

Integration of STEM into the process of teaching mathematics to middle school students

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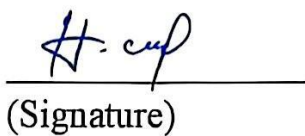
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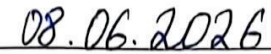
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List of Abbreviations

STEM – Science, Technology, Engineering, and Mathematics

STEAM – Science, Technology, Engineering, Arts, and Mathematics

PISA – Programme for International Student Assessment

TIMSS – Trends in International Mathematics and Science Study

NSF – National Science Foundation

SMET – Science, Mathematics, Engineering, and Technology

METS – Mathematics, Engineering, Technology, and Science

ICT – Information and Communication Technology

WRO – World Robot Olympiad

USSR – Union of Soviet Socialist Republics

MEA – Model-Eliciting Activities

PBL – Problem-Based Learning

CTT – Classical Test Theory

NYSTP – New York State Testing Program

ELA – English Language Arts

IBL – Inquiry-Based Learning

ABSTRACT

This study examines the effect of STEM on the academic performance in mathematics of fifth-grade students in middle school. The research design included an achievement test and a brief questionnaire. The study involved two groups: 12 students in the control group and 13 students in the experimental group. The achievement test, which included a pre-test and a post-test, measured students' performance before and after the STEM education. In the control group, students were taught using traditional teaching methods, while the experimental group was taught using STEM. Analysis of the achievement test results showed that the experimental group achieved significantly higher results in mathematics compared to the control group. This, in turn, demonstrates the effectiveness of STEM in improving students' mathematics performance. The questionnaire was administered to the 13 students in the experimental group before and after instruction. The results showed that after participating in STEM-based instruction, students demonstrated improved understanding of mathematics.

These results indicate that STEM-based instruction not only improves mathematics performance but also has a positive effect on students' understanding of the subject. These two advantages highlight the importance of integrating STEM into the mathematics curriculum.

Key words: STEM, academic performance, middle school students, students' understanding of mathematics

АНДАТПА

Бұл зерттеу STEM-нің орта мектептің бесінші сынып оқушыларының математика пәні бойынша оқу үлгеріміне әсерін қарастырады. Зерттеу дизайны оқу үлгерімін өлшеуге арналған тест пен қысқаша сауалнаманы қамтыды. Зерттеуге екі топ қатысты: бақылау тобында 12 оқушы және эксперименттік топта 13 оқушы болды. Алдын ала тестілеу мен кейінгі тестілеуді қамтитын үлгерім тесті оқушылардың STEM-ге дейінгі және кейінгі үлгерімін өлшеді. Бақылау тобында оқушылар дәстүрлі оқыту әдісі бойынша, ал эксперименттік топта STEM бойынша оқытылды. Үлгерім тестінің нәтижелерін талдау барысында эксперименттік топтың бақылау тобымен салыстырғанда математикадан айтарлықтай жоғары нәтижелерге ие екенін көрсетті. Бұл өз кезегінде оқушылардың математика бойынша үлгерімін арттырудағы STEM тиімділігін көрсетеді. Сауалнама эксперименттік топтағы 13 оқушыға оқытуға дейін және кейін берілді. Нәтижелер STEM негізінде оқытуға қатысқаннан кейін оқушылардың математиканы жақсырақ түсіне бастағаны анықталды.

Бұл нәтижелер STEM негізіндегі оқыту математикадағы үлгерімді арттырып қана қоймай, оқушылардың пәнді оңай түсінуіне де оң әсер ететінін көрсетеді. Осы екі артықшылық STEM математика оқу бағдарламасына енгізудің маңыздылығын айқындайды.

Түйінді сөздер: STEM, оқу үлгерімі, орта мектеп оқушылары, оқушылардың математиканы түсінуі

АННОТАЦИЯ

Данное исследование рассматривает влияние STEM на академическую успеваемость по математике у учащихся пятого класса средней школы. Дизайн исследования включал тест на академическую успеваемость и краткий опрос. В исследовании приняли участие две группы: 12 учеников в контрольной группе и 13 учеников в экспериментальной группе. Тест на успеваемость, включавший предварительное и итоговое тестирование, измерял результаты учащихся до и после внедрения STEM-обучения. В контрольной группе обучение проводилось с использованием традиционных методов, тогда как в экспериментальной группе применялось STEM. Анализ результатов теста показал, что учащиеся экспериментальной группы достигли значительно более высоких результатов по математике по сравнению с контрольной группой. Это, в свою очередь, демонстрирует эффективность STEM в повышении математической успеваемости учащихся. Опрос был проведён среди 13 учащихся экспериментальной группы до и после обучения. Результаты показали, что после участия в STEM-обучении учащиеся стали лучше понимать математику.

Полученные результаты свидетельствуют о том, что STEM-обучение не только повышает успеваемость по математике, но и положительно влияет на понимание предмета. Эти два преимущества подчёркивают важность интеграции STEM в учебную программу по математике.

Ключевые слова: STEM, академическая успеваемость, учащиеся средней школы, понимание учащимися математики

1. INTRODUCTION

Currently, technology is developing rapidly around the world. Every industry requires mastery of modern technologies. In this regard, some changes are also being made in the field of education, with other approaches to learning being adopted in addition to traditional methods. This means that in the future, students will have to compete not only with experienced professionals, but also with artificial intelligence, in line with the requirements of the new era. In other words, students need to achieve creative and critical thinking abilities. This will teach them to solve any problems innovatively in the future, as well as to quickly adapt to science and technology. Undoubtedly, people with such skills will have more opportunities in the future.

And in order to help students quickly master technology and science in the developed world, STEM education is currently being used extensively in education. The STEM education ensures that students develop functional literacy and the capacity to apply the knowledge they have acquired in real life. In other words, it is an integrated approach to learning that includes interdisciplinary connections. It teaches students not only to memorize theory, but also to apply it correctly. With the help of the STEM, students become closer to science by performing tasks such as teamwork and scientific projects.

The application of the STEM in math instruction is frequently presented merely as a minor heading. However, the place and role of mathematics is now much higher. One of the problems faced by modern students is that they do not understand mathematical concepts and cannot use them correctly. Considering these facets, the incorporation of STEM into the instruction of mathematics for middle school learners is examined in greater depth.

The relevance of the study the reality is that in today's learning environment it is important to promote analytical thinking and solution skills in students. By integrating STEM in mathematics, you will increase students' interest and promote their better understanding of mathematics. In the future, this will ensure that there are specialists who are well versed in science and technology. This method also increases

their competitiveness and creates conditions for them to be one step ahead in their future careers. Thus, one of the paramount methods to boost pupils' enthusiasm for mathematics involves enhancing the standard of instruction. Consequently, this thesis will examine the incorporation of the STEM education into the procedure of teaching mathematics in middle school.

The object of the study is the process of teaching mathematics to middle school students.

The aim of the study is to investigate the role of STEM in improving the process of teaching mathematics in middle school students.

The scientific prediction of the study is that if STEM is used systematically and purposefully in mathematics lessons, students' mathematical skills, academic performance, and interest in the subject will develop to a higher level than with traditional teaching approaches.

Research Objectives:

1. To study the theoretical foundations of the use of STEM in the process of teaching mathematics to middle school students.
2. To examine ways of integrating STEM into the mathematics teaching process and applying it in educational practice.
3. To evaluate the effectiveness of the methodology through a pedagogical experiment.
4. Based on the results of the pedagogical experiment, to develop methodological recommendations for the effective use of STEM in mathematics lessons.

Research methods:

1. Experimental observation method. Using various software tools and approaches to solve mathematical problems.
2. Theoretical method. Analysis of literature, scientific studies, and articles.
3. Empirical method: achievement test and questionnaire to determine the influence of STEM on students' academic performance.

Scientific novelty and theoretical significance of the study. Theoretically, the teaching of mathematics to middle school students using the STEM was analyzed, and its effectiveness was confirmed experimentally. A conceptual framework has been developed to assess the impact of the introduction of the STEM in mathematical pedagogy on the learning process.

Practical Significance of the Study. In middle school mathematics instruction, teachers can use ready-made methodological materials and tools to conduct STEM-based project-based and practical lessons. Students' readiness to apply their acquired understanding in real life is increased, and they choose careers in technical and scientific fields.

Research Questions:

1. What theoretical and pedagogical foundations underpin the integration of STEM into mathematics education?
2. How does the integration of STEM affect students' academic performance in mathematics?

2. LITERATURE REVIEW

2.1 Theoretical foundations of STEM

According to Elsayed (2022), the acronym STEM brings together four subject areas "science, technology, engineering, and mathematics" which, in both educational and professional practice, do not appear in isolation but rather function as an integrated whole.

Regarding the science component (S), it comprises three interconnected levels: foundational knowledge, the capability to install significant attitude between these ideas, and the research practices and modes of thinking required to explore the natural world and address authentic problems.

Technological competence (T) refers to the capacity to work with technology understanding it, using it, managing it, and evaluating it. Learners must not only acquire hands-on skills but also recognize how technology reshapes the natural environment to meet human of necessity and aspiration.

The engineering dimension (E) is characterized by being a systematic design approach: a coordinated method of developing processes, subject matter and systems that respond to human requirements. Through this learning, students learn to apply technical thinking in novel situations. The key elements are the identification and clear formulation of solvable problems, the generation and empirical testing of possible solutions, as well as the iterative refinement of the design based on functional, ethical, economic and aesthetic discussion to achieve an optimal result.

Finally, mathematical competence (M) this is made clear by the functions that mathematics performs in the real world. A mathematically literate person is able to draw logically sound conclusions. In addition, the active introduction of mathematics into practice develops critical thinking and helps people meet their daily needs more effectively. Where critical thinking and functional literacy are developed (Elsayed, 2022).

STEM learning is a move to separate the four elements and to confirm the pupil enhance their troubleshooting skills in daily existence. STEM instruction is a method include "science, technology, engineering, and mathematics" to foster pupils' innovation via issue resolution. The globe has acknowledged the requirement for science, technology, engineering, and mathematics to be merged. According to Rifandi and Rahmi (2019), STEM integration denotes a teaching approach that merges table of contents and practices from corrective knowledge especially science and mathematics with the engineering design procedure and the application of pertinent technologies. Specialists in the field describe this form of STEM education as a lesson that incorporates all four STEM components required in professional contexts.

Before the term STEM appeared, it was the application of principles to create important technological successes. This includes things we all know, from light bulbs to the phone. STEM became the main focus during World War II, where it literally depended on technology and equipment. This is how all the attention was involved to create a multitude of innovations combining science and technology. It is essential to keep in mind that the STEM was not yet known at that time. Consequently, we see that STEM has always been actively used in various periods of history (Rifandi & Rahmi, 2019). Internationally, Russia had already begun developing STEM education as early as 1957. In the United States, research and implementation efforts in this new educational direction started in the early 1990s. However, American research on STEM education actually dates back to 1969, when "The National Assessment of Educational Progress" published reports on students' mathematics and science abilities, which at the time remained comparable to those of other countries.

Despite continued endeavors, the United States consistently ranked lower than other advanced nations such as New Zealand, Iceland, and Denmark in PISA and TIMSS evaluations. Furthermore, the quality of mathematics and science instruction, along with teacher effectiveness, showed little improvement between 1990 and 2005. A positive shift occurred after 2000, when numerous companies began funding STEM

research, which subsequently had a beneficial impact on the quality of education (Rifandi & Rahmi, 2019).

One of the most essential achievements of school education in the 21st century, STEM has been widely recognized. Unlike the standard approach, which considers mathematics as an independent subject, its most important origin links the teaching of mathematics with science, technology and engineering and uses the basic ideas accumulated in all four areas.

Therefore, STEM has proven to be a very encouraging means of teaching mathematics and researching teaching. Academic institutions introducing STEM curricula present math, technology, engineering, and science in an engaging style focused on solving real challenges. In these environments, scientists are obliged to use and integrate their current understanding, skills and knowledge in mathematics, science and technology. In addition, scientific reasoning becomes a useful tool, and the connections between STEM ideas, on the one hand, and extracurricular existence and job requirements, on the other, are clarified (Elsayed, 2022).

Presently, mainstream secondary schools employ a subject-focused method in the learning process. The core of this approach involves academic subjects being taught somewhat in an "isolated" way. Nevertheless, this approach does not entirely satisfy the demands of contemporary education. Frequently, pupils' understanding is separated from actual life, and there is a lack of cohesion in building and advancing knowledge and abilities, work methods, which are the proficiencies vital for existing in rapidly shifting environments. Educators globally are seeking novel and productive techniques and technologies to cultivate the proficiencies required by today's youth the skills of the 21st century. One such technology toward the close of the 20th century was STEM instruction (Salahub, 2020). Currently, the concept of STEM education is widely used in numerous academic programs across the country, STEM centers are being created, global symposiums are being held, and collaboration groups are being formed. According to Kennedy and Odell (2014), STEM education establishes a link between scientific research and engineering planning. In particular, students initially ask

questions that can be tested in practice. The answers they receive as a result of this research help them gain information before moving on to the engineering design stage, where they use their discoveries to solve real-world problems.

With more institutions and educators emphasizing STEM education, it is becoming clearer that the area lacks a distinct, cohesive meaning. Brown et al. (2011) observe that the phrase "STEM" is often clarified merely by enumerating the "four subjects' science, technology, engineering, and mathematics" in parentheses, without providing a more profound theoretical grasp of what STEM blending truly involves.

Bybee (2013) argues that teaching in STEM is aimed at achieving goals that go far beyond ordinary academic success. For example, where in traditional methods the teacher only looks at exam results or content, STEM strives to promote the development of students' critical abilities, classroom teaching embraces not only memorizing topics or complex rules, but also devoting time to practical tasks and contexts. The most important skills for this method are teamwork, discussion, research, solving difficulties from real life, prudence and ingenuity, which are of great importance for prosperity in modern civilization., regardless of the student's special inclinations or possible career ambitions. Where the student can freely express his idea and achieve the goal.

Based on a meticulous review of previous curricula, Bybee (2013) identifies five main goals of STEM education. First of all, students should understand the importance of the four disciplines of "science, technology, engineering and mathematics", and they should have an understanding of these subjects. Secondly, they need to learn how to link understanding in these four areas when solving real-world problems outside of school. Where each concept has its own significant role and is not considered as a separate subject. Third, teaching should purposefully develop a wide range of abilities, including critical thinking, finding any problems that arise, inventive thinking, exchanging ideas, and using technical skills. Fourth, STEM education is aimed at preparing people to meet the requirements of the global labor market and successfully

compete at the global industry level. Finally, Bybee (2013) emphasizes the importance of encouraging knowledge, achievements, and talents that enable students to recognize important issues and difficulties in common life, expound both natural and artificial systems, and make informed verdict about STEM-related issues.

