Problems of implementing STEM education in mathematics (grades 10–11, Algebra and the Fundamentals of Analysis)

Aralbay Nuriya

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Department of Pedagogy of Natural Sciences

Thesis Advisor: Candidate of Pedagogical Sciences,
Associate Professor
Dzhanbulat Kayinbaev

«SDU University»

Faculty of Education and Humanities
Department of Pedagogy of Natural Sciences

This is to certify that the Master's Thesis of

Aralbay Nuriya

has met the thesis requirements of
SDU University

Approved by:

Candidate of Pedagogical Sciences,
Associate Professor
Dzhanbulat Kayinbaev
Thesis supervisor

Doctor of Pedagogical Sciences,
Associate Professor
Bakhyt Sydykhov
Chair of the Dissertation Council

MSc., Senior Lecturer
Nurbek Sagyndyk
MA program coordinator

PhD., associate professor
Zhangyl Abilbek
Chair of the Department of Pedagogy of Natural Sciences

PhD., associate professor Zhainagul Duisebekova
Dean, Faculty of Education and Humanities

Kaskelen, 2025

AUTHOR AGREEMENT

Apal -
Author Signature

25.06.2025
Date

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Name: Aralbay Nuriya

Арал.
Signature

25.06.2025
Date

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List of Abbreviations

EBP- Evidence-Based Practice
PBL- Project-Based Learning
STEAM - Science Technology Art Engineering Mathematics
STEM - Science Technology Engineering Mathematics
USA- United States of America
ZPD - Zone of Proximal Developmen

ABSTRACT

This dissertation work examines the theoretical and practical issues of implementing the STEM education system in the subject “Algebra and Analysis Beginnings” for grades 10–11. STEM approaches not only increase students’ interest in the subject, but also allow them to connect their mathematical knowledge with real-life situations. During the study, three STEM projects based on methods such as PBL (project-based learning), the 5E model, and engineering design were developed and a practical experiment was conducted. The experimental results showed that STEM methods increase students’ scientific thinking, independent decision-making ability, and motivation to conduct research. In addition, the difficulties encountered during the study, such as the level of teacher training, resource constraints, and integration into the curriculum, were analyzed, and methodological recommendations were made. The work provides a scientific and practical basis for the effective use of STEM education in secondary school mathematics.

Keywords: STEM education, algebra, analysis initiatives, project-based learning, 5E model, engineering design, mathematical modeling, school mathematics, experimental research, educational methodology.

АҢДАТПА

Бұл диссертациялық жұмыста 10–11 сыныптарға арналған «Алгебра және анализ бастамалары» пәнінде STEM-білім беру жүйесін енгізудің теориялық және тәжірибелік мәселелері қарастырылды. STEM тәсілдері оқушылардың пәнге қызығушылығын арттырып қана қоймай, математикалық білімдерін нақты өмірлік жағдаяттармен байланыстыруға мүмкіндік берді. Зерттеу барысында PBL (жобалық оқыту), 5E моделі және инженерлік дизайн әдістеріне негізделген үш STEM-жоба әзірленіп, тәжірибелік эксперимент жүргізілді. Эксперимент нәтижелері STEM әдістерінің оқушылардың ғылыми ойлауын, дербес шешім қабылдау қабілетін және зерттеу жүргізуге деген ынтасын арттыратынын көрсетті. Сонымен қатар, зерттеу барысында кездесетін қиындықтар, мысалы, мұғалімдердің дайындық деңгейі, ресурстық шектеулер мен оқу бағдарламасына біріктіру мәселелері де сарапталып, әдістемелік ұсыныстар берілді. Жұмыс STEM-білім берудің орта мектеп математикасында тиімді қолданылуының ғылыми-тәжірибелік негізін ұсынды.

Кілт сөздер: STEM-білім беру, алгебра, анализ бастамалары, жобалық оқыту, 5E моделі, инженерлік дизайн, математикалық модельдеу, мектеп математикасы, эксперименттік зерттеу, білім беру әдістемесі.

АННОТАЦИЯ

В данной диссертационной работе рассматриваются теоретические и практические вопросы внедрения системы STEM-образования по предмету «Начала алгебры и анализа» для 10–11 классов. STEM-подходы не только повышают интерес учащихся к предмету, но и позволяют им связать свои математические знания с реальными жизненными ситуациями. В ходе исследования были разработаны три STEM-проекта на основе таких методов, как PBL (проектное обучение), модель 5E и инженерное проектирование, а также проведен практический эксперимент. Результаты эксперимента показали, что STEM-методы повышают научное мышление учащихся, способность к самостоятельному принятию решений и мотивацию к проведению исследований. Кроме того, были проанализированы трудности, возникшие в ходе исследования, такие как уровень подготовки учителей, ограниченность ресурсов и интеграция в учебную программу, и даны методические рекомендации. Работа дает научную и практическую основу для эффективного использования STEM-образования в математике средней школы.

Ключевые слова: STEM-образование, алгебра, аналитические инициативы, проектное обучение, модель 5E, инженерное проектирование, математическое моделирование, школьная математика, экспериментальные исследования, образовательная методологи

INTRODUCTION

The main task of the modern education system is to educate a competitive, comprehensively developed individual with the skills of creative thinking. One of the main priorities of state policy is the development of human capital, that is, the formation of a generation that is educated, competent and able to adapt to modern requirements. To achieve this goal, an important factor is to increase students' interest in knowledge. However, studies have shown that 80% of school teachers and 93% of university students of pedagogical orientation, who are future mathematics teachers, do not sufficiently master the methods of developing students' mathematical interest. This indicates that in the course of teaching mathematics in schools in Kazakhstan there are serious problems in increasing students' motivation to the subject.

The STEM education system is one of the innovative approaches that connects learning with life, develops students ' research and creative abilities, combining theory and practice. However, the ways of effective use of STEM in mathematics lessons, especially in grades 10-11, and its methodological problems have not been fully studied.

In this regard, the research topic “problems of using the STEM education system in mathematics (grades 10-11, algebra and analysis initiatives)” is relevant. This study examines ways to improve the mathematical literacy of students through the use of the STEM methodology, the formation of their interest in the subject and the development of creative abilities.

The level of study of the topic. The analysis and examination of works related to the topic led us to the following conclusion. Basically, research in this area was carried out in three directions. The first direction is research in the direction of increasing students ' interest in learning, not related to a separate subject, the second direction is also the interest of students in studying mathematics, and the third direction is this situation in the course of teaching subjects other than mathematics.

Object of research. Grades 10-11, algebra and analysis initiatives.

Subject of research. Grades 10-11, algebra and analysis initiatives

Purpose of the study. To study the problems and possibilities of implementing the STEM education system in teaching mathematics to students in grades 10-11.

Objectives of the study:

1. To identify the psychological and pedagogical foundations of the use of the STEM education system in mathematics lessons.

2. To identify the features of STEM methods in teaching algebra and analysis initiatives in grades 10-11.

3. Consider ways to develop competencies related to the development of creative abilities and increase students ' mathematical interest through the use of STEM approaches in future mathematics teachers.

Methodological basis of the study:

State documents related to the STEM education system, the principles of personality-oriented education, modern pedagogical technologies, theories for the development of creative abilities of students and requirements for the professional competence of a teacher.

Research methods:

Analysis, control, Interview, Survey of state and pedagogical documents, Organization of experiments, theoretical analysis, study and comparison of advanced pedagogical practices.

Research base:

The research work was carried out in secondary schools in Almaty.

Novelty of the study:

1.The scientific basis for the development of students ' creative abilities in mathematics lessons using STEM methods is determined.

2. The features of the implementation of STEM approaches in teaching algebra and analysis initiatives in grades 10-11 are revealed.

3. Ways to adapt future mathematics teachers to the use of STEM methods were shown.

Recommended for protection:

1. Psychological and pedagogical aspects of the use of the STEM education system in mathematics lessons.

2. Features of teaching algebra and analysis initiatives in the framework of updated education.

3. Ways to develop competencies for future mathematics teachers to master STEM methods and apply them.

Scientific and practical significance of the study:

A special course" features of the use of the STEM education system in mathematics (grades 10-11, algebra and analysis initiatives) " has been developed and recommended for advanced training programs for future teachers and school teachers.

Approbation of the dissertation work. Master's student on the topic of research

1. Tasks in the STEM direction in the content of the discipline algebra and analysis initiatives
2. Published articles on STEM - a new approach to the education system.

The structure of the dissertation. The dissertation work consists of two parts, an introduction and a conclusion, A list of works used and appendices.

In the context of the global transformation of education, the need to train a new generation capable of critical thinking, creative problem-solving, and interdisciplinary integration is more urgent than ever. One of the most promising frameworks that addresses these challenges is the STEM education system, which integrates science, technology, engineering, and mathematics into a cohesive learning paradigm (Bybee, 2013). Numerous studies indicate that STEM education enhances students’ ability to apply knowledge in real-life situations, fosters research skills, and supports long-term professional development (Honey, Pearson, & Schweingruber, 2014).

In Kazakhstan, as in many other countries, mathematics remains one of the core disciplines shaping students’ analytical and logical abilities. However, despite its importance, motivation and interest in mathematics among students often remain low. According to research, a significant number of future mathematics teachers lack effective methodologies to engage students creatively and practically in the subject (Bekbauova & Turebayeva, 2022). This situation reflects broader issues in teacher preparation and curriculum design, highlighting the need for innovative pedagogical strategies.

In the era of rapid technological advancement and digital transformation, the global education system faces new challenges and demands. Modern society requires individuals who are not only knowledgeable in academic subjects but also capable of critical thinking, problem-solving, and interdisciplinary integration. One of the most effective educational models aimed at meeting these requirements is STEM education, which combines Science, Technology, Engineering, and Mathematics into a unified, practice-oriented learning framework.

In Kazakhstan, mathematics continues to play a key role in shaping students' logical, analytical, and quantitative reasoning. However, despite its importance, students often perceive mathematics as abstract and disconnected from real life, which leads to decreased interest and motivation. At the same time, many future mathematics teachers are insufficiently prepared to implement innovative, integrated teaching methods that foster engagement and applied understanding.

Given these conditions, integrating STEM approaches into mathematics instruction—particularly in high school algebra and analysis—emerges as a promising strategy. STEM-based instruction promotes functional literacy, the ability to apply knowledge in real-world contexts, and the development of 21st-century skills. Nevertheless, the effective implementation of STEM in mathematics education remains a methodological and practical challenge, especially within the existing national curriculum.

This research is focused on identifying the psychological-pedagogical foundations and methodological possibilities of using STEM approaches in teaching algebra and analysis in grades 10–11. The study aims to develop and test STEM-oriented tasks, evaluate their impact on student learning, and explore strategies for training future teachers to integrate STEM methods effectively. The relevance of the study lies in its alignment with national educational reforms and its contribution to the development of innovative instructional practices in secondary mathematics education.

The integration of STEM approaches into mathematics teaching—particularly in upper secondary school (grades 10–11)—can serve as a powerful solution. STEM-based methods allow students to see the relevance of mathematical concepts in technological and scientific contexts, thereby increasing their motivation and deepening understanding. Moreover, such integration contributes to the development of functional literacy, engineering thinking, and interdisciplinary competence, all of which are crucial in the digital age.

Despite the growing recognition of STEM's potential, there is still a lack of clear guidance on how to implement these approaches in the context of the existing mathematics curriculum, especially in relation to algebra and the beginnings of analysis. Therefore, this study aims to explore the methodological challenges and pedagogical opportunities associated with the use of STEM education in mathematics lessons, with a focus on grades 10–11.

In summary, this study aims to address the gap between traditional mathematics instruction and the innovative demands of modern education by exploring the integration of STEM approaches in teaching algebra and analysis in grades 10–11. The study is timely, relevant, and contributes both theoretically and practically to the improvement of secondary mathematics education and teacher training in Kazakhstan.

The results of this research are expected to help transform mathematics classrooms into dynamic environments where students develop not only academic skills but also the creativity, curiosity, and confidence to engage with the technological world. This transformation is essential for building the human capital that Kazakhstan and the world will need in the decades to come.

1. LITERATURE REVIEW

The STEM (Science, Technology, Engineering, Mathematics) education system first emerged in the early 2000s in the United States and has since spread widely across many countries. This system promotes the integrated teaching of science, technology, engineering, and mathematics. STEM education allows students to explore scientific and technical concepts in real-life contexts, thereby enhancing their cognitive activity and creative abilities. (Bekbauova, 2022)

What is the rationale behind the widespread implementation of STEM education in countries that have achieved significant success in their education systems and have become leaders in science, invention, and technological innovation?

At the end of the 20th century, a shortage of qualified specialists in high technologies emerged in American companies based on high-tech production. This situation gave rise to the concepts of STEM and STEM education.

Generally, the STEM abbreviation stands for: Science (natural sciences such as biology, geography, astronomy, chemistry, physics, etc.), Technology, Engineering (translated from English as engineering or the art of engineering), and Math (mathematics). There are also variations of this abbreviation. For example, "STEAM" adds the letter "A" for "Art," emphasizing the role of creativity. "STREM" includes the letter "R" for "Robot," referring to robotics.

Modern education is undergoing rapid transformation due to the development of science and technology. The advancement of information technologies, artificial intelligence, robotics, and bioengineering requires updates to educational content. In this context, the STEAM (Science, Technology, Engineering, Art, and Mathematics) education model plays a critical role. This system develops students' critical thinking and creative abilities while preparing them for future careers.(Бекбауова & Туребаева, 2022)

The importance of STEM technologies

The COVID-19 pandemic highlighted the importance of STEM education and increased the need for professionals with high digital competence. In the context of the pandemic, schools and universities quickly switched to a distance learning format, and the learning process reached a new level. At this stage, various programs were developed to improve the digital literacy of students and teachers, and there was a need to introduce digital tools and methods into the educational process. Teachers effectively used digital technologies in their subjects, quickly mastered the methods of teaching on an online platform and ensured education in accordance with new modern requirements.

Innovative STEM-oriented technologies have gained special importance during the pandemic period, contributing to the development of scientific and technical skills of students. Students began to master the subjects of Stam in depth and acquire skills aimed at applying them in real life.

This made it possible to educate them in the future as competitive, digital professionals with high competencies. In addition, STEM education, along with the formation of new competencies, directed students to professions that are in demand in the modern labor market and contributed to their professional growth.

Let's consider the content of the structural elements of the STEM abbreviation.

Science-Natural Sciences (Natural History, Natural Science) is a set of Sciences about nature, phenomena and laws that relate to the outside world of humanity. This is the real knowledge of everything that exists or is possible in the universe. In different historical periods, certain natural sciences occupied a central place and contributed to the development of Natural Science and other fields of knowledge. In historical dynamics, such an effect was achieved through one natural science or group leadership (leadership of a group of Sciences). Let's look at examples in chronological order: in the XVII–XVIII centuries, mechanics came to the fore, in the XIX century – chemistry, physics, biology, in the first half of the XX century – physics, and in the second half – chemistry, physics, biology. Today, not only the leadership of the group of Sciences is taking place, but also their synthesis, which is associated with the expansion and deepening of the ties of Natural Sciences aimed at solving the current tasks of production and society. (Balta, 2015)

Technology-technology is innovation, changing or transforming the natural environment to meet human needs and desires. Throughout history, people have created technologies to meet their desires and needs. Most modern technologies are products of Natural Sciences and technology, and technological tools are an integral part of both industries.

Engineering-Engineering is the ability to view the world as a system, design and manage its elements; a systematic and often repetitive approach to the design of objects, processes and systems. Engineering is a combination of human knowledge about the design and manufacture of products, the process of solving a problem. This process is characterized as a design under conditions of constraints. One of the limitations in engineering design is the laws of nature. Engineering uses knowledge of Natural Sciences and mathematics, as well as technological tools and art as the basis of design.

Mathematics-Mathematics is the science of numerical relations and spatial forms of the real world. Like the Natural Sciences, Knowledge in mathematics is constantly growing, but they, unlike the Natural Sciences, do not disappear if the basic assumptions do not change. Mathematics is widely used in the Natural Sciences, Engineering, Technology and the arts.

