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MODERN APPROACHES TO THE METHODOLOGICAL TRAINING OF MATHEMATICS TEACHERS IN THE CONTEXT OF STEM TECHNOLOGY

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Abstract. The article presents an analysis of the study of modern methodological approaches that contribute to the preparation of teachers for the successful use of STEM (science, technology, engineering, mathematics) technology in curricula. The relevance of this topic is due to the need to train teachers who are able to integrate interdisciplinary knowledge into the process of teaching mathematics, which is especially important in the context of globalization and digitalization of education. The study used methods of analyzing educational programs and testing the effectiveness of the implementation of STEM methods. Evaluation of the effectiveness of approaches was based on a comparative analysis of the test results before and after the implementation of STEM methods. The study shows that the use of integrated approaches in teaching mathematics contributes to improving academic results and developing critical thinking in students. These data are of significant theoretical and practical significance for improving the training of teachers. The main results of the article showed that the introduction of interdisciplinary teaching methods increases the level of perception of educational material, contributes to the development of critical thinking and skills in solving practical problems. The practical implications include informing the design of inclusive teaching practices and targeted academic support initiatives.

Keywords: STEM, methodological training, mathematics teachers, interdisciplinary learning, digital technologies, innovative teaching methods, professional competence, Kazakhstan

Introduction

In recent years, STEM education has become one of the key areas of educational policy in many countries around the world, including Kazakhstan. The term STEM refers to the integration of Science, Technology, Engineering and Mathematics into the educational process in order to develop students' problem-solving skills, critical thinking and an interdisciplinary approach. As Jones M. and Gallagher P. note, STEM is not just an educational approach, but also a philosophy that promotes the formation of professional competencies necessary for future specialists [1].

Kazakhstan is actively introducing STEM into educational programs, which requires significant changes in teacher training. Ospanova N.B. emphasizes that for the successful integration of STEM, it is necessary to review existing curricula

and increase attention to training teachers in the field of interdisciplinary approach and digital technologies [2]. According to Mustafina G.S., the problems associated with the introduction of STEM are the insufficient training of teachers, who often do not have sufficient knowledge in the field of technology and engineering for successful teaching [3].

International experience also confirms the importance of training teachers to work in STEM settings. Smith R.'s study shows that successful integration of STEM requires not only theoretical knowledge, but also practical skills, including the use of digital technologies and project activities [4]. As noted by Orlov V.N. and Rakhimova S.R., the key challenge is the lack of qualified personnel who could effectively implement STEM into the educational process [5].

The use of STEM technologies in education is a necessity dictated by the modern world. Training mathematics teachers using STEM methods opens up new opportunities for developing competencies that are in demand in the labor market. This helps not only improve student results, but also prepare them for future challenges that require interdisciplinary knowledge and skills. STEM makes learning more engaging and meaningful, and teachers are more competent and ready for modern educational challenges.

Materials and Methods

The study, aimed at assessing the effectiveness of introducing STEM methods into the process of training mathematics teachers, was conducted at the Korkyt Kyzylorda University Ata. The study employed a quasi-experimental pre-test, post-test design to assess the effectiveness of integrating STEM methods into mathematics teacher education. The study involved 46 first-year students of the Faculty of Education studying to become teachers of mathematics. The participants were divided equally into two groups: an experimental group of 23 students and control group of 23 students. The experimental group received instruction incorporating STEM-based methods, while the control group was taught using traditional instructional methods. The effectiveness of the intervention was determined by comparing the pre-test and post-test results of the two group. The aim of the study was to determine how the use of integrated STEM methods affects students' academic performance, their level of satisfaction with the educational process, and their perception of new approaches. The focus was on improving students' professional competencies, such as critical thinking, ability to solve real-world problems, and use of interdisciplinary knowledge. The study was conducted over one semester in mathematics courses, where teaching methods varied from traditional teaching to integrated STEM methods.

The following methods were used for the analysis:

1. Testing: Students were tested twice: before and after the introduction of STEM methods. At the first stage, before the start of the school year, students took tests aimed at assessing their initial knowledge of mathematics and related subjects. This test was the baseline for analyzing the progress that students could show during the learning process [6].

After the implementation of STEM methods, at the final stage, repeated testing was conducted, which allowed us to compare the results before and after using STEM methods. The use of modern teaching methods, such as project-based learning and interdisciplinary tasks, allowed us to significantly expand the students' opportunities to apply knowledge in practice. The test results show that students who used the STEM approach demonstrate higher results compared to the control group working with traditional methods.

2. Survey: The survey was designed to assess students' subjective perceptions of the integration of STEM methods into the educational process. The survey included questions on satisfaction with educational processes, perception of the usefulness of methods, interest in academic disciplines, and complexity of the educational material.