To many, it denotes simply science and mathematics, though the outcomes of technology and engineering have so greatly affected daily existence. Practical STEM instruction ought to assist learners in grasping how things operate and employing technology more capably. Moreover, STEM learning should incorporate more engineering understanding throughout the preparation for higher education entry. Engineering is directly related to problem solving and invention, two areas that receive a lot of attention in each country's plans. Considering its financial relevance to society, students ought to learn about engineering and cultivate some of the talents and opportunity linked to the design method (Bybee, 2010).

Integrated STEM teaching differs significantly from conventional learning on the basis of established subjects and requires a reevaluation of brainstorming as a process or activity that can be divided into different frameworks and can take place within an individual's cognition or in mutual interactions. The point of view of different thinking styles suggests that students' understanding can be improved by specifying certain thinking patterns and carefully combining them with various decisive and appropriate resources, methods and compromises. If this point of view turns out to be meaningful and enjoyable, STEM education can provide unique perspectives that allow students to cultivate different ways of thinking (Li et al., 2019).

The writings suggest that the notion of STEM instruction began in the United States during the 1990s, when R. Colwell introduced the acronym. The NSF subsequently embraced STEM as a unified designation for science, technology, engineering, and mathematics. Initial variations included SMET and METS, but in 2001 J. Ramaley solidified the existing sequence of letters. After this, STEM-focused coursework broadened beyond the U.S. to numerous other nations (Sanders, 2008).

A pivotal moment in the history of STEM education occurred in 2005, when "Virginia Tech University" introduced the first academic degree program explicitly titled "STEM education". Prior to this development, according to Sanders (2008) reports that Friedman (2005), the movement had struggled to gain traction. The establishment of this degree signaled the beginning of a gradual international expansion that would eventually lead to STEM's widespread recognition and adoption. This institutional shift did not happen in a vacuum. It was driven by growing concerns among key US policy and scientific bodies. For instance, a joint report from the "National Academy of Sciences", the "National Academy of Engineering, and the Institute of Medicine" revealed that STEM competencies among American students were underdeveloped relative to their international counterparts. At the same time, the "National Governor's Association" argued that fostering a cohesive "STEM identity" was essential for preserving the nation's economic competitiveness (Martín-Páez et al., 2019). In response to these pressures, STEM principles gradually migrated into the educational domain. Education became framed as a critical tool for addressing the rising demand for skilled human capital in STEM sectors. As Caprile, Palmén, Sanz, and Dente (2015) conclude, this trajectory demonstrates that delivering solid, high-quality STEM training is an urgent necessity in the current era. Mathematics encompasses a number of subfields, including mathematical reasoning, probability, geometry, each representing problem-solving tasks that require rigorous critical analysis by students and teachers. Using geometry as an illustration: Performance in this area largely depends on the ability to visualize spatial relationships. However, a noticeable part of students has difficulties in creating mental representations of three-dimensional entities. This challenge of understanding mathematical ideas often leads to disappointments, which subsequently lead to poor academic results. To address these learning obstacles, inventive teaching methods that integrate STEM concepts into math lessons have gained importance.

The success of such methods depends mainly on the willingness of teachers and their ability to present STEM material throughout the course. Teachers who understand

well how to implement integrated STEM learning, where there is less interest in the subject, or low academic performance, have every opportunity to arouse students' curiosity and motivate them to study STEM subjects in more depth. Effective implementation of a unified STEM education also requires teachers to develop teaching skills capable of developing students' abilities in the twenty-first century, where knowledge and technology skills are developed and required. According to Zakeri et al. (2023), to address the problem of a decrease in the number of interested students in STEM fields, teachers need to use their knowledge in they chose teaching methods that correspond exactly to the different levels of student achievement.

According to Erbolovna et al. (2019), Kazakhstan has also begun to actively develop STEM education. Evidence of this commitment can be seen in the State Program for the "Development of Education and Science for 2016–2019", which explicitly calls for a transition to an updated school curriculum within a STEM framework. To implement this new educational policy, the government plans to integrate STEM elements aimed at fostering new technologies, scientific innovation, and mathematical modeling into teacher training programs. A new cross-disciplinary and project-based approach to instruction is expected to be introduced. This approach is designed to help school students strengthen their research capacity and scientific-technological potential, while also developing critical, innovative, and creative thinking skills, as well as problem-solving, interaction, and cooperation abilities. The number of interdisciplinary connections between science, technology, engineering, and mathematics will increase.

Beginning in the 2015–2016 academic year, every first-grade student has studied "Natural Sciences", a subject that serves as a foundation for more advanced study of natural sciences in higher grades. Furthermore, from the 2016–2017 academic year onward, plans have been made to equip all ICT-focused schools with digital educational resources and Internet access. Additionally, starting in 2019, natural sciences and mathematics subjects at the high school level will be taught in English,

which is expected to facilitate access to new knowledge in the original language and promote integration into the global scientific community.

Special attention in Kazakhstan is devoted to the development of educational robotics. Since 2014, the annual "Republican Robotics Olympiad" has been held for students of general education schools and Nazarbayev Intellectual Schools. Winners of these national competitions have the possibility to contribute in the "World Robotics Olympiad (WRO)". Moreover, since 2015, the annual international robotics festival "RoboLand" has taken place in Karaganda, with participants from other countries as well. In 2016, the first educational robotics laboratories began to open. The first such laboratory was established at Gymnasium No. 159 in Almaty. In the near future, the opening of 90 additional laboratories is planned at other schools across the country. At the same time, teacher training is underway: currently, 64 instructors have been trained in an elective course on robotics.

There is also positive international cooperation in the field of STEM education. For example, since 2014, the "Newton-al-Farabi" five-year partnership program between the UK and Kazakhstan has been implemented with a total budget of 20 million pounds. The objective of this program is to grow cooperation between the two countries in strengthening scientific and innovative potential, facilitating the exchange of personnel and the creation of joint research centers.

Erbolovna et al. (2019) concludes that Kazakhstan is moving in the same direction as developed countries. STEM education serves as a link between academic school and academic career. His concept prepares children for life in a technologically advanced world. Future specialists will need comprehensive training and knowledge covering various fields of education, including science, engineering, technology, and mathematics.

Following an examination of the theoretical underpinnings of STEM, the principal phases of its history may be discerned based on the research by Dilnaz (2024).

1. Industrial Revolution: During the Industrial Revolution, the progress of science and technology played a decisive role in improving production

methods. This era showed the need to apply mathematical calculations and train technical experts. Inclusion of natural sciences in the curriculum: In the nineteenth century, many nations began to include physics, chemistry and mathematics in their curricula.

2. Space Race: In the 1950s and 1960s, a space contest commenced between the United States and the USSR. Following the USSR's launch of its initial artificial satellite, Sputnik 1, in 1957, there was a specific emphasis on advancing science and technology in the United States. This circumstance set the stage for the STEM concept in pedagogy. Educational Revisions: The 1958 "National Defense Education Act" in the US underscored the requirement to weave STEM subjects into the curriculum.
3. Origin of the Term STEM: In the 1990s, the United States experienced a considerable lack of experts in the domains of science and technology. At that juncture, there was a need to consolidate " science, technology, engineering, and mathematics " subjects within the educational framework. The designation STEM was initially employed by the U.S.NSF. Evolution of Methodological Concepts: Throughout this time, the STEM method started to be perceived as more than mere subject integration, but rather as an instrument for furnishing learners with practical proficiencies.
4. The Global Expansion Phase of STEM. The Era of Invention: The progress of information technology and artificial intelligence in the 21st century has elevated the necessity for STEM instruction. Numerous countries have begun rolling out STEM-focused initiatives at the national level. STEM and STEAM: In the 2010s, the Arts were appended to STEM, resulting in the STEAM framework. This was a merger intended to foster ingenuity and inventive thought.
5. Adoption of the STEM Method: In Kazakhstan, the STEM method started to be integrated into the schooling system during the 2010s. The opening moves were performed using Nazarbayev Intellectual Schools and specific

groundbreaking projects. Government Initiatives: Under the "Digital Kazakhstan" plan, particular focus is being given to fostering robotics, coding, and engineering in schools (Dilnaz, 2024).

This subsection discussed the origins of the term STEM. Engineers and scientists have always worked together to create scientific and technological innovations. The convergence of disciplines occurred in practice to achieve success in civilian sectors. It was not until the 1990s, after the lag in U.S. education was noted, that the integration of disciplines was made a priority in education. Beginning in 2001, STEM evolved into an educational policy that was reflected in school curricula.

2.2 STEM in modern schools

According to Kennedy and Odell (2014), STEM education equips young people by providing opportunities for hands-on, hands-on experiments. These companies allow students to study scientific terms first-hand and develop a deeper understanding of the environment around them. Through testing, scientists gain the freedom to conduct research, validate their ideas and forge new ones, thus fostering their curiosity and sense of reverence for the physical realm.

Teo and Choy (2021) emphasized that STEM education helps students understand that making miscalculation is a natural and rewarding learning process. By allowing pupils to err and gain knowledge from those errors, STEM instruction assists in fostering tenacity, adaptability, and robust analytical abilities. Should learners face challenges or issues during exploration, they are urged to examine their misstep, modify their method, and reattempt. This strategy strengthens the notion that setbacks should not be shunned, but rather signify a chance for advancement and study (Tavdgiridze et al., 2024).

In present day rapid, technology driven world, STEM education signifies more than just an academic mandate; it is a crucial need for readying learners to confront the intricate trials of the 21st century. The expanding focus on STEM areas stems from a rising need for experts who hold scientific understanding and technical aptitudes in a

global marketplace that is increasingly technology focused. Moreover, STEM instruction fosters inventive thought, imagination, and analytical capacities, all of which are vital for achievement in any profession. The impact of STEM extends beyond private employment opportunities; it holds an important function in propelling technological advancement, fiscal expansion, and wider community progress (Marzuki et al., 2024).

According to LaForce et al. (2016), this component is aimed at studying aspects of student development that are not related to learning. It includes creating a supportive school environment and giving students the opportunity to express their feelings. Many STEM comprehensive schools consider the school atmosphere to be the most important aspect of student achievement. Some educational institutions describe themselves as having a "kindred" environment, while others emphasize that an atmosphere of competence reigns in the school. Further illustrations of elements belonging to this component include: "personnel bolster the necessities of the entire pupil," "learners interact with one another showing reliance and regard," "pupils participate in school planning," and "personnel highlight a school standard of conduct and ethics."

Nowadays, more and more solutions are being found in the field of STEM education to eliminate problems such as competitiveness and economics. But the main task remains to study the impact on students' academic performance and their possibility to apply knowledge in critical situations. And does this help students become interested in their future profession? Also, the main task of the authors is to develop models for the introduction of STEM in educational schools. The main problem is how STEM works better and what conditions are necessary for this, therefore it is important to determine how STEM affects the choice of a future profession and knowledge (Morrison et al., 2015).

Teachers must adhere to stem initiatives specifically designed to groom and prepare subject matter experts for the introduction of STEM learning in schools. These initiatives are important because they help teachers internalize the core disciplinary concepts and general topics of STEM education so that they can keep pace with 21st

century learning approaches (Dong et al., 2020). The training aims to develop clear competencies according to the criterion established by the study and repeated application. Through these trainings, teachers gain a thorough understanding of STEM fundamentals and learn how to adjust the classroom situation accordingly. In addition, you will improve analytical and quantitative skills in the context of STEM and gain knowledge of study-and project-based learning methods. This arrangement allows you to safely introduce these methods into the learning process and vigorously promote the variability of STEM courses for each student (Li et al., 2019).

Despite broad acceptance and comprehension of the STEM acronym, there is slight agreement on how instruction and study in STEM ought to be handled in schools. Broadly speaking, STEM remains defined by its distinct subjects, and it is introduced this way in formal curriculum paperwork. While curriculum bodies aim to enhance STEM teaching, discussion persists about whether and how the STEM subjects should be merged into learning schedules, as well as what curriculum, teaching, and structural frameworks would best foster such merging. While diverse methods for STEM education have been noted, interdisciplinary frameworks are generally regarded as the most beneficial. In these frameworks, pupils build and utilize STEM expertise and abilities by crafting or simulating answers to "actual life" issues, necessities, or chances, frequently utilizing problem-centered or project-centered study blueprints that match design thinking concepts. Nevertheless, although these tactics might boost STEM understanding and render it more pertinent to pupils, they pose a considerable hurdle to established single-subject curriculum and evaluation practices. Moreover, interdisciplinary project-based and problem-based setups are frequently viewed as inconsistent with secondary schools' current focus on separate subject periods. In numerous nations, these difficulties are compounded by the lack of a STEM curriculum that features system-level directions for structuring and instructing (Falloon et al., 2021).

In addition, the results suggest that STEM offers a method to address different ways of thinking and create energetic learning environments focused on creativity and

exploration. This research showed that the success of a STEM-oriented elementary school comes from the willingness of educators to expand their subject and teaching competence, so that they can refine their methods and at the same time try new ways of student development. Elementary schools that emphasize STEM may perform better if they are located in a STEM-led school jurisdiction that promotes logical STEM progress from kindergarten through twelfth grade. STEM-oriented elementary schools provide students with early access, which could lay the foundation for linking academic subjects with practical situations. The drive to furnish pupils with excellent education has spurred a shift in the responsibilities of school executives, both in the area offices and within the buildings. This transition emerged from the requirement to handle teaching concerns inside schools and shifted administrators from supervisors to teaching guides (Waters & Orange, 2022).

As per Dulatkyzy and Akbayeva (2025), STEM is actively advancing in Kazakhstan, particularly under the umbrella of the Digital Kazakhstan initiative. Particular focus is being placed on incorporating robotics, coding, and 3D modeling, especially in "Nazarbayev Intellectual Schools". Although a standardized approach to STEM education is still in the formative stages, these efforts, according to the authors, mean significant progress in updating the national structure of school education and bringing it in line with international standards. According to Yesnazar et al. (2025), Kazakhstan has achieved significant strides in adopting STEM technologies across areas like robotics, physics, engineering, and informatics. Various academic centers such as STEM fields such as "Academia, Inventor, and Quantum" have been founded to bolster the growth of STEM instruction. These efforts mirror Kazakhstan's increasing commitment to furnishing learners with scientific understanding, engineering and technical proficiencies, analytical capabilities, and sound judgment. Consequently, the appeal and deployment of STEM education in Kazakhstan are accelerating swiftly, extending beyond primary schools into tertiary establishments. STEM education includes a rigorous methodology that focuses on collaboration, focused learning, the use of modern technological tools, and a combination of different

subjects. It promotes ingenuity, problem solving, and the emergence of new ideas through interdisciplinary pedagogy and promising teaching.

