

MODERN METHODS OF INTEGRATING PHYSICS AND MATHEMATICS: FROM SCHOOL TO COSMONAUTICS

Annotation

The article discusses modern approaches to the integration of physics and mathematics in the educational system of Uzbekistan. Special attention is paid to the formation of interdisciplinary competencies among schoolchildren and students through the introduction of STEM education, project and research activities, digital laboratories and modern pedagogical technologies. The article describes the experience of specialized institutions — Presidential schools, the Al-Khorezmi Lyceum, Temurbekov schools and the Karakul School — in preparing students for national and international Olympiads, scientific conferences and engineering projects. The importance of studying exact sciences for the development of 21st century competencies and strategic directions of the country, including cosmonautics, robotics and information technology, is emphasized. The article demonstrates that the integration of physics and mathematics contributes to the development of systems thinking, research skills and practical application of knowledge in real scientific and technical projects.

Keywords: *integration, physics, mathematics, STEM education, interdisciplinary approach, astronautics and engineering sciences competencies.*

Introduction

The modern education system places new demands on the preparation of students, assuming the development of skills of system analysis, research thinking and the ability to apply knowledge in practice. In these conditions, the integration of physics and mathematics is considered as an effective teaching method that provides a holistic understanding of the processes underlying the natural sciences.

Physics relies on mathematical apparatus, and mathematics receives practical content through physical tasks. Therefore, combining these disciplines is not only a methodological necessity, but also an important condition for the formation of fundamental scientific competencies.

The relevance of the topic is due to:

- the growing need for training specialists in high-tech fields (engineering, IT, robotics);
- Development of a STEM approach based on interdisciplinary learning;
- the need to increase students' motivation to study the exact sciences;
- The transition of schools to updated educational standards involving the integration of academic subjects;
- the need for schoolchildren and students to develop skills in solving research problems.

The purpose of the study

To identify effective modern approaches to the integration of physics and mathematics in the educational process and to determine their role in improving the quality of education.

Research objectives

1. To analyze the theoretical foundations of the integration of physics and mathematics.
2. To study modern pedagogical technologies used in integrated learning.
3. To consider practical examples of the implementation of integration in school and university education.
4. To assess the impact of the integrated approach on the development of students' scientific competencies.
5. Formulate conclusions and recommendations for improving the educational process.

The main part

Theoretical foundations of discipline integration

The integration of physics and mathematics is the creation of a single educational space in which knowledge from one field is used as a tool for studying another. The following forms of integration are distinguished in the scientific literature:

- Meaningful integration is the mutual enrichment of curricula, when the topics and concepts of one discipline support and complement the study of another.
- Methodological integration — the use of unified methods for solving problems, such as modeling, experiment, analysis, which forms a systematic approach to learning.
- Competence integration — the formation of complex skills, including analytical thinking, computational abilities and research skills.
- Project integration — the implementation of interdisciplinary projects that require the combined application of mathematical and physical knowledge.

This approach allows students to gain a deeper understanding of the nature of physical processes through mathematical models, see the practical application of abstract mathematical methods, and form systems thinking.

To implement the integration approach, modern pedagogical technologies are used, which contribute to the development of logical, spatial and causal thinking.:

- STEM/STEAM learning — combining science, technology, engineering, mathematics and creativity for a comprehensive study of phenomena.
- Design and research activities — independent performance of research tasks and experiments.
- Problem—based learning is when students independently discover new knowledge and formulate solutions.
- Digital laboratories and virtual simulators — the use of technologies for modeling physical processes and visualizing mathematical dependencies.
- Interactive techniques — case studies, learning experiments and simulations that make learning visual and meaningful.

The use of these methods ensures the formation of students' skills in analyzing, forecasting and scientifically substantiating the results, as well as activates educational activities.

In practice, the integration of physics and mathematics can be implemented through the following models:

- Joint lessons — physics and mathematics are taught in the same lesson as solving applied problems.
- Integrated modules — study of a physical phenomenon simultaneously with its mathematical description (for example, kinematics and functions, laws of motion of bodies).
- Interdisciplinary projects such as:
 - o simulation of planetary motion;
 - o Electrical circuit analysis;
 - o plotting of real physical processes.
- Olympiad tasks that require in-depth knowledge of both disciplines and the ability to apply an integration approach.

Such models allow students to directly see the relationship between mathematics and physics, which increases the meaningfulness of learning. Research shows that the joint study of physics and mathematics:

- increases motivation to learn;
- builds the ability to apply knowledge in new conditions;
- develops research skills;
- promotes a deeper understanding of scientific patterns;
- Improves academic performance.

