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PRACTICAL ASPECTS OF THE DEVELOPMENT OF STEM EDUCATION IN KAZAKHSTAN

Annotation

The article discusses the importance of STEM education for workforce preparation in the context of Kazakhstan's economic development. The main issue addressed is the need to prove the integration of new technologies into educational programs, as this is crucial for preparing skilled specialists in a rapidly changing world. The aim of the study is to describe new methods of implementing STEM education and to identify successful practices.

Research methods include analyzing current educational programs, studying examples of successful STEM methodology implementation, and conducting professional development courses for teachers. The article describes problem-based learning (PBL) methods that contribute to deeper student engagement and the development of critical thinking skills.

The research results show that, despite significant progress in integrating STEM into educational programs and successful examples of applying innovative methods, challenges remain, such as unequal access to resources and a shortage of qualified specialists. However, successful initiatives, such as «STEM for All» programs, demonstrate a positive impact on the accessibility and quality of STEM education.

The conclusions emphasize that for effective implementation of STEM education, it is necessary to focus on innovative teaching methods, address gender and socio-economic barriers, and adapt education to future technological trends. In this way, Kazakhstan can develop a STEM education system that prepares students for the demands of a rapidly changing world. The future of the country's economy depends on the ability to cultivate a new generation of scientists, engineers, and innovators who will contribute to sustainable development and economic growth.

Key words: STEM education, interdisciplinary integration, engineering design, curriculum, technologies, problem-based learning, research.

Introduction. With the development of the economy of Kazakhstan, the role of STEM education in the training of future personnel is becoming more and more important. In his Address to the people of Kazakhstan “A Fair Kazakhstan: Law and Order, Economic Growth, Public Optimism”, the President noted that 2025 was declared the Year of Professional Professions. He stressed the need to promote the values of hard work and professionalism in society, emphasizing the importance of blue-collar professions [1]. Integration of new technologies, such as artificial intelligence, robotics and biotechnology, in the curriculum is necessary to prepare students for future professional professions. However, this requires continued investment in teacher training, curriculum development and infrastructure.

High-tech production of Industry 4.0 today is changing all spheres of modern society. In today's world, there are many factors that lead to an increase in human needs. Therefore, robotics and STEM are becoming one of the main trends in global education. Thanks to the rapid development of technology, new professions are emerging, and the demand for STEM specialists is growing massively. In the field of robotics and STEM, other countries are intensively working on a strategic long-term plan, using various teaching materials and the activities of the resource center [2].

STEM education is increasingly recognized as a critical factor in preparing the workforce of the future in Kazakhstan. As the country seeks to diversify its economy and reduce its dependence on natural resources, STEM education plays a key role in equipping the next generation with the skills needed to succeed in the knowledge-based economy.

Kazakhstan's education system has made significant strides toward integrating STEM subjects into the curriculum. With a focus on modernizing education, in particular through initiatives such as the 100 Concrete Steps program, the government has increased investment in STEM-related infrastructure and teacher training. However, the implementation of STEM education faces a number of challenges, including uneven access to resources, especially in rural areas, and a shortage of STEM specialists among teachers [3].

Despite the challenges, Kazakhstan has examples of successful innovative STEM teaching methods that effectively engage students and develop critical thinking. For example, schools in Kazakhstan are introducing problem-based learning to make STEM subjects more accessible and practical. In problem-based learning, students work on real-world problems, such as developing sustainable energy solutions or technologies for smart cities, allowing them to put theoretical knowledge into practice. Another successful initiative is the "STEM for All" program, aimed at increasing access to STEM education for girls and students from low-income families [4]. This program offers free workshops, mentorship programs, and access to online resources, helping to close the STEM participation gap.

Methods and materials. To achieve these goals, various approaches and methods are used to contribute to a deeper involvement of students in the educational process and the development of their skills. Among them, methods for STEM education in natural science subjects stand out:

- a research-based module using the 5E learning cycle;
- engineering design;
- Problem-Based Learning (PBL)

Table 1 describes teaching methodologies based on the 5E cycle, engineering design, and problem-based learning (PBL), as well as their application [5].

