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THE INFLUENCE OF STEM EDUCATION ON MOTIVATION TO LEARN IN MATHEMATICS LESSONS

Abstract. This study examined the impact of STEM (Science, Technology, Engineering, and Mathematics) education on 8th-grade students' motivation towards learning mathematics at a Nazarbayev Intellectual School in Almaty. The research aimed to assess how STEM education influences motivational factors such as intrinsic value, self-regulation, self-efficacy, utility value, attainment value, and test anxiety. An experimental design was employed with 52 participants divided into two groups: a control group using traditional teaching methods and an experimental group engaging in STEM approaches. The Mathematics Motivation Questionnaire (MMQ), adapted from the Science Motivation Questionnaire (SMQ), was utilized for data collection before and after the intervention. Results from paired samples T-tests and descriptive statistics showed significant enhancements in the motivational levels of students in the experimental group, indicating that STEM education effectively boosts motivation towards mathematics learning. This research underscores the significance of incorporating STEM educational practices into mathematics curricula to create a more engaging and motivating learning atmosphere. These findings are crucial for educators, curriculum designers, and policymakers focused on improving mathematics education and fostering a greater interest in STEM fields among middle school students, contributing to the existing literature on educational motivation.

Keywords: Motivation, STEM education, middle School, mathematics, students.

Introduction

Motivation is important in all disciplines, but research shows that mathematics imposes unique motivational barriers, including feelings of anxiety (Dowker A., et al., 2016: 7, 508) and beliefs that mathematics does not present personal interest or value in life (Peterson J. L., & Hyde J. S., 2017: 438–456). Low motivation towards mathematics is particularly prevalent when students transition to middle school - a critical period during which students develop their identity as learners (Hogheim S., & Reber R., 2015: 17–25). Unfortunately, many middle school students experience a decrease in motivation and performance in mathematics, partly due to differences in school context and teaching methods, as well as increased complexity of the material (Eccles J. S., et al., 1993: 553–574). Student motivation to learn is crucial, as motivated students are more likely to put effort into learning the material, use effective self- regulation strategies, persevere in the face of difficulties, and demonstrate higher levels of achievement (Renninger K. A., & Hidi S., Eds., 2019). On the other hand, unmotivated students usually do not tackle challenging academic tasks and do not use labor-intensive learning strategies due to their unproductive beliefs held regarding their own abilities or the value of the material they are learning (Wigfield A., et al., 2016: 55–74).

Identifying and supporting unmotivated students during critical periods, such as transitioning to middle school, is important in preventing academic declines in subsequent years. This is especially important in STEM disciplines, where issues related to equity, persistence, and achievement are of particular interest to STEM educators and researchers and impact the future global STEM workforce (Cromley J. G., et al., 2016: 4–11). Mathematics, in particular, can serve as a crucial filter from which students ultimately decide to pursue a specialty and career in STEM (Watt H. M., et al., 2017: 254–271). Research by Dabney, K. P. et al. found that interest in mathematics in middle school was positively associated with later career interest in STEM (Dabney K. P., et al., 2012: 63–79). Another study showed that teenagers' beliefs in their mathematical abilities predicted career growth in STEM

(Blotnicky K. A., et al., 2018: 1–15). Therefore, understanding the factors that influence mathematical motivation in middle school students can contribute to increasing students' participation in STEM disciplines (Pintrich P. R., 2003: 667–686).

The aim of this study is to investigate the impact of STEM education on students' motivation to learn in mathematics lessons. The findings of this research have significant implications for both theory and practice. From a theoretical perspective, this study contributes to increasing knowledge about the impact of STEM education on motivation in mathematics lessons, providing empirical data on the prevalence and differentiation of specific types of motivation among eighth graders (Marsh H. W., et al., 2019: 331–353). Thus, we can improve existing theoretical foundations and develop more effective methods to enhance motivation in students' mathematical education. From a practical perspective, this study offers valuable insights for educators, policymakers, and curriculum designers (Zimmerman B. J., et al., 1992: 663– 676).

