ISSN 2518-1467 (Online),
ISSN 1991-3494 (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ
АКАДЕМИЯСЫ» РҚБ

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Х А Б А Р Ш Ы С Ы

ВЕСТНИК

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН»

THE BULLETIN

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN

PUBLISHED SINCE 1944

4 (410)

July – August 2024

ALMATY, NAS RK

«Қазақстан Республикасы Ұлттық ғылым академиясы РҚБ-нің Хабаршысы».
ISSN 2518-1467 (Online),
ISSN 1991-3494 (Print).
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 12.02.2018 ж. берілген
№ 16895-Ж мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *әлеуметтік ғылымдар саласындағы зерттеулерге арналған.*
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.bulletin-science.kz/index.php/en/

«Вестник РОО «Национальной академии наук Республики Казахстан».
ISSN 2518-1467 (Online),
ISSN 1991-3494 (Print).
Собственник: РОО «Национальная академия наук Республики Казахстан» (г. Алматы). Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан **№ 16895-Ж,** выданное 12.02.2018 г.
Тематическая направленность: *посвящен исследованиям в области социальных наук.*
Периодичность: 6 раз в год.
Тираж: 300 экземпляров.
Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, тел. 272-13-19
http://www.bulletin-science.kz/index.php/en/

Bulletin of the National Academy of Sciences of the Republic of Kazakhstan.
ISSN 2518-1467 (Online),
ISSN 1991-3494 (Print).
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty). The certificate of registration of
a periodical printed publication in the Committee of information of the Ministry of Information and Communications
of the Republic of Kazakhstan **No. 16895-Ж,** issued on 12.02.2018.
Thematic focus: *it is dedicated to research in the field of social sciences.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 220, Almaty, 050010, tel. 272-13-19
http://www.bulletin-science.kz/index.php/en/

BULLETIN OF NATIONAL ACADEMY OF
SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
ISSN 1991-3494
Volume 4. Number 410 (2024), 96–106
https://doi.org/10.32014/2024.2518-1467.790
УДК: 372.851
МРНТИ: 27.01.45

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METHODOLOGICAL FOUNDATIONS OF USING STEM TECHNOLOGY IN MATHEMATICS: THE CASE OF KAZAKHSTAN

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Abstract. This research essay explores the efforts of Kazakhstan to integrate STEM education, including mathematics, into its national education system. The country has implemented several initiatives, including the establishment of specialized STEM schools, teacher training programs, and a new national curriculum to emphasize the teaching and learning of STEM subjects. To examine the effectiveness of the country's efforts, the essay employs a literature review, swot analysis, and statistical analysis. The literature review explores previous studies on STEM education and its impact on students' academic and career success. The SWOT analysis shows using of STEM in teaching math in Kazakhstan. Finally, the statistical analysis evaluates the trends and patterns in the use of STEM in math education based on available data. The research essay concludes that Kazakhstan's efforts to reform its education system and integrate STEM education, including mathematics, into its curriculum are promising. However, ongoing efforts are needed to address challenges such as teacher shortages and unequal access to resources to ensure the success of STEM education in the country. The findings can serve as a reference for policymakers and educators in Kazakhstan and other countries that aim to improve their education system through the

integration of STEM subjects.

Keywords: Kazakhstan, STEM education, mathematics education, educational reform, teacher training, curriculum development, project-based learning, digital resources

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МАТЕМАТИКАДА STEM ТЕХНОЛОГИЯСЫН ПАЙДАЛАНУДЫҢ ӘДІСТЕМЕЛІК НЕГІЗДЕРІ: ҚАЗАҚСТАН МЫСАЛЫНДА

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Аннотация. Мақалада Қазақстанның ұлттық білім беру жүйесіне STEM-білім беруді, соның ішінде математиканы енгізу бойынша қалыптасқан әдіс тәсілдерді зерттейді. Қазақстанда STEM-білім беруді енгізуде әлі де қиындықтар бар, соның ішінде білікті мұғалімдердің тапшылығы және елдің кейбір аймақтарында ресурстарға бірдей қолжетімділік болмау және т.ю мәселер қалыптасып отыр. Мақалада, әдебиеттерге шолу STEM білім беру бойынша алдыңғы зерттеулерді және оның оқушылардың академиялық және мансаптық жетістіктеріне ықпалын әдістемелік тұрғыда зерттейді. SWOT талдау Қазақстанда математиканы оқытуда STEM қолданудың күшті, әлсіз жақтарын, мүмкіндіктері мен қауіптерін бағалайды. Соңында, статистикалық талдау қолда бар деректер негізінде математикалық білім беруде STEM-ді қолданудың үрдістері мен заңдылықтарына талдау жасалынады. Зерттеу мақаласында Қазақстанның білім беру жүйесін реформалау және STEM білім беруді, оның ішінде математиканы оның оқу бағдарламасына интеграциялау бойынша реформаларға әдістемелік талдаулар жасалынады.Алайда, елдегі STEM білім берудің табыстылығын қамтамасыз ету үшін мұғалімдер тапшылығы және ресурстарға тең емес қолжетімділік сияқты мәселелерді шешу үшін тұрақты күш-жігер қажет. Бұл