Table 1. Teaching methodologies based on the 5E cycle, engineering design and problem-based learning (PBL)

Method	Description	Application
Learning Cycle 5E	A methodology that includes 5 stages: involvement, research, explanation, deepening and evaluation.	*Engagement:* An intriguing question or challenge to engage. *Research:* Work on the problem, experiments. Explanation: Interpretation of results, understanding of concepts. Deepening: Application of knowledge in new situations. Assessment: Tests, projects or presentations.
Engineering Design	The process of creating and optimizing products or solutions develops critical thinking and creativity.	Definition of the problem: Study of the problem. Research: Gathering information and studying existing solutions. Ideation: Generation of ideas and development of concepts. Prototyping: Creating models and prototypes. Testing and improvement: Validating solutions and making changes.
Problem-Based Learning (PBL)	Focuses on solving real-world problems that require knowledge from different STEM fields.	Problem definition: A difficult task to solve. Research: Collecting information, analyzing data, exploring approaches. Solution development: Creating and testing solutions. Presentation: Presentation of solutions, development of communication and critical analysis skills.

Source: developed by the author.

These methods make STEM learning more interactive, practical, and relevant to the demands of the modern world, developing important skills and competencies in students.

Results and discussion. Successful implementation of STEM education requires not only enthusiasm and innovation, but also significant investment in teacher training, curriculum development and infrastructure improvement. In this context, professional development courses, such as those offered by Orleu, play a key role education, including the application of STEM education, the introduction of experiential teaching methods, design, modeling, research and robotics based on the principles of interdisciplinary integration.

The relevance of the program is due to three main factors:

1. Develops teachers' interest in science through the formation of research skills;

2. Complements the changing needs of the workforce, which require more complex and flexible knowledge, skills and abilities that meet the requirements of the 21st century;

3. Meets the demand for STEM literacy needed to solve technological and environmental problems.

The purpose of this program is to improve subject competencies and update the educational work of teachers of the natural science cycle in the field of STEM education.

The practical significance of the program is aimed at orienting science teachers in the STEM field. Learning outcomes have a positive impact on teachers: they acquire the ability to effectively plan daily activities, deepen their knowledge of ICT, and increase students' interest in lessons. Their research skills are improved and respectful relationships with students are strengthened.

Expected results:

1. apply theory and practice in the educational process of STEM learning;
2. explore interdisciplinary integration, methods of experimental knowledge, design, modeling, robotics;
3. demonstrate skills in constructing STEM learning lessons in PBL design.

Understanding the need for continuous improvement of pedagogical skills and their impact on the educational process, a course for teachers of the natural science cycle was held on the basis of the Karaganda "Orleu". This course focused on teaching robotics and STEM education techniques, providing students with a unique opportunity to deepen their knowledge of modern educational technologies and master their practical application. At this course, students had a unique opportunity to immerse themselves in the world of modern educational technologies and learn how to apply them in practice.

To provide teachers not only with theoretical knowledge, but also with practical skills, the course was built in such a way that teachers could introduce innovative approaches to the educational process. They have mastered the 5E methods, problem-based learning, interdisciplinary integration, and the use of robotics as a tool to develop critical thinking and engineering skills in students. One of the key methods that received special attention was problem-based learning (PBL). This method actively involves students in the process of finding and solving problem situations. Instead of simply transferring knowledge, educators create an environment in which learners are confronted with real or imagined problems that require independent or team solutions.

The structure of interaction between students in a lesson using PBL consists of four stages:

Stage 1 - students study the context and get acquainted with the problem.

Stage 2 - development of understanding of the problem, learning new information and developing problem-solving skills.

Stage 3 - problem solving.

Stage 4 – communication.

At the first stage, a group of students is created, as practice has shown that groups of 4-5 students work more effectively. They discuss the problem in the group of understanding the situation [6].