In addition, students' interest in STEM can be fueled by scientific and technical training; for example, in physics lessons, an instructor can perform tasks that allow them to gain practical experience. In fact, when science classes are not limited to one area, but are taught by combining several STEM fields, students' interest in individual subjects increases. In particular, the introduction of STEM teaching methods in arithmetic helps to develop students' research skills and their ability to express their views. Students' interest in mathematics is declining not because of the complexity of the subject, but because arithmetic is insufficiently explained. This has stimulated a growing interest in STEM from the regions. The question of students' views on the basic approach to learning, in general, in educational institutions is also in the focus of researchers' attention. In this context, Yesnazar et al. (2025) explore the nature and importance of using STEM technology.

2.3 The role of mathematics in STEM education

In recent times, STEM training has emerged as a meta-discipline intending to embrace an integrated approach and, therefore, maintains a comprehensive view of STEM instruction. If someone considers the notion of STEM entirely, it should not lead to a disadvantage in any single area. However, in educational studies these past years, the viewpoint of science is commonly focused upon, while math stays secondary. Mathematics often performs an auxiliary function within the framework of educational scenarios related to natural sciences, acting as an auxiliary subject. In this context, students use established concepts and basic working methods, such as calculations, to solve numerical problems. On the one hand, it's difficult, because that's what modern machines are capable of. On the other hand, it indicates that this poses a problem for the improvement of mathematical concepts and competencies of students.

Insufficient attention to STEM from the point of view of teaching mathematics was perceived as an opportunity to look at the subject from this point of view. Recently, several studies have explored how mathematics can and should be integrated into

STEM, as well as what additional benefits mathematics can bring. Simple innovative technologies require computation, but mathematics itself is the foundation of critical thinking and functional literacy. An important element of STEM education is its connection to the real world: understanding the world around them and social situations is possible only when students have mastered fundamental mathematical skills that allow them to use mathematical approaches both descriptively and prescriptively. Mathematics, for example, holds a vital function in comprehending and articulating premises (Just & Siller, 2022).

Fitzallen (2015) advocated for a greater focus on the mutual connection between STEM and mathematics. On one side, STEM can function as a setting for acquiring mathematical knowledge. Conversely, mathematics is vital for grasping the notions and concepts within the other STEM subjects. However, Fitzallen (2015) pointed out that, in general, in much of the current writings, STEM tasks focus on using STEM as a basis for studying mathematics, while the reverse flow, which emphasizes the function of mathematics to understand knowledge of other areas of STEM, seems much less common. Recognizing mathematics as fundamental to other subjects is not enough. If mathematics is involved only incidentally, there is a risk that it will be considered only as a complementary function in integrated STEM methods. To strengthen the position of mathematics, a move away from random inclusion towards a more direct inclusion that emphasizes the practical benefits of mathematics could be a valuable tactic.

Many researchers find the role of mathematics in STEM education unclear. In their study of the new learning technologies curriculum, Den Braber et al. (2019) it was noted that students find mathematics uninteresting and also believe their knowledge in this area is low. Consequently, teachers are also biased against such students. Such findings highlight the need for further investigation into the function of mathematics within STEM education. Also, numerous researches on scientific analysis shows that science teachers most of the time consider mathematics as not the main problem. All attention is paid specifically in the field of science, technology and engineering, as in

this concept mathematics is not considered as a solution to problems. This is a major problem for mathematical researchers who seek a more balanced and equitable position for mathematics within the STEM framework (Makonye & Moodley, 2023).

Shaughnessy (2013) also endorsed the utilization of problem-based methods in STEM instruction, while concurrently warning that mathematics as a field might become quiet if it doesn't get particular notice. Mathematics can assume a core function in tackling genuine world issues; mathematical modeling, for example, provides a means to explore and resolve such difficulties. An emphasis on mathematical modeling is one tactic for promoting mathematics education within STEM frameworks due to the inherent link between mathematical modeling and the real world (Maass et al., 2019). The complexity of improving mathematical results using integrative methods requires a lot of attention, especially in terms of consistency and coverage of the mathematical program. Scientific papers often reveal that learning opportunities within STEM education provide the conditions for the improvement of mathematical competencies. However, these illustrations often ignore the reciprocal nature of the relationship among mathematics and STEM. They show examples in which STEM education helps to form mathematical concepts and principles, but do not show how mathematics can impact the understanding of concepts and concepts found in other STEM fields and contribute to their assimilation.

In some cases, mathematics unwittingly becomes only the main focus of homework. Let's take a detailed example from Fitzallen (2015): a special exercise that helps students study the properties of aluminum baseball bats and understand how resistant they are to impacts. This work is designed to develop students' analytical abilities. The mathematical idea of measuring the central trend was used to calculate the average value of aluminum crystals on the surface of bats. In this situation, mathematics was not crucial to completing the task; instead, it helped to get clear results. The task did not lead to the use or development of proportional thinking skills necessary to understand density, which is directly related to bat endurance.

"When mathematics is an integral part of STEM, it also changes the focus of the content in mathematics. Traditionally, mathematics has often had an explicit focus on skills and routines (Niss & Jensen, 2011), but Gravemeijer et al. (2017) noted that mathematics education for the future must complement the work that can be done by computers, so mathematical education must focus more on modelling and application. This new focus fits well with the goals of STEM, which are often described as 21st-century skills" (Kristensen et al., 2024, p.420).

Mathematics is often described as a bedrock for the other STEM disciplines, as it offers a shared vocabulary for "science, engineering, and technology" (Schmidt & Houang, 2007). Still, this brings up the query: is this adequate appraisal of the possible function of mathematics in STEM learning settings? Depicting mathematics as a base position it in a secondary capacity within integrated STEM education. Ideally, mathematics ought to be afforded more significance and seen as an activator or a vital prerequisite for boosting comprehension across other fields. One method to render mathematics more apparent within STEM learning situation and endeavors is to move the emphasis away from its passive appearance toward its functional aspect (Fitzallen, 2015). A study by Ozhibayeva and Abdoldinova (2024) argues that STEM education provides students with the opportunity to show interest in arithmetic by leveraging their current fascination with other fields of study. Arithmetic, on the other hand, provides a general tool for description and evaluation, as well as for modeling real-world scenarios. Every science teacher should have the fundamental quantitative skills necessary for their core discipline, and in turn, every mathematics teacher should consider knowledge of other disciplines as appropriate support, emphasizing the "value" of mathematics. Brief and accurate practical examples in arithmetic textbooks usually present facts about specific events and circumstances out of context. Therefore, such exercises are not very popular among teachers or students and are therefore often completely ignored.

Investigators observe three possibilities to boost the importance of mathematics within STEM. In their research, they propose linking STEM education with the following:

1. the mastering of 21st-century skills;
2. the meaningful integration of mathematical modeling into school education;
3. the cultivation of responsible citizenship.

Ozhibaeva and Abdoldinova (2024) concluded that mathematics is a foundational discipline that unites all STEM disciplines. Without mathematics, it is impossible to master other STEM disciplines. By using innovative strategies, mathematics can be made successful for all students. To engage students, they should be motivated to study mathematics, the natural sciences, technology, and engineering. An additional advantage is starting at an early age.

Research projects should be promoted, and educational programs and curricula designed for STEM integration must be developed with equal attention given to all disciplines, particularly mathematics. Mathematics teachers have a responsibility to integrate STEM disciplines effectively, and the role of mathematics within STEM needs to be further reinforced. When appropriate teaching approaches are used correctly, they can establish a meaningful learning environment that enhances students' attitudes and motivation toward acquiring knowledge in STEM subjects. STEM integration that employs real world problems and projects has the potential to create meaningful learning experiences. Teaching and learning through a comprehensive STEM approach offers an alternative way to foster students' interest in mathematics.

To conclude this subsection, it should be noted that mathematics is often undervalued as part of the STEM disciplines. Most students view mathematics solely as a means of solving problems, while they believe that only science, technology, and engineering can be used to create innovations.

This perception may arise due to the complexity of the subject in educational institutions. Many researchers recommend demonstrating the practical application of mathematics in real life and using various exercises to inspire confidence that other

disciplines cannot be mastered without mathematics. Without mathematics, the other three disciplines lose their precision, as mathematics serves as both a tool and a language. Thus, the effectiveness of STEM education largely depends on students' ability to use mathematics as a thinking tool, and not just to perform calculations. The main problem is that, in the opinion of most students, they believe that mathematics is necessary only in school. And so, teachers should show the importance mathematics of each topic during the lesson.

2.4 STEM-based approaches in teaching mathematics

Mathematics, like the STEM section, is a discipline that students often find challenging and may even try to avoid. This leads to a lack of understanding of mathematical concepts and their use in everyday life. Despite the fact that mathematics constantly surrounds us, even when we try to move away from it, we eventually return to it. The problem is not related to mathematics itself, but to people with whom, unfortunately, there were no favorable meetings when studying this subject. Therefore, as teachers, we are obliged to regularly create positive moments during the teaching of mathematics. Standard or monotonous study of mathematics tends to reduce interest in the subject. However, when mathematics is presented in a fun way, and its principles are connected to everyday activities in a fun way, it can also become an intriguing activity. The lack of actual practice of teaching mathematics in schools remains a serious obstacle to learning. Other courses, such as natural sciences, often allow young people to put into practice the concepts they are taught, while mathematics still rarely provides such opportunities (Firdaus et al., 2020).

The STEM methodology can be conveyed via diverse instruction techniques, one being the "Engineering Design Process". As per the "Accreditation Board for Engineering and Technology, engineering design" is characterized as the method of conceiving a system, element, or procedure to satisfy required needs. It is a judgment process, frequently repetitive, where fundamental "sciences, mathematics, and engineering" principles are employed to best transform resources to attain a declared goal.

The "Engineering Design Process" constitutes an interdisciplinary teaching technique that incorporates elements of "science, technology, engineering, and mathematics". Alongside STEM, this instructional method is gaining greater prevalence since it is thought capable of tackling forthcoming difficulties. This stems from the reality that this approach is abundant in learning activities that exercise skills of the 21st century, widely termed the "4Cs: Critical Thinking, Collaboration, Communication, and Creativity" (Firdaus et al., 2020).

Stohlmann (2020) studied technology incorporated STEM education within the framework of open play learning. Game-based learning has generated worldwide interest and has been proposed as an effective educational approach that can enhance students' interest in mathematics and academic performance. Students often interact with technology games either through video games or through portable applications. However, when game-based learning is used in math lessons, it is often not used in the very effective way. For example, quite of the games used in previous math lessons were based on memorization and repetition.

According to Stohlmann (2020), STEM learning through game learning has several key characteristics that contribute to more effective application. Initially, the introduction of technology should make it possible to develop new types of activities that would be impossible without the use of technology, or significantly change the form of activity. Therefore, the activities used should be useful, which implies that there are no rules or procedures established, and there should be no feeling that there is a "correct" solution method. The activity must meet the criteria at the class level. Fourth, courses should allow students to work with different perceptions. Technology should ensure the contribution of students. Finally, the courses should be unlimited and promote dialogue and achieve multiple outcomes.

When skillfully crafted, technology-focused math endeavors can engage students in calculations and assist in establishing their meaningful understanding. One sample of game-based teaching that secondary school math instructors might employ involves coding and automated gadgets. There is a growing drive for districts to require

computer science subjects for older pupils. As learners' competence in computer science increases, the chance for math teachers to include programming and game-based learning also expands. Modern programming instruments are becoming more approachable as well, which might make math educators more eager to incorporate coding. Offering pupils this type of challenge is crucial, since application software developers constitute the largest STEM vocation (Stohlmann, 2018). And there is a need for more qualified workers in this field.

Akiri, Tor, and Dori (2021) evaluated traditional teaching methods that include digital screens, conversations, whiteboards, videos, and alternative methods that do not require active student participation. These methods are considered teacher-oriented. On the contrary, attractive learning approaches are new strategies that encourage students to actively participate and allow them to independently determine the learning rate and control the learning process. Engaging methods encourage students to acquire knowledge based on first-hand experience. They are considered student-centered teaching methods and are most closely related to constructivist theory, which advocates meaningful and active learning. Highlighted learning styles include: project-based learning, inquiry-based learning, content or context-based learning, teamwork, and group conversations.

Kong and Mohd Matore (2021) investigated the application of STEM in mathematics teaching and concluded that inquiry-based teaching and problem-solving methods can significantly improve students' understanding and problem-solving ability. During their studies, students participated in tasks such as conceptualizing and building an ideal home using three-dimensional geometric shapes such as cuboids, cylinders, and cones, which helped them apply mathematical principles to real-world environments.

The authors highlighted that, unlike conventional teaching methods that focus primarily on individual learning and memorization, the STEM approach emphasizes collaborative group work and interactive tasks. Through these activities, students develop higher-order thinking skills, critical reasoning, and a deeper understanding of

geometric formulas by actively exploring and applying them rather than merely memorizing. Overall, Kong and Mohd Matore (2021) concluded that STEM-based learning fosters collaboration, critical thinking, and meaningful engagement with mathematical concepts.

By the time students move into high school, it becomes more likely that they are familiar with engineering design to some extent. Several other states have also included engineering design in their scientific standards. Then the implementation of engineering projects will be quite easy. In addition, it may increase interest in future career choices. Even if learners have not encountered engineering design before entering high school, there are activities that secondary mathematics instructors can employ known as "Model Eliciting Activities", which have a strong basis in both research and application within mathematics instruction. These activities were explicitly designed to concentrate on the mathematical knowledge and competencies required for success beyond the school setting. The world contains many complex systems, and individuals who can grasp these systems are likely to be more successful.

The engineering design process is integrated within MEAs as students express, validate, and refine their concepts. MEAs assist students in realizing that most engineering challenges lack a single correct answer and underscore the innovative aspect of engineering. Furthermore, MEAs can function as a formative evaluation instrument or as a means for students to utilize the mathematics they grasped in prior instruction (Stohlmann, 2020).

The method of creating media embodies an effective pedagogical approach within the framework of STEM education, which requires students to create digital multimedia content using various technological tools. Creating multimedia helps students understand complex concepts and apply this knowledge accordingly. In addition, it helps students to better cope with dilemmas, develop control, inventive thinking and interpersonal skills, as well as conceptual understanding, commitment and participation in the learning process.

Modern devices can forge distinct routes for incorporating media creation procedures into schooling. Illustrations of media creation employed in education involve public service broadcasts, digital narratives, and animated sequences. Public service broadcasts have been employed in academic environments to elevate students' cognizance of societal and ecological matters (Karahan et al., 2015).

According to Jawad et al. (2021), STEM transforms the methods used to teach mathematics and school sciences. Through this approach, students become fully immersed in scientific knowledge, abilities, and mental habits. They actively search for information on their own, provide creative solutions to problems, and develop sound scientific thinking. STEM also plays a role in reshaping the visions and goals of education, shifting the focus toward achieving comprehension of mathematics and science along with their applications for all individuals, rather than exclusively for an elite class.