This study followed survey design and was guided by the following research questions:

1. What is the level of motivation of mathematics emotions of middle school students?
2. Which of the six motivational factors of middle-level students is most influenced by STEM education?
3. How does STEM education influence the motivation of middle school students?

Motivation is a psychological condition that triggers and maintains actions aimed at achieving goals (Rosenzweig E. Q., et al., 2019: 617–644). Based on expectancy-value theory (Weidinger A. F., et al., 2020: 413–422), motivation is influenced by students' self-perceptions (expectancies) and their attitudes towards the task (values) (Ryan R. M., & Deci E. L., 2017). Expectancies are about students' confidence in their success or their self- assurance in excelling in a particular domain. This concept of success expectation aligns closely with what is referred to as self-efficacy in other motivational theories (Zimmerman B. J., & Labuhn A. S., 2012: 399–425). For instance, queries regarding self-efficacy might involve asking students about their confidence levels in grasping the taught concepts or in finishing their homework on schedule (Ramirez G., et al., 2018: 145–164). Expectancy-value theory further categorizes values into three types: intrinsic value, utility value, and achievement value (Kazelskis R., et al., 2000: 137–146). Intrinsic value is related to the joy derived from completing a specific academic activity (Graham

M. J., et al., 2013); utility value is about the relevance of an academic activity to one's present or future objectives (Margot K. C., & Kettler T., 2019); and achievement value concerns the significance of excelling in academic tasks for an individual (Farwati R., et al., 2021: 11–32). Both intrinsic and utility values partially tie back to elements of the self-determination theory (Armaludin U., et al., 2021: 70–79), which differentiates between intrinsic motivation (acting for personal satisfaction) and extrinsic motivation (acting for external rewards) (Li Y., & Schoenfeld A. H., 2019).

Despite variations in theoretical frameworks, there is an agreement that self-beliefs and task perceptions are critical to academic motivation (Puspita L., et al., 2020: 82–89). The intertwining of students' beliefs and values significantly influences their eagerness and capacity to manage their learning autonomously (Glynn S. M., et al., 2009: 127–146). Self-regulation theory describes the cognitive system responsible for managing students' learning approaches (Wigfield A., et al., 2016: 55–74). Self-regulating students set objectives, select educational strategies, arrange a supportive study environment, track their progress, and allocate their resources wisely (Logan Fiorella et al., 2021: 14).

Moreover, a critical factor is the level of anxiety students experience, especially concerning mathematics (Puspita L., et al., 2020: 82–89). Math anxiety represents an adverse emotional response to learning or facing mathematical challenges (Glynn S. M., et al., 2009: 127–146). One aspect of math anxiety includes the dread felt before a math test or the distress caused by receiving a math grade (Wigfield A., et al., 2016: 55–74). Students who suffer from heightened math anxiety or test anxiety generally hold negative views towards math, avoid math-related activities, and show lower performance in mathematics (Logan Fiorella et al., 2021: 14).

Science, technology, engineering, and mathematics (STEM) education is integrated into school curricula to equip students with the skills necessary to tackle problems aimed at enhancing human welfare (Puspita L., et al., 2020: 82– 89). STEM education emphasizes the importance of crafting methodologies (techniques) through analytical processes and mathematical data computation (mathematics) to devise problem-solving strategies (Glynn S. M., et al., 2009: 127–146). This educational approach encompasses a framework that involves recognizing learning processes and anticipating student behaviors (Wigfield A., et al., 2016: 55–74). These aspects can be influenced through various interventions and several initiatives aimed at retaining STEM engagement (Logan Fiorella et al., 2021: 14). Success in STEM education is often attributed to effectively addressing these components (Farwati R., et al., 2021: 11–32). Furthermore, this approach enhances students' critical thinking and motivational levels, both of which are crucial for academic achievement (Armaludin U., et al., 2021: 70–79).