зерттеудің нәтижелері STEM пәндерін интеграциялау арқылы білім беру жүйесін жақсартуды мақсат ететін Қазақстандағы және басқа елдердегі білім саласына менеджерлері мен педагогтар үшін негізгі бағыттық құрал бола алады.

Түйін сөздер: Қазақстан, STEM білім беру, математикалық білім, білім беру реформасы, мұғалімдердің біліктілігін арттыру, оқу бағдарламаларын әзірлеу, жобалық оқыту, цифрлық ресурстар.

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МЕТОДОЛОГИЧЕСКИЕ ОСНОВЫ ИСПОЛЬЗОВАНИЯ STEM-ТЕХНОЛОГИЙ В МАТЕМАТИКЕ: НА ПРИМЕРЕ КАЗАХСТАНА

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Аннотация. В статье рассматриваются усилия Казахстана по интеграции STEM-образования, включая математику, в национальную систему образования. В стране реализовано несколько инициатив, в том числе создание специализированных школ STEM, программ подготовки учителей и новой национальной учебной программы, в которой особое внимание уделяется преподаванию и изучению предметов STEM. Несмотря на многообещающие усилия, в реализации STEM-образования в Казахстане все еще есть проблемы, в том числе нехватка квалифицированных учителей и неравный доступ к ресурсам в некоторых частях страны. Чтобы изучить эффективность усилий страны, в статье используется литературный обзор, SWOT-анализ и статистический анализ. В обзоре литературы рассматриваются предыдущие исследования по STEM-образованию и его влияние на академический и карьерный успех учащихся. Наконец, статистический анализ оценивает тенденции и модели использования STEM в математическом образовании на основе имеющихся данных. В исследовательском

эссе делается вывод о том, что усилия Казахстана по реформированию своей системы образования и интеграции STEM-образования, включая математику, в его учебную программу, являются многообещающими. Однако необходимы постоянные усилия для решения таких проблем, как нехватка учителей и неравный доступ к ресурсам, чтобы обеспечить успех образования STEM в стране. Результаты этого исследования могут послужить ориентиром для политиков и педагогов в Казахстане и других странах, которые стремятся улучшить свою систему образования за счет интеграции предметов STEM.

Ключевые слова: Казахстан, STEM-образование, математическое образование, образовательная реформа, подготовка учителей, разработка учебных программ, проектное обучение, цифровые ресурсы

Introduction

The integration of STEM technology in mathematics education is one of the popular topics. It has been proven that the use of this technology can improve teaching and learning by making mathematics interactive, relevant. The purpose of this work is to discuss the methodological foundations of the use of STEM technology in mathematical education and its application in Kazakhstan. STEM (science, technology, engineering and mathematics) education is a rapidly growing field that seeks to combine disciplines in an interdisciplinary way. According to Manan (Manan, 2023), the integration of these disciplines is important for developing critical thinking and problem-solving skills necessary for success in the 21st century. In mathematical education, STEM technoology is becoming an important component of education, as it can be used to improve teaching and learning in the subject. Belbase (Belbase, 2022) technology provides a tool to engage students, provide visual and interactive experiences, and help them learn mathematical concepts effectively. As a result, many teachers are exploring ways to introduce STEM technology into mathematical education in order to increase student engagement and performance. Integrated STEM increases students ‘ interest in STEM education. However, before students learn the basic principles of STEM, their teachers must first master these basic principles themselves (Goos, 2023).