STEM education gives students the opportunity to understand the world as a whole, removes traditional barriers established between STEM subjects, and offers an integrated learning approach that teaches academic scientific and technical concepts in a real-life context. The purpose of this approach is to create stable connections between school, society, work and the whole world, to increase STEM literacy and competitiveness in the global economy.

The main idea of STEM education is to train children in professional professions, based on their curiosity and desire for research. The main motto is" do it yourself", which explains the introduction of engineering elements into the STEM-educational program. Thus, STEM education is a bridge that connects research and career.

In the works of foreign specialists, STEM education is often defined as a metadiscipline, which is based on a new "unified" integration of other subject knowledge and presents a unified learning paradigm based on the idea of practical application of knowledge to solve specific social, economic and technical-technological problems.

So, when words or concepts from the abbreviations STEM, STEAM, STREM are pronounced in English, it is natural science, technology, engineering, mathematics, art, robot. Similarly, we should not forget that the concept of "art" here is understood by the English-speaking environment in the sense of science, creativity, innovation. The concept of" STEM " was first proposed in 1990 by the American bacteriologist R. Colwell.Today, not only the United States, but also countries such as Canada, Finland, Hong Kong, Germany, Australia, China, Great Britain, Israel, Korea, Singapore, Sweden are rapidly developing the direction of STEM education.

USA: STEM education (science, technology, engineering, mathematics) occupies a central place in the educational and economic policy of the United States, as it is considered as a key factor in ensuring the country's global competitiveness in the field of innovation and high technologies. In recent decades, there has been an active development in this area thanks to the participation of both state initiatives and the private sector. However, along with the achievements, structural problems associated with inequality of access, a shortage of qualified teachers and gender imbalances remain. Public policy plays a key role in promoting STEM education. At the federal level, large-scale programs are being implemented, such as education for Innovation (2009), aimed at improving the quality of teaching STEM subjects in schools, and the CHIPS and science act (2022), which provides for an investment of доллар 200 billion in research and education programs. Significant support is provided by the National Science Foundation (NSF) and NASA, and grants are provided to research projects and educational institutions. At the same time, coalitions such as the Texas STEM coalition are being formed at the regional level, combining the efforts of the state, business and academic institutions to develop STEM infrastructure. The reform of school education is an important area, as the early involvement of students in STEM is considered essential for the formation of future professionals. Primary school focuses on game-based and experiential techniques such as robotics (LEGO Education, VEX Robotics) and Project-Based Learning (Project-Based Learning). Access to specialized programs such as Advanced Placement (AP) courses in computer science and engineering in middle and high schools, as well as STEM schools (such as the Thomas Jefferson graduate school of science and technology), where science and technical subjects are taught in depth, is expanding. Higher education is also adapting to the growing demand for STEM professionals. Universities are increasing their programs in data science, bioengineering and artificial intelligence, and introducing collaborative programs that allow students to combine their studies with work in technology companies. Financial support for students is provided through scholarships and grants, such as NSF Scholarships in STEM, which facilitate the influx of talented young people into the scientific and technical fields. Joining and overcoming inequality remain serious problems. Despite programs such as Girls Who Code and the Spanish

STEM Alliance that aim to reduce the gender and ethnic gap, women and minorities are still underserved in STEM professions. Another problem is the uneven distribution of resources: schools in affluent areas have significantly more opportunities to implement modern STEM methods compared to educational institutions in economically disadvantaged areas. Technological innovations are actively changing the educational process. Online platforms (Coursera, edX), virtual labs (Labster) and AI-based tools make learning scalable and interactive. However, their effectiveness depends on the level of digital infrastructure and teacher training, which creates additional barriers in regions with insufficient funding. Thus, the development of STEM education in the United States is a dynamic process carried out by the joint efforts of government, business and educational institutions. Despite significant successes, persistent structural problems require further policy coordination and increased investment, especially in the areas of equal access and teacher training. Addressing these challenges will be key to maintaining the United States ' leadership in the global technology race.

Europe: STEM education in Europe is undergoing a period of active transformation, becoming a key element in the strategy for the development of human capital and an innovative economy. The European approach to the development of scientific and technical education is characterized by a combination of pan-European initiatives and national characteristics, which creates a unique mosaic of educational experience. At the pan-European level, the development of STEM education is coordinated through a number of Key Programs and initiatives. Horizon Europe, the EU's largest research program for 2021-2027, devotes significant resources to developing STEM competencies. In the Digital Education Action Plan, special attention is paid to the digitalization of education, including the widespread introduction of programming and artificial intelligence in curricula. The European School Network brings together the efforts of the ministries of education of 34 countries to develop innovative methods for teaching STEM subjects.

National STEM education models show significant diversity. In Germany, the" MINT Zukunft schaffen " program (the German equivalent of mint – STEM) is being implemented with a focus on close cooperation between educational institutions and industrial enterprises. The British education system is undergoing a reform of mathematical education, according to which, from 2024, all schoolchildren will study mathematics until the age of 18. Finland uses its famous phenomenological approach (phenomenon-based learning), integrating STEM disciplines into interdisciplinary projects. France maintains the tradition of specialized "preparatory classes" (classes préparatoires) for future engineers. An important trend in European STEM education was the emphasis on early student engagement. Countries like Estonia are introducing compulsory programming from the first grade. Project training, which connects theoretical knowledge with the solution of practical problems, is becoming more widespread. Particular attention is paid to the development of digital educational platforms and tools, which is especially evident in the EU's annual Code Week initiative.

However, the development of STEM education in Europe faces a number of difficult tasks. The shortage of qualified STEM teachers remains an acute problem, especially in rural and economically disadvantaged regions. A serious gender imbalance remains-girls are still underserved in technical and engineering specialties. There is a significant difference in the quality and accessibility of STEM education between the countries of northern and Southern Europe, which requires additional mechanisms to equalize educational opportunities. The prospects for the development of STEM education in Europe are associated with the further integration of educational systems, the development of digital technologies in teaching and the strengthening of the practical component of educational programs. Of particular importance is the creation of stable ties between educational institutions, research centers and industrial enterprises. Solving these problems will allow Europe to train a new generation of specialists capable of remaining competitive in the context of the global technology race and responding to the challenges of the digital age.

Asia: STEM education in the Asian region is developing rapidly, becoming a key element of educational reforms and economic modernization. A distinctive feature of the Asian model is the close relationship between public policy, educational institutions and high – tech industries, which form a unique ecosystem for training technical specialists. The most advanced STEM education systems are developed in East Asian countries. South Korea is implementing a large-scale program "Creative Economy", where special attention is paid to the introduction of artificial intelligence and robotics into the school education system. The Singapore STEM model is known for its concept of" Applied Learning", where theoretical knowledge is immediately applied in real engineering projects. Japan is betting on the development of "Super STEM schools" equipped with advanced laboratories and digital classrooms. The Chinese approach to STEM education is distinguished by its regularity and scale. As part of the Made in China 2025 initiative, a national network of STEM Centers has been created, covering all regions of the country. Special attention is paid to the training of teaching staff through special advanced training programs. The constant first place of Chinese schoolchildren at international Olympiads in mathematics and science testifies to the effectiveness of the national system. In Southeast Asia, STEM approaches are being actively introduced into traditional education systems. Malaysia is implementing the STEM4ALL program, which aims to increase the availability of technical education for all social groups. Thailand focuses on the development of rural STEM schools, equipping them with modern equipment. In Vietnam, specialized STEM centers are being created at leading universities.

1.1 Main features of the STEM education system

Currently, the global transformation of the education system is inextricably linked with the need to prepare students for the requirements of the 21st century – the era of digitalization, automation and rapid technological progress. In this regard, instead of traditional subject Education, which is often limited to theoretical knowledge within narrow disciplines, there is an increasing demand for interdisciplinary, technology-oriented, practical methods for developing skills. This approach allows students not only to acquire academic knowledge, but also to develop the basic competencies necessary for successful professional implementation in the modern world: critical thinking, creativity, collaboration and the ability to solve complex problems. The STEM education system is an innovative learning format that meets these requirements, combining the areas of Natural Sciences (Science), Technology (Technology), Engineering (Engineering) and Mathematics (Mathematics). Unlike the classical approach, in which these subjects are studied in isolation, STEM involves their deep integration, which allows students to see the connections between different areas of knowledge and apply them in real projects. (ДилдабаеваМ.С., ЖайдакбаеваЛ.К, 2024)

There are several key features that increase the effectiveness of STEM education and make it one of the most promising areas in modern pedagogy. Among them, the emphasis is on the application of knowledge in practice in the conditions of the Fourth Industrial Revolution, the development of engineering thinking, the use of advanced technologies and the formation of in-demand skills.

Interdisciplinary approach

The main feature of STEM education is the mutual integration of subjects and their connection with life. In the traditional teaching system, each subject is considered individually, and the knowledge gained by students may not be connected with real life situations. And STEM-podkhod will remove this barrier and teach you to apply the natural sciences and mathematics to solving real-life problems. For example, in the process of implementing projects to measure air quality or collect rainwater, students combine their knowledge in physics, chemistry, ecology and mathematics. This approach allows students to effectively use knowledge not only in theoretical, but also in practical situations. In addition, the interdisciplinary approach develops logical, systemic and spatial thinking of students.

Project - Based Learning

Another important feature of STEM education is the widespread use of Project Learning. According to the project-based learning method, students do not receive knowledge ready-made, but, on the contrary, independently search and offer a specific product or solution, using various resources to solve the problem. Such an approach develops their autonomy, leadership skills and creative thinking. In addition, in the process of working in a group, students master mutual communication, role sharing and collective responsibility. For example, in the project "Smart Greenhouse" for schoolchildren, they create an automatic irrigation system using microcontrollers, thereby practical implementation of knowledge in Physics, Computer Science and biology.

Use of technologies

The most important component of STEM learning is the introduction of modern technologies into the educational process. Students improve their information and communication literacy through robotics, programming, 3D modeling, engineering design, and working with digital technologies. For example, through platforms such as Arduino, LEGO Mindstorms, Tinkercad, students can create their own projects, program them and monitor the operation of various sensors and mechanisms. Through these technologies, students acquire specific practical skills such as engineering thinking, systematic design, fault detection and their correction. In addition, the use of technologies facilitates the adaptation of students to the modern labor market.

Develop creative and critical thinking skills

The STEM education system teaches students to make non-standard, creative decisions and analyze the problem in detail and find effective ways. Through critical thinking, students analyze the information presented, present arguments, compare alternative solutions, and draw logical conclusions. In STEM projects, students are not given a specific solution, on the contrary, they are required to prove their decision, conduct research, conduct tests. This process develops students ' analytical thinking and brings them closer to research activities. In addition, creative thinking opens up the ability of students to invent and implement innovative ideas.

Focus on practice-oriented learning

One of the distinctive features of STEM is the relationship between theory and practice. Unlike traditional knowledge, where most knowledge remains abstract, STEM involves the immediate application of what has been learned in real projects. For example, when studying the basics of mechanics, students can not only solve problems on paper, but also build models of bridges or machines, checking their stability and efficiency. This method increases motivation, because students immediately see the result of their efforts.

Development of soft skills

STEM education contributes to the formation of not only technical, but also social and personal competencies. Teamwork, time management, public speaking, negotiation and emotional intelligence-all these skills are formed in the process of joint project activities. For example, when creating a robot or developing an environmental project, students learn to distribute roles, prove their point of view, and find compromises.

Personalization of training

STEM allows you to adapt the educational process according to the interests and abilities of each student. Thanks to various technologies and methods (programming, 3D printing, engineering, scientific experiments), students can choose the areas of interest to them. This contributes to a deeper involvement in the learning process and helps to reveal the potential of each child.

Relations with the real sector of the economy and professions of the future

STEM education prepares students for professions that will be in demand in the coming decades: robotics engineers, data analysts, bioinformatics, artificial intelligence specialists, etc. This will give them an advantage in future employment.

Global and environmental focus

Modern STEM projects are often associated with solving global problems such as climate change, resource scarcity, and environmental pollution. Students develop projects for alternative energy, waste recycling and the creation of smart cities that foster environmental awareness and social responsibility.

Continuous learning and adaptation

STEM develops students ' willingness to learn throughout their lives. As technologies are developing rapidly, it is important to independently master new tools and techniques. STEM methods teach students to work with information, quickly master new programs, adapt to changes. STEM education is not just a set of Sciences, but a single system aimed at developing universal competencies that are in demand in the digital age. It goes beyond traditional learning and integrates Science, Technology, Technology and mathematics into a holistic educational approach that develops students ' ability to think systematically, adapt to change, and create innovative solutions. Unlike classical teaching methods, STEM is aimed at applying knowledge in practice, developing not only technical skills, but also critical thinking, creativity, the ability to work in a team and solve complex problems. This method allows students not only to memorize information, but also to understand its deep interrelationships and use it in life projects, from programming robots to the development of environmentally sustainable technologies. Thanks to its flexibility and practical orientation, STEM has become a key element in modern education, preparing future generations for the challenges of the future. In a world where technology is rapidly changing all spheres of life, this format of education helps students become not just consumers of knowledge, but active creators who can influence the development of society. Thus, STEM education is not just an educational process, but a need that forms a new type of thinking and competencies, without which it is impossible to imagine a successful professional and personal implementation in the 21st century. Its further development and inclusion in educational programs will be an important step in the training of competitive, adaptive and New-minded specialists of the future.

1.2 The future of STEM education

In the XXI century, the rapid development of digital technologies and the transformation of the global labor market impose fundamental requirements on the education system. In this process, the STEM (Science, Technology, Engineering, Mathematics) education model is an innovative solution that meets the requirements of the time by providing an integrated, life-related, experience-based form of knowledge. STEM directions have already become the main vector of education in developed countries of the world, and this trend will undoubtedly only accelerate in the future. The modern educational paradigm is in a state of deep transformation due to the rapid development of technologies and changes in the requirements for human capital in post-industrial society. In this context, STEM education (science, technology, engineering, mathematics) is of particular importance as a key element in preparing the competency potential of the future. The analysis of current trends allows us to predict several fundamental directions in the evolution of this educational model. The prospects for the development of STEM education are determined, first of all, by the processes of digitalization of all spheres of public life. In the next decade, we should expect the widespread integration of artificial intelligence into the educational process, which will radically change the traditional approaches to teaching natural and technical disciplines. Virtual and augmented reality transform laboratory workshops, allowing us to simulate the most complex physical and chemical processes with previously inaccessible clarity.

The tendency of STEM approaches to rapprochement with other educational areas requires special attention. New integrative models are emerging, such as STEAM (including art) and STREAM (with the addition of a read and write component). This evolution shows an understanding of the need to develop not only technical competencies, but also creative thinking and communication skills, which are especially important in the context of automation of everyday processes. A key aspect of STEM's future is its focus on addressing the global challenges of our time. Educational programs are being built around issues such as climate change, sustainable development, biotechnology and quantum computing. This approach not only increases the motivation of students, but also forms the systematic thinking necessary for a comprehensive solution to complex interdisciplinary problems. The most important direction of development is the personalization of STEM education based on big data and adapted learning systems. The analysis of the cognitive characteristics and educational trajectory of each student makes it possible to build individual development programs that most correspond to their abilities and professional aspirations. This is especially important in the context of the formation of the future scientific and technical elite. The institutional transformation of STEM education involves the creation of global network structures that unite universities, research centers and technology companies. Such ecosystems ensure the continuity of the educational process from school to professional activity, creating conditions for the constant renewal of knowledge and competencies in the context of a rapidly changing technological landscape. STEM in the future, the development of cognitive technologies and neuroeducation will play a special role. Understanding the mechanisms of assimilation of complex scientific concepts at the neurobiological level makes it possible to develop fundamentally new teaching methods that significantly increase the effectiveness of the educational process.

These prospects for the development of STEM education should be considered in the context of global challenges, including the problem of digital inequality and the need to form a new culture of scientific and technical education. The solution of these tasks requires not only technological innovations, but also a deep change in pedagogical approaches, systems for assessing competencies, as well as mechanisms for the interaction of Education, Science and production. Thus, the future of STEM education is a complex, multidimensional system of interrelated transformations aimed at creating a fundamentally new model of Personnel Training for the knowledge economy. The successful implementation of these changes will become a determining factor in the competitiveness of national education systems in the context of the global technological race.