In addition to fostering critical thinking, STEM methodologies are also effective in boosting students' motivational levels (Kazelskis R., et al., 2000: 137–146). Studies, including one by Burke et al. (2020), have demonstrated that STEM-focused worksheets can significantly enhance students' enthusiasm for learning (Graham M. J., et al., 2013). Furthermore, research by Farwati et al. [23] suggests that students show a high level of motivation in science subjects when engaged in STEM-based learning, highlighting the potential of the STEM approach in increasing student motivation for learning (Farwati R., et al., 2021: 11–32). Armaludin et al. [24] argue that while motivation can be externally stimulated, it inherently originates from within, observable in various scenarios. In educational settings, it is crucial for teachers to employ diverse strategies to inspire active student participation in learning processes. This aligns with the STEM pedagogy, which prioritizes real-life problem-solving skills (Armaludin U., et al., 2021: 70–79). Engaging students in practical activities during learning sessions can prevent boredom and make education more impactful. According to research by Puspita et al., the STEM approach significantly elevates students' interest in learning mathematics, underscoring the effectiveness of STEM in enhancing student motivation (Puspita L., et al., 2020: 82–89).

Methods and materials

In conducting the study, we used the Mathematics Motivation Questionnaire (MMQ) for high school students, which was adapted from the popular and well-validated Science Motivation Questionnaire for college students (Logan Fiorella et al., 2021: 14). The MMQ targets students' beliefs, values, self-regulation strategies, and their commitment to learning and performance in mathematics (Glynn S. M., et al., 2009: 127–146). We focused on middle school students because the decline in mathematics motivation at this age is more pronounced compared to other academic domains (Wigfield A., et al., 2016: 55–74). The SMQ was developed based on established theories of academic motivation to examine the relationships between important motivational factors and academic achievement among college students (Zimmerman B. J., & Labuhn A. S., 2012: 399–425). A study by Logan Fiorella et al. examined the construct validity and reliability of this test, with results indicating that the MMQ provides a reliable, valid, and feasible assessment of specific factors underlying mathematics motivation among middle school students (Logan Fiorella et al., 2021: 14). In this MMQ are six constructs: intrinsic value (e.g., "I enjoy learning math"), attainment value (e.g., "Earning a good math grade is important to me), self-regulation (e.g., "I use strategies to ensure I learn math well"), self-efficacy (e.g., "I am confdent I will do well on math assignments and projects"), utility value (e.g., "Te math I learn is relevant to my life"), and test anxiety (e.g., "I am nervous about how I will do on math tests"). Each of the 30 total items asks students to use a fve-point scale to select "never", "rarely", "sometimes", "usually", or "always". Each item is evaluated on a 5-point Likert-like scale where one is not true at all, two is hardly true, three is somewhat true, four is largely true, and five is exactly true. Since the participant already speaks English, at least at the B2 level, and the items are worded in a simple fashion, we did not translate them into Kazakh language. The questionnaire took about 10 min.

We used an experimental method. Participants in the study were purposively selected and randomly assigned to two groups: a control group consisting of 26 students who studied mathematics in a traditional way, and an experimental group consisting of 26 students who studied the same content using a STEM approach.

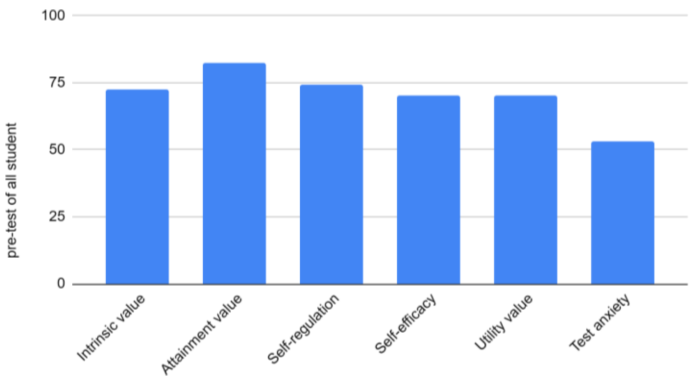
The one of the author works as a mathematics teacher in one of the Nazarbayev Intellectual school (NIS), where we collected data. The sample comprises 52 secondary students in 8th grade who voluntarily accepted participation. The data used in this study were collected from students attending five NIS in Almaty-Kazakhstan.

