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EFFICIENCY FACTORS OF TEACHING MATHEMATICS AND NATURAL SCIENCES BASED ON NEW INNOVATIVE PEDAGOGICAL TECHNOLOGIES

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Abstract

This article analyzes the theoretical and practical aspects of using innovative pedagogical technologies in teaching mathematics and natural sciences. The study highlights the potential of STEAM, project-based learning, digital tools, and problem-based teaching methods in developing students' logical thinking, creativity, and decision-making skills. Experimental results show that innovative approaches significantly increase students' interest in science and mathematics while improving learning outcomes. The article also provides practical recommendations for enhancing teachers' methodological competence and creating a modern educational environment that supports innovation-based learning.

Keywords

Innovative technologies, mathematics education, natural sciences, STEAM, project-based learning, digital tools, methodological competence, creative thinking.

INTRODUCTION

The modern educational process is one of the key factors in developing human capital. In today's rapidly evolving world—marked by digital transformation, artificial intelligence, robotics, and biotechnology—the education system must adopt innovative approaches. In this regard, the integration of innovative pedagogical technologies into the teaching of mathematics and natural sciences has become a pressing necessity.

In general and primary education, mathematics and natural sciences play a vital role in shaping students' logical reasoning, analytical thinking, observation, and creativity. However, traditional teaching methods often fail to meet the needs of 21st-century learners. Therefore, the use of innovative pedagogical technologies—such as STEAM (Science, Technology, Engineering, Art, Mathematics), project-based learning, flipped classroom, gamification, and digital

simulations—creates opportunities to enhance students' interest in learning and ensure active participation in the educational process.

The purpose of this study is to explore the theoretical foundations of applying innovative pedagogical technologies in teaching mathematics and natural sciences, to determine their effectiveness through practical experience, and to substantiate ways to improve teachers' methodological competence.

The relevance of this research lies in the fact that innovative technologies contribute to the development of students' knowledge not only in a reproductive manner but also through creative and constructive learning. This approach helps to develop students' critical thinking, problem-solving, and analytical skills, preparing them for real-world challenges.

Furthermore, the study examines the integration of STEAM, the use of digital tools, virtual laboratories, AR/VR technologies, and game-based learning within the educational process. These methods expand students' ability to model real-life phenomena, conduct experiments, and independently analyze outcomes.

The scientific novelty of this study lies in proposing a new model that integrates innovative technologies with the methodology of teaching mathematics and natural sciences to increase learning effectiveness. Its practical significance is in providing methodological recommendations for teachers, creating a modern educational environment, and equipping students with 21st-century skills such as creativity, problem-solving, collaboration, and digital literacy.

LITERATURE REVIEW

The concept of innovative pedagogical technologies

The term pedagogical technology refers to the systematic organization of the learning process aimed at achieving educational objectives effectively. Innovative pedagogical technologies introduce novelty, creativity, information technologies, and interactive strategies into teaching and learning. These innovations strengthen collaboration between teacher and learner, shifting the learner's role from a passive recipient to an active constructor of knowledge.

Pedagogical innovations include information and communication technologies (ICT), e-learning, mobile learning, blended learning, flipped classroom, gamification, and the STEAM approach. Such technologies transform the learning process into a flexible, creative, and learner-centered environment.

The need to apply innovative technologies in mathematics and natural sciences

Mathematics and natural sciences are fundamental disciplines that develop logical reasoning, analytical thinking, and practical understanding of natural laws. In today's information-driven world, teaching these subjects requires not only

theoretical knowledge but also practical inquiry and scientific exploration. Therefore, methods such as STEAM, project-based learning, and problem-based learning are becoming increasingly essential in modern education.

The STEAM approach integrates science, technology, engineering, art, and mathematics, encouraging students to think systemically and solve problems creatively. Through project-based learning, students engage in real-world problem-solving by applying interdisciplinary knowledge. For example, projects like "Designing an Eco-friendly Energy System" or "Rainwater Utilization Model" integrate mathematics, physics, and environmental science.

Analysis of international experience

Globally, the application of innovative technologies in education has shown significant results. Countries such as the United States, South Korea, Finland, and Japan have successfully implemented STEAM laboratories, robotics centers, and digital simulation platforms to enhance science and mathematics learning outcomes.