At the stage of developing an understanding of the problem, learning new information and developing problem-solving skills make up a list of facts extracted from the problem. At this stage, it is recommended to start filling in the FILA table.

The FILA (Facts, Ideas, Learning Issues, Action Plan) table is an intelligent tool that is used to develop the thinking process of students as they go through the PBL process. Learners can use this table to list the key facts about the problem in the form of bullet points, as well as relevant ideas, explore the problems and the necessary actions to take in relation to these facts, as presented in Table 2.

At the problem-solving stage, students generate ideas that would help them understand the problem or solve the problem. They can organize their ideas and previous knowledge related to the problem and try to outline the nature of the problem. Questions are written down in the order in which they arise during the discussion. The work is divided among the members of the group. Some research problems may require the whole group to be involved, while others require participants to conduct research in different areas, on different topics. Students then begin to search for information and learn

the necessary facts about the learning problem, either individually or as a group. After that, the collected information is summarized [7].

Table 2. The FILA Method

F	I	L	A
Facts	Ideas	Learning of the problem (questions)	Action plan
Facts specified in the problem (e.g., time, size, place, address, diagnosis, formula, animal, model, device, price, currency, etc.)	Ideas are formulated on the basis of facts and can be put forward in the form of hypotheses. All the ideas of the group are written down without discussion. Ideas can be subject to change and revision	Questions that arise from ideas. The questions should form the basis of the action plan and be consistent with the program's learning objectives. Issues can be reconsidered	It is created on the basis of questions on the study of the problem. An action plan helps to solve the problem. The actions of the plan sound like verbs

Source: developed by the author.

At the last stage, students reflect on the work done independently, analyze the functioning of the group, the process of solving the problem, the knowledge gained and the contribution of the assistant to its solution.

The assessment process in PBL covers many aspects and aims to comprehensively measure students' achievements, including their knowledge, skills, and competencies. The use of a variety of assessment methods and tools allows you to more accurately reflect the individual success of students and contributes to their further development. Clearly organized forms of assessment ensure transparency and objectivity, making the process understandable and useful for all participants in the educational process. For example, the following table 3 has been developed for the evaluation of reports and subsequent self-analysis on issues related to the assessment of student success in PBL.

Table 3. Report Assessment Form

Assessment Subjects	**Assessment criteria**	**Descriptors, points**				
		5	**4**	**3**	**2**	**1**
Report Grading Forms	The solution to the problem is right	a complete and accurate solution to the problem, all aspects are taken into account	The solution to the problem is mostly correct, minor flaws	The solution to the problem is partially correct, there are significant errors	Most aspects of the problem are not resolved, there are many errors	Problem Not Solved or Solution Incorrect, Serious Errors
	The problem is considered in full	All aspects of the problem have been considered, nothing has been missed	The problem is considered as a whole, but some details are omitted	The problem was partially considered, important aspects were left out of attention	only certain aspects of the problem are considered, most of them are not taken into account	The problem is practically not considered, there is no understanding of the task
	Various sources used	many different and reliable sources have been used, all relevant	A few reliable sources have been used, but not all are relevant	limited sources are used, some of which are insignificant	sources are few and they are not diverse, many are irrelevant	there are no sources or they are irrelevant, there is no justification at all
	The report is logically structured	The report is clearly structured, all parts are logically	The structure of the report is good, but there are minor	The structure of the report is generally clear, but there are	The report is poorly structured, the parts are	there is no structure of the report, complete

		connected and combined	inconsistencies in the logic	significant logical gaps	not logically connected	disorganization of information
	Terminology used correctly	all terms are used correctly and appropriately	mostly correct use of terms, minor errors	partially correct use of terms, errors occur	most of the terms are misused or inappropriate	terms are used completely incorrectly or not at all

Source: developed by the author.