Results and Discussion

To analyze the data and address the research questions outlined in the study, I'll summarize the key findings based on the analysis section and discuss their implications in relation to the research questions posed. The study aimed to investigate the impact of STEM education on students' motivation towards learning mathematics among 8th-grade students in a Nazarbayev Intellectual School in Almaty, focusing on intrinsic value, self-regulation, self-efficacy, utility value, attainment value, and test anxiety as motivational factors.

Research Question 1: What is the level of motivation of mathematics emotions of middle school students?

Figure 1 - Pre-test of all students



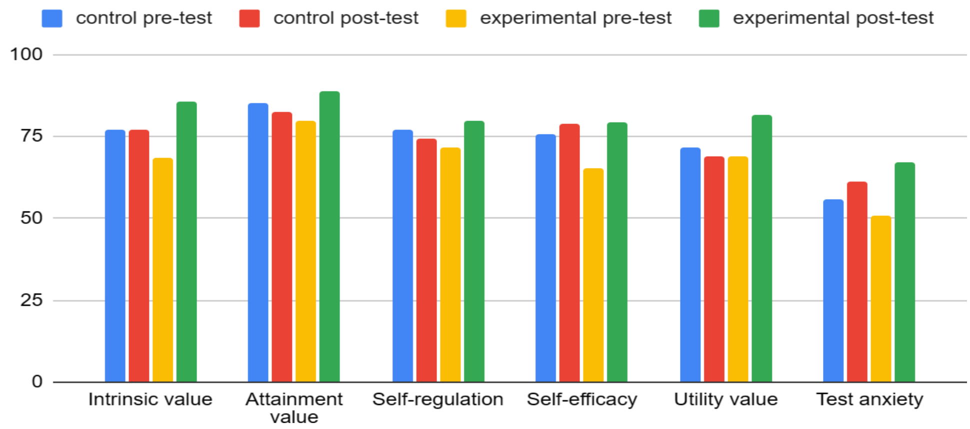
The graph shows the level of motivation among all students, including both experimental and control groups, before the experiment (pre-test). The data presented allows us to see the initial level of motivation in six different parameters. The average scores for each of the motivational factors range from approximately 55 to 75 points, where 100 points would be the maximum possible score. The graph shows that the highest scores are observed for the factors "intrinsic value" and "self-efficacy," while the lowest scores are for "test anxiety."

Research Question 2: Which of the six motivational factors of middle-level students is most influenced by STEM education?

To answer the research question, we compared changes in mean scores in the experimental group before and after the tests. From the presented diagram, we see the results of pretests and posttests of the control and experimental groups of students at the secondary level of education on six motivational factors in the field of STEM education: intrinsic value, achieved value, self-regulation, self- efficacy, practical value and test anxiety.

Based on this comparison, the most significant change occurred in the self-efficacy category. This can be seen by the increase in height of the green bar compared to the yellow bar in this category, indicating an increase in the average value after the experiment compared to the initial condition. It can also be noted that the experimental group's post-test scores in the categories of intrinsic value, achieved value, and practical value increased slightly, although these changes were not as significant as in the category of self-efficacy. In the control group, the changes between pretest and posttest were not as pronounced, which suggests that the intervention in the experimental group contributed to an increase in motivational factors.

Figure 2 - Results of the mean values of the experimental and control groups



Research Question 3: How does STEM education influence the motivation of middle school students?

The findings, specifically the significant improvement in the experimental group's post-test scores compared to the pre-test (with a statistical significance $p < .001$), indicate that STEM education has a positive influence on the motivation of middle school students towards learning mathematics. The improvement suggests that the integration of STEM education approaches can effectively enhance students' motivation, potentially across various motivational factors such as intrinsic value, self-regulation, self- efficacy, and utility value.