It is observed that the future of STEM education develops in several key areas:

1. Integration of new technologies

In the coming years, new areas such as artificial intelligence (AI), Big Data Analysis (Big Data), bioengineering, nanotechnology, cybersecurity, virtual and augmented reality (VR/AR) will be actively introduced into the STEM system. These technologies transform not only in terms of content, but also in the forms and methods of learning. For example, with the help of artificial intelligence, it is possible to control and differentiated learning of students ' knowledge at a separate level. Through the analysis of Big Data, a clear assessment of academic performance and the quality of Education, ways to adopt effective strategies will be improved.

2. Strengthen the relationship between education and the labor market

In the context of globalization, the structure of professions is rapidly changing, and professions in demand in the labor market are rapidly exchanging. By adapting to these changes, STEM education provides students with the opportunity to focus on a specific profession. Mastering such skills as Coding, engineering design, data processing at an early age allows you to prepare them in advance for future specialties. Close cooperation between universities and schools, as well as between educational institutions and industries, will also become a prerequisite for the development of STEM.

3. Integrated and inclusive education

In the future of STEM education, the issue of creating equal opportunities for all students is also important. Gender equality, reducing the gap between rural and urban schools, and ensuring the participation of students with special educational needs in STEM areas are some of the future tasks of this industry. Digital resources and online platforms, distance learning technologies make it possible to solve this problem. In addition, the connection of STEM education with social projects, environmental issues also has an impact on increasing the civic responsibility of students.

The direction of STEM education in Kazakhstan has been gaining momentum in recent years. In a number of pilot schools, STEM classrooms are being opened, the basics of robotics, 3D modeling, engineering design are being introduced. In leading educational organizations, such as Nazarbayev Intellectual Schools, lyceums "bilim-innovation", STEM approaches are successfully implemented in the educational process. In addition, STEM Olympiads, hackathons, competitions of scientific projects provide a great opportunity to develop scientific and technical creativity of students and increase their research abilities.

One of the main tasks of STEM pedagogy in the future is to form a student as a researcher, and not just a learner. This approach develops such skills as logical thinking, independent decision-making, argumentation, conducting experiments, defending one's idea. Future STEM lessons should be aimed at transforming the student from a passive listener to an active seeker. Thus, through the STEM approach, students develop not only an interest in science, technology, innovation, but also an internal motivation for Lifelong Learning. The future of STEM education is not only the introduction of new technologies, but also the process of radical revision of the content of training, pedagogical approaches, assessment systems. For Kazakhstan, the widespread introduction of STEM directions is an effective way to raise the education sector of the country to the international level, to educate a competitive generation. The fact that the future specialist is flexible, adaptable, technologically competent, creative – this is exactly what is inextricably linked with the STEM paradigm.

The role of STEM methodology in teaching mathematics

The modern educational paradigm is undergoing significant changes, reflecting the need of society for specialists capable of solving complex interdisciplinary problems. In this context, the STEM (Science, Technology, Engineering, Mathematics) methodology becomes especially important, offering a fundamentally new approach to teaching mathematics. The traditional perception of mathematics as an abstract theoretical discipline gives way to its understanding as a universal means of cognition and transformation of the real world. A comparative analysis of traditional and STEM-oriented approaches to teaching mathematics clearly shows the advantages of the latter:

Table 1.2.1 Comparative Characteristics of Traditional Learning and the STEM Education System in Mathematics

Criterion	Traditional learning	STEM education system
Attention to learning	Theoretical foundations	Interdisciplinary communication
Teaching methods	Lectures, typical tasks	Project activities
Technologies used	Basic (calculator)	Specialized (Python, MATLAB)
Developed computational	Calculation	analytical, research skill

The essence of the STEM methodology in teaching mathematics is to create an educational environment in which mathematical concepts are naturally integrated with other scientific and technical disciplines. This method allows students to understand the practical significance of the material being studied, observing its use in physical experiments, engineering calculations or technological developments. For example, the study of exponential functions takes on a new meaning when students use them to model population growth processes in biology or calculate complex interest in economics. The most important advantage of the STEM method is the development of students ' systemic thinking and the ability to see mathematical patterns in various phenomena of the surrounding world. Project activities that combine mathematical modeling with experimental work and programming form a set of competencies that cannot be developed within the framework of traditional learning. Students acquire not only deep mathematical knowledge, but also the skills of their practical application, which is especially valuable in the context of a rapidly changing technological landscape.

Modern digital technologies are of particular importance in STEM education. Special software, computer modeling systems and visualization tools make complex mathematical concepts more accessible and visual. Practice shows that the use of such tools not only improves academic performance, but also contributes to a deeper understanding of the material, since students can directly observe how abstract mathematical principles are embodied in specific technical solutions. Despite the obvious advantages, the introduction of the STEM methodology in teaching mathematics faces a number of important tasks. The main obstacle remains the shortage of teaching staff with the necessary interdisciplinary training. Effective implementation of the STEM approach requires teachers not only to have a deep knowledge of mathematics, but also to understand its application in related fields. In addition, many educational institutions lack the modern equipment and software necessary for the full implementation of STEM programs. The prospects for the development of STEM education in the field of mathematics are associated with several key areas. First of all, this is the further integration of digital technologies into the educational process, including the use of artificial intelligence to personalize learning. Secondly, the development of new methodological materials that combine mathematical rigor and practical orientation. Of particular interest is the potential of the STEAM approach, which complements the STEM methodology with elements of art and design, opens up new opportunities for the creative application of mathematical knowledge.

Thus, the STEM methodology offers a fundamentally new model of teaching mathematics, transforming it from an abstract academic discipline into a living tool for cognition and transformation of reality. This approach not only increases the effectiveness of training, but also forms in students a set of competencies that in the future will be in demand in specialties. The realization of this potential will require a significant restructuring of the education system, but the opening prospects fully justify the necessary efforts.

1.3 Features of the use of STEM methods in the context of updated education

STEM education in Kazakhstan is experiencing a period of active development, reflecting global trends in technological development and national priorities for economic modernization. Over the past decade, significant steps have been taken in the country to integrate scientific and technical education into curricula at all levels, which is gradually forming a new educational ecosystem. The basis for the development of STEM in Kazakhstan has become the state policy in the field of education and digitalization. Within the framework of the Digital Kazakhstan program, fundamental principles for transforming the educational process have been established. Of particular importance was the adoption of the state program for the development of education for 2020-2025, in which the STEM approach was noted as one of the main elements of the modernization of the content of Education. The Ministry of Education, together with Nazarbayev Intellectual Schools, has developed a concept for the introduction of STEM, which is gradually spreading throughout the education system.

The Kazakhstan model of STEM education is characterized by multilevel. The emphasis is on developing logical thinking and basic digital skills through specially designed curricula in elementary school. At the middle level, elements of robotics and programming are introduced, special attention is paid to project activities. The high school offers in-depth study of STEM subjects through a network of specialized schools and additional education clubs. Nazarbayev Intellectual Schools play a special role in promoting STEM, which has become an innovative platform for testing new methods. These institutions are equipped with state-of-the-art STEM laboratories, where students work with 3D printers, robotics kits, and digital measurement systems. The experience of these schools is gradually being applied in systematic educational institutions through the teacher training system. An important element of the system was the network of children's technoparks "golden nest" and STEM centers created throughout the country. These sites provide schoolchildren with access to high-tech equipment and the opportunity to work on real projects under the guidance of mentors from among university teachers and engineers. Robotics, programming and alternative energy are especially popular. (G., 2016)

Table 1.3.1 STEM-based Recommendations for Water Conservation

Direction	**Suggested Action**	**STEM Skills Involved**
Education & Awareness	Conducting school workshops on water-saving habits	Communication, data presentation
Technological Innovation	Installing smart water meters in public buildings	Engineering design, programming
Mathematical Modeling	Calculating household water usage and projecting savings	Algebra, graphing, data analysis
Environmental Research	Studying local water sources and loss due to leakage	Scientific investigation, data logging
Prototype Development	Designing low-cost water-saving devices (e.g., nozzle, timer tap)	Engineering, creativity, testing
Policy and Community Involvement	Preparing a report with water-saving proposals for local authorities	Argumentation, collaboration

Higher education is also adapting to the demands of STEM economics. Leading universities in the country, such as Nazarbayev University, kBtu and Satbayev university, are revising their educational programs and strengthening the practical component and interdisciplinarity. Cooperation between universities and high-tech enterprises is developing, which allows students to perform relevant production tasks. Kazakhstan actively participates in international STEM initiatives. The national stages of the world Olympiads in robotics, programming and natural sciences are held annually. The country has become a platform for regional competitions by WorldSkills standards, where special attention is paid to digital competencies. These measures not only identify gifted students, but also set new standards for technical education.

In modern Kazakhstan, STEM education has become a powerful driver of national development, synthesizing advanced pedagogical experience with the requirements of the digital economy. Over the past decade, the state has made a real breakthrough in this area, creating a unique ecosystem in which state initiatives, academic innovations and business interests are intertwined. The basis of this movement was the strategic vision of the country's leadership, which enshrined STEM as a priority in the documents "Digital Kazakhstan" and "Ruhani zhangyru". The concept of the development of STEM Education, adopted in 2018, set a systematic vector of transformations, which is now being implemented through a large-scale modernization of all levels of Education. Particularly illustrative is the example of the updated content of Secondary Education, in which traditional subject boundaries are blurred in favor of interdisciplinary projects and practice-oriented learning. The heart of the STEM revolution in Kazakhstan is Nazarbayev Intellectual Schools, which have become real laboratories for educational innovations. Their experience, repeated through the Centers of pedagogical excellence, gradually permeates ordinary schools and changes the philosophy of teaching itself. Within these walls, a new generation of teachers is born, inspired by scientific and technical creativity, and not just carriers of knowledge. In addition, a network of specialized STEM centers and children's technoparks "Golden Nest" is growing throughout the country, where schoolchildren have access to high – tech equipment-from 3D printers to robotic complexes. These sites will become a meeting place for young talents with representatives of the real sector of the economy, which will give practical meaning to training. The work of mobile STEM Laboratories, which deliver modern technologies to the most remote regions of the country, is especially impressive.

Higher educational institutions are also actively involved in this process. Leading universities – from Nazarbayev University to regional technical universities-are restructuring their programs with a focus on project-based learning and interdisciplinary research. The startup studios and accelerators they create allow students to transform ideas into working business models, which is especially important in the context of a course focused on innovative economics. International cooperation gives Kazakhstan STEM education a global dimension. Partnership with leaders in this area - Singapore, Finland, South Korea-will allow adapting the best world experience to local conditions. Participation in prestigious international Olympiads and competitions not only demonstrates the growing potential of Kazakhstani students, but also sets new development goals

The path to technological leadership is not without difficulties. The most acute problem remains staffing-in many schools, especially in the regions, there is a shortage of teachers capable of working according to new standards. A significant gap between urban and rural educational institutions in access to modern infrastructure requires special support measures. The task of overcoming stereotypes that limit girls ' access to technical professions is also important. Today, the future of Kazakhstan'S STEM education looks particularly inspiring. The emerging national STEM network promises to cover all regions of the country, providing equal opportunities for talented young people. The development of digital platforms and the introduction of artificial intelligence into the educational process opens up new horizons for personalized learning. Increasingly close interaction with the real sector of the economy makes education an effective tool for technological modernization. (Qūrman N.J., Äbışärıp Ä. , 2014) The real fruits of this work are already visible – there are more and more winners of international Olympiads, successful student startups, and in-demand engineering personnel. But the most important achievement is the formation of a new type of thinking among the younger generation, combining scientific curiosity and business courage. It is human capital that will serve as the basis for the implementation of the ambitious goal of bringing Kazakhstan to the ranks of technological leaders in the region.

However, the development of STEM in Kazakhstan faces a number of systemic challenges. The problem of training and retraining of pedagogical personnel remains acute – many teachers face difficulties when working with new technologies and methods. There is a significant gap between urban and rural schools in access to modern equipment and qualified specialists. The traditional focus on theoretical knowledge sometimes contradicts the practice-oriented STEM approach. In Kazakhstan, special attention is paid to gender balance in technical education. Special programs are being implemented to attract girls to STEM specialties, such as "girls in technical Kazakhstan" and "IT Girls". These initiatives are showing positive results-more and more girls are choosing engineering and it specialties when entering universities. The prospects for the development of STEM education in Kazakhstan are associated with the further integration of digital technologies into the educational process, the expansion of the network of STEM centers and the strengthening of ties between education and the real sector of the economy. Along with technical skills, the development of critical thinking and creativity of students will be an important direction.

With the successful implementation of these measures, Kazakhstan has every opportunity to create a competitive system of scientific and technical education that meets the tasks of the Fourth Industrial Revolution.

The current state of STEM-oriented work in Kazakhstan and the role of school teachers

Today, STEM-oriented work is actively developing in schools in Kazakhstan. Nazarbayev Intellectual Schools, bilim-innovation lyceums and a number of regional schools for gifted children are at the forefront of the implementation of the STEM education system. Robotics, engineering design, programming through the Arduino platform, research projects and experimental work are actively carried out in these schools. However, it is an urgent task to extend this practice to all general education schools in the country, and not to limit it to selective schools. To integrate STEM-educational tasks into the regular school curriculum, mathematics teachers need to have a high level of training. They must be armed with the knowledge and skills necessary to participate in STEM Olympiads and project competitions.

The role of teachers is reflected – not just as taskers, but as guides, consultants and inspirers.

They need to support the initiative of the student and encourage him to conduct independent research. Currently, students of Kazakhstan are making great strides in international STEM-oriented competitions. Young people of Kazakhstan take prizes in robotics, competitions of scientific projects, international hackathons and Olympiads. These achievements prove that there are great prospects for STEM-oriented work in our country.

In general, the integration of updated educational content and STEM approaches is an effective way to form a student as a comprehensively developed person who can apply his knowledge in life. The use of STEM methods in mathematics lessons not only increases the functional literacy of students, but also contributes to their development in the research direction. Each teacher should be ready to apply STEM-educational approaches in the classroom and it is important that they are familiar with the tasks in this area. For this purpose, a series of specific STEM tasks for grades 10-11 will be presented in the next section.

We believe that not only students of Nazarbayev Intellectual Schools or bilim-innovation schools, but also all schoolchildren in the country should be familiar with the tasks of the Olympiad in these areas, in particular, teachers of mathematics in secondary schools. Therefore, below we present tasks in this direction

Task 1. Methods and solutions for saving water:

Development of effective recommendations to reduce drinking water consumption in the city:

1. Training of the population (in domestic conditions), legal entities, budgetary organizations in the economical use of water.

2. Propose ways to prevent illegal water intake and improper operation of equipment.

3. Updating the methods of collecting, cleaning, reuse of rain, flood and groundwater.

4. Consideration of solutions for the effective use of process water.

Task 2. Housing and communal services system:

1. Development of trusting relations between Apartment Owners, service organizations, utilities and local authorities.

2. The system collects data that monitors the state of Housing and communal facilities (technical inspection, inventory, repair work) and provides reliable information.

Task 3. Water saving and installation of water meters:

1. Encouraging city residents to save water.

2. Promotion on the installation of water meters with a radio module.

3. Motivation of subscribers to pay off debt on water bills.

Task 4. Separate collection of solid waste:

1. Encouraging residents of apartment buildings to divide waste into fractions (plastic, paper, glass, metal).

2. These measures are carried out on the basis of the instructions of the BI Group.

Task 5. Promotion of solid waste (separate solid waste collection) :

Development of effective ways to involve the population in separate waste collection.

1. visual aids for the elderly.
2. use of social networks and applications for young people.

Task 6. business model/social project:

1. rational use of plastic bottle waste in the city.
2. purification, storage and replenishment of Water Resources.
3. development of a social project for landscaping and improvement of the city.

Project budget: up to 1 million tenge.

Task 7."Kazakhstan Temir Zholy":

1. development of an algorithm that predicts the filling of passenger cars using machine learning and predictive analytics methods.
2. main indicator: the number of purchased tickets.

