Psikoislamika: Jurnal Psikologi dan Psikologi Islam
Volume 21, No 2 (2024), pp. 151-172
ISSN 1829-5703 (p), 2655-5034 (e)
https://doi.org/10.18860/psi.v21i2.29164

Secondary School Students' STEM Education Anxiety: The Role of Teachers' Teaching Self-Efficacy Beliefs and Outcome Expectancy Beliefs

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Received October 15, 2024 | Accepted September 18, 2024| Published November 30, 2024

Abstract: STEM education is a method of instruction that allows students to apply concepts from science, technology, engineering, and mathematics to a variety of contexts, preparing students for the real world by teaching them to respond to change and equipping them with skills such as critical thinking, problem-solving, and creativity and STEM anxiety is the worry, avoidance, or fear of studying science or mathematics. The study sought to investigate the relationship between students' STEM education anxiety and instructors' self-efficacy and expectancy-value beliefs, as there has been little empirical research into the impact of such factors on anxiety. This study examined the association between Bangladeshi secondary school students' STEM education anxiety and their teachers' own teaching efficacy and teaching outcome expectancy beliefs. The convenience sampling method was used to collect responses from 165 secondary school pupils and their 50 teachers. Surveys were administered to assess teachers' self-efficacy and outcome expectations, as well as students' STEM education anxiety. The analyses included mean, standard deviation, correlation, independent sample t-test, and multiple regression analysis. Teachers' teaching efficacy and beliefs (PTEB) and teaching outcome expectancy beliefs (TOEB) were negatively correlated with students' STEM education anxiety. The study highlights how teachers' self-efficacy and outcome expectations affect students' STEM-related anxiety.

Keywords: STEM (Science, Technology, Engineering, and Mathematics), STEM anxiety, Personal Teaching Efficacy and Beliefs (PTEB), Teaching Outcome Expectancy Beliefs (TOEB).

Introduction

STEM (Science, Technology, Engineering, and Mathematics) is an integrated educational approach that aims to develop students' creative thinking abilities (He et al., 2023). Brown et al., (2011) defined STEM education as a standards-based, meta-discipline residing at the school

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level in which all teachers, particularly science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning in which discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study. STEM education has received increased attention and has proliferated during this period, with the United States, Australia, and the Netherlands being the most productive countries in STEM education research (Irwanto et al., 2022). However, Bangladesh lags behind the STEM education paradigm in improving technical and economic growth, thus it is essential to study the benefits and risks of incorporating STEM into Bangladesh's educational system (Islam et al., 2019).

Despite the growing demand for professionals, numerous studies demonstrate a drop in STEM as a career option across the lifespan (Leu, 2017). Intense laboratory, project-based, and lecture-based coursework, greater classroom competitiveness, and the intellectual challenge of STEM courses are just a few of the obstacles STEM students face. As a result, many students frequently exhibit STEM-related anxiety, which manifests as anxiety, avoidance, or fear of learning science or math concepts (Rask, 2010; Thiry et al., 2011). Students who suffer from this anxiety are more likely to avoid careers in science, technology, engineering, and mathematics (STEM) (Osborne et al., 2003). Students' anxiety about STEM education, can be viewed as a negative value that diminishes their motivation and interest in STEM topics and vocations.

There are a variety of factors that cause young people to forego STEM (Beilock & Maloney, 2015; Picha, 2018). Researchers and teachers have found that mathematics anxiety can be a barrier to success in STEM fields (Picha, 2018). Tobias & Weissbrod, (1980) define mathematics anxiety as "fear and helplessness when solving a mathematics problem." Anxiety over science develops when fearful thoughts and feelings get in the way of studying for science-related courses (Mallow, 1978). As a student advances through school, their level of science anxiety grows (Hassan, 2008; Ucak & Say, 2019). People may not engage in exercises designed to improve their spatial abilities if they suffer from spatial anxiety. Nearly seven decades of research (Gladieux, 1958; Wai et al., 2009) have established that spatial skills are essential for success in the STEM fields. It has been suggested that an aptitude for spatial thinking and reasoning can lead to better results in STEM fields (Stieff & Uttal, 2015; Uttal & Cohen, 2012).

The quality and efficacy of tseachers, especially their belief in teaching, have been proven to have a greater impact on student's educational experiences than any other single modifiable component (Leinhardt & Greeno, 1986; Nye et al., 2004). Teachers' knowledge, beliefs, and attitudes shape their classroom exercises and professional activities, shaping the classroom environment and students' interest and learning (Fang, 1996; OECD, 2009) (Fang, 1996; O.E.C.D., 2009)according to theoretical frameworks in educational, cognitive, and social psychology. Some studies of teachers' efficacy beliefs consider two distinct dimensions based on the self-efficacy theory (Hassan, 2008). The first factor, personal teaching efficacy, indicates how confident teachers are in their ability to teach effectively. According to Swars et al., (2007), the second component, teaching outcome expectancy, is a teacher's belief that successful instruction may result in student learning despite outside variables including the student's home environment, family background, and parental influences.

Teachers' expectancy-value beliefs and efficacy have enormous psychological importance. For this, these variables have an impact on the level of anxiety experienced in

STEM education (Ates & Sungur GÜL, 2023). Research indicates that STEM educators who possess robust self-efficacy beliefs exhibit greater confidence in delivering STEM curricula. In addition, they can effectively manage complex classroom scenarios (Han et al., 2021). Teachers can substantially impact student motivation and learning in STEM topics and vocations by creating instructional and social learning environments (Kelley et al., 2020). Teachers' self-efficacy, outcome expectations, and STEM teaching can be influenced by various factors such as instructional, curriculum, institutional, student, and assessment concerns. To succeed, it is necessary to address and overcome these obstacles, while also providing instructors with sufficient resources, training, advice, feedback, and acknowledgment. These enhancements will elevate their belief in their ability to succeed and their anticipation of positive results in integrated STEM training (Margot & Kettler, 2019).