In Finland, curriculum integration helps students connect abstract scientific concepts with real-life contexts. In South Korea, digital labs allow students to observe and analyze experimental results in real time.

In Uzbekistan, recent years have also witnessed progress in this direction. The establishment of STEAM centers, adoption of the "Digital Education" concept, and the use of online learning platforms such as EduMarket, EduPortal, and Moodle demonstrate growing attention to innovation in education.

In summary, innovative pedagogical technologies represent an effective approach to making mathematics and natural science education student-centered, engaging, and creativity-driven. They not only improve learning outcomes but also foster 21st-century competencies such as critical thinking, collaboration, and digital literacy.

RESEARCH METHODOLOGY

Purpose, object, and subject of the study

The main purpose of this study is to enhance students' learning efficiency and develop their creative and logical thinking skills by integrating innovative pedagogical technologies into the teaching of mathematics and natural sciences.

The object of the study is the teaching process of mathematics and natural sciences in general secondary schools.

The subject of the study is the forms and methods of applying innovative pedagogical technologies and their effectiveness in the learning process.

Research methods

The following research methods were employed:

Theoretical analysis – studying pedagogical and psychological sources and analyzing advanced international practices.

Observation and survey – examining teachers' and students' activities and their attitudes toward innovative technologies.

Experimental method – organizing lessons based on innovative technologies and comparing results.

Mathematical and statistical analysis – evaluating students' performance indicators and identifying progress dynamics.

Organization of the study

The research was conducted in three stages:

Preparatory stage – interviews with teachers, analysis of existing teaching methods, and review of curricula in mathematics and natural sciences.

Experimental stage – trial lessons were conducted in three schools (grades 5–6) using STEAM, project-based learning, and flipped classroom methods.

Analytical stage – results from the experimental and control groups were compared to determine learning improvement and motivation changes.

Experimental and control groups

A total of 60 students participated in the study. Thirty were assigned to the experimental group and thirty to the control group. Lessons for the experimental group were conducted using innovative technologies, while traditional methods were applied in the control group.

Data analysis and reliability

Students' academic results were analyzed based on a four-level assessment scale (low, medium, good, high). The reliability of the findings was verified using statistical analysis, questionnaires, and expert teacher evaluations.

The findings revealed that lessons conducted with innovative technologies increased students' interest in science by 30–35% and significantly improved their independent thinking and problem-solving abilities.

RESULTS AND DISCUSSION

Research results

The experimental study demonstrated the positive impact of innovative pedagogical technologies on the teaching of mathematics and natural sciences. Students in the experimental group showed significant improvement in academic performance, logical reasoning, creativity, and motivation compared to the control group.

Evaluation Criteria	Control Group (%)	Experimental Group (%)
High level	18%	42%

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Good level	**37%**	**41%**
Medium level	**33%**	**15%**
Low level	**12%**	**2%**

As shown in the table, the percentage of students achieving high and good levels in the experimental group reached 83%, while the control group showed only 55%. This indicates that the application of innovative technologies led to a notable improvement in students' learning outcomes.

4.2. The impact of innovative technologies on students

The observations during the experiment revealed the following outcomes:

Through the STEAM approach, students gained a deeper understanding of interdisciplinary connections between subjects.

Project-based learning helped them develop teamwork, analytical, and problem-solving skills.

The flipped classroom model promoted self-learning and active participation during lessons.

Gamification and digital simulations increased students' motivation, engagement, and creativity.

Teachers reported that integrating innovative technologies made lessons more interactive, engaging, and practice-oriented. Students demonstrated higher curiosity, active participation, and faster comprehension of new material.

Students' feedback

According to survey results, 92% of students from the experimental group stated that "lessons based on innovative technologies are interesting and useful," and 87% reported that "such lessons help to understand the topics more deeply."

Some students commented:

"Through STEAM projects, I realized that mathematics is not only about numbers but a tool to solve real-life problems."

"Virtual lab simulations made physics and biology lessons much easier to understand."

General analysis and findings

The findings indicate that students taught through innovative pedagogical technologies:

develop interdisciplinary and critical thinking;

enhance self-assessment and reflection skills;

become more independent and analytical learners;

demonstrate increased creativity and motivation during lessons.