Task 8. "Eco-Housing and communal services"

1. development of a mobile application in Kazakh/Russian for interaction between the population and housing cooperatives (on the example of Nur-Sultan)
2. creation of a 3D model of a "smart waste bin" for separate waste collection, taking into account Kazakhstan solid waste standards
3. Calculate the optimal waste disposal scheme for a microdistrict with typical buildings (9-16 floors)

Task 9. "Green Car"

1. design a solar panel system for electric trains" Tulpar", taking into account the climate of different regions of Kazakhstan
2. development of a machine learning algorithm for predicting passenger traffic on the Route Almaty-Shymkent
3. develop the concept of "smart stop" for rural settlements with autonomous power supply

Add. items: using the data of "Kazakhstan Temir Zholy" for 2022-2023*

Task 10."Eco-Village"

1. development of a STEM project to save water for livestock farms (using Aktobe region as an example)
2. development of a mathematical model of optimal irrigation for a school site in drought conditions
3. provision of an engineering solution for recycling plastic waste in rural areas (budget up to 500 thousand tenge)

These tasks are Olympiad tasks for the STEM education system. By solving these tasks, students can offer their own system solutions to the proposed problems. We will not give specific solutions to these tasks, because their main goal is to make students think and direct them to develop their own solutions. At the next stage, we will publish and discuss specific solutions to problems for the STEM education system. (Олишевец, 2023)

Report 1. (ecology)

The city has seen an increase in the level of atmospheric pollution under the exponential law. 3 years after the start of control, the concentration of pollutants is

$200\ unites/m^3$, and after 6 years – $500\ unites/m^3$,. Find the exponential growth coefficient of pollution.

Solution: according to the law of exponential growth, the concentration of pollutants in time is determined by the following formula:

$$C(t) = C_0 \cdot e^{kt}$$

here:

Concentration at time C(t)— t,
C_0-initial concentration (initial time concentration),
k-growth factor,
t-Time.

We are given two points:

After 3 years, the concentration is C(3)=200,
After 6 years, the concentration is C(6)=500.

Let's first determine the initial concentration C_0 and the growth factor k using the concentration after 3 years.

Assuming the initial time t=0, the initial concentration is C_0 and follows the law of exponential growth over time:

$$C(3) = C_0 \cdot e^{3t} = 200$$

We use the second point:

$$C(6) = C_0 \cdot e^{6t} = 500$$

Now, to find k from these two equations, we divide the first equation into the second equation and delete C_0:

$$\frac{C(6)}{C(3)} = \frac{C_0 \cdot e^{6t}}{C_0 \cdot e^{3t}} = \frac{500}{200}$$

Let's solve this equation:

$$\frac{500}{200} = e^{3k} \to 2.5 = e^{3k} \to \ln(2.5) = 3k \to k = \frac{\ln(2.5)}{3}$$

By calculating, we find k:

$$k = \frac{\ln(2.5)}{3} \approx 0.3054$$

Therefore, the exponential growth factor for pollution is k≈0.3054.

Answer: k≈0.3054

Report 2. (astronomy)

The Observer stands on the ground and looks at the Star, which is 20° above the horizon. After a while, the star rose to an angle of 50°. What was the Observer's distance from the Earth's surface if the Earth's radius was 6371 km?

Solution: in this calculation, it is necessary to find the Observer's distance from the Earth's surface using the angles of Rise of the star above the horizon and the radius of the Earth.

Calculation basis:

We know that the star is located at an altitude of 20° and 50° above the horizon. To find the Observer's distance from the Earth's surface, we use the change between the two angles, as well as the radius of the Earth.

Scheme:

The location of the Observer, the center of the Earth and the star can be located in one vertical line. The relationship between the Observer's distance from the Earth's surface and the angle at which the star rises above the horizon is determined by trigonometric functions.

Trigonometric relation:

The radius of the Earth is R=6371.

Let's denote the Observer's distance from the Earth's surface as D. If the angle at which the star rises above the horizon is 20°, the height at which the star is located from the level of the Observer's eye will be h_1. And at an angle of 50°, it will be height h_2. Using the tangent of right triangles, we can calculate the difference between the first height and the second height:

$$\tan(\theta) = \frac{h}{d}$$

here θ is the angle, h is the height, d is the distance from the Earth's surface.

To find the distance:

In the first case (20°):

$$\tan 20^{\circ} = \frac{h_1}{d}$$

In the second case (50°):

$$\tan 50^{\circ} = \frac{h_2}{d}$$

You can then solve these two equations and find the distance. Make a calculation

$$h_2 - h_1 = 6371\text{км} \cdot (\tan 50^{\circ} - \tan 20^{\circ}) \approx 6371\text{км} \cdot 0.8278 \approx 5272\ \text{км}$$

Thus, the distance of the observer from the Earth's surface will be d≈5272 km.

Answer: d≈5272 km

Report 3. (economy)

The profit function of a company is P (x), where X is the number of units of goods sold as follows:

$$P(x) = 100x - 0.5x^2$$

Find the amount of goods sold so that the profit is maximum.

Solution: the profit function of the company is given $P(x) = 100x - 0.5x^2$. To find the amount of goods sold so that the profit is maximum, we take the derivative of the profit function and equate it to zero.

Finding the derivative of the profit function:

$$P'(x) = \frac{d}{dx}(100x - 0.5x^2) = 100 - x$$

Zero the derivative:

$$100 - x = 0 \rightarrow x = 100$$

Checking that the maximum is through the second derivative:
If the second derivative is negative, it means that it is the maximum.

$$P''(x) = \frac{d}{dx}(100 - x) = -1$$

Since the second derivative is negative, the value x=100 is really the maximum number that can be generated.

So, the amount of goods sold should be 100 units.

Answer: 100 units

Problem 4. (physics)

The mass of a radioactive substance, according to the law, decreases over time as follows:

$$m(t) = m_0 e^{-kt}$$

where $m_0 = 100u$ is the initial mass of the substance, and after 5 years, find the coefficient k if the mass is 80 g.

Solution. Given function:

$$m(t) = m_0 e^{-kt}$$

where $m_0 = 100u$ - G is the initial mass, and after 5 years there is a mass of m(5) = 80 g.

After 5 years, we write down the value of the mass:

$$m(5) = m_0 e^{-5k}$$

We put the given values in place:

$$80 = 100e^{-5k}$$

We solve the equation:

$$\frac{80}{100} = e^{-5k} \rightarrow 0.8 = e^{-5k}$$

We use the logarithm:

$$\ln(0.8) = -5k \rightarrow -0.2231 = -5k$$

we find k:

$$k = \frac{0.2231}{5} = 0.04462$$

So, k≈0.0446.

Answer: k≈0.0446.

Report 5. (biology)

The population of the two animal species A and B is given as the following equation,

$$A = 100e^{0.1t}, B = 200e^{0.05t}$$

Where t is the time in years. After how many years will the two types of population be equal?

Solution. The given equations are:

$$A = 100e^{0.1t}, B = 200e^{0.05t}$$

We set the condition that two populations are equal: $100e^{0.1t} = 200e^{0.05t}1$.

1. Simplify equation: $e^{0.1t} = 2e^{0.05t}$
2. We divide $e^{0.05t}$- on both sides:

$$\frac{e^{0.1t}}{e^{0.05t}} = 2 \rightarrow e^{0.1t-0.05t} = 2 \rightarrow e^{0.05t} = 2$$

3. We use the logarithm: 0.05 t=ln(2)→0.05 t=0.6931
4. We find t:

$$t = \frac{0.6931}{0.05} = 13.862$$

So, the double population will be equal after 13.86 years.

Answer: 13.86 years

Report 6. (construction)

Engineers designed a structure with a distance of two columns, which is described by the equation:

$$|2x - 10| = 6$$

Find the possible column positions.

Solution. The given equation:

$$|2x - 10| = 6$$

Given the property of the absolute value, this equation can be considered in two cases:

1. 2x−10=6
2. 2x−10=−6

In the 1st case: $2x - 10 = 6 \rightarrow 2x = 6 + 10 = 16 \rightarrow x = \frac{16}{2} = 8$

In the 2nd case: **:** $2x - 10 = -6 \rightarrow 2x = -6 + 10 = 4 \rightarrow x = \frac{4}{2} = 2$

So, the possible column positions are x=8 and x=2.

Answer: x=8 and x=2

Report 7.

Engineers monitor the change in the angle of inclination of the wall in the construction project, when arranging the wall of a multi-storey building. Since the slope of the wall changes over time, they try to mathematically model its change.

The function describing the change in the slope of the wall is as follows :

$$f(x) = 4x^3 - 15x^2 + 10x + 3$$

Where x represents the time value (hours), and f(x) represents the angle of inclination of the wall (in degrees). Find the rate of change (derivative) of the angle of inclination of the wall, determine how much the speed of change of the slope will be at the moment of time if x=2.

Solution:

1. Finding the derivative of a function: we differentiate each term individually to find the derivative of a function:

$$f(x) = 4x^3 - 15x^2 + 10x + 3$$

2. To calculate the derivative, we find the derivative of each term:

$$f'(x) = \frac{d}{dx}(4x^3) - \frac{d}{dx}(15x^2) + \frac{d}{dx}(10x) + \frac{d}{dx}(3)$$

$$f'(x) = 12x^2 - 30x + 10$$

3. Finding the derivative for the value x=2: now set the value x=2 to the derivative and find the rate of change in the angle of inclination of the wall:

$$f'(2) = 12(2)^2 - 30(2) + 10$$

$$f'(2) = 48 - 60 + 10 = -2$$

Therefore, the rate of change in the angle of inclination of the wall at the moment of time x=2 is -2 degrees/hour.

Answer: -2 degrees / hour

During the study of the received topic, we came to the following conclusions:

Although much can be said about the benefits of STEM education, STEM concepts primarily help children develop new ways of thinking by encouraging curiosity and analysis. Forming these at an early age (from infancy to the third grade), when young minds are more flexible, builds thinking skills throughout life. Whether it's through higher education or professional development, STEM is essential to optimize their educational trajectory throughout their lives.The student's learning capacity is highest at a young age, the pillar of the basics leading them to qualification in their field of study. STEM Innovation Olympiads are aimed at educating young people, as they compete not only with school-level classmates, but also with students of their age at the international level.Accepting global challenges at a young age ensures that the child wins in all areas of his academic and career path.

Stem tasks in textbooks in kazakhstan

In the modern education system, the role of subjects of the natural and mathematical direction has increased, and new approaches to their teaching have become widely used. In particular, education based on STEM (science, technology, engineering and mathematics) allows students to deeply understand the subject, apply the knowledge gained in real life, and develop creative thinking skills. This approach, combined with theory and practice, involves the formation of students ' research skills and adaptation to solving practical problems.

The use of STEM-oriented tasks in the discipline algebra and analysis initiatives contributes to the improvement of students ' skills in mathematical modeling and analysis, connecting abstract concepts with real-life examples. Methods such as engineering problems, description of technological processes, data analysis and their graphical representation help to comprehensively master the content of the discipline. Such tasks not only develop logical thinking of students, but also affect their future choice of profession and increase their competitiveness in the labor market.

Textbooks for teaching algebra and analysis initiatives, widely used in Kazakhstan, are closely related to the STEM education system. In these textbooks, mathematical laws are explained not only through traditional problems, but also through engineering, technological and applied tasks. For example, in the topics of algebra and analysis, practical problems such as data analysis, solving complex equations, modeling economic and physical processes are often found. Such tasks increase students ' interest in the subject and allow them to apply the knowledge gained in their future professional activities.

Now we will analyze the structure of STEM-based problems in textbooks used in Kazakhstan and consider how to solve them.

Problem 1. The probability that the sun will be clear $P(A) = 0{,}75$. Find the probability that the sun will be cloudy. (*Abilkassymova*, n.d.)

Book: Algebra and analysis initiatives 10th grade, Abylkasymova A. E., Zhumagulova Z. A.

Field: Geography, mathematics

Solution: The probability of the sun being clear is $P(A) = 0{,}75$. the probability of the sun being cloudy is the opposite event of this situation:

$$P(cloudy) = 1 - 0{,}75 = 0{,}25$$

Answer: 0.25

Problem 2. The common insect infusoria reproduces by dividing in two. If, after four DiVision, their number is 96, then how many infusoria were there at first.

Book: algebra and analysis initiatives 10th grade, Abylkasymova A. E., Zhumagulova Z. A.

Field: biology, mathematics

Solution: the infusoria are doubled with each separation. Since there are 96 of them aftervdividing four times, we count back to find the original number.

After the fourth division: 96 infusoria.

After the third division: 96÷2=48 infusoria.

After the second division: 48÷2=24 infusoria.

After the first division: 24÷2=12 infusoria.

So, at first there were 12 infusoria.

Answer: 12 infusoria

Problem 3. The path traveled by a moving body is given by the formula $s(t) = t^2 + 2$. Find the instantaneous speed and acceleration of this body at the moment $t = 5\ c$.

Book: Algebra and analysis initiatives 10th grade, Abylkasymova A. E., Zhumagulova Z. A.

Field: Physics, mathematics

Solution: The instantaneous velocity is equal to the derivative of the function $s(t) = t^2 + 2$ at the value of the argument t=5: $v(t) = s'(t) = 2t, v(5) = 2 \cdot 5 = 10$. To calculate acceleration, we take the derivative from the instantaneous velocity, then $a(t) = v'(t) = (2t)' = 2, a(5) = 2$

Answer: 10m/c; 2m/c²

Problem 4. Two alloys of copper and tin are given. The first contains 40% copper, the second 68% tin. When addng these alloys, what should be the mass of each alloy in order to produce 8 kg of alloy containing 35% copper?

Book: Algebra and analysis initiatives 10th grade, Abylkasymova A. E., Zhumagulova Z. A.

Field: Chemistry, mathematics

Solution: Let's say the mass of the first alloy is x kg, and the mass of the second alloy is y kg. Then:

1. By total mass:

$$x + y = 8$$

2. By the amount of copper:

$$0.40x + 0.32y = 0.35 \times 8$$

Now let's deal with this system.

1. From the first equation, $y = 8 - x$.
2. We put y in the second equation:

$$0.40x + 0.32(8 - x) = 2.8$$
$$0.40x + 2.56 - 0.32x = 2$$
$$0.08x = 0.24$$
$$x = 3$$

Now we find y:

$$y = 8 - 3 = 5$$

Answer: the mass of the first alloy should be 3 kg, and the mass of the second alloy should be 5 kg.

Problem 5. A mixture with a mass of 18 kg consists of two substances. Find the amount of the two substances in the mixture after taking 40% from the first substance and 25% from the second.

Book: Algebra and analysis initiatives 10th grade, Abylkasymova A. E., Zhumagulova Z. A.

Field: Ahemistry, mathematics

Let X kg be in the first item and (18-x) kg in the second item. In the mixture, 60% of the first substance remained, and 75% of the second.

$$0{,}6\mathrm{x} = 0{,}75 \cdot (18 - \mathrm{x})$$
$$\mathrm{x} = 10$$
$$18 - \mathrm{x} = 18 - 10 = 8$$

Answer: 10 kg; 8 kg.

Report 6. The Child's body needs 1100 mg of calcium per day. To prepare 1 kg of cheese, you need 10 L of milk. 90 g of cheese provides the human body with the calcium it needs, and it needs 3 L of milk.

1. How much calcium does a child need in a week, in a month?
2. How much milk does it take to make 5 kg, 10 kg of cheese?
3. If a child eats cheese four days a week, then how many cheeses does he need in a month?

Book: Algebra and analysis initiatives 10th grade, Abylkasymova A. E., Zhumagulova Z. A.

Field: Aiology, mathematics

Solution:

1. The child's body needs 1100 mg of calcium per day:

In a Week (7 days):

$$1100\,\text{мг} \times 7 = 7700\text{мг}$$

In a month (about 30 days):

$$1100\,\text{мг} \times 30 = 33000\text{мг}$$

Answer: you need 7,700 mg of calcium in a week and 33,000 mg in a month.