2.5 Digital technologies in STEM-oriented mathematics teaching

In today's world, characterized by the rapid pace of technological development, teaching STEM disciplines is becoming not only an essential component of the educational process but also a challenge for the instructional community. With the introduction of digital technologies into pedagogic practices, a new era has begun in which educators and learners must adapt to a quickly changing information environment. Digital technologies in STEM instruction present numerous new opportunities, while at the same time posing considerable difficulties.

Given this context, STEM training is regarded within the academic community as a purposeful approach for preparing a new generation of specialists who are better equipped to handle the demands of the current technological landscape. STEM education aims to reflect the real world, where tasks and challenges often require the application of knowledge from diverse scientific and technological fields. Within STEM education, educators ensure that curricula are practical, help students develop their technical abilities, and spark their interest in science and technology. This

approach seeks to prepare young people for the opportunities and challenges of a technologically advanced modern world (Cirneanu & Moldoveanu, 2024).

One of the main goals of integrating digital technologies into mathematics education is to improve understanding. This goal has long been considered attractive and remains a dominant theme over time: digital technologies can offer new ways to promote understanding, make learning more productive, and stimulate deeper learning. The perspective supporting this goal seems to be based on the idea that mathematics itself remains fundamentally unchanged due to the availability of digital technologies. Therefore, the essence of practicing and understanding mathematics does not really change. Doing math using digital technology is in many ways similar to working with non-digital tools, although it is also noticeably different. Rather than changing the nature of mathematics, digital technologies simply offer new ways of understanding concepts that may prove more effective, whether in terms of understanding, evaluating, or learning effectiveness (Drijvers & Sinclair, 2024).

The application of digital technology can improve integrated mathematics instruction by offering interactive and captivating instruments for learning and rehearsal. Digital technology may be integrated into mathematics instruction via the following avenues:

1. If a student doesn't fully understand a topic, they can use online resources. Video lessons can help them understand or supplement their theoretical knowledge, and then, using practical exercises provided in the resource, they can apply their knowledge of the materials.
2. Many applications are available that allow students to develop mathematical skills in an enjoyable and motivating way. Software such as Khan Academy offers immediate feedback and helps students track their progress on digital platforms (Cirneanu & Moldoveanu, 2024).

Digital technologies can also reinforce constructivist teaching methods. This approach encourages students to independently discover answers and draw conclusions. Digital tools also help students more easily understand a topic

using various visual concepts. This, in turn, develops interest in the subject and experience with technology. For instance, engaging simulations and online assessments can permit learners to proactively investigate ideas alone, letting them shape their understanding via firsthand experience. Moreover, digital instruments can offer students access to assorted viewpoints and data origins, permitting them to construct their expertise founded on numerous standpoints. Furthermore, from the viewpoint of the Technology Acceptance Model, several elements that might affect students' uptake and utilization of digital apparatuses can be pinpointed. Pursuant to Technology Acceptance Model, two main elements impact users' readiness to accept technology:

3. When teachers struggle to explain geometry topics, such as 3D figures, theoretically, they use technology. Consequently, visualization and a deeper understanding of the subject become easier and simpler.
4. Students also use technology to solve complex problems. It's also used in project work to facilitate research.

Learners' contentment with digital instruments is probably to be greater if they see them as worthwhile and advantageous for their scholastic and private requirements (Cirneanu & Moldoveanu, 2024).

Given the expanding usage of technology, outlined five separate stages in employing digital implements in mathematics instruction, detailing diverse manners that digital resources impact this domain. Conceptual viewpoints have arisen that stress the significance of tools and the broader function of technology in knowledge generation. There is a rising inclination toward seeing knowledge building as something formed not just by groups comprising people solely, but by collectives that incorporate both people and objects. Scholars both inside and outside mathematics education support this stance and suggest different methods for perceiving how digital apparatus is increasingly altering how we understand, as well as what we understand. Frameworks concerning how we know and what we know highlight the influence of objects (Borba et al., 2023).

The idea of "humans with media" was formalized by Borba et al. (2023), who combined how this concept might be interpreted based on the research of Borba et al. (2023) and Villarreal et al. (2023) and Lévy (1993), furthering the notion that education is communal. This general aspect of learning implies that it affects not only the individual, but also "objects" such as applications, devices, and the Internet. Borba (2021) illustrated how different environments shape people, and also provided examples of how people influence technology. It described in detail the interaction between the software and the interaction of students with applications and the teacher. When relevant assignments appear, a group of students and teachers can use software to put forward hypotheses and evaluate them, then groups of people can use software and written materials to find evidence during the lesson. There are times when students and teachers have used the software in ways that the creators did not expect (for example, spreadsheets). Consequently, the conception of humans with media as a single entity builds understanding, with technology forming people and people molding technology. Jacinto and Carreira (2017) employed this viewpoint to examine how pupils alongside GeoGebra resolved issues in elementary schooling. Others, such as Villarreal et al. (2023), utilized this structure to examine how digital tools altered instruction and learning throughout the pandemic.

The query regarding whether digital innovations can offer different avenues for undertaking mathematics instruction has frequently been posed. Borba (2016) employed the theoretical framework of humans with media to link the pandemic to varied directions in mathematics pedagogy: the utilization of digital tools, theory of mathematics education, and critical mathematics instruction. He broadened the influence of digital platforms to encompass residences as well. Amid the pandemic, the function of homes grew more apparent as a core participant in mathematics teaching, demonstrating that suitable settings at home and accessible web connectivity were essential. This significance does not appear to have decreased following the pandemic. Indeed, the crisis helped reveal the part that diverse domestic circumstances, or the influence of home, played in grasping mathematics (Borba et al., 2023). With the

increasing visibility of AI instruments, the concept that technology possesses agency, inherent in the idea of humans with media, has gained even greater force (Engelbrecht & Borba, 2024).

Easton et al. (2020) examined integrated STEM projects that employ digital technologies to foster comprehension of mathematics. One such endeavor includes Kitsi Blocks, which can be utilized to promote successful integrated STEM instruction with a notable focus on technology and mathematics. The visual coding language of Kitsi is straightforward to grasp and employ. As a visual programming framework that also provides the selection of script coding, Kitsi is reachable for pupils from early grades up to higher education. It serves as an effective tool for studying the interaction between physical components and software, as well as for developing computational thinking abilities. These skills expand and strengthen the ability to find mathematical solutions, allowing students to learn new mathematical methods and acquire knowledge in a variety of settings. In addition, students will increase their passion and interest in mathematics and technology.

Additionally, this technology depends significantly on numeracy and mathematical understanding, where thirteen of its Logic Gates directly utilize mathematical terms, including concepts like summation, exceeding or falling short of, and equation, while also necessitating numerical calculation. This correlation with mathematical language is very helpful for cultivating mathematical proficiency, which frequently presents a significant barrier to education. Employing a logic-based block coding system as a component of the Kitsi technology makes it a potent instrument for advancing students' computational thought abilities. Building logic using logical blocks instead of the dialect of text encoding emphasizes the development of the four pillars of computer thinking: abstraction, separation, finding common ground and identifying trends and methodical thinking. This is because students can focus on building logical sequences instead of learning the grammar of a programming language.

Easton et al. (2020) also examined an alternative method, employing Problem Based Learning (PBL) as a base for implementing Kitsi in combined STEM undertakings with a focus on mathematics instruction. The problem-centered methodology is a robust substitute for conventional math teaching, as it fosters students' conceptual grasp of the subject matter while concurrently enhancing their mathematical comprehension, proficiency, logic, and problem-solving abilities. Three principal tenets underpin PBL:

1. The students of the part fill out the application for the solution of the program for a long time.
2. Students have the opportunity to solve many questions.
3. Classes should be organized in a framework based on mathematical concepts.

Employing digital tools like Kitsi Blocks can aid in promoting STEM tasks with practical relevance, such as the construction of a heart rate sensor project detailed by Easton et al. (2020).

Current conditions of societal development, along with labor market analysis and established research sources, demonstrate the necessity of employing modern digital tools, as well as selecting and creating online environments that can help develop the required competencies. These tools aim not only to achieve educational objectives but also to enhance learning overall.

STEM education often uses digital tools that make it easier for students to experiment and explore. One of the most important tools is virtual laboratories that help students study and observe the impact, review the data. Most often, educational institution does not use digital tools in those subjects that are necessary for studying, but instead introduce theory. It is important to understand the need of technology, including virtual reality, which is important for science education (Hrynevych et al., 2021). Nowadays, technology is rapidly advancing, requiring everyone to understand the basics and be able to use them optimally. However, there is an exception: the development of digital technologies has led to changes in mathematics. The most significant shift has occurred in how people use mathematics, with which various

mathematical procedures can be calculated. This has definitely impacted mathematics instruction, with an increasing number of students dismissing the subject, citing technology as a reason. Nevertheless, this transformation represents a distinct opportunity to develop effective users of mathematics (Devlin, 2021)

2.6 Effectiveness of the STEM in mathematics

The success of teaching STEM concepts depends on using effective learning approaches. Learning approaches can be defined as specific methods used to feed learning material. Scientists have determined that learning approaches are one of the main factors affecting students' concentration, comprehension, and memory. A lecture course is an approach to learning that is most often used in the general education system, followed by collaborative learning and conversation (Smith, Rayfield, & McKim, 2015). Arithmetic furnishes the needed instruments and vocabulary to investigate scientific occurrences, examine facts, and devise technical answers. Lacking a firm grasp of arithmetic, learners would face difficulty comprehending the intricacies of "science, technology, and engineering." Within STEM instruction, arithmetic is not instructed separately but is woven into actual situations. Pupils learn to utilize mathematical notions and guidelines to resolve practical issues. This method, focused on practical use, makes arithmetic more relevant and valuable, as students can observe its direct impact on their lives and their environment. This practical teaching method allows students to notice the importance of arithmetic in their daily lives, doing it more pleasant and valuable. Thus, to show that mathematics surrounds us and even simple things (Eshaq, 2024).

Moreover, technology provides learners with chances for joint study and worldwide links. It is vital for instructors to employ technology successfully in STEM instruction to boost math acquisition. Through incorporating technology into the classroom, teachers can fashion captivating and participatory learning settings that inspire pupils to investigate and excel in mathematics. Numerous investigations have shown that weaving STEM themes into the classroom boosts pupils' mathematical proficiencies. Initially, evidence suggests that STEM instruction improves

mathematical comprehension by offering concrete uses and direct involvement. Mathematical learning encompasses honing analytical, problem solving, and reasoning talents in youngsters, all of which are promoted by STEM endeavors. An additional advantage of STEM schooling is that it stimulates cross curricular study, permitting students to forge links between mathematics and other STEM disciplines. This blending results in greater achievement levels by reinforcing learners' capability to use mathematical concepts in actual scenarios (Eshaq, 2024).

STEM initiatives emphasize critical thought and functional expertise, readying pupils to confront the demands of the twenty-first century. This suggests that STEM instruction transcends mere memorization and prompts students to utilize their learning in actual scenarios. This form of schooling fosters the development of inventive projects within STEM fields (Nağaç & Kalaycı, 2021). The practical method enables learners to employ their understanding and troubleshooting abilities in novel manners. By furnishing students with STEM proficiencies, they are better positioned to join the job market and aid sectors dependent on science and technology. It endeavors to cultivate scientific awareness among students. Many investigations have consistently shown that integrating STEM education within mathematics teaching boosts children's calculation skill. Students engaged in STEM tasks display improved troubleshooting talents, the aptitude for analytical pondering, and a stronger conceptual grip of numerical concepts. Constructivism, which champions active learning and experiential activities, and the socio-cultural theory, which stresses the worth of social exchanges and group study in math instruction, are two theoretical foundations backing the positive outcomes of STEM education on math success (Crabtree et al., 2019). These foundations endorse student-focused and investigative teaching approaches, which correspond with the principles of STEM education. This entails not only transferring subject-specific wisdom but also instructing pupils how to reason critically and apply scientific concepts to diverse circumstances (Fufa et al., 2023).

In this study, the implementation of various methods shown significant results, and no inconsistencies were found in the experiment. To improve student performance

and motivation, practical skills that enhance critical thinking were used. A research approach and group projects were also used. The authors of this study also recommend that future studies examine the implementation of STEM education in various student classes and educational institutions (Gnagey & Lavertu, 2016). This would help clarify your understanding of the impact of STEM education.

Numerous previous studies examining the positive effects of Science, Technology, Engineering, and Mathematics (STEM) programs on student attainment attitudes, interest, communication skills, and problem solving have alerted the education community to the need for reforming instructional approaches in STEM subjects (Han et al., 2015; Kazu & Kurtoglu Yalcin, 2021). Furthermore, incorporating STEM education into mathematics instruction suggests that additional research could provide insights into its broader impact (Eshaq, 2024).

Elsayed (2022) pointed out the rising attention to the STEM method amid the interdisciplinary trend that combines "science, technology, engineering, and mathematics". The study emphasized that the creation and implementation of STEM-based educational plans can enhance students' mathematical skills through the development of conceptual understanding, precision procedures, strategic skills, adaptive thinking, and productive attitudes. The paper also examines the successful use of cloud computing tools within the STEM framework.

Elsayed (2022) recommended incorporating cloud-based tools and activities that relate to students' daily lives and surrounding environment, as these strategies make mathematical knowledge more engaging and meaningful. In addition, the study identified classroom practices and educational community support as key factors in enhancing students' mathematical proficiency. The findings also highlighted those strategies such as SCAMPER-a mental brainstorming technique can effectively promote mathematical thinking and problem-solving skills among university students. In summary, Elsayed (2022) determined that incorporating STEM methods into mathematics syllabi not only enhances learning results but also fosters analytical thought, inventiveness, and lively involvement in practical settings.

Niam and Asikin (2020) used a research and development approach to develop and evaluate STEM-oriented mathematical learning resources designed to develop mathematical communication skills in students. The research focused on developing a textbook for students on systems of linear equations, which was tested by seven experts and then tested in a real learning environment. The research procedure included problem identification, data collection, product concept development, validation, application testing, pilot evaluation before and after testing, and product completion. The results showed that the created learning resources were reliable, useful, and effective in improving students' ability to connect mathematical ideas. In particular, the results of early and subsequent tests showed a marked increase in mathematical skills after using STEM-oriented content. The authors noted that linking textbooks directly to aspects of STEM, as well as involving and contextualizing learning activities, sets this study apart from other studies by providing specific and applicable material for classroom implementation. In addition, the textbooks were copyrighted.

To summarize, Niam and Asikin (2020) emphasized the importance of developing STEM-based learning tools that are not only theoretically sound, but also practically capable of developing critical mathematical skills, providing a suitable framework for incorporating STEM principles into mathematics education.