Assessment in PBL is a multifaceted process that involves the use of a variety of methods and tools to build a complete picture of student achievement. Evaluation of reports, self-assessment, mutual evaluation, as well as evaluation of presentations and teamwork allow not only to assess the knowledge and skills of students, but also their personal development, ability to work independently and effectively interact in a team. This approach guarantees the objectivity and comprehensiveness of assessment within the framework of problem-based learning.

The assessment process is closely related to teamwork, which plays a key role in solving real problems. Working in teams helps students to see the connection between the learning process and life, developing coping and cooperation skills. These methods are especially relevant when discussing and implementing STEM lessons, where teachers not only consider theory, but also actively integrate robotics into school curricula. Thanks to this approach, the course participants were able to exchange experiences and best practices, receiving the necessary tools to create more interesting and useful lessons that will help prepare students for a successful career in scientific and technical fields.

Problem-based learning within STEM significantly expanded their understanding of the role of the teacher as a facilitator capable of guiding students in independent research and problem solving. This approach not only increases student engagement, but also fosters their ability to think critically, adapt to new situations, and find innovative solutions. These skills are especially important in today's world, where technological change is happening rapidly. Reflection also showed that the use of problem-based learning requires teachers to constantly develop professionally and be ready to introduce new methods, which ultimately enriches the educational process and prepares students for a successful career in high-tech fields.

Upon completion of the course, the teachers expressed confidence that the knowledge and skills gained will help them effectively implement STEM education and robotics in their schools, which, in turn, will improve the quality of education and prepare students for the challenges of the future. Particular attention was paid to the integration of various disciplines, which contributes to the development of students' critical thinking and problem-solving skills. The course was focused on the practical application of knowledge, including experimentation, design and modeling, which allowed teachers not only to study the theory, but also to immediately apply new approaches in their work.

However, despite the obvious advantages of the course, the students also noted some disadvantages:

1. for the successful implementation of STEM education, additional material resources are required, including specialized equipment and software, which can become a financial burden for educational institutions;
2. STEM approaches require a revision of established teaching methods and changes in curricula, which can cause difficulties for teachers, especially those who are used to working according to traditional schemes;
3. STEM education involves constant updating of knowledge and skills, which requires teachers to regularly take advanced training courses and self-education;
4. not all teachers have sufficient training to effectively master and apply STEM methods, which can lead to heterogeneity in the implementation of these approaches in different schools.

Nevertheless, despite these shortcomings, the course participants noted its importance and necessity for improving the quality of education. They expressed confidence that the knowledge

gained will help them to more effectively prepare students for the requirements of the modern world, despite the challenges they faced during their studies.

Conclusion. In order for this knowledge and skills to lead to maximum results, educational reforms are needed to help bring STEM education in Kazakhstan in line with international standards. Cooperation between schools, universities and industry representatives is becoming a key factor in the creation of relevant and practical STEM programs. Through partnerships with technology companies and research institutes, Kazakhstani schools can provide students with practical experience and acquaintance with the latest technological achievements, which will allow them to be competitive in the future.

STEM education in Kazakhstan is at a crossroads, significant progress has been made in recent years, but there are also significant challenges that need to be addressed. By focusing on innovative teaching methods, addressing gender and socioeconomic barriers, and aligning education with future technological trends, Kazakhstan can create a solid STEM education system that prepares its students for the demands of a rapidly evolving world [8]. The future of a country's economy depends on its ability to nurture the next generation of scientists, engineers, and innovators who can contribute to sustainable development and economic growth.

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ҚАЗАҚСТАНДА STEM-БІЛІМ БЕРУДІ ДАМЫТУДЫҢ ПРАКТИКАЛЫҚ АСПЕКТІЛЕРІ

Аңдатпа

Мақалада Қазақстанның экономикалық дамуы жағдайында кадрларды даярлау үшін STEM-білімнің маңыздылығы көрсетілген. Мақаланың негізгі мәселесі – жаңа технологияларды білім беру бағдарламаларына енгізудің қажеттілігін негіздеу, себебі бұл жылдам өзгеріп жатқан әлемде білікті мамандарды даярлау үшін маңызды. Зерттеудің мақсаты – STEM-білім беруді енгізудің жаңа әдістерін сипаттап, табысты тәжірибелерді анықтау.