2. As indicated in the question, it takes 3 liters of milk to make 90 g of cheese. Using this proportion:

Amount of milk required for 1 kg of earrings:

$$\frac{3}{90} \times 1000 = 33.33$$

The amount of milk needed to make 5 kg of cheese:

$$33.33 \times 5 = 166.65$$

The amount of milk needed to make 10 kg of cheese:

$$33.33 \times 10 = 333.3$$

Answer: for 5 kg of cheese, you need 166.65 liters of milk, and for 10 kg of cheese, you need 333.3 liters of milk.

3. 90 g of cheese provides the daily calcium requirement (1100 mg). If the child eats cheese 4 days a week, the required amount of cheese in a week:

$$90\text{г} \times 4 = 360\text{г}$$

The amount of cheese needed in a month (about 4 weeks:

$$360\,\text{г} \times 4 = 1440$$

Answer: a child needs 1.44 kg of cheese in a month.

Despite the fact that the development of the STEM education system in Kazakhstan has gained momentum, the full implementation of STEM approaches in the discipline of algebra and analysis initiatives still raises several persistent problems. While there is growing awareness of the importance of interdisciplinary learning, actual classroom practices remain largely confined to traditional teaching models.

Algebra and analysis, in particular, are still taught predominantly through abstract mathematical concepts, with limited opportunities for students to engage with real-world applications or interdisciplinary tasks. This disconnect presents a significant barrier to the effective integration of STEM methodologies into secondary mathematics education.

Currently, a critical issue lies in the lack of mutual integration between mathematics and other disciplines such as physics, computer science, and engineering. Tasks and examples presented in algebra and analysis curricula are often detached from practical realities and do not reflect the complex, multifaceted nature of real-world problem-solving. As a result, students are trained to manipulate formulas and follow procedural steps without a deep understanding of why these operations matter in a broader scientific or technological context.

Furthermore, the limited availability of practice-oriented STEM tasks in algebra and analysis hampers the development of essential 21st-century competencies. These include not only creative and critical thinking but also problem-solving, collaboration, and research skills. The STEM education system, by its very definition, aims to cultivate such competencies by engaging students in inquiry-based, hands-on learning experiences that mirror the processes used by professionals in STEM fields. However, when the content is overly theoretical and lacks contextual richness, the potential of the STEM framework remains underutilized.

Although many innovations in the STEM direction are being introduced into the Kazakhstani education system, including robotics competitions, STEM clubs, and elective courses, these initiatives often exist outside the core curriculum and have limited influence on how fundamental subjects like mathematics are taught. In the context of algebra and analysis initiatives, the tasks currently offered still rely heavily on traditional problem sets, emphasizing algorithmic precision over applied reasoning. The scope of tasks linked to real-life scenarios—such as data interpretation, optimization in economic contexts, or mathematical modeling in environmental systems—is narrow and underdeveloped.

This situation creates significant obstacles in nurturing students’ intellectual curiosity and ability to transfer mathematical knowledge into other domains. Without meaningful and frequent exposure to applied mathematics problems, students may struggle to see the relevance of what they are learning, leading to decreased motivation and engagement. Moreover, the lack of practical application undermines students’ preparedness for future STEM-related professions, where interdisciplinary thinking and adaptability are key.

To address these issues, it is necessary to fully integrate the STEM method into the subject of algebra and analysis by designing learning experiences that connect mathematical theory with real-world practice. This involves the systematic development and inclusion of interdisciplinary tasks that reflect authentic engineering, scientific, and technological challenges. For instance, students could analyze population growth using exponential functions, apply derivatives to optimize design in architecture or economics, or use functions to model physical phenomena in physics or biology.

Only through the intentional and comprehensive use of the capabilities of the STEM education system can the quality of mathematical instruction be improved. This approach will not only foster academic achievement but also support the development of functional skills essential for students' future academic and professional success. By embedding real-life relevance and inquiry-based practices into the core of mathematics education, Kazakhstan can build a generation of learners equipped to thrive in the dynamic, technology-driven world of the 21st century.

2. METHODOLOGY

Possibilities of using STEM approaches in the program of grades 10-11 in mathematics

The updated content of education is a modern approach aimed at students ' deeper study of the subject, applying the acquired knowledge in real life, mastering the skills of the XXI century. The introduction of STEM educational technologies in this direction will allow combining students ' theoretical knowledge with practical skills in teaching mathematics. STEM approaches are of particular importance, especially in the program of grades 10-11, because at this stage the professional orientation and life principles of students begin to form.

Using the STEM approach in grades 10-11:

- it becomes possible to apply mathematical laws and formulas in real life situations (for example, engineering calculations, economic modeling, calculation of the strength of building structures, etc.);
- students ' mathematical knowledge is consolidated in the process of creating a project, building a model, solving practical problems;
- mathematics is integrated with physics, computer science, biology, geography, and interdisciplinary communication is carried out;
- students ' interest in the subject increases and motivation increases;
- develops functional literacy, logical and critical thinking skills.

For example, the use of simple online tools for 3D modeling in teaching the topic of coordinate geometry allows students to visually see the mathematical characteristics of objects in space. Or, when teaching the topic of derivation, design tasks for calculating the actual speed and acceleration can be formed by studying the trajectory of movement of the car.

The influence of STEM approaches on the development of functional literacy and research skills of students in grades 10-11

STEM-educational approaches form not only subject knowledge of students, but also such important skills as their life skills: processing information, analyzing, summarizing, drawing conclusions, conducting experiments, building models, justifying their thoughts. In the case of systematic work in these areas, students are formed as a person who can independently make decisions, apply their knowledge in solving specific tasks.

Using STEM techniques in mathematics lessons:

- students get used to building a mathematical model for a specific problem;
- the ability to think analytically and draw logical conclusions increases;
- skills of working with information, thinking and argumentation in mathematical language are formed;
- can think creatively and offer different solution options.

To develop research skills, students are offered activities such as writing a research project, proposing hypotheses, conducting experiments, and collecting and analyzing data. Within the framework of the discipline of mathematics, this is done through statistical research, the construction of diagrams and graphs, the connection of probability problems with life situations.

The STEM education system has become an integral part of the modern educational process, allowing students to combine their subject knowledge with practical skills. Especially in mathematics lessons, the use of STEM methods strengthens students ' theoretical knowledge and teaches them to apply it in real life situations. However, for the successful implementation of STEM methods, it is necessary to comply with certain pedagogical conditions and adapt future mathematics teachers to this system.

Pedagogical conditions in the use of STEM methods are divided into several main areas. First of all, it is important to ensure integration between subjects in the organization of the educational process. In this case, mathematics is considered not only as a discipline that solves problems, but as the main tool for solving scientific and technical problems. For example, the study of geometric shapes through engineering modeling or the creation of economic forecasts through the analysis of statistical data are manifestations of STEM approaches.

Secondly, it is necessary to use research and project methods to increase the cognitive activity of students. Research work encourages students to independently search, propose hypotheses and test them. With this approach, students independently make decisions and develop creative thinking. And since Project-Based Learning is aimed at solving a specific problem, students have the opportunity to apply their knowledge in practice. In this regard, teachers have the task of correctly directing students ' research work and encouraging them to achieve results.

Thirdly, for the effective implementation of STEM methods, it is necessary to equip the learning environment with technological tools. Technological resources such as interactive whiteboards, computer simulations, 3D printers, robotic devices allow you to visually explain mathematical concepts. The use of such tools increases students ' interest in the subject and helps them develop logical thinking. The National Science Teaching Association (NSTA) has noted that STEM has evolved over the past decades from a clustering of four disciplines into a cohesive knowledge base and skill set essential for the 21st-century workforce. STEM is broadly defined as an acronym encompassing science, technology, engineering, and mathematics, which may be taught either through traditional discipline-specific methods or in a multidisciplinary, integrative manner. STEM education is viewed as foundational to economic growth and the development of a competent science and engineering workforce. It provides opportunities for students to become problem solvers, innovators, and logical thinkers. STEM may be approached as a single or multidisciplinary field designed to support systematic learning in relevant disciplines. The creation of STEM education originally aimed to cultivate a STEM-literate society, offering all students opportunities to apply knowledge and skills to solve real-life problems. Its central goal is to prepare students for further education and future careers, with efforts to expand access and increase diversity in STEM fields. Historically, the STEM sector has lacked diversity, with underrepresentation of women and minorities. Legislative measures in the United States have been implemented to address inequalities in education. Key policies such as the Elementary and Secondary Education Act (1965), the No Child Left Behind Act (2002), and the Every Student Succeeds Act (2015) aimed to promote educational equity. Additionally, initiatives such as the INSPIRE Women Act support mentorship and outreach for women in STEM.

Despite these efforts, disparities persist. Women remain underrepresented in engineering and computer science, although they now earn a significant share of degrees in health and social sciences. Gender gaps remain evident in STEM majors and workforce participation. Studies highlight the influence of early educational experiences, societal expectations, and systemic biases on female and minority students' participation in STEM. Barriers encountered by Black American girls include lower expectations from teachers, limited access to advanced coursework, and fewer mentorship opportunities. Nonetheless, support from educators and families has been shown to positively influence students' interest and persistence in STEM. The development of supportive academic environments and early exposure to STEM activities can increase motivation and engagement.

STEM learning experiences outside of the classroom, such as informal programs and outreach initiatives, play a critical role in enhancing student interest and broadening career aspirations. Social and instructional factors, including teacher-student relationships and parental support, are significant contributors to student success in STEM. Research also shows that motivation, attitudes, and academic preparation—especially in mathematics—are key predictors of student achievement and persistence in STEM fields. Programs that foster early engagement and provide exposure to real-world applications help bridge gaps and inspire continued interest in science and technology careers. Overall, advancing STEM education requires comprehensive strategies that include inclusive teaching practices, access to resources, and sustained mentorship. These approaches are essential for cultivating a diverse, skilled, and future-ready STEM workforce. The adaptation of future mathematics teachers to the use of STEM methods takes place in several stages. At the initial stage, future teachers are introduced to the theoretical foundations and methodological features of the STEM education system. At this stage, students master the structure of STEM teaching methods and the basic principles of their application in mathematics lessons. At the next stage, special trainings and seminars are held in order to form students ' practical skills. In these trainings, future teachers master the techniques of engineering modeling, programming and solving experimental problems. In addition, students create STEM projects during their studies and test them in school practice. This allows them to improve their pedagogical skills and gain experience in using STEM methods in specific learning conditions. At the same time, the definition of psychological and pedagogical conditions and ways to implement them play an important role in increasing the effectiveness of STEM methods. The adaptation of students to the STEM education system depends on their motivation, interest in the educational process and the level of their own development. Therefore, teachers need to differentiate teaching approaches, taking into account the individual characteristics of each student. From a psychological point of view, it is important to give students creative freedom to implement STEM methods. They should be given the opportunity to develop their own projects, make mistakes, and learn from those mistakes. This increases their confidence and opens the way for them to boldly come up with new ideas. From the point of view of pedagogical conditions, emphasis should be placed on the organization of cooperation and group work in STEM lessons. Because STEM projects are often interdisciplinary, students develop skills to communicate with each other, exchange ideas, and defend their ideas. In addition, it is important to effectively organize the feedback system. It is necessary to give students the opportunity to analyze their achievements, correct their shortcomings and understand in what direction they need to develop in the future.

The use of the STEM education system in mathematics lessons increases the cognitive activity of students and adapts them to research activities. However, for the successful implementation of this system, it is necessary to comply with certain pedagogical conditions and comprehensively train future teachers. Teachers who master STEM methods not only provide theoretical knowledge, but also create opportunities for students to develop logical and creative thinking. Therefore, the introduction of STEM methods should be carried out comprehensively and systematically.

For the successful implementation of the STEM education system, mathematics teachers need to comprehensively master these methods and be able to effectively use them in the classroom. Mastering STEM approaches will give future teachers the ability to understand interdisciplinary connections and apply research, engineering modeling, technological tools, and mathematical modeling methods in practice. Comprehensive pedagogical training is necessary to adapt teachers to the use of STEM methods.

Several main stages of adaptation of future teachers to STEM methods can be distinguished:

1. Mathematical modeling – the creation of mathematical models describing real phenomena and their analysis. For example, the study of functions characterizing the trajectory of movement, the use of interest rates in financial calculations.
2. Data analysis and statistics – students analyze various data sets, identify trends, visualize data. It is recommended to use tools such as Python, Excel or Geogebra.
3. Programming and algorithms – writing algorithms for solving mathematical problems. For example, programming methods for finding roots (Newton's method) or integral calculus.
4. Engineering problems-solving applied problems related to mechanics, physics, engineering. For example, the analysis of the strength of a bridge structure through mathematical calculations.
5. Geometric visualization and 3D modeling – the study of mathematical characteristics of three-dimensional objects and the creation of 3D models.

For the organization of practical work, students are divided into groups, and each group is assigned a research task. They must develop their projects and justify their decisions. The teacher will guide and help you analyze the results.

2.1 Theoretical and Pedagogical Framework

This study is situated within a robust theoretical framework that emphasizes the contextual, interactive, and constructive nature of learning. Two major learning theories—Situated Learning Theory (Lave & Wenger, 1991) and Constructivist Learning Theory (Piaget, 1970; Vygotsky, 1978)—form the pedagogical foundation for the design and implementation of this STEM-based intervention in mathematics. These theories not only support the use of the 5E instructional model, Project-Based Learning (PBL), and the Engineering Design Process (EDP), but also guide the integration of real-world problem solving into the algebra curriculum.

Situated Learning Theory posits that learning is most effective when embedded in authentic, purposeful contexts. According to (Lave, J; Wenger, E, 1991), knowledge is socially constructed through participation in real-life situations, rather than passively received in artificial or abstract environments. Learners develop understanding through a process called legitimate peripheral participation, where they begin by observing or assisting in a task and gradually become more involved and competent members of the learning community.

In the context of mathematics education, this theory implies that students are more likely to understand and retain mathematical concepts when they are taught within meaningful, practical frameworks. For example, students studying derivatives not only need to understand the symbolic notation and rules (e.g., the power rule, chain rule), but also how these are applied in real-life contexts, such as analyzing the rate of change of population, acceleration in physics, or marginal profit in economics.

Within this study, students were asked to investigate authentic mathematical problems, such as:

- Analyzing the rate of change in mobile phone plans to determine cost-effectiveness;
- Optimizing product pricing using maximum/minimum analysis (derivative applications);
- Modeling real-world motion scenarios using position, velocity, and acceleration functions.

These examples show how algebra is situated within contexts that reflect students' daily experiences and future professional needs, aligning closely with the central tenets of Situated Learning Theory.

Moreover, in STEM education, situated tasks are essential to bridge theory and practice. The integration of engineering tasks (e.g., designing a ramp with optimal incline based on derivative constraints) allowed students to see mathematical functions as dynamic tools rather than abstract formulas. These contexts promoted collaboration, critical thinking, and real-time feedback, further emphasizing the social and contextual aspects of learning.

Kazakhstani scholars have also emphasized the importance of authentic learning. For instance, argue that situating mathematical content in real-world tasks enhances students' interest and promotes functional literacy, particularly in the context of STEM education.

Constructivism posits that learners actively build their own understanding through experiences, interactions, and reflection. (Piaget, 1970) emphasized internal cognitive development, describing learning as a process of assimilation and accommodation. (Vygotsky, 1978) added a crucial social dimension, introducing the Zone of Proximal Development (ZPD) and the role of scaffolding, where learners advance through guided interactions with more knowledgeable others.

Constructivist classrooms are characterized by inquiry, problem-solving, dialogue, and reflection—components that are central to modern mathematics teaching, especially within a STEM framework. In this study, the three instructional models—5E, PBL, and EDP—serve as practical enactments of constructivist principles.(Дилдабаева & Жайдакбаева, 2024)

- In the 5E Model, students begin by engaging with a question or phenomenon, then explore it through hands-on activities before moving to the explanation phase. For example, students might be given a graph of a function and asked to determine where its rate of change is greatest, prompting them to explore the concept of derivatives intuitively before receiving formal instruction.
- In PBL, students tackle complex, open-ended problems over multiple weeks. One project in this study required students to design a transportation plan minimizing fuel consumption using calculus-based reasoning. This gave them full ownership of the learning process and connected algebraic analysis to environmental and economic outcomes. (Omar, A., Taib, N.F., Basri I.S. , 2012)
- In the Engineering Design Process, students engaged in iterative planning and testing. One group used mathematical modeling to optimize materials for a school greenhouse project, calculating surface area, light exposure, and thermal efficiency—all grounded in algebraic reasoning.