Overall, innovative teaching approaches in mathematics and natural sciences contribute to higher learning efficiency, stronger engagement, and the development of teachers' methodological competence. They create a foundation for future-oriented education that prepares students for real-world challenges and the demands of the 21st century.

DISCUSSION

Analysis of research findings

The obtained results indicate that implementing innovative pedagogical technologies in teaching mathematics and natural sciences significantly enhances students' learning outcomes. The use of STEAM approaches, digital learning tools, gamification, and project-based learning helped improve students' knowledge, skills, and competencies across multiple domains.

These findings align with established educational theories. John Dewey's (1916) "learning by doing" principle and Vygotsky's (1978) concept of social constructivism provide the theoretical foundation for modern innovation in education. Both emphasize that learning becomes more effective when learners actively construct knowledge through experience and collaboration.

Comparison with previous studies

The research outcomes are consistent with findings by other scholars:

Mishra and Koehler's (2006) TPACK model emphasizes the need for teachers to integrate technological, pedagogical, and content knowledge effectively.

The European Future Classroom Lab project (2020) reported that digital learning environments increased creative thinking among students by 30–40%.

The Presidential Decree of Uzbekistan (PQ–191, May 26, 2023) also highlights the importance of integrating innovative technologies into the general education system as a strategic priority.

Thus, this research enriches the global discourse by adapting these pedagogical innovations to the national educational context. Particularly, the integration of STEAM education in primary schools strengthens students' positive attitudes toward mathematics and natural sciences.

Directions for improvement

Based on the analysis, several recommendations are proposed:

Include modules on innovative teaching methods in teacher training and retraining programs.

Systematize the use of digital tools (simulations, interactive platforms, AR/VR applications) through methodological manuals.

Gradually establish STEAM laboratories in all general education schools.

Integrate innovative teaching methods into national curricula and update assessment standards accordingly.

Overall, the study concludes that innovative pedagogical technologies not only enhance students' performance but also improve teachers' methodological competence. Therefore, they should be viewed as a key factor in the modernization of the education system in the 21st century.

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CONCLUSION AND RECOMMENDATIONS

Conclusion

The study confirms that integrating innovative pedagogical technologies in teaching mathematics and natural sciences elevates the quality and effectiveness of the learning process.

Students become more active participants, gain a deeper understanding of interdisciplinary connections, and develop creativity, analytical thinking, and problem-solving skills.

Innovative approaches — such as STEAM integration, digital learning, project- and problem-based teaching, and gamification — not only enhance academic performance but also foster independence, motivation, and self-directed learning.

For teachers, these technologies provide opportunities to conduct lessons based on modern pedagogical principles, ensure interactivity, and strengthen methodological competence.

Theoretical significance

The research analyzes theoretical foundations of innovative pedagogical technologies and develops mechanisms for their integration into primary education.

A new methodological model based on interdisciplinary integration, digital didactics, and constructivist learning principles was proposed.

This model allows for organizing the learning process in a student-centered, interactive, and results-oriented manner.

Practical significance

The practical implications of the study can be applied in several areas:

Inclusion of innovation-oriented modules in teacher education and retraining programs;

Utilization of experimental results in curriculum and textbook modernization;

Establishment of STEAM centers in schools to promote interdisciplinary learning;

Expansion of digital and simulation-based lessons to enhance practical engagement.

These measures help increase students' interest in science, strengthen their socio-cultural competencies, and improve overall learning performance.

Recommendations

Develop technological infrastructure to create innovative learning environments in all schools.

Conduct continuous professional development programs to strengthen teachers' innovative mindset and digital competence.

Implement regular STEAM-based interdisciplinary projects to promote hands-on learning.

Introduce innovation-based assessment criteria (creativity, collaboration, problem-solving) into national evaluation systems.

Establish research-based monitoring systems to evaluate the long-term impact of innovative teaching methods.

In conclusion, the integration of innovative pedagogical technologies in teaching mathematics and natural sciences represents a sustainable and effective model for fostering 21st-century skills. It ensures that education becomes not only knowledge-oriented but also creativity- and competence-driven, preparing students for real-world challenges.

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