Of particular importance is the development of mathematical modeling skills, which is becoming a key competence of the 21st century.

In recent years, Uzbekistan has been implementing a comprehensive education modernization policy aimed at training competitive youth and developing exact sciences. These reforms create favorable conditions for the integration of physics and mathematics and create an environment in which students can master interdisciplinary knowledge practically.

Modernization of educational standards

The adopted new State Educational Standards (SES) are focused on a competence-based approach, which means a transition from rote memorization of facts to mastering skills in solving practical and research problems. The standards provide for the inclusion of interdisciplinary links, which creates a normative framework for combining physics and mathematics in educational modules and projects. For example, mathematical modeling of physical processes and performing research tasks allow students to consciously see the interrelationship of disciplines, apply abstract mathematical methods to real physical phenomena, forming systematic thinking.

Development of STEM education and specialized schools

STEM education is a key tool for integrating science, technology, engineering, and mathematics. It is being actively implemented in Uzbekistan through the creation of specialized schools, lyceums and Presidential schools, where mathematics and physics are priority subjects.

Specialized educational institutions that create conditions for simultaneous and practical study of these disciplines are of particular importance in the development of the integration of physics and mathematics. These institutions include the Presidential Schools, the Al-Khorezmi Lyceum, and the Temurbekov Schools.

Presidential schools provide a high level of teaching of exact sciences and provide students with the opportunity to participate in Olympiads, scientific competitions and international projects, which builds their research skills and the ability to apply theoretical knowledge in practice.

The Al-Khorezmi Lyceum is notable for the introduction of modern laboratories, digital learning, and interdisciplinary courses focused on engineering and scientific fields. Here, students study physics and mathematics in close relationship, which allows them to see the specific application of mathematical methods to physical phenomena.

Temurbekov's schools are focused on the in-depth study of natural science disciplines with the active application of design and research activities. This approach stimulates the development of critical thinking, analysis and modeling skills necessary to solve complex problems.

Together, these institutions create an educational environment where mathematics and physics are studied not in isolation, but in an integrated manner. This allows students to see the interrelationship of disciplines in practice, form universal competencies of the 21st century and prepare for future professional activities in high-tech fields. In modern Uzbekistan, special attention is paid to the introduction of STEM education, which creates conditions for the integration of physics and mathematics, combining science, technology, engineering and mathematics into a single educational process. This approach forms a practice-oriented mindset among students, develops research skills and allows them to apply theoretical knowledge to real-world tasks. Specialized institutions that create an environment for the simultaneous and practical study of exact sciences are of particular importance:

Presidential schools provide a high level of teaching in physics and mathematics, as well as provide students with the opportunity to participate in Olympiads, scientific competitions and international projects. This builds research skills, critical thinking, and the ability to apply knowledge in practice.

The Al-Khorezmi Lyceum is notable for the introduction of modern laboratories, digital learning, and interdisciplinary courses focused on engineering and scientific fields. Students study physics and mathematics in close relationship, which allows them to see the direct application of mathematical apparatus to physical phenomena.

Temurbekov's schools are focused on the in-depth study of natural science disciplines with the active application of design and research activities. This approach helps to develop the skills of analysis, modeling and solving complex problems.

It is also important to note that the Karakul School in Uzbekistan is an example of a specialized educational institution focused on the in-depth study of exact sciences — mathematics and physics. The main goal of the school is to create conditions under which students not only master theoretical knowledge, but also have the opportunity to apply it in practice, developing analytical, critical and research thinking.

The educational process is based on a competence-based and integrative approach, in which mathematics and physics are considered not as separate disciplines, but as interrelated fields of knowledge. This allows students to see physical processes through mathematical models and simultaneously use mathematical tools to analyze real-world phenomena.

To achieve this integration, the school actively applies project and research activities. Students perform tasks that require an integrated approach: modeling physical processes, conducting experiments, analyzing data, and constructing mathematical relationships. In addition, modern digital technologies are widely used — virtual simulators, digital laboratories, interactive platforms (PhET, GeoGebra), which make learning visual and allow you to test theoretical hypotheses in practice.

Special attention is paid to the formation of the ability to solve non-standard tasks, develop logical and causal thinking. For this purpose, regular internal competitions and Olympiad training are held, which help identify the strongest students and develop their abilities.