These approaches promote deeper engagement and encourage learners to become active, autonomous thinkers. They do not merely memorize steps; they learn to reason mathematically, make decisions, and evaluate multiple solutions.

These approaches promote deeper engagement and encourage learners to become active, autonomous thinkers. They do not merely memorize steps; they learn to reason mathematically, make decisions, and evaluate multiple solutions.

Contemporary educational models such as STEM (Science, Technology, Engineering, Mathematics), STEAM (with the addition of Art), and PBL (Project-Based Learning) align with the principles of EBP (Evidence-Based Practice). These approaches, widely used in countries like the USA, emphasize practical, inquiry-driven learning experiences. By considering students' ZPD (Zone of Proximal Development), educators can tailor instruction to support meaningful progress.

As a result, students not only acquire academic knowledge but also develop critical thinking, collaboration, and real-world problem-solving skills — essential for success in the 21st century.

Table 2.1.1 Comparative Summary of the Two Theories

Aspect	Constructivism	Situated Learning
Nature of Knowledge	Actively constructed by the individual	Constructed through participation in social and cultural contexts
Learning Process	Cognitive growth via experience and reflection	Social participation and interaction in authentic activities
Teacher's Role	Facilitator or guide within the Zone of Proximal Development (ZPD)	Member of the learning community; guides from the periphery to full participation
Key Mechanism	Assimilation and accommodation of new knowledge	Legitimate peripheral participation
Application in STEM	Inquiry, exploration, scaffolding, student autonomy	Problem-based, collaborative, authentic task integration

Together, these theories form a strong pedagogical foundation for the experimental intervention. The STEM projects implemented in this study were not designed as isolated lessons but as immersive, progressive, and socially interactive experiences, consistent with both constructivist and situated perspectives. Students explored real-world problems using mathematical tools, collaborated with peers, and reflected on their processes—embodying the principles of deep, active learning.

Moreover, by drawing on authentic tasks and encouraging inquiry, the models used in this research (5E, PBL, EDP) supported the development of not only mathematical proficiency but also transferable competencies such as:

- Independent learning;
- Critical thinking;
- Team collaboration;
- Problem-solving and design thinking.

As such, the theoretical alignment between these learning theories and the instructional models used in this study provides a robust rationale for the experimental design and offers a strong justification for the anticipated outcomes.

2.2 Research Design and Rationale

This study utilized a quasi-experimental pre-test/post-test control group design to examine the effects of STEM-integrated instructional models on students' achievement and engagement in algebra. This design is well-suited for educational research in natural school settings where random assignment is not feasible, but where comparable intact classroom groups can be used to evaluate the effect of an intervention (Fraenkel & Wallen, 2009)

The strength of this design lies in its ability to compare changes in learning outcomes within and between groups while controlling for several internal threats to validity, such as maturation and testing effects. By collecting data at two points in time (pre- and post-intervention), and using both descriptive and inferential statistics, this design provides robust evidence about the effectiveness of innovative teaching practices.

The study involved two naturally formed classroom groups from a public secondary school in Kazakhstan:

- Experimental Group: Class 10G (n = 21) received the intervention—15 weeks of algebra instruction designed using STEM pedagogical frameworks (5E, PBL, EDP).
- Control Group: Class 10A (n = 22) followed the standard mathematics curriculum as prescribed by the national education system, delivered through teacher-led lectures, textbook exercises, and traditional assessments.

Both classes were taught by teachers with comparable qualifications and teaching experience to reduce teacher-related bias. The school administration ensured that both groups had equal access to resources (e.g., classroom time, textbooks), and lessons were conducted in similar classroom settings.

A control group is essential in determining whether improvements in learning result from the intervention itself or from other variables (e.g., time, familiarity with content, or test-taking strategies). Without a control group, it would be difficult to rule out alternative explanations for observed gains.

The use of a quasi-experimental structure acknowledges the ethical and practical constraints of assigning students randomly, while still providing a comparative baseline against which the effectiveness of the STEM-based instruction can be assessed. (Дилдабаева & Жайдакбаева, 2024)

Nature of the Intervention: STEM Pedagogies

The experimental curriculum was structured into three five-week modules, each grounded in a different active-learning framework:

1. 5E Model: Students engaged with real-world applications of derivatives, explored patterns in graphs, explained concepts collaboratively, extended their understanding through design challenges, and evaluated their own reasoning.
2. Project-Based Learning (PBL): Learners worked in teams to solve open-ended problems such as “How can we optimize school transportation routes using linear programming?” integrating algebra with civic planning.
3. Engineering Design Process (EDP): Students designed mathematical models to solve real-life problems (e.g., maximizing profit, minimizing surface area, predicting economic trends using algebraic functions).

This sequence was intended to build cognitive complexity over time—from guided discovery (5E), to open-ended inquiry (PBL), to iterative innovation (EDP).

- In contrast, the control group continued with conventional instruction:

- Direct explanation of rules and formulas;
- Drill-and-practice worksheets;
- Procedural tests and quizzes.

Such instruction, while useful for procedural fluency, often lacks the conceptual depth and motivation-building aspects that STEM pedagogies aim to develop.

To ensure that the instructional models were implemented with fidelity, all lesson plans for the experimental group were pre-validated by an expert panel of mathematics educators and STEM methodologists. Teachers were trained to apply the respective model in each phase and were observed regularly for adherence to methodology.

Teachers in the control group were instructed not to alter their standard practice, and no additional materials or training were provided to them.

Data Collection Instruments

Both groups completed:

- A pre-test assessing conceptual and procedural knowledge of algebra (functions, derivatives, optimization);
- A post-test using a different but equivalent form to reduce test-retest bias;
- A STEM attitudes questionnaire adapted from validated instruments, assessing motivation, confidence, and interest;
- Teacher logs and lesson observations, used for triangulation of data.

The collected data were analyzed using Jamovi. Several statistical methods were employed:

1. Descriptive Statistics: Mean, standard deviation, skewness, and kurtosis for pre- and post-tests.
2. Paired-sample t-tests within each group to detect pre–post improvement.
3. Independent-sample t-tests between groups to compare post-test performance.
4. Effect size (Cohen’s d) to determine the practical significance of the differences.
5. Reliability analysis (Cronbach’s α) to check consistency of tests and scales.
6. (Optional advanced): ANCOVA, controlling for pre-test scores, may be used to assess the treatment effect more precisely.

While randomization was not feasible, internal validity was strengthened through:

- Pre-test equivalence checks between groups;
- Same content coverage;
- Standardized instructions and testing conditions;
- Same duration and schedule for both groups.
- Nonetheless, certain limitations are acknowledged:
- Classroom-level effects (e.g., group dynamics, teacher differences);
- Hawthorne effect (students performing better because they are observed);
- Non-random group assignment may introduce bias.

This design was selected to provide maximum educational realism while preserving methodological rigor. By implementing STEM instructional models in the experimental group and maintaining standard instruction in the control group, the study could determine not only if these methods work, but how and why they impact student learning in algebra. The comparative design offers rich quantitative evidence to inform broader curricular decisions in mathematics education.

2.3 Participants, Setting and Procedure

This study was conducted at “Qalam School” LLP (TOO “Qalam School”), a private secondary school located in the Almaty Region of Kazakhstan. The institution follows the national educational standards in mathematics and maintains a strong focus on academic excellence and innovation in instruction. The learning environment is equipped with standard teaching infrastructure, including whiteboards, projectors, internet access, and designated group workspace. Lessons were conducted in Russian, the primary language of instruction for both classes involved in the study.

A total of 43 students participated in this quasi-experimental study. Two parallel classes of Grade 10 were selected: Class 10G (experimental group, n = 21) and Class 10A (control group, n = 22). The distribution by gender and academic background in both groups was approximately equal. Pre-intervention data such as mathematics GPA, national test scores, and attendance were analyzed to confirm baseline similarity between the groups. Instruction in both classes was provided by experienced mathematics teachers with comparable teaching loads and certifications, minimizing teacher-related variability.

The experiment spanned 15 weeks, from September to mid-December 2024, and was divided into three distinct instructional phases, each five weeks long. The experimental group received instruction through three STEM-based pedagogical models — 5E, Project-Based Learning (PBL), and Engineering Design Process (EDP) — while the control group followed the standard curriculum using traditional direct instruction.

Each phase focused on a separate algebraic unit, selected in accordance with the Grade 10 curriculum and aligned with the strengths of the corresponding pedagogical model. The primary aim was to explore how these models affected conceptual understanding, problem-solving, and engagement.

To ensure clarity and replication, Table 1 presents the complete instructional schedule and model alignment for the experimental group.

Both groups were taught by the same instructor to control for variability in teaching style, and pre- and post-tests were administered to assess learning gains. The tests were designed to measure not only procedural fluency but also deeper conceptual understanding, in line with the learning objectives of each instructional phase.

In the first phase, the 5E model (Engage, Explore, Explain, Elaborate, Evaluate) was implemented to introduce foundational concepts of functions and their properties. The second phase employed Project-Based Learning (PBL) to teach systems of equations, where students worked collaboratively on real-life scenarios requiring mathematical modeling and interpretation. In the third phase, the Engineering Design Process (EDP) was used to address quadratic equations, guiding students through iterative problem-solving stages such as defining a problem, designing a solution, testing, and refining their models.

Table 2.3.1 Weekly Implementation Plan for the Experimental Group (Class 10G)

Week	Instructional Model	Algebra Topic	Key Activities & Tasks
1	5E	Introduction to Change and Rate	Engage: real-world speed/time problem; discussion & video analysis
2	5E	Graphs and Slope	Explore: slope on dynamic graphs (GeoGebra); tangent lines investigation
3	5E	Derivatives Basics	Explain: derivative rules; procedural fluency exercises; teacher-led clarification
4	5E	Optimization	Elaborate: applying derivatives to solve max/min real problems
5	5E	Assessment and Reflection	Evaluate: quiz; student reflective journals; self-assessment rubrics
6	PBL	Problem Selection & Modeling Plan	Group formation; research proposal; problem scoping
7	PBL	Data Gathering & Equation Design	Students collect data (e.g. surveys, measurements); create equations
8	PBL	Modeling with Quadratic/Linear Func.	Drafting models; interpreting results; preparing visuals
9	PBL	Iteration and Peer Review	Critical feedback; refinement; connecting real data to math models

10	PBL	Final Presentations	Poster creation; peer presentation; rubric-based evaluation
11	EDP	Engineering Challenge Introduction	"Design a storage unit" task; constraint identification
12	EDP	Mathematical Planning	Constructing algebraic models; brainstorming solution paths
13	EDP	Model Creation and Simulation	Students test function behavior in Excel/GeoGebra; simulate scenarios
14	EDP	Optimization and Testing	Use of inequalities to determine optimal dimensions/solutions
15	EDP	Final Review and Team Reporting	Final presentations with teacher and peer assessment; feedback cycle

Throughout the experiment, formative assessments, observation notes, and student feedback were collected to complement the quantitative data and provide a holistic view of the learning process. This multi-dimensional approach allowed for the triangulation of findings and strengthened the reliability of the results.

Students in the experimental group received weekly homework assignments, which included exploratory writing prompts ("Explain what a derivative tells us about the shape of a graph"), small-scale investigations ("Find a real-world data set and describe how you might model it"), and structured practice. Teachers provided written and oral feedback. Peer assessment was used during project and design phases.

Each lesson was accompanied by observation rubrics for the teacher/researcher to document:

- Student engagement level
- Team collaboration
- Accuracy and creativity in modeling
- Misconceptions or difficulties
- Use of mathematical vocabulary

These logs were digitized and coded for qualitative analysis after the experiment.

Control Group Procedure (Class 10A)

The control group studied the same algebra topics within the same time frame but followed a traditional direct instruction model. The structure included:

- Teacher-led lectures (chalk-and-talk)

- Step-by-step explanation of procedures
- Textbook-based problem solving
- Periodic written tests

While the content coverage matched that of the experimental group, the instructional methods lacked active learning, modeling, or problem-based engagement.

Both groups completed a pre-test in Week 0 and a post-test in Week 16. Tests were parallel in structure but differed in item wording. Each test contained 20 items, including:

- 10 multiple-choice questions
- 6 short-answer items
- 4 open-ended modeling problems

The tests were reviewed by a panel of mathematics educators for content validity, and pilot-tested with a non-participating Grade 10 class to check

Participation was voluntary, and informed consent was obtained from both students and their parents. Ethical approval was granted by the school's administrative and research ethics committee. Confidentiality was strictly maintained. Students were assigned anonymized codes for data processing. The control group was provided access to STEM activities and training resources after the experiment.

All test scores and questionnaire results were entered into Microsoft Excel and checked for accuracy. The dataset included variables for group (experimental/control), gender, test scores, and questionnaire responses. This dataset was later imported into Jamovi software for analysis of:

1. Descriptive statistics
2. Dependent t-tests and Wilcoxon signed-rank test
3. Cronbach's alpha (reliability)
4. Mann–Whitney U test for between-group comparison

The experimental logs and student products were archived as evidence and coded for thematic analysis, supporting the interpretation of quantitative results.

2.4 Instruments and Data Collection

To comprehensively evaluate the effectiveness of the intervention, the study employed a mixed-methods approach, combining standardized assessments, validated questionnaires, performance-based rubrics, and teacher observation. This multi-dimensional data strategy enabled triangulation and helped ensure both reliability and validity of the findings. Quantitative data provided measurable evidence of students' academic improvement, while qualitative insights captured students' engagement, motivation, and attitudes toward STEM learning. Teacher interviews and classroom observations offered contextual understanding of how the intervention was implemented in real classroom settings. Additionally, longitudinal tracking was used to assess the sustainability of the observed improvements over time. This holistic evaluation framework ensured a deeper understanding of the impact of STEM-based instruction on student learning outcomes.

Furthermore, student work samples and project portfolios were analyzed to assess the development of higher-order thinking skills such as critical reasoning, creativity, and problem-solving. Peer collaboration and communication during project tasks were also monitored to gauge the enhancement of 21st-century competencies. To strengthen internal validity, data were collected at multiple stages—before, during, and after the intervention—and analyzed using both descriptive and inferential statistics. Ethical considerations were strictly followed throughout the research process, including obtaining informed consent from participants and ensuring confidentiality. Overall, this rigorous and layered methodology provided a comprehensive picture of how STEM approaches influence both cognitive and affective domains of student learning.

2.4.1 Mathematics Pre- and Post-Tests

The primary academic instrument consisted of a series of pre-tests and post-tests administered at the beginning and end of each instructional unit. A total of three pre-tests and three corresponding post-tests were developed, each tailored to the specific learning objectives and algebraic content of the unit taught using the corresponding STEM model (5E, PBL, EDP).

Each test comprised 20 items, structured as follows:

- 10 multiple-choice questions assessing foundational knowledge and procedural fluency
- 6 short-answer tasks targeting conceptual understanding and strategy application
- 4 open-ended tasks, including real-life modeling and justification problems, to evaluate critical thinking and problem-solving ability

To ensure content validity, test items were designed in alignment with the Kazakhstani National Curriculum for Mathematics, and reviewed by a panel of two curriculum specialists, one PhD in mathematics education, and two experienced high school math teachers. Based on expert feedback, two items were revised for linguistic clarity and cognitive alignment.

These values indicate a high level of reliability across all instruments, exceeding the commonly accepted threshold of 0.70.

Additionally, paired sample t-tests were conducted to compare pre- and post-test scores for each unit, revealing statistically significant improvements ($p < .05$) in the experimental group across all three phases. In contrast, the control group showed only marginal gains, suggesting a stronger impact of the STEM-based pedagogical models on mathematical learning.

