independent solving of a previously stated problem with subsequent demonstration of the results of the executed work [10].

According to many researchers, including R.I. Btemirova, the project method as a component of the education system represents such an organization of independent student activity aimed at solving a problem to achieve a certain result [11]. According to T.V. Zelentsova, the project method is oriented and based on the subjective relationship between participants in the educational process and stimulates students' interest in certain problems, assuming possession of a certain amount of knowledge and, through project activity, foreseeing the solution of these problems and the ability to practically apply acquired knowledge and develop reflective thinking [12].

In the scientific work of Yu.G. Shikhvarger, the project method is reflected as the main linking element of the program, which allows qualitatively adjusting the content and correctness of the distribution of 22 hours for studying various sections, optimally selecting and compiling the necessary educational material taking into account the age characteristics of students [13]. T.A. Vlasova defines the project method as organized research and investigative activity of students, individual or group, which implies not just achieving a certain result manifested in the form of a specific practical output, but organizing the process of achieving this result [14]. K.B. Seitkanova highlights the project method as professional training of students across various academic disciplines to establish more solid interdisciplinary connections, as well as for closer interaction between theory and practice during the educational process [15].

The essence of the project method lies in the idea that constitutes the meaning of the concept of «project», its pragmatic orientation towards a result obtained when solving a certain practically or theoretically significant problem. This result can be seen, understood, and applied in real practical activity. To achieve such a result, it is necessary to teach students to think independently, to find and solve problems by drawing on knowledge from various areas, the ability to predict the outcomes and possible consequences of different solution options, and the skills to establish cause-and-effect relationships.

The project approach is applicable to the study of any school subject and is especially effective in natural science lessons aimed at establishing interdisciplinary connections. The essence is that our students discover facts that are subjectively new to them and construct new concepts for themselves, rather than receiving them ready-made from the teacher. They become pioneers every time.

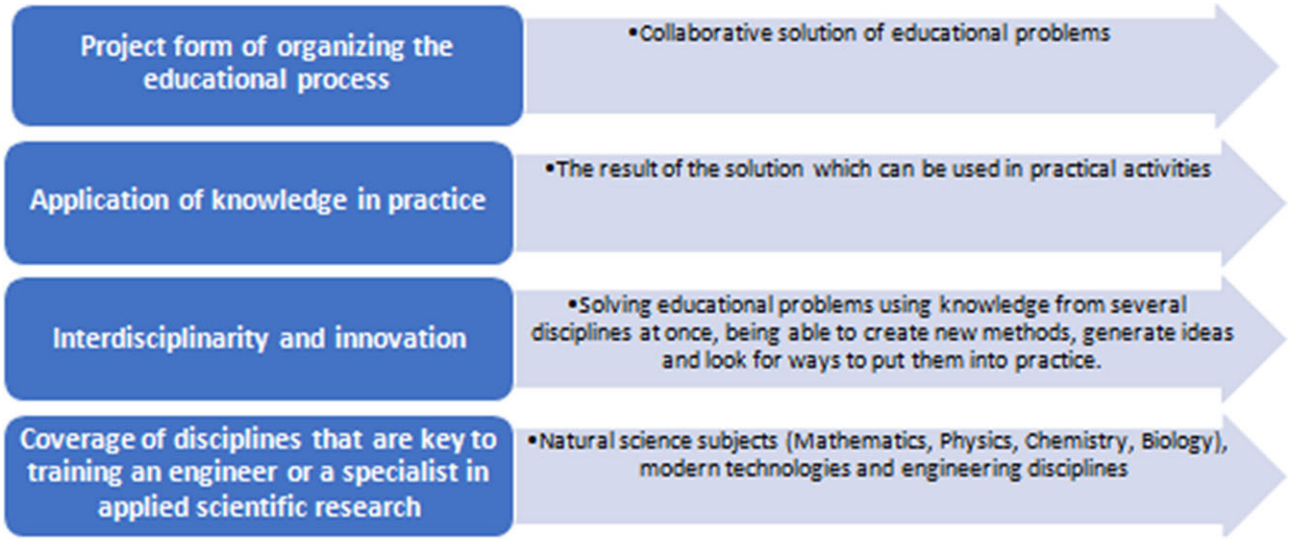
The use of modern project methodologies implies collaboration between individual students and teachers, as well as the use of public experience, scientific and technical regularities.