In the education system of Kazakhstan, as in many other countries, the use of STEM technology in mathematical education is increasing. Over the past 5 years, the Government of Kazakhstan has been investing heavily in education, especially in STEM and digital technologies. As a result, these subjects are being introduced into the country’s education system at all levels, from primary school to university. This is leading to a greater focus on the use of STEM technology in math education, as teachers strive to provide students with the tools they need to succeed in a 21st century world. As Almukhambetova and Kuzhabekova (Almukhambetova et al., 2020) note, the introduction of new educational standards makes Kazakhstan pay more attention to the use of technology in mathematical education. Although there is a high interest in the use of STEM technology in mathematical education, there are still many problems that need to be solved. These include the need to properly train special teachers, the development of effective curriculum materials, as well as constant monitoring of the impact of technology on student learning. To implement the state of STEM technology in mathematical education, there is a need to work on solving these tasks and developing an integrated approach to the integration of technology in the teaching and learning of mathematics. As Su and Moyer-Pakenham suggest, teacher education is

an important component of this process, as teachers themselves must have the necessary knowledge and skills to integrate technology into teaching practices.

Recent research has proven the importance of integrating STEM education, including mathematics, into national education systems to prepare students to be strong in the modern economy. According to National Statistics (Spikic, 2023), the emphasis on STEM education covers the need for people with higher quantitative and technical skills in high-tech industries. In addition, researchers such as Bybee have emphasized the importance of stem education in developing students ' critical thinking, effective problem solving, and creativity. Other studies have highlighted the use of technology in teaching mathematics, with scientists such as Hoyles and LaGrange (2010) pointing out the need to integrate digital tools and resources to support teaching and learning mathematics. In the context of Kazakhstan, scientists such as L. He, G. Zhou, G. Salinitri and L. Xu noted the importance of introducing STEM education into the national curriculum in order to train students to become strong specialists in the country's growing high-tech industries (He, 2020). In general, the literature shows that STEM education, including in mathematics lessons, is important in preparing students for the requirements of modern economics and in developing critical thinking and problem-solving skills.

In addition to the above research work, there are several other studies that have studied the effectiveness of integrating STEM technology in mathematical education. For example, a study by Kebritchi et al. (2010) found that using online learning tools in math classes improves student engagement, motivation, and achievement. In the same way, a study by Martinovich et al. (2012) found that the use of computer modeling in teaching mathematics has a beneficial effect on students ' cognitive understanding and problem-solving skills.

In another area of research, the benefits of integrating applications into mathematical learning are shown. In a study conducted by (Popova et al., 2023) found that the use of real-world problems and projects in teaching mathematics increased students ' critical thinking and problem-solving skills, as well as their motivation and activity for the subject.

In general, the literature states that the integration of STEM technology into mathematical education can have a positive effect on student performance, motivation. However, effective implementation requires the consideration of pedagogical approaches, teacher training and access to resources. Further research is needed to explore the most effective ways to integrate STEM technology in math education and address issues such as teacher training and resource inaccessibility.

Results and discussion

Another relevant approach to the use of STEM technology in mathematics education is social constructivism, which highlights the role of social interactions and collaborative learning in knowledge construction. As Vygotsky suggests, learning is a social process that is mediated through interactions with others and with the environment. In mathematics education, social constructivism can be applied through the use of collaborative learning activities, such as problem-solving tasks and group projects, that encourage students to work together to explore and understand mathematical concepts.

The use of STEM technology in mathematics education can also be informed by contemporary theories of learning, such as connectivism. Connectivism emphasizes the importance of networked learning and knowledge creation through the use of digital tools and resources. In mathematics education, this approach can be applied through the use of

online resources, such as video tutorials and interactive simulations, that allow students to connect with others and explore mathematical concepts in a more collaborative and flexible manner. As Siemens (2005) argues, connectivism represents a new paradigm for learning that is well-suited to the fast-paced and dynamic nature of the digital age.

In Kazakhstan, the use of STEM technology in mathematics education is gaining popularity. The country has developed a national strategy for the development of STEM education, which includes the use of technology in teaching and learning. The strategy emphasizes the importance of developing students' skills in using technology for problem-solving, data analysis, and communication.

One example of the application of STEM technology in mathematics education in Kazakhstan is the use of interactive whiteboards in classrooms. These whiteboards allow teachers to present mathematical concepts in a more interactive and engaging way, and provide students with opportunities to explore and manipulate mathematical concepts. Another example is the use of online resources and simulations to support inquiry-based learning. These resources allow students to investigate mathematical concepts in a more hands-on way, and can help to make mathematics more relevant and meaningful.