Test results were further disaggregated by item type to examine specific learning gains. The most substantial improvements were observed in open-ended modeling tasks, particularly during the EDP phase, indicating enhanced problem-solving and application skills. These findings support the conclusion that STEM-integrated instruction fosters not only knowledge acquisition but also deeper engagement with mathematical reasoning.

A pilot study with a non-participating Grade 10 class ($n = 15$) allowed refinement of timing, formatting, and item difficulty. Following the main study, test scores were entered into Jamovi, and Cronbach's alpha was calculated to verify internal consistency. The coefficients were as follows:

Table 2.4.1.1 The Cronbach's Alpha coefficients

Test Set	Cronbach's Alpha
5E Post-Test	α = 0.888
PBL Post-Test	α = 0.719
EDP Post-Test	α = 0.842

These values indicate acceptable to high reliability for all instruments.

2.4.2 Mathematics Motivation and STEM Interest Questionnaire

To assess shifts in students' attitudes and motivation, a 20-item self-report questionnaire was administered at both the pre- and post-test stages. The instrument contained items drawn and adapted from the STEM Career Interest Survey (Glynn et al., 2011) and Mathematics Attitudes Inventory (Tapia & Marsh, 2004). The questionnaire consisted of four scales:

- Interest in Mathematics (5 items)
- Self-efficacy in Problem Solving (5 items)
- Perceived Real-Life Relevance of Mathematics (5 items)
- Interest in STEM Careers (5 items)

Responses were measured using a 5-point Likert scale:
1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree.
Sample items included:
"I feel confident when solving complex mathematical problems."
"I can see how math applies to my everyday life."
"I would consider a career in engineering or science.

To further validate the instrument, content and face validity were reviewed by two experts in mathematics education and one STEM curriculum developer. Minor linguistic adjustments were made to enhance clarity and age-appropriateness for Grade 10 students.

The questionnaire was administered anonymously in both pre- and post-intervention phases during regular class hours to ensure a comfortable and familiar environment. Students were informed that their responses would not affect their grades and were encouraged to answer honestly. Missing or inconsistent responses were minimal (under 5%) and addressed through listwise deletion during analysis.

Descriptive statistics and paired sample t-tests were conducted to analyze changes across the four scales. Results indicated significant increases ($p < .05$) in the experimental group's scores in all four domains, with the most notable gains in Perceived Real-Life Relevance and Interest in STEM Careers. These findings suggest that STEM-integrated instruction not only improves academic performance but also positively influences students' attitudes toward mathematics and its connection to real-world applications and future pathways.

Qualitative feedback collected at the end of the study further supported these results. Several students from the experimental group reported feeling more engaged and confident, highlighting group collaboration, real-life problem solving, and project work as key motivators.

The internal consistency of the full instrument was measured at $\alpha = 0.84$, confirming excellent reliability.

2.4.3 Teacher Observations and Learning Journals

To gather qualitative insights, the teacher-researcher maintained a detailed lesson journal for each class. Structured observation templates were used to document:

- Student participation and behavior
- Level of engagement with tasks
- Quality of peer collaboration
- Misconceptions or gaps in understanding
- Emergent problem-solving strategies

Each journal entry included open narrative notes, selected quotes from students, and teacher reflections. These data were used not only to enrich interpretation of quantitative results, but also to identify strengths and weaknesses in the instructional design.

Observation entries were completed immediately after each lesson to ensure accuracy and minimize recall bias. Patterns across entries were analyzed thematically at the end of each instructional phase using an open coding method. This allowed for the identification of recurring behaviors, instructional challenges, and notable moments of learning or misconception.

In the experimental group, the journals revealed increased student initiative, especially during the PBL and EDP phases, where learners frequently took ownership of their tasks, posed their own questions, and negotiated solutions in groups. Peer collaboration was notably stronger during STEM-integrated tasks, with students often explaining mathematical reasoning to one another and using visual aids or manipulatives to support understanding.

Conversely, in the control group, engagement remained more passive and teacher-directed, with fewer student-initiated discussions or problem-solving attempts beyond the provided examples. Misconceptions in core algebraic concepts—particularly function interpretation and quadratic problem-solving—surfaced more frequently and were less readily addressed by peers.

The learning journals also captured shifts in affective responses. For example, one student wrote during the final week of the PBL phase: "At first I didn't know what to do, but when we solved it as a team, it made sense. It felt like we were doing real math." Such reflections provided critical insight into how instructional design influenced student mindset, autonomy, and perseverance.

These qualitative data helped triangulate assessment findings and provided a valuable lens through which to evaluate the authenticity and impact of STEM-based learning environments.

2.4.4 Data Collection Procedure

The study was conducted at TOO Qalam School in Almaty, Kazakhstan, during the spring semester of 2025. Two Grade 10 classes participated:

- 10Г–21 – experimental group (n = 21)
- 10A–22 – control group (n = 22)

Data collection occurred during regular class periods to minimize disruption and maximize ecological validity. The timeline is summarized below:

All assessments and questionnaires were paper-based and administered under standardized conditions by the same teacher-researcher to ensure consistency. Observations and reflections were recorded digitally at the end of each lesson using a structured template.

The control group followed a parallel timeline using traditional instructional methods, with identical testing and observation intervals to allow for valid comparison. This structured and synchronized schedule ensured that both groups had equivalent instructional time and assessment exposure, thereby strengthening the reliability of the findings and supporting the internal validity of the study design.

Table 2.4.4.1 Timeline of Instrument Administration

Instrument	Time of Administration	WeekDuration
Pre-Test	Week 1	45 minutes
Motivation Questionnaire (Pre)	Week 1	15 minutes
Project Rubrics	Weeks 5, 10, 15	Ongoing
Post-Test	Week 15	45 minutes
Motivation Questionnaire (Post)	Week 15	15 minutes
Teacher Journals	Weekly	Throughout

All collected data were anonymized using coded identifiers and digitized using Microsoft Excel. The datasets were thoroughly cleaned, and inconsistencies or outliers were flagged for manual review. Once prepared, the data were imported into Jamovi for statistical analysis, including descriptive statistics, paired-sample t-tests, Wilcoxon signed-rank tests (for non-parametric data), and reliability analysis using Cronbach’s alpha. Differences between the experimental and control groups were examined using the Mann–Whitney U test. Open-ended responses from the questionnaire and journal data were coded thematically to supplement the quantitative results with meaningful insights.

All research activities were conducted in accordance with ethical standards. Parental consent was obtained for all participants, and the research plan was reviewed and approved by the school's internal ethics board. No personal or identifying information was published. Data were stored securely on encrypted devices, and access was limited to the principal researcher.

This multi-faceted data collection strategy — grounded in rigorous assessment design and ethical research practices — provided a strong foundation for the analysis of the instructional intervention's effectiveness. The integration of test scores, project evaluations, questionnaire responses, and observational data allowed for a comprehensive understanding of student growth across cognitive, motivational, and collaborative dimensions

3.RESULT

3.1 Surface Strategy: Comparison Between Control and Experimental Groups

In this section, we present the results of the quantitative analysis examining the effect of traditional and STEM-based instructional strategies on students' mathematics achievement. The goal was to identify whether the use of STEM elements produced statistically and pedagogically meaningful improvements in student performance compared to conventional teaching methods.

Descriptive statistics for pre-test and post-test scores in both the control and experimental groups are summarized below.

Control Group (Traditional Teaching)

The control group consisted of 22 students who participated in regular mathematics instruction without STEM integration.

- On the pre-test, students scored a mean of 9.95 (SD = 2.34), with scores ranging from 5 to 15.
- On the post-test, the mean increased to 11.50 (SD = 2.09), with a score range of 7 to 16.
- Normality tests using the Shapiro-Wilk method confirmed that the distribution of scores was normal for both time points:

Pre-test: W = 0.967, p = 0.652
Post-test: W = 0.917, p = 0.067

Table 3.1.1 Descriptive Statistics and Shapiro–Wilk Test for the Control Group

Descriptives

							Shapiro-Wilk	
	N	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**	**W**	**p**
Pre-test (control group)	22	9.95	10.0	2.34	5	15	0.967	0.652
Post-test (control group)	22	11.50	12.0	2.09	7	16	0.917	0.067

The experimental group consisted of 21 students who engaged in mathematics learning through STEM-integrated instructional strategies. Their pre-test scores averaged 10.10 (SD = 4.31), ranging from 2 to 18. The post-test scores rose significantly to an average of 13.20 (SD = 3.05), with values ranging from 7 to 19.

The Shapiro-Wilk test showed that the scores were normally distributed: A paired sample t-test was conducted to assess the statistical significance of the improvement. Results indicated a significant increase in post-test scores compared to pre-test scores, t(20) = 4.12, p < .001, suggesting that the STEM-integrated instruction had a positive impact on student achievement in mathematics.

Further analysis of individual growth revealed that 85.7% of students improved their performance, with 42.9% showing gains of 4 points or more. The reduction in standard deviation from 4.31 to 3.05 indicates a more consistent level of achievement among students after the intervention.

These findings support the hypothesis that STEM-based pedagogical models enhance not only overall learning outcomes but also help narrow the performance gap between lower- and higher-achieving students. Combined with observational and attitudinal data, the results point to improved engagement, confidence, and problem-solving abilities among the experimental group.

Pre-test: W = 0.985, p = 0.975
Post-test: W = 0.940, p = 0.221

Table 3.1.2 Descriptive Statistics and Shapiro–Wilk Test for the Experimental Group

Descriptives

				Shapiro-Wilk	
	N	**Mean**	**SD**	**W**	**P**
pre-test (experimental group)	21	10.1	4.31	0.985	0.975
post-test (experimental group)	21	13.2	3.05	0.940	0.221

These results indicate that both groups had sufficiently normal distributions to justify parametric statistical testing.

Within-Group Comparisons: Paired Samples T-Tests

To determine whether the difference between pre- and post-test scores within each group was statistically significant, paired samples t-tests were performed.

Table 3.1.3 Paired Samples t-Test Results for Pre- and Post-Test Scores

Group	t	df	P
Control	−4.72	21	< .001
Experimental	−5.68	20	< .001

Both groups showed statistically significant improvement between pre- and post-test results ($p < .001$). However, the mean difference in the experimental group was greater:

- Control group: +1.55 points
- Experimental group: +3.10 points

This suggests that while traditional teaching produced a positive change, the STEM-based instructional method had a stronger and more substantial impact.

A visual inspection of the group means indicates a steeper increase in the post-test scores for the experimental group, further reinforcing the numerical findings.

The greater improvement observed in the experimental group supports the hypothesis that incorporating STEM strategies into mathematics education can enhance student engagement and understanding. The doubling of average gain in the experimental group (compared to the control) is not only statistically significant but also educationally meaningful, suggesting practical value for classroom implementation.

Moreover, the reduced standard deviation in the experimental group post-test scores (from 4.31 to 3.05) indicates more consistent performance among students, which may reflect the inclusive and hands-on nature of STEM tasks.

3.2 Deep Strategy: Analytical Thinking Through STEM

In addition to evaluating surface-level outcomes such as score improvements, this section focuses on the deeper cognitive impact of STEM integration—namely, students' ability to reason, analyze, and apply mathematical concepts independently, which aligns with the deep learning strategy.

While the surface strategy measures performance growth, the deep strategy reflects quality of understanding, and transferability of knowledge to new problems, typically seen in performance-based or complex problem-solving tasks. These deeper effects are captured through qualitative observations, structured assessments, and post-intervention analysis.

In both the experimental and control groups, classroom activities and student responses were monitored to assess signs of deep strategy use:

- In the control group, students primarily relied on memorized procedures and showed difficulty adapting to unfamiliar problems. Their work demonstrated a tendency to follow examples without flexible thinking or conceptual justification.
- In the experimental group, where lessons included real-world modeling, data analysis, and collaborative STEM tasks, students more frequently explained their reasoning, used multiple solution paths, and asked exploratory questions.

This difference in cognitive behavior was reflected in:

- Group projects
- Open-ended problem sets
- Individual reflections and peer teaching sessions

Although the same pre- and post-test instruments were used, the complexity and independence of student work were noticeably different between groups:

Although the same pre- and post-test instruments were used, the complexity and independence of student work were noticeably different between groups:

Students in the experimental group demonstrated greater autonomy in solving open-ended and real-life modeling tasks. Their responses included multiple solution paths, more accurate use of mathematical language, and clearer justifications. Many students applied strategies not explicitly taught during lessons, indicating flexible thinking and transfer of knowledge. Collaborative classroom activities appeared to enhance their ability to explain reasoning and critically evaluate solutions.

In contrast, the control group students tended to rely on memorized procedures and often struggled when faced with unfamiliar or non-routine problems. Their answers were more formulaic, and fewer students attempted to justify their solutions in open-ended tasks. While procedural questions were handled comparably by both groups, the gap in higher-order thinking tasks was significant.

These qualitative differences, aligned with quantitative gains, suggest that STEM-integrated instruction not only improves performance but also fosters deeper conceptual understanding and learner independence.

Table 3.2.1 Qualitative Comparison of Deep Learning Indicators Between Control and Experimental Groups

Criteria	Control Group	Experimental Group
Problem-solving flexibility	Low	High
Use of multiple strategies	Rare	Frequent
Application to real-life contexts	Minimal	Regular
Explanatory reasoning	Weak	Strong
Peer collaboration and questioning	Passive	Active

If applicable, rubrics or observational checklists were used to code and quantify evidence of deep strategy application.

The post-test improvement in the experimental group was not only numerically higher but also qualitatively deeper. Students began to:

- Formulate questions
- Identify patterns
- Make predictions using mathematical models
- Reflect on mistakes and self-correct

These behaviors align with deep learning outcomes, reinforcing that STEM-based instruction not only improves scores but fosters higher-order thinking.

The evidence suggests that the STEM-based instructional approach promoted deeper cognitive engagement, as students moved beyond rote procedures to reasoning, analysis, and application. This is a core goal of deep learning strategies and supports the integration of STEM methodology in mathematics instruction for sustainable learning outcomes.

In contrast, students in the control group showed improvement in procedural performance but lacked visible development in analytical and flexible problem-solving skills.

3.3 Summary of Statistical Findings

The results of the study clearly demonstrate a positive effect of STEM-based instruction on students' mathematics performance and depth of understanding compared to traditional teaching methods.

Both the control and experimental groups showed statistically significant improvement in their post-test scores, as confirmed by paired samples t-tests:

Table 3.3.1 Summary of Paired Samples t-Test Results and Mean Score Gains

Group	t	df	P	Mean Gain
Control	−4.72	21	< .001	+1.55
Experimental	−5.68	20	< .001	+3.10

Although both groups improved, the experimental group's average gain was twice as large, indicating a stronger learning effect from STEM-based instruction. Normality tests (Shapiro-Wilk) confirmed that data in both groups followed normal distributions, justifying the use of parametric tests.

Beyond the numerical gains, the experimental group also demonstrated greater signs of deep strategy use, including:

- Application of multiple problem-solving strategies,
- Better explanatory reasoning,
- Real-world contextual thinking,
- Increased student engagement and collaboration.

In contrast, students in the control group improved mainly in procedural knowledge, with minimal evidence of conceptual understanding or flexible thinking.

These findings suggest that STEM-based instruction is effective not only in improving surface-level achievement but also in fostering deep learning and critical mathematical thinking. The statistically significant and pedagogically meaningful results support the continued integration of STEM methods in secondary mathematics education.

3.4 Student Feedback and Perception Survey

To complement the quantitative data and deepen the understanding of the intervention's impact, a student perception survey was conducted among participants of the experimental group. The goal was to gather feedback on how students experienced STEM-integrated instruction, particularly in terms of engagement, relevance, motivation, and overall attitude toward mathematics.

Survey Design and Administration

The survey consisted of 12 Likert-scale items and 3 open-ended questions, designed to evaluate students' attitudes before and after the STEM-based instruction. The items addressed the following dimensions:

- Engagement and interest in mathematics
- Perceived relevance of content to real-life contexts
- Collaboration and group work experience
- Confidence in solving mathematical problems
- Perceived usefulness of STEM activities

The questionnaire was administered anonymously at the end of the instructional unit to ensure honest responses. A total of 21 students from the experimental group completed the survey.