The data analysis and the significant findings in the experimental group highlight the effectiveness of STEM education in enhancing students' motivation towards mathematics. This is evident from the statistically significant improvement in motivational levels post-intervention, suggesting that STEM approaches not only aid in improving students' understanding and skills in mathematics but also positively influence their motivation by making learning more relevant, engaging, and connected to real-world applications. These findings underscore the importance of incorporating STEM-based learning strategies in mathematics education to foster a more motivated and engaged learning environment.

Table 1 - Paired Samples T-Test for control group Paired Samples T-Test

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference
Control group post-test	Control group pre-test	Student's t	0.105	25.0	0.917	0.346	3.28

Note. $H_a\ \mu_{\text{Measure 1 - Measure 2}} \neq 0$

Normality Test (Shapiro-Wilk)

			W	p
Control group post-test	-	Control group pre-test	0.982	0.919

Note. A low p-value suggests a violation of the assumption of normality

Descriptives

	N	Mean	Median	SD	SE
Control group post-test	26	109	108	12.0	2.35
Control group pre-test	26	109	109	11.7	2.29

Table 2 - *Paired Samples T-Test for control group*

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference
Experimental group post-test	Experimental group pre-test	Student's t	4.98	25.0	< .001	19.3	3.88

Note. H_a $\mu_{\text{Measure 1 - Measure 2}} \neq 0$

Normality Test (Shapiro-Wilk)

			W	p
Experimental group post-test	-	Experimental group pre-test	0.943	0.156

Note. A low p-value suggests a violation of the assumption of normality

Descriptives

	N	Mean	Median	SD	SE
Experimental group post-test	26	119	119	10.0	1.97
Experimental group pre-test	26	100	101	17.3	3.40

The analysis provided in the study employed paired samples T-tests to evaluate changes in motivation levels among 8th-grade students, comparing scores before and after the intervention in both a control group (traditional teaching methods) and an experimental group (STEM approach). The results indicated a statistically significant increase in motivation levels within the experimental group, as evidenced by a mean difference of 19.3 ($p < .001$) between pre-test and post-test scores. Conversely, the control group showed no significant change in motivation levels, with a mean difference of 0.346 and a p-value of 0.917, indicating that traditional teaching methods did not significantly affect students'motivation towards learning mathematics.

The substantial improvement in motivation among students in the experimental group highlights the efficacy of STEM education in engaging and motivating middle school students in mathematics. STEM education's emphasis on real-world applications, problem-solving, and interdisciplinary learning likely contributed to this positive outcome. These approaches make learning more relevant and interesting to students, potentially influencing various motivational factors such as intrinsic value (enjoyment of learning math), utility value (relevance of math to real-life), and self-efficacy (confidence in math abilities).

The stark contrast in motivation levels between the experimental and control groups underscores the limitations of traditional teaching methods in fostering motivation towards mathematics. The lack of significant change in the control group's motivation might be attributed to conventional strategies not adequately addressing students' needs for engagement, relevance, and self- directed learning opportunities—elements that are central to the STEM approach.

Conclusion

The study's findings indicate a statistically significant increase in themotivation levels among students exposed to the STEM education approach, as evidenced by the paired samples T-tests comparing pre-test and post-test scores within the experimental group. This increase in motivation contrasts with the control group's outcomes, where traditional teaching methods did not produce a significant change in students' motivational levels towards mathematics. This discrepancy underscores the potential of STEM education to foster a more engaging and stimulating learning environment, effectively addressing the unique motivational barriers that mathematics presents.

Key to the study's implications is the understanding that motivation in mathematics education is multifaceted, encompassing intrinsic value, self- regulation, self-efficacy, utility value, and test anxiety among other factors. The positive shift in motivation observed in the experimental group suggests that STEM education's integrated, real-world application of mathematics not only makes learning more relevant and enjoyable but also enhances students' confidence in their abilities and the value they attribute to mathematics in their lives and future careers.