In this main part of this academic essay focuses on analysing the use of STEM technology in mathematics education based on the previously discussed methodological foundations. The three main methodologies explored are behaviorism, constructivism, and connectivism, each offering unique approaches to facilitating student learning.

Behaviorism emphasizes the importance of external reinforcement and rewards in promoting learning, which can be achieved through the use of educational games and simulations that provide immediate feedback and rewards for correct answers. However, it has been criticized for focusing on surface-level behaviors and outcomes, which may not encourage a deeper understanding of mathematical concepts.

Connectivism emphasizes the networked nature of learning and the importance of building connections with others and with digital resources. This methodology allows for students to learn collaboratively and engage with a wider range of resources beyond traditional textbooks and lectures. However, it may require a higher level of technological proficiency and self-regulated learning skills from students, which may not be feasible for all learners.

It is important to note that these methodological approaches are not mutually exclusive, and educators may integrate elements of each approach depending on the specific learning goals and needs of their students. For example, educational games may incorporate behaviorist principles for immediate feedback and rewards, but also provide opportunities for constructivist learning through inquiry-based challenges and problem-solving. Online collaborative environments may allow for connectivist learning through networked interactions, but also scaffold learning through prompts and guidance (Tezer, 2021).

Based on the analysis of the three methodological approaches, it is clear that each approach offers unique strengths and limitations for integrating STEM technology into mathematics education.Behaviorism offers the advantage of providing immediate feedback and rewards for correct answers, which can be highly motivating for students. This is particularly useful for repetitive practice activities, such as memorizing mathematical facts or practicing computational skills. However, behaviorism may not be as effective in promoting deep understanding of mathematical concepts, as it focuses more on surface-level behaviours and outcomes.Constructivism, on the other hand, offers the advantage

of promoting active exploration and problem-solving, which can lead to a deeper understanding of mathematical concepts. This approach encourages students to construct their own knowledge through inquiry-based and project-based learning experiences, rather than simply memorizing information. However, constructivism may not be as efficient in covering a large amount of content in a short amount of time, as it focuses more on in-depth exploration and understanding of a limited number of concepts.

In practice, educators may integrate elements of each approach depending on the specific learning goals and needs of their students. For example, educational games may incorporate behaviorist principles for immediate feedback and rewards, but also provide opportunities for constructivist learning through inquiry-based challenges and problem-solving. Online collaborative environments may allow for connectivist learning through networked interactions, but also scaffold learning through prompts and guidance.Overall, the integration of STEM technology in mathematics education requires careful consideration of the methodological foundations of behaviorism, constructivism, and connectivism, and how they can be adapted and integrated to create effective and engaging learning experiences for students. Further research is necessary to explore the most effective ways to incorporate STEM technology in mathematics education, particularly in the context of Kazakhstan and other countries seeking to enhance their STEM education initiatives.In support of the advantages and limitations of each methodological approach, there is a growing body of research by prominent scholars in the field of education.For behaviorism, B.F. Skinner's research on operant conditioning has shown the effectiveness of reinforcement in shaping behavior. Skinner's work has been applied to the development of educational games and simulations that provide immediate feedback and rewards for correct answers, as noted by Schmidt and Ralphs (2019) (Maratkyzy, 2023).

In constructivism, Jean Piaget's theory of cognitive development emphasizes the importance of active exploration and discovery in constructing knowledge. Lev Vygotsky's sociocultural theory emphasizes the role of social interaction and scaffolding in supporting learning, as noted by Kozulin (2003). Seymour Papert's constructionist approach emphasizes the use of technology, particularly programming languages, to support student learning and creativity, as noted by Kafai and Resnick (1996).Connectivism has been championed by George Siemens and Stephen Downes, who advocate for the importance of networked learning in a digital age. Siemens' theory of connectivism emphasizes the role of networked resources and connections in learning, while Downes' concept of a personal learning environment emphasizes the importance of learners taking control of their own learning and building connections with others and with digital resources, as noted by Downes (2012).

Overall, the work of these scholars supports the importance of understanding the strengths and limitations of each methodological approach and adapting them to create effective and engaging learning experiences for students, particularly in the context of STEM education in Kazakhstan and other countries.