Bekiyeva, Yazdurdyeva, and Orazova (2025) investigated the implementation of the STEM method in mathematics education, emphasizing its practical application and success. The study showed that the fundamental principle of the STEM approach is to connect mathematics with real-life problems, which allows students to understand the meaning of mathematical ideas in everyday life and in various fields. As an illustration, students can use algebraic formulas to determine the cost of resources needed to implement initiatives, or use geometric rules to build an arc, develop analytical thinking, collaborative efforts, and problem-solving skills.

The authors also examined the use of technology in mathematics teaching as a central element of the STEM method. Tools such as programs, calculators, and emulators allow students to represent and operate mathematical concepts. For example,

in geometry lessons, students can use software like GeoGebra to calculate the extent, edges, and rotations of shapes, while noting how changes in measurements affect these calculations. This technological combination enhances students' understanding and gives them the skills they need to work in STEM.

Furthermore, Bekiyeva et al. (2025) stressed the function of project-based study (PBL) and cross-curricular links. PBL promotes pupils to partake in extended tasks that necessitate utilizing mathematical expertise for practical issues. In one case, students studied data on air pollution in neighboring areas using statistical methods, which shows the important role of mathematics in environmental research and other STEM fields. The study concluded that the STEM approach increases student engagement by linking mathematics with practical applications and interdisciplinary projects. When students realize the real value of what they are learning, they become more motivated to effectively understand and apply mathematical concepts.

The most frequently mentioned support method for improving the effectiveness of STEM teaching is to allow teachers to develop their skills to skillfully incorporate STEM materials into their lesson plans. Educators at various professional stages have experienced a significant increase in their confidence, understanding, and sense of competence in STEM teaching after attending teacher training courses (Margot and Kettler, 2019). Good professional development or continuing education should provide teachers with sufficient duration and a foundation to explore how STEM can be integrated into what they teach, while paying more attention to educating teachers about the subject and practical interaction with STEM. The findings suggest that these aspects have a direct impact on teaching methods and student participation (Margot & Kettler, 2019).

Teachers were looking for additional methods to improve students' academic performance in engineering and design activities. Educators need help integrating engineering design into their math and science programs. Teachers believe that preparation and execution should be conducted on an ongoing basis and include

learning resources that they can use to improve student academic performance (Margot & Kettler, 2019).

2.7 Challenges of implementing STEM in mathematics teaching

Hubal et al. (2024) analyze the utilization of digital technologies in the procedure of instructing STEM subjects, concentrating on both hurdles and outlooks. This study identifies new and successful approaches and tools for STEM education using digital technologies, highlighting the potential for new creative achievements in this field. The authors also face specific challenges that arise when teaching STEM using electronic media, which include technical, pedagogical, and managerial obstacles. In addition, the study evaluates the impact of digital technologies on STEM studies based on research and offers prospects for their application in real-world settings.

The study uses interview and questionnaire methods, and the authors acknowledge the limitations associated with these methods. Regarding interviews, the influence of the interviewer on the responses can skew the results, as different interviewers can shape the participants' opinions in different ways. Subjects may also give false answers or socially acceptable answers due to the interviewer effect. Similarly, the survey method has its drawbacks. These include a low response rate, especially if participants don't show interest or realize the importance of the topic. In addition, the questionnaire limits the ability to obtain detailed explanations of respondents' responses and may be less effective in verifying the accuracy of the information collected than other research methods. The main concern relates to mathematics educators' views on the usefulness of STEM activities in secondary school mathematics instruction. A significant limitation involves connecting STEM tasks to specific content or competencies within the mathematics syllabus. This also affects teachers who introduce STEM methods without preparation or a clear definition. In mathematics, it's important to emphasize its role and relevance in other areas. Ignoring this fact negatively impacts the motivation and interest of students struggling with the subject.

Wang (2013) noted that the main obstacles for teachers are programming restrictions, as well as technological and resource constraints during STEM tasks, which leads to difficulties in applying STEM tasks in practice. Although some resources for the development and execution of STEM tasks are readily available, other technological components are still difficult to find or manufacture, in particular (Sevimli and Ünal, 2022).

Although the majority of math teachers (over 90%) believe that integrating STEM teaching provides effective learning strategies, the main problem in terms of learning is time. Although these teachers believe that STEM integration makes math materials more accessible for student-centered learning, about 70% of them are concerned about the need to increase study time. Other studies have reported similar problems related to weather conditions. For instance, Bagiati and Evangelou (2015) emphasized in their study that teachers need to find additional time to plan with other subject areas and to prepare materials for students. This makes lack of time one of the teachers' primary concerns when implementing STEM. These studies also highlighted those teachers were concerned about the increased workload associated with STEM programming (Koklu & Phan, 2020).

One of the main challenges in introducing STEM into mathematics in schools is the format of instruction they are accustomed to. Students who have already mastered traditional methods may find it difficult to understand real-world problem solving and see the communication between mathematics and other subjects. The advantage of STEM is that the problems are developed for real-life situations that can be solved in various ways, while students accustomed to calculations using formulas will be more difficult to master.

In their study, Koomanova and Kaldybaev (2025) identified several challenges associated with implementing STEM in schools. Among the main challenges is the shortage of qualified teachers. In spite of the yearly commencement of many university scholars, the nation persists in confronting a severe lack of experts in diverse sectors, such as instruction. The current academic setting imposes heightened expectations

upon educators' proficiencies, particularly within STEM instruction. Conventional instruction techniques centered on sharing theoretical expertise are proving inadequate for readying pupils for the swiftly evolving needs of a technologically superior populace. Integrating STEM technologies suggests a movement toward more engaging and practical instructional techniques, necessitating that tutors embrace an altered perspective on structuring the educational venture. Many mentors consider themselves insufficiently prepared to implement STEM learning, which corresponds to a lack of training and ongoing support. It is difficult for teachers to integrate STEM approaches into their subjects, especially if their core background is different from STEM. The lack of competent instructors is not the only problem faced by the education system in implementing STEM strategies. Even when teachers have the necessary pedagogical skills and methods, their successful use largely depends on access to appropriate educational materials and tools. The lack of educational equipment and infrastructure is a major obstacle to successful STEM teaching. Many modern educational institutions do not have well-equipped laboratories, computer labs, 3D printers or other modern tools necessary for practical activities. As a result, students have few opportunities to conduct experiments, work with real data and master technologies that are actively used in scientific and technical practice. In addition, limited resources lead to a lack of time and space for STEM activities. In educational institutions, especially in developing countries, class schedules often do not include overtime devoted to research activities, and classrooms and labs can be used for traditional classes, making it difficult to organize STEM projects. This reduces students' chances of participating in active learning by hindering the development of core STEM skills such as critical thinking, problem solving, and collaboration.

Combining various STEM fields into a single learning process is a complex task that requires significant changes in established teaching methods. Unlike discipline-specific teaching, where each area is taught in isolation, STEM teaching requires combining them to solve practical problems, develop analytical thinking, and use practical experience (Koomanova & Kaldybaev, 2025).

3. METHODOLOGY

3.1 Research instruments

The study used a quantitative research design. In this study, these instruments were used to measure the influence of STEM on fifth grade students' performance in mathematics and their attitudes toward the subject: an achievement test and a questionnaire. The questionnaire was not used as a qualitative research tool, as it consisted of closed multiple-choice questions. The answers were analyzed quantitatively and presented in the form of percentages and diagrams. These tools can be used to glean both quantitative data on students' mathematical knowledge and information about their interest, and attitude toward the subject.

The achievement test was designed to assess students' proficiency in mathematics. This test includes a variety of tasks that cover the curriculum. The test ranges from simple calculations to word problems. The test consisted of several selection questions. The content validity of the test was ensured in several ways. First, the test was borrowed from a scientific article in which its reliability was evaluated and confirmed by the authors of the study. Second, to enhance content validity in the context of this study, the test was additionally reviewed by experienced mathematics teachers. The tasks were evaluated for their alignment with the curriculum, learning objectives, and the age-specific characteristics of the students, which confirmed its applicability within the framework of this study.

The reliability of the instrument was determined exploitation Generalizability Theory (*G-theory*), which allows for the analysis of various sources of variability in the results. This method serves to assess the degree of stability and consistency of the data obtained.

For the purpose of analysis, reliability coefficients (*G-coefficients*) were calculated. The results showed that with the participation of a single expert, the level of reliability is not sufficiently high. However, when two or three evaluators are involved, reliability increases significantly, reaching acceptable levels. Additionally,

item analysis was implemented to ascertain the obstacle level and differentiation index of each question, ensuring that the test was both challenging and fair.

The student questionnaire serves as a supplementary research tool. It was used to assess students' interest in mathematics, as well as their perceptions of teaching methods within the STEM framework. It makes it possible to assess their level of interest in the subject, the attitude of students towards their learning in mathematics and as well as their awareness of STEM-based learning. In addition, the questionnaire helps to identify STEM-based activities that students recognize in the learning process.

The collected data makes it possible to analyze the influence STEM on student engagement and their perception of mathematics. The questionnaire's structure, which includes multiple-choice questions, facilitates data processing. Thus, this tool plays a role in identifying patterns and trends related to the effectiveness of modern educational methods in middle schools.

The questionnaire for this study was adapted from a previously published article by Zhotabai and Kadirbaeva (2025), which described an experiment similar in scope to this study. That article utilized a pre-existing tool to assess students' attitudes toward mathematics and their perceiving of STEM teaching methods. In this study, the questionnaire was used virtually unchanged.

By employing these two robust instruments, the study aimed to assure a comprehensive understanding of how STEM learning factors both the mathematical performance and the approach of fifth grade students towards mathematics. The findings can be used to further improve STEM education and implement learning in schools. Thus, the study confirms the importance of combining theoretical training with practical approaches in mathematics education.

3.1.1 Achievement test

Administering and scoring academic performance tests is a crucial part of the study. Since this tool is a key factor in determining the outcome of the experiment, it is designed to ensure the validity and reliability of the data. This test was taken from the "New York State Testing Program Grade 5 Mathematics Test".

Multiple-choice assignments are typical standards for teaching mathematics in New York State. Multiple-choice items incorporate both the grade-level benchmarks and the standards for mathematical practices. Numerous questions are set within the setting of real-world uses or necessitate pupils to finish several steps. Similarly, many of these items are connected to over one standard, utilizing the concurrent execution of multiple abilities and ideas. This test is discussed in the article "Rater Variability and Reliability of Constructed Response Questions in New York State High-Stakes Tests of English Language Arts and Mathematics" by Huang and Whipple (2023). The study analyzes reliability; this process involved several key stages.

First, the fifth-grade test was evaluated by various experts. Using generalizability theory, random effects were also considered. This allowed to determine the test's reliability. Second, a test was conducted that requires explanation. To ensure complete reliability, different grades were selected.

"*CTT* and *G*-theory are both used as methods for detecting rater variation. However, *G*-theory is a more powerful approach in the detection of rater variation (Brennan, 2001). Brennan (2000) urges the use of *G*-theory as a method for examining performance assessments due to the focus on discerning which facets are fixed and which are random as an effort toward improving reliability. To sum up, although there is a significant research base regarding assessment reliability across the psychometric and educational canon, it is important to consider sources of variance, as well as important indicators of quality, most specifically rater reliability, on assessments that are administered to an entire population of students regardless of any categorical designation, i.e., the NYSTP in ELA and mathematics. Accountability is a critical element of consideration regarding the administration and uses of assessments and the inferences derived from them, in the current context of these assessments" (Huang & Whipple, 2023, pp. 4-5).

The *G*-studies results for four open-ended math exercises in fifth grade revealed that most of the variance is attributable to the measured object (p), that is, differences among students. The proportion of this "target" variability was 81.20%, 70.58%, 63%,

and 91.22% of the total variance for the four tasks, respectively. The residual variance, reflecting the influence of unaccounted-for factors and random errors, amounted to 17.15%, 25.66%, 34.68%, and 7.48%, respectively, ranking second in terms of magnitude. The influence of the rater variance, which is recognized as undesirable variability, proved to be insignificant, reaching only 1.65%, 3.77%, 2.33%, and 1.12%, respectively, for the four tasks. This indicates a high degree of consistency in evaluation among the experts.

The following formula was used to calculate the *G*-coefficients for interpreting reliability: $\rho^2 = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_\delta^2}$, where: σ_p^2 –the variance associated with the measurement object (students), σ_δ^2 –the total measurement error (including residual and other sources of error). The subsequent reliability coefficients were obtained: 0.83; 0.73; 0.64, and 0.92. As a result, the study shows that the fifth-grade math test is reliable. The inter-rater reliability was low, indicating a large degree of agreement among the raters. The reliability coefficients for most items were at a good level (≥ 0.80). Therefore, it may be inferred that the accomplishment measure is a trustworthy tool (Huang & Whipple, 2023).

The researcher also consulted with education experts to ensure validity. At this stage, the tasks were also validated through expert review to ensure their objectivity, lack of bias, and appropriate level of difficulty. Prior to the main administration, a pilot test was conducted on a sample of students who did not participate in the main study. This permissible for the identification of any potential ambiguities or errors in the tasks. Based on the results and feedback, adjustments were made to improve the clarity and effectiveness of the test.

The researcher arranged for the test to be conducted in the familiar setting where classes had previously been held, so that the students would feel comfortable in a familiar atmosphere. On the day of the test, all students were given general instructions. Each student also had a personal code to ensure the confidentiality of their results, which was explained before the test began. Academic integrity was upheld throughout

the test. To ensure equal conditions for all participants in both groups, time limits were strictly enforced and prohibited materials were not permitted. Upon completion of the test, a secure collection of completed assignments was organized. Throughout the process, special attention was paid to adherence to ethical principles, which ensured the reliability of the results and their relevance to educational practice and guidelines.

3.1.2 Questionnaire

The researcher also administered a questionnaire to the students before the experiment. Where each questionnaire included instructions. The confidentiality of participants' responses was ensured, and the data collected was used exclusively for research purposes. The questionnaire consisted of closed-ended questions, with only one answer per question. There were no correctly or incorrectly answers the only thing that mattered was the students' opinions. This instrument was implement in accordance with the research question to determine the importance of STEM in teaching mathematics, based on a theoretical analysis of pedagogical and scientific articles. To determine students' attitudes towards STEM education and its importance among fifth-grade students. Questionnaire consisted of seven questions and was conducted anonymously on paper. It was determined that the questions in the questionnaire could be used to identify how STEM is reflected in math lessons.

The validity of the questionnaire was ensured through expert review. A pilot test was implement on a sample of students who did not participate in the main study. This allowed to verify the clarity and accuracy of the questions. Since the questionnaire did not constitute a scale measuring a single construct, internal consistency coefficients (e.g., Cronbach's alpha) were not applied.

During the survey, other teachers were present to follow the process and ensure the anonymity of the participants when filling out the questionnaires. The questionnaire was in paper form, as students find it easier to work with paper than with electronic surveys. They are not distracted by cell phones or computers and have a better understanding of the questions. Additionally, the survey was conducted simultaneously for everyone under the same conditions.