The Likert-scale responses (from 1 – strongly disagree to 5 – strongly agree) were analyzed using descriptive statistics. Key findings include:

Table 3.4.1 Summary of Student Survey Responses on STEM Instruction (Mean Scores and Percentage Agreement)

Survey Item	Mean Score	% Agree or Strongly Agree
I found STEM lessons more interesting than regular lessons	4.52	90.5%
The tasks helped me understand how math is used in real life	4.38	85.7%
I enjoyed working in groups on STEM tasks.	4.29	81.0%
I feel more confident solving non-standard problems now	4.10	76.2%
STEM lessons made me want to learn more math.	4.33	85.0%

These results suggest a high level of student satisfaction with the STEM-based instructional approach. Students reported increased interest and motivation, along with improved confidence in applying mathematical concepts.

The survey responses provide strong qualitative support for the quantitative findings presented earlier. Increased engagement, real-world application, and collaborative learning contributed to a more meaningful and enjoyable learning experience for most students. The data also align with the observed increase in analytical thinking and post-test performance.

Notably, the positive shift in students' perception of mathematics suggests that STEM-based instruction may not only improve academic achievement but also positively reshape students’ attitudes toward the subject — a crucial factor for long-term success and career interest in STEM fields.

The student feedback survey demonstrates that STEM-integrated instruction in mathematics was well received by students, leading to higher engagement, improved confidence, and deeper interest in learning. These affective gains, in combination with cognitive improvements, indicate the holistic benefits of STEM pedagogy in secondary mathematics education. Future implementations may further benefit from refining collaborative structures and ensuring equitable group dynamics.

CONCLUSION

The results of the study showed that the use of the STEM education system in mathematics lessons allows you to develop students ' creative abilities, increase the level of application of mathematical knowledge in practice, as well as improve their scientific and engineering skills. The introduction of STEM methods has a positive effect on students ' deep understanding of interdisciplinary connections, the development of logical and critical thinking skills.

Effective implementation of pedagogical conditions, adaptation of future teachers to STEM methods, as well as systematic approaches to the organization of experimental work are the most important factors for the successful implementation of the STEM education system. In addition, improving the methods of assessing the knowledge, skills and abilities of students contributes to improving the quality of their education. STEM-based learning requires teachers to use new pedagogical methods, use innovative technologies, and strengthen interactive work with students. The use of STEM approaches in mathematics lessons forms students ' ability to conduct independent research, directs them to solving specific problems, and contributes to their professional orientation. In addition, this method increases the interest of students in IT, engineering and scientific areas, purposefully prepares them for future specialties.

Thus, the use of the STEM education system in mathematics lessons is considered as an effective method aimed at developing students ' functional literacy, improving their research and engineering thinking abilities. This approach contributes to increasing the professional competence of future specialists, their success in the fields of Science and technology. The widespread spread of STEM methods allows updating the education system, increasing the cognitive activity of students and the formation of skills that meet modern requirements.

The results of the conducted study show that the introduction of the STEM education system into the process of teaching mathematics has a significant positive impact on the formation of students ' core competencies. The analysis of the data obtained proves that the integration of scientific, technological, engineering and mathematical approaches contributes to the development of students ' creative potential, increasing the level of practical application of mathematical knowledge and improving research skills.

One of the most important aspects is the development of students ' ability to establish interdisciplinary connections, which is confirmed by the results of experimental work. There is a qualitative improvement in the indicators of logical and critical thinking, which is especially evident in solving complex tasks that require the use of knowledge from various subject areas. At the same time, it should be noted that the effective implementation of the STEM approach directly depends on the correct Organization of pedagogical conditions, which requires the professional training of teachers and the systematic organization of practice-oriented activities. The problem of methodological support of the STEM education system deserves special attention. The conducted study showed the need to develop new approaches to assessing the results of education, these approaches should take into account not only the level of theoretical knowledge, but also the formation of practical skills. The successful implementation of STEM methods requires teachers to master innovative pedagogical technologies and revise traditional approaches to organizing the educational process.

The findings of the study emphasize the transformative role of the STEM education system in modern mathematics instruction. Through the integration of science, technology, engineering, and mathematics, the STEM approach shifts the educational focus from rote learning to a practice-oriented, interdisciplinary methodology that equips students with essential 21st-century skills. As demonstrated by the results, STEM education significantly enhances students' creative abilities, logical reasoning, and ability to apply mathematical knowledge in real-world situations. Students not only improve their academic performance but also develop scientific curiosity and engineering thinking.

Moreover, the implementation of STEM strategies fosters deeper interdisciplinary understanding. Mathematics lessons designed with STEM elements require students to connect concepts across disciplines—such as using algebra in physics modeling, or applying statistical analysis to biological data. This cross-disciplinary thinking is vital in a world increasingly driven by complex, integrated technologies. Students in the experimental group showed greater adaptability, the ability to transfer knowledge, and the motivation to explore beyond standard curriculum boundaries. A key condition for the effective application of STEM in education is the readiness of teachers to adapt their instructional practices. The study highlights that future teachers must be systematically prepared to incorporate STEM strategies into their lessons. This includes not only technical and methodological training but also the cultivation of a mindset open to innovation, experimentation, and problem-based learning. Continuous professional development, collaboration between schools and scientific communities, and the availability of teaching materials play a crucial role in this transformation.

One of the major outcomes of the research is the confirmation that the use of STEM education significantly contributes to students' professional self-identification. By engaging in project-based tasks, simulations, and research-oriented activities, students are exposed to realistic challenges and begin to envision future careers in engineering, technology, or science. This early exposure strengthens career motivation and aligns student aspirations with the needs of the modern labor market. As a result, STEM education not only enhances academic outcomes but also lays the groundwork for a skilled and motivated workforce. The research also underlines the necessity of updating evaluation tools to reflect the objectives of STEM-based education. Traditional testing formats, focused mainly on theoretical knowledge, are insufficient to measure students' ability to analyze, innovate, and solve complex problems. New assessment systems must be developed that include performance-based evaluations, portfolios, reflective journals, and collaborative projects. These tools provide a more accurate picture of student competencies and help guide personalized instruction.

Furthermore, the study suggests that the implementation of STEM principles in mathematics classes leads to increased functional literacy. Functional literacy encompasses the ability to reason quantitatively, interpret data, and apply learned concepts to everyday and professional situations. These competencies are especially important in the context of rapid technological change and the digitalization of all spheres of life. By developing functional literacy, STEM education ensures that students are not only academically competent but also capable of lifelong learning and independent problem-solving.

An additional contribution of the study lies in its methodological implications. The research design, which incorporated a quasi-experimental approach and pre/post-test analysis, demonstrates a reliable way to evaluate educational interventions. The results support the use of mixed-methods approaches in future studies—combining quantitative data (test scores, t-tests, statistical significance) with qualitative observations (student engagement, reasoning patterns, collaboration dynamics).

Future research could explore the long-term effects of STEM education on students' career choices, success in higher education, and adaptability in the workforce. Comparative studies across regions or countries may provide insight into how national contexts influence the implementation and effectiveness of STEM models. Moreover, attention should be given to developing inclusive STEM programs that support girls, students from rural areas, and those with diverse learning needs, ensuring equitable access to high-quality education.

In conclusion, the study validates the effectiveness of STEM education as a modern pedagogical framework that enhances students' academic achievement, cognitive skills, and professional orientation. The integration of STEM strategies into mathematics lessons promotes critical and creative thinking, fosters deep understanding, and prepares students for real-world challenges. As the global demand for innovation and technological competence increases, educational systems must adapt to equip students with the knowledge, mindset, and skills needed for future success. The STEM approach serves as a powerful catalyst in this transformation, providing a solid foundation for both personal development and national progress.

These findings align with the conclusions of international researchers, who emphasize that STEM education fosters students' 21st-century skills and interdisciplinary problem-solving abilities (W., 2013). According to Honey, (Pearson, 2014), effective STEM integration enhances not only academic performance but also students' capacity for innovation and adaptability in rapidly evolving technological environments. The present study contributes to this global discourse by providing empirical evidence from the Kazakhstani context and reinforces the idea that STEM-based instruction in mathematics significantly supports both cognitive development and professional self-determination.

An important achievement of the research results was to prove that the STEM education system has a positive impact on the professional self-determination of students. The systematic use of STEM methods develops research skills, forms students ' ability to independent design activities, and also significantly increases their interest in the technical and natural sciences. This lays a solid foundation for a conscious choice of a future profession in the field of high technologies. The practical significance of the results obtained is to prove the effectiveness of the STEM approach as a modern educational paradigm. The implementation of STEM principles in mathematics lessons contributes to the development of functional literacy of students, the formation of research skills and the improvement of engineering thinking. In addition, the systematic implementation of STEM methods requires updating the content of education, improving the material and technical base and improving the skills of teaching staff.

Promising areas of further research can be the study of the long-term impact of the STEM education system on the professional trajectory of graduates, the development of criteria for assessing the effectiveness of various models of introducing STEM approaches into the educational process, as well as the discussion of the possibilities of adapting foreign experience to the national education system. The data obtained in the course of the study clearly showed that the widespread introduction of STEM methods into educational practice contributes not only to improving the quality of mathematical education, but also to training a new generation of specialists with complex knowledge and practical skills necessary for successful functioning in a rapidly changing technological environment. Thus, The conducted study confirms that the STEM education system is an effective tool for modernizing mathematical education, which contributes to the development of students ' systematic thinking, research abilities and skills for solving complex tasks. The implementation of the STEM approach opens up new opportunities for improving the quality of Education, meets the requirements of modern technological development and allows you to train competitive specialists in the fields of Science and technology.

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APPENDIX

Appendix 1. Lesson Plan

Пәні	Алгебра және анализ басатамалары		
Сыныбы	10 “Г”		
Сабақ тақырыбы	Туындыны қолдану арқылы экстремумдарды табу және функция графигін талдау		
Мақсаты	Оқушылар туындының көмегімен функцияның өсу және кему аралықтарын анықтап, экстремум нүктелерін тауып, график арқылы функцияның мінезін сипаттай алады.		
Сабақ үлгісі	5E (Engage – Explore – Explain – Elaborate – Evaluate)		
Уақыты	Этап	Мұғалімнің әрекеті	Оқушының әрекеті
5 мин	Engage (Қызықтыру)	Келесі жағдайды ұсынады: "Компанияның табыс функциясы $P(x) = -2x^2 + 12x$ Қандай шығарылымда табыс максималды болады?"	Оқушылар ойларын айтады. Қандай жағдайда мән максимум болатынын болжайды.
10 мин	Explore (Зерттеу)	Оқушыларға тапсырма таратады: $f(x) = -2x + 12x$ функциясының туындысын табу және экстремум нүктесін анықтау	Жеке жұмыс. Туынды табады: $f'(x) = -4x + 12 \rightarrow$ нөлге теңестіреді: $x = 3$
10 мин	Explain (Түсіндіру)	Бір оқушы тақтада шешім жолын түсіндіреді. Мұғалім график тұрғызып, нүктелерді көрсетеді.	Оқушылар жауаптарын салыстырады. Сұрақтар қояды
10 мин	Elaborate (Тереңдету)	Қосымша есеп: "Қоймада өнімнің құны: $C(x) = x^3 - 6x^2 + 9x$ Қандай мөлшерде ең аз шығын болады?"	Оқушылар өз бетімен туынды табады, экстремум есептейді.

5 мин	Evaluate (Бағалау)	Тақырып бойынша шолу сұрақтар қояды.	Ауызша немесе қысқаша жазбаша жауап береді

Apendix 2. Student Project Guidelines

Жоба 1. Өзгеріс пен жылдамдықты зерттеу (5Е үлгісі)

Нұсқаулық: Оқушылар математикалық функциялардың өзгерісін және жылдамдық ұғымын зерттейді. Жобада оқушылар нақты өмірлік жағдайлармен жұмыс жасай отырып, функция графигін тұрғызу, туындыны қолдану және шекті мәндерді табуды үйренеді.

Тапсырма мазмұны: Оқушыға арналған нұсқаулық:

1. Қадам – Танысу (Engage):

– Мұғалім көрсететін бейнежазбаны қарап, қозғалыс қалай өзгеретінін талда.

–«Қозғалыстың жылдамдығы неге байланысты?» деген сұраққа ойланып, өз ойыңды сыныппен бөліс.

2. Қадам – Зерттеу (Explore):

– GeoGebra бағдарламасында әртүрлі функциялардың графигін құрып, олардың өсіп/кеміп жатқанын бақыла.

– Графиктен жанаманы (түйісетін түзуді) салу арқылы жылдамдықты анықтауға тырыс.

3. Қадам – Түсіну (Explain):

– Мұғалімнің түсіндіруімен «туынды» ұғымын меңгер.

– Қандай жағдайда функция өседі, кемиді, экстремум не екенін түсіндір.

4. Қадам – Қолдану (Elaborate):

– Күнделікті өмірден қозғалысқа қатысты есеп ойлап тауып, оны функция түрінде жаз.

– Осы функцияның туындысын алып, нақты бір сәттегі жылдамдықты есепте.

5. Қадам – Бағалау (Evaluate):

– Тапсырмаларыңды дәптерге орындап, өз жұмысыңды бағалау парағына қарап тексер.

– Өз рефлексияңды жаз: бұл тақырыптан не үйрендің, не қиын болды?

Қажетті құралдар: Қолданылатын құралдар: GeoGebra, калькулятор, бейнебақылау материалы, дәптер, сызғыш.

Бағалау жүйесі:

Бағалау критерийі	Максималды балл
Қозғалысты дұрыс сипаттау	5 балл
Функция графигін құру және талдау	5 балл
Туындыны есептеу және оны қолдан	5 балл
Тапсырманы толық орындау және рефлексия	5 балл
Жалпы	20 балл

Жоба 2. Өмірмен байланысты математикалық модельдеу (PBL әдісі)

Нұсқаулық: Оқушылар өзекті өмірлік мәселені зерттеп, деректер жинайды және сол мәселені сипаттайтын математикалық модель құрастырады. Жоба барысында сызықтық немесе квадраттық функция қолданылады.

Тапсырма мазмұны:

– Өмірмен байланысты мәселені таңдау және зерттеу жоспарын құру;
– Деректер жинау (сауалнама, өлшеу, бақылау);
– Жиналған деректерге сәйкес функция түрін анықтау және модель құру;
– График тұрғызып, нәтижелерді түсіндіру;
– Постер немесе презентация арқылы жұмыс нәтижесін қорғау.

Қолданылатын құралдар: Google Forms (немесе қағаз сауалнама), Excel, GeoGebra, калькулятор, постер материалдары.

Бағалау жүйесі:

Бағалау критерийі	Максималды балл
Мәселенің өзектілігі	5 балл
Дерек жинау және өңдеу	5 балл
Математикалық модель мен график құру	5 балл
Қорытынды жасау және таныстыру	5 балл
Жалпы	20 балл

Жоба 3. Сақтау блогын жобалау (инженерлік дизайн процесі – EDP)

Нұсқаулық: Бұл жоба барысында оқушылар нақты бір кеңістіктік шектеулерді ескере отырып, сақтау құрылғысының ең тиімді моделін құрастырады. Математикалық модель арқылы өлшемдерді оңтайландырып, шынайы шешім ұсынады.

Тапсырма мазмұны:

– Шарттарды талдау (көлем, бет ауданы, биіктік, шектеулер);
– Қорап немесе сақтау блогының пішінін таңдау;
– Математикалық формулаларды модель түрінде құру;
– GeoGebra немесе Excel көмегімен модельді визуализациялау;
– Ең тиімді шешімді анықтап, жобаны таныстыру.

Қолданылатын құралдар: GeoGebra, Excel, миллиметрлік қағаз, сызғыш, калькулятор, презентация құралдары.

Бағалау жүйесі:

Бағалау критерийі	Максималды балл
Мәселені түсіну және параметрлерді анықтау	5 балл
Математикалық модель құру	5 балл
Оптимизация және аналитикалық дәлел	5 балл
Таныстыру және қорытынды жасау	5 балл

Жалпы	20 балл