Kazakhstan has been making significant efforts to reform its education system and integrate STEM subjects, including mathematics, into its curriculum. The country's education reform agenda is part of a larger national development strategy aimed at improving the country's economic and social development through human capital investment.In 2011, Kazakhstan launched a major education reform initiative called «New Kazakhstan Education Development», which included a number of measures aimed at improving the quality and relevance of education at all levels. One of the key objectives of the reform was to strengthen

the teaching and learning of STEM subjects, including mathematics, in order to prepare students for careers in the country's growing high-tech industries. As part of this initiative, the government has invested heavily in upgrading school infrastructure and teacher training programs to support the implementation of STEM education. The government has also established partnerships with leading international organizations and educational institutions to provide expertise and support for STEM education initiatives. One of the major initiatives undertaken by the government is the establishment of specialized STEM schools, where students receive a high-quality education focused on science, technology, engineering, and mathematics. These schools are designed to provide students with the knowledge and skills needed to pursue careers in STEM fields (Abdrakhmanova, 2022).

Another significant effort has been the development of a new national curriculum that emphasizes the teaching and learning of STEM subjects. The curriculum includes a focus on project-based learning and the integration of technology in mathematics instruction. The government has also introduced a new standardized test, the National Assessment of Educational Achievement, which includes an emphasis on STEM subjects. While these efforts have been promising, there are still challenges to be addressed in the implementation of STEM education in Kazakhstan. One challenge is the shortage of qualified teachers with expertise in STEM subjects. To address this, the government has implemented teacher training programs to provide teachers with the skills and knowledge needed to effectively teach STEM subjects.

Another challenge is the lack of access to modern technology and educational resources in some parts of the country, particularly in rural areas. To address this, the government has invested in upgrading school infrastructure and providing access to digital resources, such as online textbooks and educational software. Kazakhstan's efforts to reform its education system and integrate STEM education, including mathematics, into its curriculum are promising. Through investment in teacher training and infrastructure, the government is taking steps to prepare its students for careers in high-tech industries and to build a more competitive and prosperous economy. However, ongoing efforts are needed to address challenges such as teacher shortages and unequal access to resources to ensure the success of STEM education in the country.

SWOT analysis is a useful tool to evaluate the strengths, weaknesses, opportunities, and threats of any system or initiative. In the case of Kazakhstan's use of STEM technology in teaching math, a SWOT analysis can help to identify the potential benefits and drawbacks of this approach (Figure 1.).

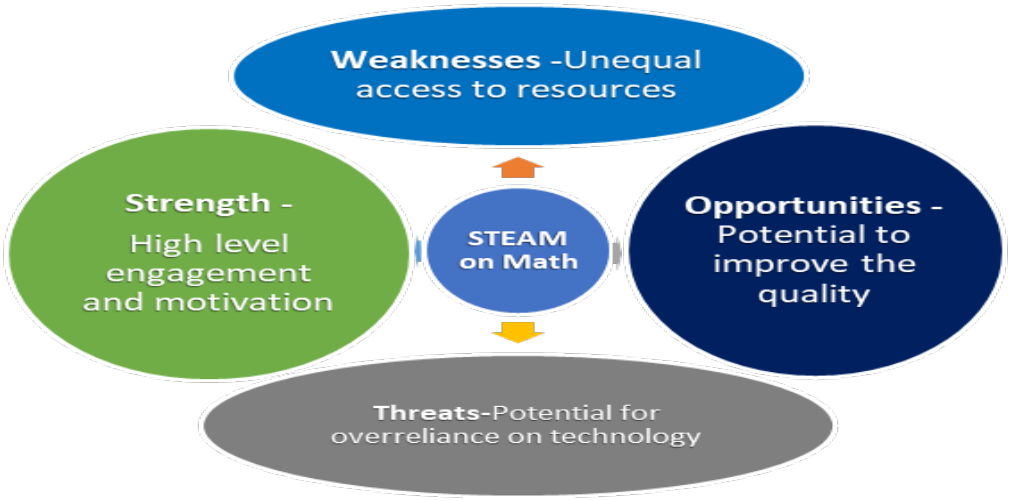

Figure 1. SWOT analysis of Kazakhstan's use of STEM technology

Strengths: One of the strengths of using STEM technology in teaching math in Kazakhstan is that it can increase student engagement and motivation. Interactive and hands-on activities, such as coding and robotics, can make math more interesting and accessible to students. Additionally, STEM technology can help to develop critical thinking, problem-solving, and analytical skills that are highly valued in the modern workforce. Another strength is that the use of STEM technology in teaching math can help to address the shortage of qualified STEM professionals in Kazakhstan. By encouraging students to pursue STEM careers, the country can build a stronger and more competitive workforce.