3.2 Participants

This study was implemented at the “ECA” Educational Center. Where students attend the center to expand their knowledge of mathematics, hoping to gain a deeper understanding of the subject and improve their proficiency. The center also serves students whose knowledge level is lower and who lack interest in mathematics. This educational center employs a variety of methods to stimulate motivation and interest among students.

Two groups of fifth graders with the Kazakh language of instruction participated in this study. This group consists of 14 girls and 11 boys, for a total of 25 students. The students are between 9 and 10 years old. There are 13 students in the experimental group and 12 in the control group.

All students were in fifth grade, where the foundations of mathematical concepts and skills are laid. The educational institution is focused on achieving academic excellence and fostering critical thinking, offering students a variety of resources, including materials designed to strengthen logic and reasoning, available in classrooms, as well as extracurricular math competitions. Republic academic competitions are held annually, in which students with the highest scores are not selected. Students with less interest also participate in such competitions to boost their motivation the key to learning. In addition, the center’s curriculum emphasizes both group and individual work in the process of learning mathematics. This learning environment is suitable for conducting experiments, as it provides all the necessary conditions.

3.3 Data Collection

The research work began with a thorough preparatory phase, during which the researcher ensured that all participating students were fully informed about the objectives and procedures of the study. This was done to meet the ethical requirement of obtaining informed consent, particularly given the involvement of minors. In addition, it was explained that the study was anonymous in order to protect the

participants' identity and personal information. Permission was also obtained from the parents of all participating students, which ensured their support and consent for their children's participation in the study. The study was designed to assess the impact of STEM-based mathematics instruction on students' mathematical performance. It included both an achievement test, which was administered to the experimental and control groups, and a questionnaire.

The achievement test was administered twice in both groups at the beginning (pre-test) and at the end (post-test) of the study. This double testing allowed for a comparison of changes over time. The study lasted seven weeks and involved the implementation of STEM education, as well as monitoring its impact on academic performance.

Permission was also obtained from the director of the educational center to collect the data. The researcher emphasized the safety and well-being of the students, as well as the confidentiality of their responses. The data was collected using a structured paper-and-pencil test administered to 25 fifth-grade students. The achievement test consisted of 15 questions, each with four answer choices, as well as a 7-question questionnaire. This format is quite familiar to students, as it is frequently used for educational purposes. During the test, students were given ample time, and other teachers were on hand to answer any questions, ensuring that students felt comfortable and reducing their test anxiety.

This careful method of data collection aimed to ensure the reliability and consistency of the knowledge gained, creating a solid foundation for studying the influence of the STEM education in teaching on students' mathematical performance and increasing their interest.

3.4 Implementation Procedure

Before introducing the STEM into the curriculum, students attended an introductory lesson focused on the education itself. This was done to help students adapt more easily; furthermore, such an explanation can spark their interest and increase their engagement in the learning process without it, they might have felt lost.

In the classroom, the teacher used tasks based on real-world problems, contexts from other STEM disciplines, inquiry-based learning, and game-based learning.

1. Use of real-world problems. Each topic includes real-life situations that help students grasp complex mathematical concepts. This approach encourages students to apply their knowledge in practical situations. Students do not simply memorize theory and formulas, but also grasp their practical value. This sparks interest in the subject, sharpens logical thinking, and enhances performance. These exercises were assigned to students both individually and in groups. Through this process, each student was able to hone their independent thinking and collaboration skills. In such tasks, students propose various ways to find solutions, which leads to an exchange of ideas. Some of the mathematical problems used in the study were adapted from PISA and TIMSS, as well as from educational websites available on the Internet.
2. Use of inquiry-based learning. Using this method, students independently master the material. In class, this approach was used as homework. Students explored new material on their own through research. But there are weaknesses, the teacher does not see the research process. Based on this, this method was also used during the lesson. The students were divided into groups where there were both strong and weak. For the whole group, a question was given, which they had to jointly search for information, discuss and analyze. Next, where the students explained their conclusions verbally or through a poster. But there were also restrictions where strong students did not allow the active participation of weak students. Consequently, the researcher used this method in some cases as homework. That is, by alternating in this way, increases the effectiveness of the method. This helps foster students' interest in future scientific research and development. In this segment, students learn to find information, which encourages them to think critically. This encourages active engagement in class, where students learn to explore issues and discuss them. With this method, students were not

simply taught to understand the topic or memorize formulas; instead, they were given the opportunity to grasp mathematical concepts through real-life examples, identify practical applications, and explain their significance.

3. Use of game-based learning. The use of game in the classroom helps students feel more at ease and reduces stress through the use of game-based warm-ups. It also helps reinforce the lesson's topic. To incorporate game-based learning elements into the learning process, interactive educational games sourced from online educational platforms were used. This process was carried out among students in groups and individually. For example, "Catching Dinosaurs: Word Problems with Fractions" in this interactive math game, students apply their knowledge of fractions to real-life situations. This activity teaches students to quickly understand word problems, while also developing their attention to detail and ability to analyze problem conditions. "Space Graph" students practice creating angles and learn how to use a protractor. By working with angles from 0 to 180 degrees, this geometry game helps children understand both acute and obtuse angles. Here, students learn to visually recognize angles. "River Rafting" students will have plenty of opportunities to practice this math skill in fifth grade while competing against their clever friends down the river. This digital game is an exciting way to master decimals and improve math performance. "Decention Jr." this game includes everything needed for this topic: percentage calculations and word problems based on real-life situations. They will learn how to solve problems involving finding a percentage of a number or a fraction of a whole. Kahoot and Quizizz a famous quiz where students compete. Students learn to solve problems quickly and memorize topics. The quiz tasks were created based on real-world tasks. Through the introduction of these methods into the learning process, lessons have become more interactive and have helped students better understand and apply mathematical concepts.

4. Use of content or context from other STEM disciplines. The curriculum is also designed to help students identify connections and apply mathematical concepts to other subjects and situations. This approach emphasizes the interconnections between mathematics and other fields. As students learn mathematics, they will notice how it is used in subjects such as science, biology, computer science, and others. When introducing topics, it is important to demonstrate the relevance of mathematics in other fields.

Using technologies such as interactive whiteboards, Desmos, and Geogebra is also useful. This approach was actively used in the geometric shapes section for fifth grade students; this method contributes to a deeper understanding of the material and prepares students for the next stage of learning - the sixth grade, where the topics become more complex. For example, demonstrating angles using a wall clock, turns on roads, or when an object is tilted. There is also a connection to technology through the use of measuring instruments such as a protractor. In a scientific context, students were asked to consider various aspects of natural phenomena. At the engineering stage, students are given the opportunity to work in groups to create simple geometric models. Through these classes, students will begin to see the connection between mathematics and other subjects.

4. ANALYSIS AND RESULTS

4.1 Questionnaire analysis

As part of this study, the results of a survey conducted to determine students' attitudes toward the STEM education and its significance were analyzed. The responses were examined separately for the experimental and control groups. The *first question* asked how students rated their interest in the subject of mathematics. In the experimental group, 77% reported a high level of interest, 15% reported no interest, and 8% reported disliking the subject; in the control group, 59% reported a high level of interest, 8% reported no interest, and 33% reported disliking the subject (Figure 4.1.1.).

Figure 4.1.1. Students' interest in mathematics

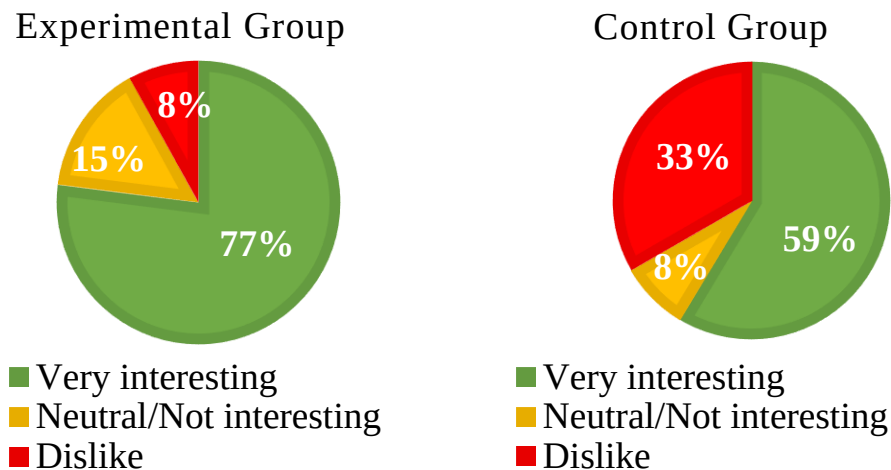
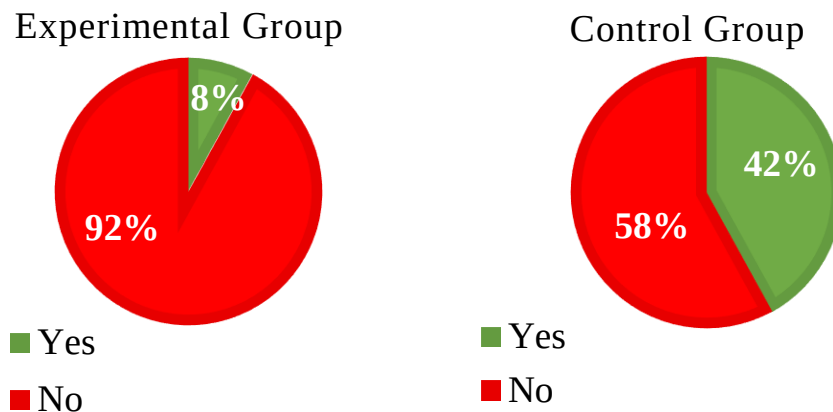


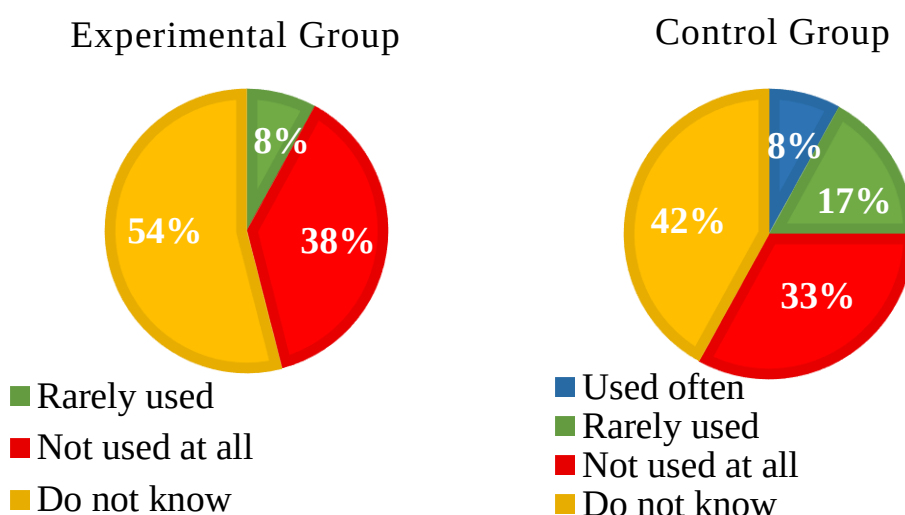
Figure 4.1.2. Students' awareness of STEM



The *second question* focused on awareness of STEM, revealing that in the experimental group, 92% of students were unaware of the STEM, while 8% had some understanding of it. In the control group, 42% were aware of this education, while 58% were not (Figure 4.1.2.). For this reason, it was decided to introduce the education of the STEM to the experimental group prior to the study.

If students answered "yes", how do they understand STEM? Answers to the *third question* showed that students view STEM as a learning method that includes hands-on activities and projects, as well as a new approach to teaching. The *fourth question* was designed to determine whether this education is used in their schools. Figure 4.1.3. shows the finding of the survey, indicating that in both groups, the majority do not know whether this education is used in class.

Figure 4.1.3. Application of STEM in schools

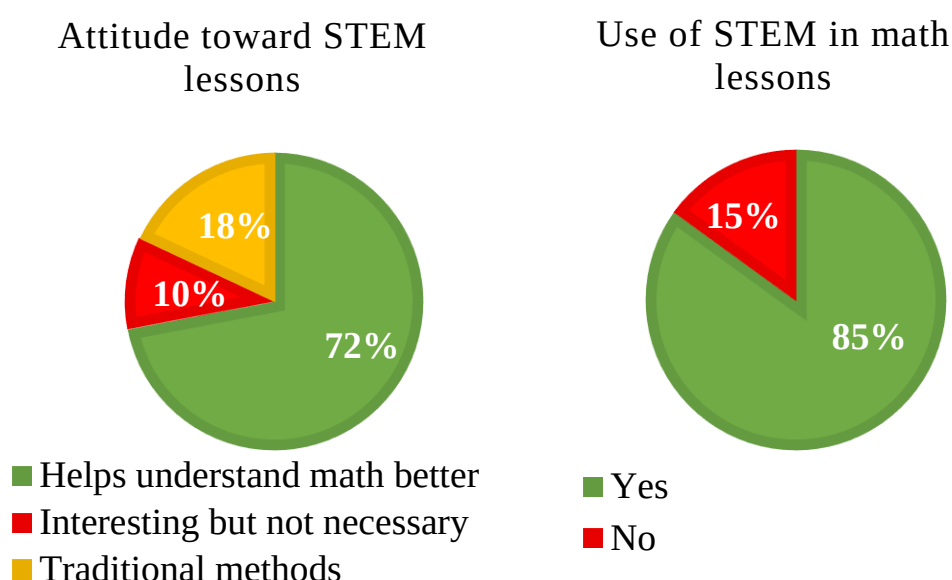


In the *fifth question*, schools where this education is used, students were asked to identify the answer they used to identify STEM elements in their lessons. Most students cited group projects. A detailed analysis results obtained on the *sixth and seventh questions*, since in the control group, according to the survey results, 42% of students knew about STEM. The seventh questions ask whether students like using STEM in math lessons, to which 80% chose the answer don't know, and 20% yes. To the sixth question of whether mathematics becomes more interesting with the help of this education, 40% answered yes and 60% choose no. These results indicate that many

of the students in the control group had insufficient experience using STEM in the lesson.

After the study, the experimental group also completed a follow-up questionnaire. The implementation led to increased interest in mathematics, and all participants were familiar with STEM education. As a result, the students changed their understanding of STEM. They now define it as a method integrating science, technology, engineering, and mathematics, as well as a method of learning through hands-on activities and projects. The main goal was to gauge their interest in mathematics after the implementation of STEM. 72% responded that it had become easier for them to understand mathematics, 10% found it interesting but not necessary for everyone, and 18% preferred traditional methods (Figure 4.1.4.). The final question asked whether students liked that STEM was frequently used in class, to which 85% answered yes and 15% answered no (Figure 4.1.4.).