Karakul School systematically prepares students to participate in national and international Olympiads, which require deep knowledge of physics and mathematics, as well as the ability to integrate this knowledge into solving complex problems. Among the Olympiads in which schoolchildren participate, it is possible to distinguish:

- The International Mathematics Olympiad (IMO), where students represent Uzbekistan at the level of the best schools in the world;
- The International Physics Olympiad (IPhO), which requires a comprehensive understanding of physical laws and the ability to apply mathematical tools to analyze them;

- International engineering and science competitions in which students develop their own projects in the field of robotics, engineering and natural sciences;
- Olympiads in programming and computer science (IOI, Bebras Challenge), where the integration of exact sciences with algorithmic thinking contributes to the development of a systematic approach to solving problems.

Systematic preparation for such events builds students' skills in analysis, modeling, and practical application of knowledge, which is a key element of 21st century competencies.

The success of the Karakul School is explained by a comprehensive and scientifically based approach to learning. First, the school creates conditions for the integration of mathematics and physics through joint study of disciplines, project work and research assignments. Secondly, the use of modern technologies and digital laboratories allows students to test hypotheses and see the connection between theory and practice. Thirdly, the school actively supports talented young people by providing opportunities to participate in Olympiads, conferences and international competitions, which stimulates motivation for the exact sciences.

Thus, the Karakul school forms an educational environment where students not only master knowledge, but also develop research and practical skills necessary for further education and professional activity. The school's experience shows that comprehensive training based on the integration of disciplines, project activities and modern methods allows students to achieve high results in the international arena and successfully develop their competencies.

Together, these institutions create an educational environment where physics and mathematics are studied in an integrated manner. Students see the interconnection of disciplines in practice, which contributes to the formation of universal competencies of the 21st century and preparation for future professional activities in high-tech fields.

In addition, the successful implementation of the STEM approach is impossible without a modern material and technical base. Physics and mathematics laboratories are being updated in schools and lyceums, digital laboratory complexes are being introduced (for example, Vernier, Arduino, Lego Education), and interactive modeling and 3D visualization of physical processes are also being used. The development of a network of "Growth Points", digital classrooms and technology parks allows for integrated lessons where students simultaneously solve mathematical problems and explore physical phenomena.

The availability of modern infrastructure makes learning visual, meaningful and motivating, builds research skills, increases students' level of education and creates conditions for effective integration of physics and mathematics.

For the successful integration of physics and mathematics, it is important to have a modern material and technical base. Laboratories are being updated in schools and lyceums, digital laboratory complexes such as Vernier, Arduino, and Lego Education are being introduced, as well as interactive simulations and 3D modeling. The development of a network of "Growth Points", digital classrooms and technology parks allows for integrated lessons where students simultaneously solve mathematical problems and explore physical phenomena. Such an infrastructure makes learning visual, meaningful and motivating, and builds students' skills in researching and applying knowledge in practice. The State pays special attention to the training of teachers capable of implementing an interdisciplinary approach:

- advanced training courses on the integration of physics and mathematics are conducted;
- New techniques based on digital technologies and a STEM approach are being introduced;
- Internships and exchange of experience with international educational institutions are organized.

This ensures a unified approach to teaching, improves the quality of learning and contributes to the successful implementation of the integration of subjects.

Effective integration of physics and mathematics is impossible without the training of qualified teachers capable of implementing an interdisciplinary approach. In this regard, the State pays special attention to improving the professional competence of teachers.

As part of the reforms, advanced training courses are being conducted aimed at mastering modern methods of integrated learning, the use of mathematical apparatus in the study of physical phenomena and project activities. New pedagogical approaches based on digital technologies and STEM methods are being introduced, which allows teachers to create learning situations that are as close as possible to real scientific and engineering practice.

In addition, international internships and exchange of experience are organized, which give teachers the opportunity to adopt successful practices from the world's leading educational systems. All these measures ensure a unified approach to teaching, improve the quality of learning and create favorable conditions for the successful implementation of the integration of physics and mathematics in the educational process.

Special conditions for gifted youth are being created in Uzbekistan to stimulate students' interest in exact sciences.

National and international Olympiads in physics and mathematics are regularly held, which motivates students to study disciplines in depth and develop research skills. Research projects and conferences are organized that allow

schoolchildren and students to apply knowledge in practice, develop their own projects and exchange ideas with colleagues.

Additionally, scholarships and grants are provided for participation in innovation and engineering competitions, which encourages young people to be active in scientific and engineering activities. Such comprehensive support contributes to the formation of motivation, research competencies and readiness for professional activity in the field of high technologies.