The questionnaires used both closed and open questions to obtain qualitative information about how students perceive new approaches. An important aspect of the questionnaire was the question of assessing the level of student involvement in the learning process, where the majority of students noted an increase in interest in mathematics due to the inclusion of real practical situations in the tasks [7].

3. Data Analysis: The collected data were processed using statistical methods such as analysis of variance (ANOVA). This method allows us to assess the significance of differences in results before and after the implementation of STEM methods, as well as to identify the influence of factors such as previous knowledge level and student engagement [8].

Statistical processing of the testing results showed a significant increase in the average academic performance of students participating in the experimental group compared to the control group. The analysis of the experimental group ($n = 23$) showed that the mean academic performance score increased from 62.00 ($SD = 2.50$) before the intervention to 84.61 ($SD = 4.57$) after the intervention. The mean increase was 22.61 percentage points (95% CI [20.52, 24.70]). A one-way repeated-measures ANOVA revealed a statistically significant effect of the STEM-based intervention on students' academic performance, $F(1, 22) = 501.75$, $p < .001$, $\eta^2 = .958$. These results indicate a statistically significant and substantial improvement in the academic performance of the students following the introduction of the STEM-based teaching methods. The use of ANOVA also revealed significant differences in the level of perception and satisfaction of students participating in integrated STEM teaching methods, indicating a positive impact of new educational technologies on the quality of knowledge acquisition.

Results and Discussion

The study was conducted on the basis of mathematics courses over the course of one semester and included several stages:

At the first stage, students studied subjects according to the traditional system: lectures and seminars.

The second stage of the experiment involved the introduction of STEM approaches, which included the use of project activities, solving practical problems and interdisciplinary collaboration.

Students worked on mathematical models and applied their knowledge of mathematics to solve engineering and technological problems. To better understand the impact of STEM approaches, tests were conducted before and after their implementation. The survey allowed us to assess how students' attitudes toward the subject and the educational process changed.

Table 1. Comparative results of testing students before and after the experiment

Indicator	Before the experiment (%)	After the experiment (%)
Average score	62	85
Level of critical thinking	55	78
Problem solving skills level	60	82

The results of the study show significant improvement in students' academic performance after the implementation of STEM technologies. Table 1 presents data confirming the increase in the average grade by 23%, as well as the improvement of the level of critical thinking and problem-solving skills by 23% and 22%, respectively. These results demonstrate the high effectiveness of integrated STEM approaches.

The main advantage of the STEM approach is that it allows students not only to acquire theoretical knowledge, but also to develop practical skills, such as project thinking and interdisciplinary collaboration. It is important to take into account that the implementation of STEM requires not only theoretical training, but also significant work on integrating practical elements into the educational process [9].

Table 2. Level of students' satisfaction with teaching methods

Indicator	Before STEM implementation (%)	After STEM implementation (%)
Satisfaction with methods	65	92
Understanding the material	68	89
Interest in the subject	60	87

An important aspect of the study was the survey of students, which allowed them to assess their perception of the introduction of new teaching methods. As shown in Table 2, the level of satisfaction with teaching methods increased by 27 %, which indicates a positive perception by students of project activities and real-life tasks included in the learning process. In addition, interest in the subject of mathematics increased by 27 %, which indicates that STEM contributes to increased motivation and involvement of students in the learning process.

Table 3. Development of students' key competencies within STEM education

Competence	Before the experiment (%)	After the experiment (%)
Logical thinking	58	80

Interdisciplinary skills	50	85
Independent decision making	54	83

Table 3 shows how the level of logical thinking increased by 22 %, interdisciplinary skills by 35%, and the ability to make independent decisions increased by 29 %. These results show that the integration of STEM methods contributes to the development of not only academic skills, but also such important professional competencies as independence, critical thinking, and the ability to solve complex problems.

The results of the study demonstrated the importance of introducing STEM methods into the process of training mathematics teachers. At all stages of the experiment, students who took part in practical classes using STEM technologies showed a higher level of involvement in the educational process, as well as improved academic performance compared to the control group.

It turned out that the use of STEM methods not only has a positive effect on students' academic performance, but also helps them develop key competencies required in the modern educational and professional environment. One of the key features of STEM education is the emphasis on the practical application of knowledge. During the experiment, students actively worked on solving real problems, which required them not only to have deep theoretical knowledge, but also to be able to apply it in practice. For example, one of the tasks was to create a mathematical model for analyzing real data in conditions of limited resources. Such tasks require an integrated approach, integration of knowledge from various disciplines, as well as creative thinking, which helps students develop a wider range of skills [10].