Figure 4.1.4. Students' perspectives on STEM education and the application of STEM in mathematics instruction



4.2 Achievement test analysis

Table 4.2.1. presents data on the distribution and main trends in the pre-test and post-test results for both the control and experimental groups.

In the control group, comprising 12 participants, the mean score was 9.08, reflecting the baseline level of students' mathematics performance. The median was 10 points, which indicates that half of the students scored below and half scored above this value. Afterward, the post-test mean score increased slightly to 10.17, indicating a small improvement in academic performance of 1.09. Also, the median has not changed. The standard deviation for the pre-test was 2.27, indicating the degree of variability, and decreased to 1.95 in the post-test. The results ranged from a minimum of 4 to a maximum of 11 in the pre-test and from 7 to 13 in the post-test. It can be noted that the maximum and minimum values showed a slight improvement in academic performance in the group.

In the experimental group, which consisted of 13 participants, the average pre-test score was 9.08. After introducing the STEM, the average post-test score increased to 12.08, an increase of 3.00, demonstrating a substantial improvement in academic performance. The median score was 10 on the pre-test and rose to 12 on the post-test. The standard deviation for the pre-test was 2.36, while in the post-test it decreased to 1.80, indicating reduced variability in students' scores. The range of scores was from 5 to 13 in the pre-test and from 9 to 15 in the post-test.

These results show that, following the application of the approach, positive changes in performance were observed in the experimental group. There is a noticeable increase in both the mean and the median, suggesting that the participants improved performance in completing the tasks. The standard deviation decreased, indicating a smaller spread of results after the intervention, that is, reduced variability among scores. Before the intervention, the differences among participants were more pronounced: some showed low performance, while others showed significantly higher performance. After the intervention, these differences decreased, meaning the group became more uniform in terms of knowledge level. The change in range improved, showing an upward shift in score distribution.

This analysis provides information about the effectiveness of STEM in improving academic performance in mathematics.

Table 4.2.1. Descriptive statistics for control and experimental group

	Pre-test	Post-test	Pre-test	Post-test
	Control group	Control group	Experimental group	Experimental group
N	12	12	13	13
Mean	9.08	10.17	9.08	12.08
Median	10	10	10	12
Standard deviation	2.27	1.95	2.36	1.80
Minimum	4	7	5	9
Maximum	11	13	13	15

Table 4.2.2. shows that the experimental and control groups were comparable before the experiment began. The nonparametric Mann-Whitney U test was used for testing. This criterion was used to compare two independent groups, including suitable for small samples. The pre-test result showed U-statistic of 74.50, and the p-value of 0.868. The resulting p-value exceeds the 0.05 significance level, indicating no statistically significant differences between the groups.

Table 4.2.2. Mann–Whitney U test for group comparability

			U	p
Pre-test	Pre-test	Mann-	74.50	0.868
Control group	Experimental group	Whitney U test		

The assumption of normality of pre-test and post-test results in both groups was tested cautiously due to the small sample size. Table 4.2.3. presents the results of the Shapiro-Wilk test conducted to test the hypothesis of the normal distribution of pre- and post-test results in the control and experimental groups. In the control group, the test statistic (W) of 0.963, and the p-value of 0.829. In the experimental group, the

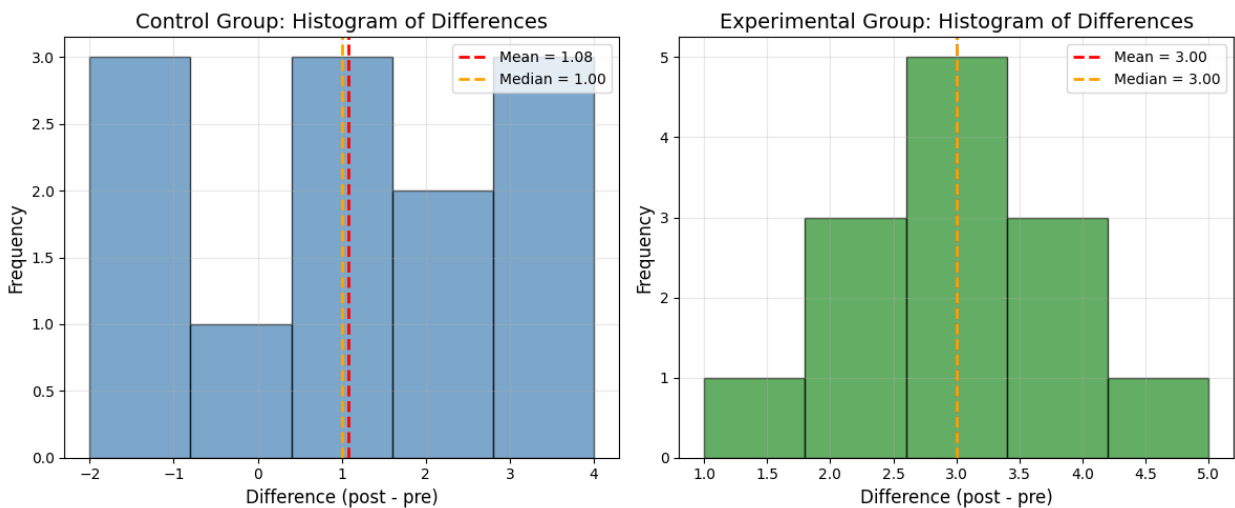
test statistic (W) of 0.942, and the p-value of 0.487. The resulting p-value in both groups exceeds the 0.05 significance level, indicating the absence of statistically significant deviations from the normal distribution. However, with a small sample, the test has low power and may not detect deviations from normality. Therefore, visual inspection, including histograms, Q-Q plots, were used to assess data distribution confirmed by the Shapiro–Wilk test.

Table 4.2.3. Normality test results for the control and experimental groups

		W	p
Control group	Post-test - Pre-test	0.963	0.829
Experimental group	Post-test - Pre-test	0.942	0.487

Figure 4.2.1. shows a histogram for the control and experimental groups. The graph should form a symmetrical bell-shaped curve. In the control group, no central peak is observed, and the data are scattered, indicating that the distribution deviates from normality. In the experimental group, a clear peak is observed, and the data are symmetrical on both sides. Therefore, the distribution can be considered normal.

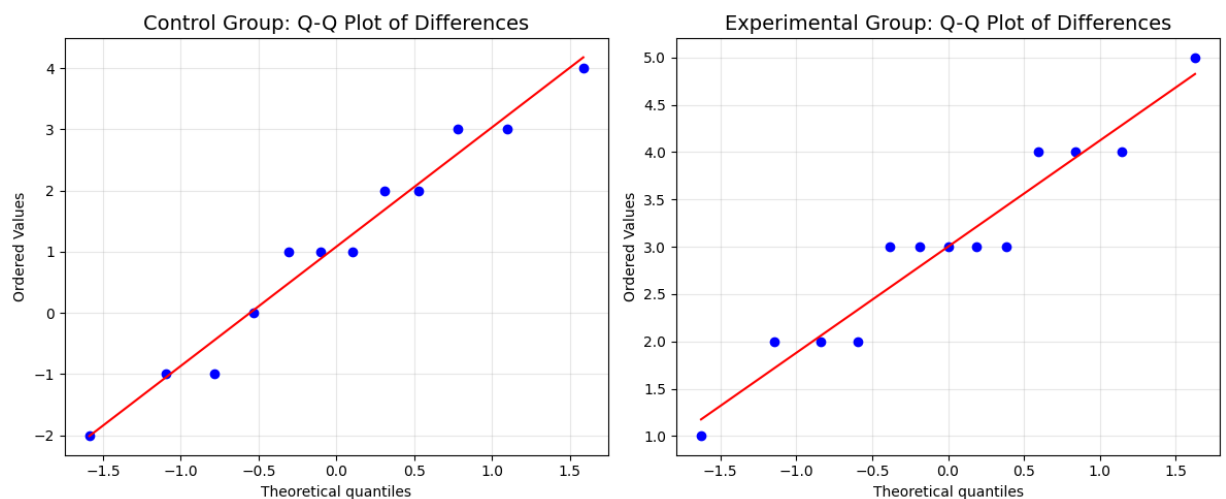
Figure 4.2.1. Visual analysis of the Histogram



Source: Generated using Python

However, for more precise verification, Q-Q plots were also considered in figure 4.2.2. In the control group, the empirical data points are located close to the theoretical line, and there are no strong deviations. There are slight deviations from the straight line in the experimental group of data points. In both figures, the violation of normality is not visible. These results are partially confirmed by histogram analysis.

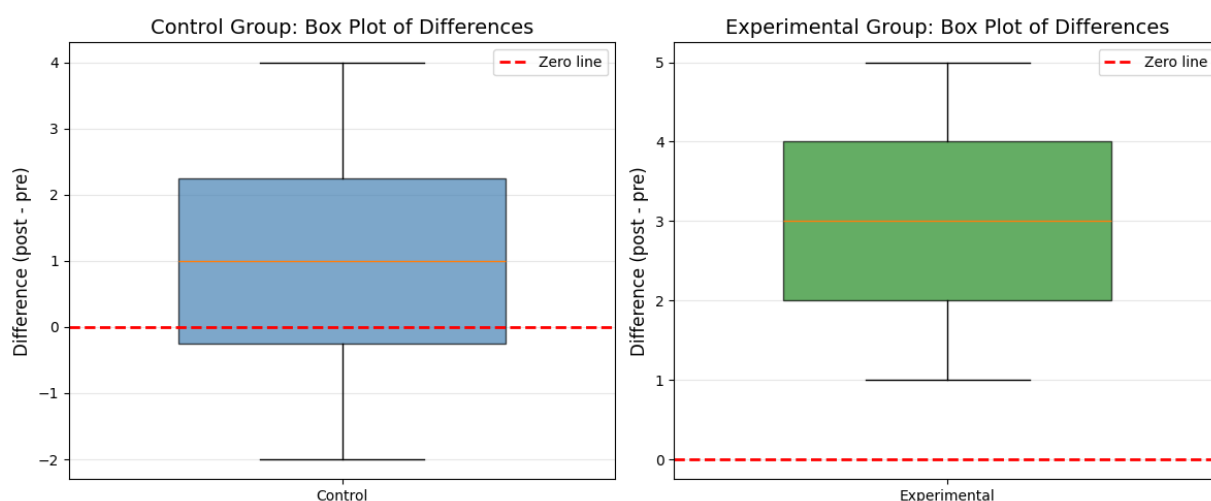
Figure 4.2.2. Visual analysis of the Q-Q plots



Source: Generated using Python

In figure 4.2.3. box plots of the differences pre-test and post-test in the control and experimental groups. A box plot is useful for visualizing the symmetry, median position, whisker length, and outliers. This figure has asymmetry (shifted median and unequal whisker lengths) may indicate a deviation from the norm. However, the box plot by itself does not confirm or deny normality, it provides only visual indicators. The figure shows that in the experimental group, all the students showed improvement, there was no deterioration in the results. It is also seen that the median growth is three times higher, in contrast to the control group. The distribution in the experimental group shows a positive trend after implementation.

Figure 4.2.3. Visual analysis of the Box plots



Source: Generated using Python

Despite the two visual analysis criteria, the nonparametric Wilcoxon sign criterion was used to obtain the results. The application of this criterion makes it possible to evaluate the reliability and changes in academic performance where two dependent samples are compared. Table 4.2.4. presents the change in the control group. The Wilcoxon signed-rank test result of 13.00 and the p-value of 0.090. Since the p-value exceeded the 0.05 significance level, no statistically significant change occurred. The finding indicate that the post-test scores have not changed from the pre-test scores.

Table 4.2.4. Wilcoxon Signed-Rank Test for the control group

			Statistics	p
Pre-test	Post-test	Wilcoxon	13.00	0.090
Control group	Control group	signed-rank		

Table 4.2.5. presents the change in the experimental group. The Wilcoxon signed-rank test result of 1.50 and the p-value of 0.001. Since the p-value is less than the significance level of 0.05, the changes are statistically significant. This suggests that the observed increase in post-test scores is not random and points to a positive effect of the teaching method used. Overall, statistical analysis of the pre-test and post-

test results in the experimental and control groups revealed varying degrees of improvement in academic performance.

Table 4.2.5. Wilcoxon Signed-Rank Test for the experimental group

			Statistics	p
Pre-test	Post-test	Wilcoxon	1.50	0.001
Experimental group	Experimental group	signed-rank		

Table 4.2.6. presents an assessment of the experimental group's performance relative to the control group based on post-test results, using nonparametric Mann-Whitney U test. The outcome revealed statistically significant differences: the experimental group (M = 12.08, SD = 1.80) and the control group (M = 10.17, SD = 1.95); U = 119.00, p = 0.026. The difference in mean scores was 1.91 points.

Table 4.2.6. Mann–Whitney U Test comparison of post-test results between experimental and control groups

			U	p
Post-test	Post-test	Mann-	119.00	0.026
Experimental group	Control group	Whitney U test		

Thus, a significant improvement in the experimental group indicates that the STEM education used in this study resulted in the experimental group surpassing the control group in its post-test results.

5. DISCUSSION AND CONCLUSION

As part of the thesis, an experiment was conducted to determine whether traditional methods of teaching mathematics are inferior to the STEM. The purpose of the research was to examine the effectiveness of the STEM education integration. To achieve this goal, articles were reviewed, methods of implementation and lesson preparation were studied. Fifth grade students took part in the study itself. The methods used were game based learning, real-world problem solving, and inquiry-based learning. These methods were chosen to develop the students' abilities. Game based learning involves increased engagement and memorization of topics. Solving real-world problems contributes to the formation of critical thinking, and IBL for the development of independence and skills in scientific research and was aimed at improving the skills of working on projects and group work. This combination of techniques contributed to a complex influence on the learning process: the form of the game reduced tension and increased interest, real tasks formed the meaning of learning, and the research method refined independence and communication skills. The experiment was conducted for seven weeks, observing the same conditions for the control and experimental groups. The collected information was processed using mathematical statistical methods, which made it possible to objectively determine discrepancies in the results between the groups.

To begin with, the researcher checked the comparability of the two groups in order to increase the reliability and accuracy of this experiment. Further, for comparison, as far as there is a change, both groups should be the same in academic performance. For this, the nonparametric Mann-Whitney U test was used. Nonparametric tests can process ordinal and ranked data and not be seriously affected by outliers. As a result both groups were comparable as a result, it meant that the experiment was fair. Before conducting the main analysis, the assumption of normality was tested for each group using the Shapiro-Wilk test. Condition the Shapiro-Wilk test is greater than 0.05, the data are normal. If it is less than 0.05, the data deviate

significantly from the normal distribution. In both groups, the distribution of scores did not differ significantly from a normal distribution. However, according to visual criteria, the distribution of data in the control group differs from normal, but in the experimental group it is closer to normal. But, given the small sample size, parametric criteria may be inaccurate. Therefore, the use of the nonparametric Wilcoxon criterion is justified. As a result, the experimental group showed a statistically significant improvement from the pre-test to the post-test ($p = 0.001 < 0.05$). In the control group, there were no statistically significant changes from the pre-test to the post-test ($p = 0.090 > 0.05$). The findings of this study demonstrate the effectiveness of the STEM within the experimental group.