Зерттеу әдістері білім беру бағдарламаларының қазіргі жағдайын талдау, STEM әдістерін сәтті енгізудің мысалдарын зерттеу және мұғалімдерге арналған біліктілікті арттыру курстарын өткізуді қамтиды. Мақалада оқушылардың оқу процесіне тереңірек қатысуы мен сыни ойлауын дамытуға ықпал ететін проблемалық оқыту (PBL) әдістері сипатталған.

Зерттеу нәтижелері STEM-ді білім беру бағдарламаларына енгізуде және инновациялық әдістерді табысты қолдануда айтарлықтай қадамдар жасалғанына қарамастан, ресурстарға біркелкі қолжетімсіздік пен білікті мамандардың жетіспеушілігі сияқты мәселелер бар екенін көрсетеді. Алайда «STEM барлығы үшін» сияқты сәтті бастамалар STEM-білім берудің қолжетімділігі мен сапасына оң әсерін тигізіп отырғанын көрсетеді.

Қорытындыларда STEM-білімді тиімді енгізу үшін инновациялық оқыту әдістеріне назар аудару, гендерлік және әлеуметтік-экономикалық кедергілерді жою және білім беруді болашақ технологиялық трендтерге бейімдеу қажеттігі атап өтіледі. Осылайша, Қазақстан STEM-білім беру жүйесін құрып, оқушыларды қарқынды дамып жатқан әлемнің талаптарына бейімдей алады. Ел экономикасының болашағы жаңа буын ғалымдарды, инженерлер мен жаңашылдарды тәрбиелеу қабілетіне байланысты, олар тұрақты даму мен экономикалық өсімге ықпал ететін болады.

Түйінді сөздер: STEM-білім беру, пәнаралық интеграция, инженерлік дизайн, оқу бағдарламасы, технологиялар, проблемалық оқыту, зерттеу.

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ПРАКТИЧЕСКИЕ АСПЕКТЫ РАЗВИТИЯ STEM-ОБРАЗОВАНИЯ В КАЗАХСТАНЕ

Аннотация

В статье показана важность STEM-образования для подготовки кадров в условиях экономического развития Казахстана. Основная проблема статьи представлена обоснованием необходимости интеграции новых технологий в образовательные программы, поскольку это важно для подготовки квалифицированных специалистов в быстро меняющемся мире. Цель исследования – описать новые методы внедрения STEM-образования и определить успешные практики.

Методы исследования включают анализ текущих образовательных программ, изучение примеров успешного внедрения STEM-методик и проведение курсов повышения квалификации для учителей. В статье описаны методы проблемного обучения (PBL), которые способствуют более глубокому вовлечению обучающихся и развитию их критического мышления.

Результаты исследования показывают, что, несмотря на значительные шаги в интеграции STEM в образовательные программы и успешные примеры применения инновационных методов, существуют проблемы, такие как неравномерный доступ к ресурсам и нехватка квалифицированных специалистов. Однако успешные инициативы, такие как программы «STEM для всех», демонстрируют положительное влияние на доступность и качество STEM-образования.

В выводах подчеркивается, что для эффективного внедрения STEM-образования необходимо обращать внимание на инновационные методы обучения, устранять гендерные и социально-экономические преграды и адаптировать образование к будущим технологическим трендам. Таким образом, Казахстан сможет создать систему STEM-образования, которая подготовит учащихся к требованиям быстро развивающегося мира. Будущее экономики страны зависит от способности воспитывать новое поколение ученых, инженеров и новаторов, которые будут способствовать устойчивому развитию и экономическому росту.

Ключевые слова: STEM-образование, междисциплинарная интеграция, инженерный дизайн, учебная программа, технологии, проблемное обучение, исследование.