The survey data also confirmed that the integration of STEM methods has a positive effect on students' motivation. More than 88% of the students in the experimental group noted that the use of interdisciplinary tasks and project assignments makes the learning process more interesting and meaningful.

The analysis of variance method (ANOVA) used to process the data showed that the differences in results between the control and experimental groups are statistically significant. This confirms that the use of STEM methods has a real impact on educational results. Significant improvement in academic performance and increased student satisfaction demonstrate the importance of moving to more practice-oriented forms of education. The results of the experiment confirm the conclusions of many researchers about the need to use STEM education to prepare future teachers [11].

The practical focus of the STEM approach helps students develop interdisciplinary integration skills. As part of the experiment, students worked on project assignments that required them to apply knowledge from various fields, such as mathematics, physics, engineering, and information technology. These assignments helped students better understand how individual disciplines can interact and complement each other in solving real-world problems [12].

One of the interesting observations from the experiment was that the experimental group showed improved results not only in tests, but also in everyday tasks that required flexibility of thinking and creative approaches to problem solving. These results highlight the importance of using practical teaching methods that help students develop not only academic knowledge, but also the professional skills needed in the future.

Thus, the conducted study demonstrates that the integration of STEM methods into the process of training mathematics teachers contributes to the improvement of students' academic performance, their involvement and interest in the educational process, as well as the development of their key professional skills. These results indicate the importance of further implementation of STEM approaches into educational practice [13].

The integration of an interdisciplinary approach into education allows students not only to better absorb the material, but also to more actively apply the acquired knowledge in practice, which is a necessary condition for the modern education system.

Conclusion

The introduction of STEM technologies into the educational process has had a significant impact on the training of future mathematics teachers at Korkyt Ata Kyzylorda University. The findings suggest that students who learn using integrated STEM methods demonstrate not only improved academic performance, but also the development of key competencies such as critical thinking, interdisciplinary collaboration, and the ability to solve real-world problems.

A 23% increase in GPA, a 23% improvement in critical thinking, and a 22% improvement in problem-solving skills confirm the effectiveness of STEM approaches. In addition, student satisfaction with teaching methods and student engagement in the learning process also increased significantly.

The results of the study confirm the need for further implementation of STEM technologies in educational programs to prepare highly qualified teachers who are able to adapt to the new requirements of modern education. Future research can be aimed at studying the influence of STEM approaches in various disciplines, as well as developing new methods for integrating technology into the learning process.

Thus, summing up this work, we will specify the conclusions and proposals on the topic of the research:

1. The research objectives have been stated more explicitly. The study aimed to: (1) examine the theoretical and methodological foundations of integrating STEM education into mathematics teacher training; (2) develop and implement a STEM-based instructional approach for prospective mathematics teachers; (3) evaluate its effects on students' academic performance, critical-thinking abilities, and problem-solving skills; and (4) identify practical implications for improving the methodological preparation of future mathematics teachers.

2. Repetition between the Results and Conclusion sections has been reduced.

The Results section now presents the empirical findings and statistical evidence, whereas the Conclusion provides a concise interpretation of the findings, their educational implications, and the study's limitations.

3. STEM-related terminology has been clarified and standardized throughout the manuscript. "STEM education" refers to the integrated teaching of science, technology, engineering, and mathematics through interdisciplinary and practice-oriented activities. "STEM-based instructional methods" refers to the specific project-based, inquiry-based, problem-solving, and design-oriented methods used in the intervention. The general expression "STEM technologies" has been replaced where appropriate with more precise terms, such as "STEM-based instructional approaches" or "digital educational tools."

4. Statements previously formulated as expected future results have been revised to describe the actual outcomes of the completed study. Future-tense expressions such as "will be developed," "will be prepared," and "will improve" have been replaced with evidence-based formulations such as "were developed," "were prepared," and "showed improvement."

The results of the study confirmed the importance of adopting practice-oriented forms of education and integrating interdisciplinary approaches into mathematics teacher training. The integration of STEM education improved the quality of the training provided to prospective mathematics teachers and demonstrated its potential to contribute to the broader development of education. The completed study produced the following outcomes.

Scientific results:

The theoretical and methodological foundations for developing students' cognitive interest and research skills through the use of STEM technologies in mathematics education were identified.

An effective model and its structural components were developed to improve prospective mathematics teachers' methodological preparation for the use of STEM technologies.

Effective methods, tools, and technologies for integrating STEM approaches into mathematics teaching were identified and systematized.

Practical results:

Methodological guidelines and practical tools for the use of STEM technologies by mathematics teachers were developed.

Lesson plans, educational projects, and a set of practical tasks integrating STEM technologies with the school mathematics curriculum were prepared.

Practical materials designed to develop students' cognitive interest and their creative, analytical, and research abilities were compiled and tested.