In conclusion, the study underscores the pivotal role of STEM education in enhancing motivation towards mathematics among middle school students, offering valuable insights for educators, policymakers, and curriculum designers. By adopting STEM-based learning strategies, there is potential not only to improve educational outcomes in mathematics but also to inspire the next generation of learners to pursue careers in STEM fields, addressing global challenges and advancing societal progress.

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МАТЕМАТИКА САБАҚТАРЫНДА ОҚУ МОТИВАЦИЯСЫНА STEM ОҚЫТУДЫҢ ӘСЕРІ

Аңдатпа. Бұл зерттеу Алматыдағы Назарбаев Зияткерлік мектебінің 8-сынып оқушылары арасында STEM (ғылым, технология, инженерия және математика) білімінің математиканы оқуға деген мотивацияға әсерін зерттеді. Зерттеудің мақсаты - STEM білім беру әдістерінің ішкі құндылық, өзін-өзі реттеу, өзін-өзі сенімділік, пайдалылық құндылығы, жетістік құндылығы және тестке деген қауіп- қатер сияқты мотивациялық факторларға қалай әсер ететінін анықтау болды. Зерттеуге дәстүрлі оқыту әдістерін қолданатын бақылау тобы және STEM әдістерімен айналысатын эксперименталдық топ болып бөлінген 52 қатысушы қатысты. Ғылыми мотивация сауалнамасынан (SMQ) бейімделген математикалық мотивация сауалнамасы (MMQ) экспериментке дейінгі және кейінгі деректерді жинау үшін пайдаланылды. Жұптық үлгідегі Т-тесттері мен сипаттамалық статистика нәтижелері эксперименттік топтағы студенттердің мотивация деңгейінің айтарлықтай жоғарылағанын көрсетті, бұл STEM білім берудің математиканы оқу мотивациясын арттыруда тиімді екенін көрсетті. Бұл зерттеу математика бағдарламаларына STEM білім беру тәсілдерін енгізу арқылы қызығушылық пен мотивацияны арттыратын оқу ортасын құрудың маңыздылығын атап өтеді. Бұл табылғандар математика білімін жақсарту және орта мектеп оқушылары арасында STEM салаларына деген қызығушылықты насихаттауға бағытталған оқытушылар, оқу бағдарламасын жобалаушылар және саясаткерлер үшін маңызды, білім беру мотивациясына қатысты бар зерттеулерге үлес қосады.

Түйін сөздер: Мотивация, STEM білім беру, орта мектеп, математика, оқушылар.

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ВЛИЯНИЕ STEM-ОБРАЗОВАНИЯ НА МОТИВАЦИЮ К ОБУЧЕНИЮ НА УРОКАХ МАТЕМАТИКИ

Аннотация. В данном исследовании изучалось влияние образования STEM (наука, технология, инженерия и математика) на мотивацию учащихся 8-х классов к изучению математики в Назарбаев Интеллектуальной школе в Алматы. Целью исследования было оценить, как образование STEM влияет на мотивационные факторы, такие как внутренняя ценность, саморегуляция, самоэффективность, ценность полезности, ценность достижений и тревога перед экзаменами. Был использован экспериментальный план с участием 52 участников, разделенных на две группы: контрольную группу, использующую традиционные методы обучения и экспериментальную группу, использующую подходы STEM. Анкета мотивации к математике (MMQ), адаптированная из анкеты мотивации к науке (SMQ), использовалась для сбора данных до и после вмешательства. Результаты парных выборочных Т-тестов и описательной статистики показали значительное повышение уровня мотивации учащихся в экспериментальной группе, указывая на то, что STEM-образование эффективно повышает мотивацию к изучению математики. Это исследование подчеркивает важность включения образовательных практик STEM в учебные программы по математике для создания более увлекательной и мотивирующей атмосферы обучения. Эти результаты имеют решающее значение для преподавателей, разработчиков учебных программ и политиков, стремящихся улучшить математическое образование и стимулировать больший интерес к областям STEM среди учащихся средних школ, внося вклад в существующую литературу по образовательной мотивации.

Ключевые слова: Мотивация, STEM-образование, средняя школа, математика, учащиеся.

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