Project activity is the main condition for forming project culture, project research, and creative thinking.

At the core of the STEM approach are four principles illustrated in Figure.

The project form of organizing education and the practical orientation of the STEM approach create motivational and subject-matter prerequisites for interdisciplinarity. The experience accumulated within the framework of STEM in the comprehensive mastery of mathematics and natural sciences, aimed at the following favorable conditions presented: organization of active educational and cognitive activities; forming the ability to apply acquired knowledge in practice, including in project situations; formation of stable cognitive interests for choosing a future profession; formation of communicative competence in interaction and cooperation with peers; application of mathematical and natural science knowledge in solving educational problems; developing skills in formulating hypotheses, planning and conducting experiments, and evaluating the results obtained; awareness of the importance of mathematics and computer science in human everyday life; understanding of the physical foundations and principles of operation of machines and mechanisms, means of transportation and communications, household appliances, industrial processes, etc.; developing the ability to model real situations in the languages of algebra and geometry, as well as explore constructed models using mathematical methods.

In Kazakhstan, STEM education has been actively developing since 2014. Schools have



Principles of the STEM Approach

Directions in STEM Education

№	Examples of STEM education
1	**STEM Education in Mathematics Lessons.** Emphasizing mathematics with the help of STEM technologies, it is necessary to implement an interdisciplinary approach on Math lessons, solving problems that visually demonstrate the connection between Mathematics and Physics, Chemistry, Biology, Computer Science, History, etc. Problems that are linked to real-life situations spark interest and the desire to solve the problem among students because such skills may later be useful in real life. For example, a lesson can be conducted on calculating the number of cells in a crystalline body and the number of atoms and showing its connection with Physics, Chemistry, and Computer Science. Guest lectures by teachers of these disciplines could be invited. A Physics teacher could talk about atoms, the arrangement of atoms in space, crystalline lattices. A Computer Science teacher could present a slideshow about figures inscribed in and circumscribed around a cube.
2	**STEM Education in English Language Lessons.** English language can be combined with many disciplines. For instance, conducting an integrated English language and robotics lesson could help students navigate the latest achievements in robotics and learn new English words on the topic. Let's consider an integrated English language and history lesson on the theme «Journey to Great Britain». Together with the history teacher, students could be acquainted with events in British history that have become landmarks for world history, using English language resources and referring to an English-Kazakh-Russian dictionary for assistance.
3	**STEM Education in Computer Science and Robotics Lessons.** Opportunities exist for conducting integrated lessons of two or more disciplines. For example, an integrated computer science and biology lesson on the study of the structure of a flower and its main parts using graphic editors could be organized. During an integrated computer science and mathematics lesson, students could be offered to construct geometric figures using the GeoGebra software environment. Robotics is an area within STEM education where the demands of the economy for the development of high-tech industries and children's natural interest in construction have most successfully intersected. Today, teachers around the world actively use robotics kits for constructing and programming robots in their professional activities. Children should be taught not only by theoretical educators but also by specialists who work on specific enterprises and real projects. Classes in laboratories with such teachers will help to better assimilate the material and practice practical skills.

opened robotics labs and clubs, about 100 STEM labs, experimental schools where new teaching methods are being developed and tested. STEM clubs are being created, operating on the principle of project laboratories for students, organizing practical research, and increasing interest in the study of sciences.

New academic disciplines are being developed that work within an interdisciplinary approach. In addition to traditional Physics, Chemistry, and Mathematics, Programming and Robotics are taught in schools. Experienced teachers use an individual approach and structure the learning process to spark a child's interest in studying the discipline.

The country has created a sequential chain of STEM processes from kindergarten to higher education institution and further to the workplace.