Weaknesses: One of the weaknesses of using STEM technology in teaching math is the potential for unequal access to resources. Students in rural or underprivileged areas may not have access to the same technology and educational resources as their urban counterparts. This can create a digital divide and exacerbate existing inequalities in the education system. Another weakness is the shortage of qualified teachers with expertise in STEM subjects. Without proper training and support, teachers may struggle to effectively integrate STEM technology into their teaching methods.

Opportunities: One of the opportunities of using STEM technology in teaching math is the potential to improve the quality and relevance of education in Kazakhstan. By incorporating modern technology and teaching methods, the country can ensure that its students are well-prepared for the demands of the modern workforce. Another opportunity is the potential for international collaboration and partnerships. By working with leading educational institutions and organizations, Kazakhstan can gain access to expertise and resources that can help to improve its STEM education initiatives.

Threats: One of the threats of using STEM technology in teaching math is the potential for overreliance on technology. If not properly balanced with traditional teaching methods, the use of STEM technology may lead to a narrow focus on technical skills at the expense of critical thinking and problem-solving. Another threat is the potential for a mismatch between the skills developed in the education system and the demands of the workforce. If the education system focuses too narrowly on STEM subjects, it may overlook the importance of other skills, such as creativity and interpersonal communication that are highly valued by

employers(Figure 2).

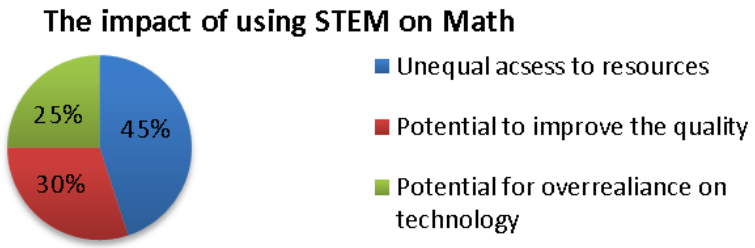

Figure 1. SWOT analysis of Kazakhstan's use of STEM technology

In general, a SWOT analysis of the use of STEM technology in teaching math in Kazakhstan reveals both strengths and weaknesses. By addressing these weaknesses and capitalizing on the opportunities presented by STEM education, Kazakhstan can build a stronger and more competitive workforce that is well-prepared for the demands of the modern economy. The use of STEM technology in mathematics education requires careful consideration of the strengths and limitations of various methodological approaches. While behaviorism, constructivism, and connectivism offer distinct perspectives on learning, they can be integrated and adapted to create meaningful and engaging learning experiences for students. Further research is necessary to explore the most effective ways to incorporate STEM technology in mathematics education, particularly in the context of Kazakhstan and other countries seeking to enhance their STEM education initiatives.

Conclusions

In conclusion, the integration of STEM education, including mathematics, into the curriculum in Kazakhstan has the potential to significantly improve the country's economic and social development. Through investment in teacher training and infrastructure, the government is taking steps to prepare its students for careers in high-tech industries and to build a more competitive and prosperous economy. However, there are still challenges to be addressed in the implementation of STEM education in the country, including the shortage of qualified teachers with expertise in STEM subjects and unequal access to resources in some parts of the country. These challenges must be addressed through ongoing efforts to ensure the success of STEM education initiatives in Kazakhstan. Despite these challenges, the government's efforts to reform the education system and integrate STEM education are promising. The establishment of specialized STEM schools, the development of a new national curriculum, and the introduction of a new standardized test all demonstrate a commitment to improving the quality and relevance of education in the country. Moreover, the SWOT analysis conducted highlights the strengths, weaknesses, opportunities, and threats associated with the integration of STEM education into the curriculum. This analysis provides a framework for addressing the challenges and maximizing the potential benefits of STEM education initiatives in Kazakhstan. In summary, the successful integration of STEM education into the curriculum has the potential to transform education and improve the economic and social development of Kazakhstan. Ongoing efforts are needed to address challenges and ensure the success of STEM education initiatives in the country.

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www: nauka-nanrk.kz
ISSN 2518–1467 (Online),
ISSN 1991–3494 (Print)
http://www.bulletin–science.kz/index.php/en

Подписано в печать 15.08.2024.
Формат 60x881/8. Бумага офсетная. Печать - ризограф.
~~46,0~~ п.л. Тираж 300. Заказ 4.

РОО «Национальная академия наук РК»
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