In recent years, Uzbekistan has seen a steady increase in the interest of schoolchildren and students in the exact and technical sciences — physics, mathematics, computer science, engineering. This is due both to the development of educational infrastructure and to the opening of new opportunities for the practical application of knowledge in real science and technology.

Modern students understand that physics and mathematics are not only school subjects, but also tools for solving complex technological and scientific problems. Areas related to astronautics and aviation, robotics and automation, information technology and programming, energy and nanotechnology are becoming particularly in demand.

Participation in scientific circles, Olympiads, design competitions and international programs builds students' awareness of the importance of exact sciences for career growth and professional development. Resolution of the President of the Republic of Uzbekistan dated May 3, 2019 No. PP-4306 "On measures to organize a continuous system for providing gifted youth and training highly qualified personnel" approves the list of international Olympiads, the winners of which are eligible for admission to higher education institutions without passing tests and additional exams.

Within the framework of this system:

- Winners are given a special certificate that confirms their achievements at international Olympiads.
- This certificate entitles you to score maximum points in the entrance exams, depending on the field of study in the relevant higher education institutions.
- The certificate is valid for three years from the date of its receipt.

Thus, this mechanism is aimed at:

1. Support for gifted youth;
2. Creating conditions for continuous selection and training of highly qualified personnel;
3. Encouraging active student participation in prestigious international Olympiads.

In July 2024, the 65th International Mathematical Olympiad (IMO 2024) was held in Bath (Great Britain), which was attended by more than 600 schoolchildren from 110 countries. The national team of Uzbekistan demonstrated high results, winning 5 medals:

- 2 silver medals
- 3 bronze medals. These achievements have become a significant event for Uzbekistan in the international mathematical community, confirming:
 1. High level of mathematical education of the country's schoolchildren;
 2. Active participation of Uzbek youth in international intellectual competitions;
 3. The potential for further development of the country's scientific and educational potential.

Success at IMO 2024 is a vivid example of how support for talented youth, systematic training and participation in prestigious international competitions contribute to strengthening Uzbekistan's image in the global educational arena.

Uzbekistan consistently demonstrates a high level of education of schoolchildren in the field of physics by participating in international Olympiads, such as the International Olympiad in Physics (IPhO), as well as in other subject Olympiads held both in the country and abroad.

Uzbek schoolchildren regularly represent the country at major international physics forums. Students compete with peers from different countries, demonstrating their knowledge, skills and creative approach to solving complex problems. The country, especially the city of Samarkand, acts as a venue for international Olympiads in physics and astronomy for high school students. Such events attract participants from different countries, promote the exchange of experience and strengthen international cooperation in the field of education.

Thus, active participation in Olympiads and large-scale intellectual competitions makes Uzbekistan an important center for international scientific and educational cooperation, stimulating the development of talented youth and strengthening the country's position in the global educational community.

Technical subjects, including physics and mathematics, play a key role in the strategic development of the country as a space and aerospace industry. Uzbekistan is actively developing national space research programs, which require highly qualified specialists with deep knowledge of mathematics, physics and engineering. Knowledge of these disciplines allows the development of satellites, spacecraft and navigation systems. Also, information technology and digitalization of the economy. Mathematics, algorithmic thinking and logic are the basis of programming, robotics and the creation of software systems for automation of production and management. Energy

and high technologies. Knowledge of physics and mathematics, including computational models and data analysis, is required for the design of power plants, renewable energy sources and complex engineering systems.

Conclusions

Thus, the study of these disciplines is directly related to the implementation of the strategic objectives of the state, and students see the prospect of applying knowledge in sought-after and prestigious fields.

Modern schools and lyceums, including Presidential Schools, Al-Khorezmi Lyceum and Temurbekov schools, create conditions for the development of this interest.:

- STEM clubs, laboratories, and technology parks are being organized.;
- practical projects and experiments are conducted that simulate real physical processes;
- Students have the opportunity to participate in scientific conferences and engineering competitions, including international programs in astronautics, robotics and aviation.

This integration of educational theory and practice builds 21st century skills among young people, including critical thinking, systems analysis, research skills, and the ability to work in interdisciplinary teams.

The integration of physics and mathematics is an urgent and promising area of modern education. It allows students to form a holistic picture of the world, develop research and analytical skills, improve the quality of learning and motivation. The use of modern pedagogical technologies, digital tools and a design and research approach makes the educational process more efficient and closer to real scientific tasks.

The results obtained confirm that the further development of the integration of disciplines is an important condition for the modernization of education and training for high-tech industries.

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