Results and Discussion

STEM education is a comprehensive approach to integrated teaching of the four profile disciplines for assimilation and acquisition of quality, new knowledge by students. Table presents examples of directions in STEM education.

Integration at all levels will be based on STEM approaches in the content of educational programs, implementing the principle of subject integration, sections, themes. Instead of the extensive increase in the number of educational subjects and the volume of theoretical materials studied, measures will be taken for reasonable integration of subjects, intensification of the educational process, application of modern educational technologies, and resources. The content of education based on STEM approaches will be aimed at forming subject-specific, cross-curricular, and basic competencies of school graduates.

Conclusions

Thus, research on the implementation of STEM education shows that the use of STEM technologies improves student performance and self-esteem, and also promotes the development of creative skills. The STEM program is oriented not only towards students but also towards teachers. Teachers must learn not only to teach students theory but also to apply it in practice. Thanks to STEM education, it is possible to prepare a qualified specialist with engineering thinking, managerial, and flexible skills.

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STEM-тәсілі – Қазақстандағы білім беруді трансформациялаудың негізгі құралдарының бірі

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Аңдатпа. *Мақала жаңа бағыт – STEM білім беру жүйесін жетілдіруді қарастырады. STEM білім беру негізінде білім беру процесін ұйымдастыру мәселелері талқыланды. STEM білім беру концепциясының мәні мен мазмұны айқындалып, проблемалар анықталды, оны дамытудың негізгі тәсілдері көрсетілді, жеке пәндерді зерттеудің пәнаралық тәжірибеге бағытталған тәсілдерінің жиынтығынан тұратын STEM білім берудің артықшылықтары мен кемшіліктері келтірілді. Креативті ойлау мен шығармашылық әлеуетті дамытуға ықпал етіп қана қоймай, болашақ кәсіби қызметте шығармашылық белсенділік үшін жағдай туғызатын STEM технологиялары мен жобалық оқыту әдісінің қолданылуына талдау жасалды. Еуропаның, Азияның және алыс шет елдердің STEM білім беруді енгізу тәжірибесі сипатталып, Қазақстанның білім беру жүйесінің тәжірибесіне қазіргі заманғы оқыту технологиялары, соның ішінде STEM-ді енгізу ұсынылды. STEM білім берудің материалды теориялық зерделеуді ғана емес, сонымен қатар практикалық қолдануды білдіретін оның күрделілігі мен әмбебаптығын атап өтілді.*

Кілт сөздер: *білім беру жүйесі, STEM білім беру, жобалық оқыту әдісі, пәнаралық әдіс, заманауи оқыту технологиялары, кіріктірілген сабақ.*

STEM-подход – один из ключевых инструментов трансформации образования Казахстана

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Аннотация. *Статья посвящена совершенствованию системы нового направления – STEM-образования. Авторами рассмотрены вопросы организации процесса образования на основе STEM-подхода. Определены сущность и содержание понятия STEM-образования, выявлены проблемы, обозначены основные подходы к его разработке, приведены преимущества и недостатки STEM-образования, которые заключаются в сочетании междисциплинарных практико-ориентированных подходов к изучению отдельных дисциплин. Проведен анализ применения STEM-технологий и проектного метода обучения, которая будет не только способствовать развитию креативного мышления и творческого потенциала, но и создавать условия для творческой деятельности в будущей профессиональной деятельности. Описаны опыт внедрения STEM-образования Европы, Азии, дальнего зарубежья, представлены внедрение современных технологий обучения, в том числе STEM в практику системы образования Казахстана. В статье авторами отмечена сложность и многогранность STEM-образования, подразумевающего не только теоретическое изучение материала, но и практическое применение. Авторами показаны примеры направлений STEM-образования, содержание которых направлено на формирование предметных, метапредметных и базовых компетенций выпускника школы на основе междисциплинарного подхода.*

Ключевые слова: *система образования, STEM-образование, проектный метод обучения, междисциплинарный подход, современные технологии обучения, интегрированный урок.*

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