Additionally, a student questionnaire was taken in the study. This questionnaire helped to find out how much students are familiar with STEM learning and their interest in mathematics. For the experimental group, the questionnaire was also collected after implementation. The results also prove the effectiveness of the approach. Most of the students chose that it became easier for them to understand mathematics. Students noted that through IBL, studying a topic on their own and solving problems from life, they realized that mathematics exists not only in school, but also has to do with everyday life. And through the games, their interest and motivation to study increased.

When comparing the posttest results of the two groups using the nonparametric Mann-Whitney test, statistically significant differences were found ($p = 0.026 < 0.05$). As a result, the effect is not only visible in the experimental group but is also confirmed between the groups. Overall, this confirms the positive improvement in academic performance and clearly establishes the superiority of STEM education over traditional methods. Thus, STEM education contributes to improved academic performance, which also indicates that this improvement translates into the superiority of one group over the control group.

Many researchers confirm the positive impact of STEM on student academic performance. They also have a significant impact compared to traditional methods. In

addition, this influence is the same at different levels of education and in different cultural contexts. Also in several studies, the experimental groups not only improved their performance in the group, but also outperformed the control groups by a statistically significant margin. In the future, further studies using larger samples will increase statistical reliability. The study showed that STEM learning led to a statistically significant improvement in academic performance in the experimental group. This conclusion is consistent with data from other studies, but also points to important limitations. Nevertheless, the research has practical value, confirming the potential of the STEM education and demonstrating the importance of pedagogical experiments.

In conclusion, during the analysis based on the literature data, the theories and ways of integrating the STEM were considered. The concept of the importance of four disciplines was defined, which, before the advent of the term STEM, were implemented as the creation of innovative achievements. Currently, STEM teaching is defined as an integrative approach. In which students learn to connect disciplines in order to solve real practical problems. In addition, most of the authors focused on teachers who have an understanding of this method and are aware of the importance and necessity for learning, may to get a student interested in mathematics. Moreover, the study suggests that the successful implementation of STEM is difficult without a reform of the teacher training system: teachers should not only realize the importance of integration, but also master specific methods of projects and research activities. Therefore, the growth prospects of STEM education are associated with the formation of an interdisciplinary learning space, where the differences between individual disciplines are weakening and the main result of learning is the ability to use cumulative knowledge to solve applied problems.

The author used various methods to introduce STEM learning in mathematics. Which were further considered in the study to increase motivation and understanding of the subject. Most of the studies have led to increased interest and motivation to study after the introduction of the approaches. Thus, the analysis of sources covers the

theoretical and pedagogical foundations underlying the integration of the STEM education. The evaluation confirmed that the introduction of STEM leads to a statistically significant increase in students' interest in mathematics. However, most of the analyzed works were of a short-term nature, which opens opportunities to study the long-term effects of such approaches on students' academic success and professional self-determination. However, it can already be argued that the integration of STEM into mathematics lessons is not only an urgent direction, but a well-thought-out pedagogical step aimed at increasing motivation.

Based on the experiment, the following *recommendations* were formulated: for middle school teachers to use STEM in time to increase interest in mathematics namely, the STEM of elements at the stages of learning that cause the greatest difficulties for students. It is recommended to start with small forms - one integrated task per week and then gradually increase the percentage of problem-oriented tasks. Teachers should emphasize the relationship between mathematical material and real-world situations; also, to create textbooks for universal use, focused on STEM. Such textbooks should include: step-by-step scenarios for creative projects, exercises for working in small teams, as well as blocks with open questions that do not have the only correct judgment. It is important to make a gradation by level of difficulty so that the teacher has the opportunity to adapt the material to a particular class; to introduce STEM in schools as an additional one. Within the framework of additional education, it is possible to organize a lesson in which students solve applied tasks in a project format. This reduces the burden on teachers and provides an opportunity to assess the interest of children. As a result, the integration of STEM into educational activities makes the study of mathematics more motivating and aims to develop academic performance.

6. LIMITATIONS

This study also has limitations: one of them is the small sample size. Twenty-five students participated in the study; with such a small sample, the results cannot be generalized with a high degree of confidence. Methodological limitations have emerged in determining the effectiveness of the implementation. In this regard, the interpretation of the effectiveness of the intervention should be approached with caution. Secondly, the experiment was conducted exclusively with fifth graders. To achieve meaningful results in the future, it is important to expand the experience and include high school students in it. Younger students demonstrate unstable motivation and interest in the connection between mathematics and scientific views. It is also important to choose tasks for IBL that will not be boring for students. Accordingly, the effectiveness also depends on the students themselves and the degree of their involvement. In addition, many researchers have noted that this approach has a more pronounced functional significance among high school students. For them, this implementation will help them choose their future profession and develop an interest in projects and scientific research.

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LIST OF APPENDICES

Appendix A. Achievement test

1. Мәні қаншаға тең $6\frac{3}{5} + 3\frac{2}{3}$?
A) $2\frac{14}{15}$ B) $9\frac{4}{15}$ C) $9\frac{5}{8}$ D) $10\frac{4}{15}$
2. Келесі салыстыруды дұрыс ететін мән қандай?
_____ $< 0,6$
A) 0,6 B) 0,7 C) 0,59 D) 0,64
3. Оқушы үй тапсырмасын 1 сағат 34 минутта орындады. Үй тапсырмасын орындауға қанша минут кетеді?
A) 26 B) 60 C) 94 D) 134
4. Төменде берілген өрнектің мәні қандай? $21,58 \div 26$
A) 0,80 B) 0,83 C) 0,86 D) 0,89
5. Қай өрнек эквивалентті $65 \times 0,15$?
A) $65 \times 0,1 + 0,05$
B) $65 \times 0,05 + 0,1$
C) $(65 \times 0.1) + (65 \times 0.5)$
D) $(65 \times 0.1) + (65 \times 0.05)$
6. Төменде берілген өрнектің мәні қандай?
$$14\frac{1}{3} - 6\frac{5}{8}$$

A) $7\frac{1}{24}$ B) $7\frac{17}{24}$ C) $8\frac{7}{24}$ D) $8\frac{23}{24}$

7. $425,378 \div 10^3$ бөліндісі туралы қай тұжырым дұрыс?
- A) Ондық нүкте 4-тің сол жағында орналасқан.
 B) Ондық нүкте 8-дің оң жағында орналасқан.
 C) Ондық нүкте 3 пен 7-нің арасында орналасқан.
 D) Ондық нүкте 4 пен 2-нің арасында орналасқан.
8. Мистер Дэвис отбасылық кешкі асқа 4 пицца сатып алды. Ол әр пиццаны 6 бөлікке бөледі. Мистер Дэвистің отбасылық кешкі асқа қанша пицца бөлігі болады?
- A) 6 B) 10 C) 20 D) 24
9. Николас таңертең $\frac{2}{3}$ литр су ішеді және түскі ас кезінде $\frac{1}{2}$ литр ішеді. Баскетбол кезінде ол тағы $\frac{2}{3}$ литр су ішеді. Николас ішкен судың жалпы көлемі литрмен қанша?
- A) $\frac{3}{5}$ B) $\frac{5}{8}$ C) $1\frac{1}{6}$ D) $1\frac{5}{6}$
10. Қай өрнек эквивалентті $\frac{2}{3} \times 7$?
- A) $2 \times 7 \div 3$
 B) $2 \times 3 \div 7$
 C) $7 \times 3 \div 2$
 D) $7 \div 2 \times 3$
11. Қай бөлшек 0,28 мәніне тең?
- A) $\frac{28}{1}$ B) $\frac{28}{10}$ C) $\frac{28}{100}$ D) $\frac{28}{1000}$
12. Қай екіөлшемді фигура әрқашан дұрыс төртбұрыш болады?
- A) Үшбұрыш B) Көпбұрыш C) Шаршы D) Тікбұрыш
13. Қай өрнектің мәні 1-ден аз?

A) $\frac{3}{4} \times \frac{4}{3}$

B) $\frac{3}{4} \times \frac{6}{3}$

C) $\frac{3}{4} \times \frac{4}{4}$

D) $\frac{3}{4} \times \frac{8}{4}$

14. Қай екіөлшемді фигура әрқашан 4 тең жаққа және 4 тік бұрышқа ие?

A) Параллелепипед B) Тікбұрыш C) Ромб D) Шаршы

15. 714,438 санында ондық нүктенің сол жағындағы 4 цифрының мәні ондық нүктенің оң жағындағы 4 цифрының мәнімен қалай салыстырылады?

- A) Сол жағындағы цифрдың мәні оң жағындағы цифрдан 10 есе үлкен
B) Сол жағындағы цифрдың мәні оң жағындағы цифрдан 100 есе үлкен
C) Сол жағындағы цифрдың мәні оң жағындағы цифрдан 10 есе кіші
D) Сол жағындағы цифрдың мәні оң жағындағы цифрға тең

Appendix B. Questionnaire

Сауалнама

1. Сіздің математика пәніне деген қызығушылығыңыз қандай?

- ☐ Өте жақсы көремін
- ☐ Қызықпаймын
- ☐ Ұнатпаймын

2. STEM технологиясы туралы естігенсіз бе?

- ☐ Ия
- ☐ Жоқ

3. Егер Иә деп жауап берсеңіз, STEMді қалай түсінесіз? (бірнеше жауап таңдауға болады)

- ☐ Ғылым, технология, инженерия және математика пәндерін біріктіретін әдіс
- ☐ Практикалық тапсырмалар мен жобалар арқылы үйрету әдісі
- ☐ Робототехникамен байланыстыра оқыту жүйесі
- ☐ Жаңа оқыту әдісі

4. Сіздің мектебіңізде STEM әдістері қолданылады ма?

- ☐ Иә, жиі қолданылады
- ☐ Сирек қолданылады
- ☐ Мүлдем қолданылмайды
- ☐ Білмеймін

5. Егер қолданылса қандай әдістер арқылы байқадыңыз?

- ☐ Ғылыми жобалар
- ☐ Роботехника
- ☐ Макеттер жасау, 3D модельдеу жасау арқылы
- ☐ Топтық жобалар арқылы

6. STEM әдісі арқылы математика сабағы қызықты болады деп ойлайсыз ба?

- ☐ Иә, математиканы түсіну жеңілдеу болады
- ☐ Қызықты, бірақ бәріне бірдей қажет емес
- ☐ Жоқ, дәстүрлі әдістер тиімді

7. Математика сабағында STEM әдістерін жиі қолдану сізге ұнайды ма?

- ☐ Иә
- ☐ Жоқ
- ☐ Білмеймін

Appendix C. Lesson plan

№2-сабақ

Сабақтың тақырыбы: Ондық бөлшектерге амалдар қолдану

Педагогтің аты-жөні:	Касымова Дильназ
Күні:	25.02.2026
Сыныбы: 5	Қатысушылар саны: 13 Қатыспағандар саны: 0
Сабақтың уақыты:	60 минут
Сабақтың мақсаты:	Оқушылардың ондық бөлшектерге қатысты өткен білімдерін жүйелеу, бекіту және оларды күнделікті өмірде қолдануға үйрету.

Сабақтың барысы:

Сабақ кезеңі	Педагогтің іс-әрекеті	Оқушының іс-әрекеті	Ресурстар
Сабақтың басы 20 минут	1. Оқушылармен амандасу, түгендеу. 2. Үй жұмыстарын талдау. 3. Тақырып пен есеп бойынша туындаған сұрақтарды талқылау, қарастыру.	1. Оқушылар мұғаліммен амандасады. 2. Сабаққа дайындалады. 3. Үй жұмысын көрсетіп, орындайды және қателерін талдайды. 4. Тақырыпты талқылауға қатысып, қиын тапсырмаларды мұғаліммен бірге қарастырады.	Оқулық, жұмыс дәптері
Сабақтың ортасы 35 минут	STEM жоба «Қай ұшақ дәлірек ұшады» Оқушылар 3-топқа бөлінеді. Әр топ қағаз ұшақ құрастырып, бірнеше сынақ ұшуын өткізеді. Ұшу нәтижелерін өлшейді, ондық бөлшектерге амалдар қолдану арқылы ең тиімді ұшақ моделін анықтайды. <i>1-кезең</i> Кіріспе. Сабақ мақсаты түсіндіріледі. Мұғалім сұрақтар қояды.	1. Қағаз ұшақ құрастырады 2. Ұшақты 3 рет ұшырады 3. Ұшу қашықтығын өлшейді 4. Ондық бөлшектермен есеп шығарады 5. Ең тиімді ұшақ моделін анықтайды	Жұмыс парағы, А4 қағаз, қайшы, қарындаш, сызғыш, өлшеу таспасы

	1) Инженерлер жаңа жобаларын қалай тексереді? 2) Неліктен тәжірибені бірнеше рет қайталайды? 2-кезең Әр топ ұшақ құрастырады 1-топ Стандартты ұшақ 2-топ Кең қанатты ұшақ 3-топ Жіңішке қанатты ұшақ 3-кезең Әр топ ұшақты 3 рет ұшырады. Қашықтықты өлшеп жұмыс парағына жазады. 4-кезең Математикалық есептеулер. Оқушылар жұмыс парағындағы тапсырмаларды есептеп, толтырады. 5-кезең Қорытынды топтар өз нәтижелерін таныстырады. Нәтиже: S-Science ұшақтың ұшу ерекшеліктерін зерттейді. T-Technology өлшеу құралдарын пайдаланады E-Engineering ұшақ моделін құрастырады. M-Mathematics ондық бөлшек амалдар қолданады.	Жұмыс парағы 1-бөлім Ұшу Қашықтық 1-ұшу _____ 2-ұшу _____ 3-ұшу _____ 2-бөлім Барлық ұшулардың қосындысы _____ + _____ + _____ = _____ m Орташа нәтиже: _____ / 3 = _____ m 3-бөлім Ең кіші мән _____ Ең үлкен мән _____ 4-бөлім 1. Қай ұшу ең дәл болды? 2. Ұшақтың пішіні ұшуға қалай әсер етеді? 3. Егер қанат үлкен болса, не өзгеруі мүмкін?	
Сабақтың соңы 5 минут	Қосымша тапсырма, есептер беріледі.	Оқушы сабақ бойынша кері байланыс пен не қиын болғанын айтады.	Тапсырма, есеп қағазы