Learning outcomes:

The implementation of STEM technologies increased students' interest in mathematics and contributed to the development of their research, problem-solving, critical-thinking, and logical-reasoning skills.

The professional competencies of prospective mathematics teachers improved, particularly their ability to use digital tools, interdisciplinary approaches, and innovative teaching technologies.

Students demonstrated improved mathematics achievement and greater interest in further learning and professional opportunities in STEM-related fields.

Innovative results:

Integrated STEM-oriented educational and methodological materials were developed to support improvements in the quality of mathematics education.

New pedagogical and digital technologies were incorporated into the educational process, promoting interdisciplinary, practice-oriented, and research-based learning.

The implementation of these materials improved students' academic performance, critical-thinking and problem-solving skills, and motivation to study mathematics. It also strengthened prospective teachers' professional competencies in using innovative pedagogical approaches and digital technologies.

In general, the research has enhanced the level of teaching mathematics; developed the professional skills of future teachers; and raised the grade point average and motivation for studying mathematics among students. The obtained results make it possible to raise a level of education, increase the professional qualification of teachers, enhance an interest of pupils on mathematics.

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STEAM ТЕХНОЛОГИЯСЫ ЖАҒДАЙЫНДА МАТЕМАТИКА МҰҒАЛІМДЕРІН ӘДІСТЕМЕЛІК ДАЯРЛАУДЫҢ ЗАМАНАУИ ТӘСІЛДЕРІ

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Аңдатпа. Мақалада мұғалімдерді білім беру бағдарламаларында STEM технологиясын табысты пайдалануға дайындауға ықпал ететін заманауи әдістемелік тәсілдерді зерттеуге талдау жасалған. Бұл тақырыптың өзектілігі білім беруді жаһандану мен цифрландыру жағдайында аса маңызды болып табылатын математиканы оқыту үдерісіне пәнаралық білімді кіріктіре алатын мұғалімдерді даярлау қажеттілігінен туындап отыр. Зерттеу барысында білім беру бағдарламаларын талдау және STEM әдістерін енгізудің тиімділігін тексеру әдістері қолданылды. Тәсілдердің тиімділігін бағалау STEM әдістерін енгізуге дейін және одан кейінгі сынақ нәтижелерін салыстырмалы талдауға негізделген. Зерттеу көрсеткендей, математиканы оқытуда кешенді тәсілдерді қолдану оқу нәтижелерін жақсартып, студенттердің сыни ойлауын дамытады. Бұл деректердің мұғалімдердің біліктілігін арттыру үшін маңызды теориялық және практикалық маңызы бар. Мақаланың негізгі нәтижелері пәнаралық оқыту әдістерін енгізу оқу материалын қабылдау деңгейін жоғарылататынын, сыни ойлау мен практикалық мәселелерді шешу дағдыларын дамытуға ықпал ететінін көрсетті. Практикалық салдарға инклюзивті оқыту әдістерін және мақсатты академиялық қолдау бастамаларын дамыту жатады.

Тірек сөздер: STEM, әдістемелік дайындық, математика мұғалімдері, пәнаралық оқыту, цифрлық технологиялар, оқытудың инновациялық әдістері, кәсіби құзыреттілік, Қазақстан

СОВРЕМЕННЫЕ ПОДХОДЫ К МЕТОДИЧЕСКОЙ ПОДГОТОВКЕ УЧИТЕЛЕЙ МАТЕМАТИКИ В УСЛОВИЯХ ТЕХНОЛОГИИ STEM

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Аннотация. В статье представлен анализ изучения современных методических подходов, которые способствуют подготовке учителей для успешного использования STEM-технологии в учебных программах. Актуальность данной темы обусловлена необходимостью подготовки педагогов, способных интегрировать междисциплинарные знания в процесс преподавания математики, что особенно важно в условиях глобализации и цифровизации образования. В исследовании были использованы методы анализа образовательных программ и тестирования эффективности внедрения STEM-методов. Оценка эффективности подходов основывалась на сравнительном анализе результатов тестирования до и после внедрения методик STEM. Исследование показывает, что использование интегрированных подходов в обучении математике способствует повышению академических результатов и развитию у студентов критического мышления. Эти данные имеют значительную теоретическую и практическую значимость для совершенствования подготовки педагогов. Основные результаты статьи показали, что внедрение междисциплинарных методов обучения повышает уровень восприятия учебного материала, способствует развитию критического мышления и навыков решения практических задач. Практические последствия включают в себя разработку инклюзивных методов обучения и целевых инициатив по академической поддержке.

Ключевые слова: STEM, методическая подготовка, учителя математики, междисциплинарное обучение, цифровые технологии, инновационные методы обучения, профессиональная компетентность, Казахстан

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