The issue of STEM education anxiety is somewhat complicated, and teachers' self-efficacy and expectancy-value beliefs could be some of the aspects that are affecting it. A study by Uzun et al. (2019) found that teachers' self-efficacy and expectancy-value beliefs towards STEM education were negatively related to students' math anxiety and science anxiety. A study by Megreya et al., (2021) found that teachers' self-efficacy and expectancy-value beliefs towards STEM education were negatively related to students' science anxiety among 1,200 students and 60 teachers from grades 7 to 12 in Saudi Arabia. Unfortunately, there has not been an ample number of empirical studies that explore the relation between them in the context of Bangladesh.

The Bangladesh government's strategy to achieve the United Nations' Sustainable Development Goals by 2030 and to become a high-income country by 2041 hinges on human capital investment and technological innovation. Encouraging FDI has immense potential to create jobs and hence achieve these goals, but investors report concern about the low-skilled labor force and technological challenges like a high risk of cyberattacks—gaps that the education sector must help fill (World Bank, 2013). According to a survey, there are fewer students studying science at the SSC and HSC levels than in previous years, with two-thirds of students being routed away from science streams as early as ninth grade (World Bank, 2013). To address the declining interest in STEM fields among secondary and upper-secondary pupils, the Bangladeshi Ministry of Education has recognized the need to increase the profile of STEM subjects in classrooms (Siddiqa & Braga, 2019). In a policy paper from the Bangladeshi context, it was reported that 30 percent of teachers identified teacher quality as a barrier, perhaps indicating a lack of awareness of their role in the challenges that hinder students from obtaining STEM education and Teachers are largely unmotivated and lacking in support, but administrators have little agency to change school conditions in an uncertain environment. This report also showed that according to students they are confident and interested in STEM subjects, but teacher quality and infrastructural challenges keep them from reaching their full potential (Siddiqa & Braga, 2019). Research explored the impact of teacher self-efficacy and result expectancy beliefs on student attitudes and academic achievement in integrated STEM, concluding that these beliefs are crucial for student STEM learning and further research is needed to understand the correlation between teacher self-efficacy and student outcomes and academic achievement, as well as its impact on student STEM interests in future careers (Han et al., 2021). In another previous literature, it was found that teachers' beliefs in their teaching efficacy and success are strong predictors of students' self-efficacy, motivation, and academic performance (Tschannen-Moran & Hoy, 2007). That is why it is essential to study the role of teacher-related variables that prohibit students from studying in STEM education-related fields in their secondary and higher secondary education in the Bangladeshi context.

Theoretical framework

This theoretical framework integrates constructs from Social cognitive theory, and Self-Determination Theory (SDT) to explore the role of teachers' self-efficacy and outcome expectancy on students' STEM education anxiety. Social Cognitive Theory Bandura, (1985) Core Constructs: Self-efficacy, outcome expectancy, modeling, and reciprocal determinism. This theory emphasizes reciprocal causation through the interplay of cognitive, behavioral, and environmental factors. Specifically, it posits that learning occurs in a social context with dynamic and reciprocal interactions among the person, environment, and behavior. This theory aligns with research as it emphasizes the role of beliefs (self-efficacy and outcome expectancy) in shaping behavior (Students' anxiety) and outcomes (students' learning). According to several studies, Teachers with high self-efficacy are likely to employ more effective teaching strategies, which can reduce student anxiety, and positive outcome expectancies can lead to greater effort and persistence in teaching, creating a supportive learning environment (Fang, 1996; O.E.C.D., 2009).

Self-Determination Theory (SDT), proposed by Grolnick et al., (1991), provides a robust framework for understanding the factors influencing individuals' motivation and well-being. This theory served as the foundation for exploring the relationship between teachers' self-efficacy and outcome expectancy beliefs and secondary students' STEM education anxiety. SDT posits that humans possess innate psychological needs for Autonomy, Competence, and Relatedness. When these needs are satisfied, individuals experience intrinsic motivation, which is characterized by enjoyment, interest, and personal satisfaction in an activity. In STEM education Teachers with high self-efficacy and positive outcome expectancies are more likely to create classroom environments that foster students' autonomy, competence, and relatedness needs. Students whose needs for autonomy, competence, and relatedness are met are less likely to experience STEM education anxiety (Han et al., 2021).

The purpose of this study was to analyze secondary school students' STEM education anxiety, teachers' self-efficacy, and expectancy-value beliefs towards STEM subjects, as well as investigate the link between these factors and examine the effects of teacher-related variables on student STEM anxiety. The present study, therefore, tries to shed more light on the association between students' STEM education anxiety and teachers' self-efficacy, and expectancy-value beliefs by answering the following major objectives 1. To estimate secondary school students' STEM education anxiety, teachers' self-efficacy, and expectancy-value beliefs. This is because this objective offers the baseline data for the other objectives and allows for the comparison of different groups of students and teachers. 2. To see if there are differences in mean anxiety ratings between male and female students and between male and female teachers in Personal Teaching Efficacy and Beliefs (PTEB) and Teaching Outcome Expectancy Beliefs (TOEB). According to a policy paper, Bangladeshi girls are confident and interested in STEM subjects, but teacher quality and infrastructural challenges keep them from reaching their full potential (Siddiqa & Braga, 2019). This objective can provide insights into this policy paper's reported findings. 3. To Explore the relationship between students' anxiety regarding STEM education and their teachers' Teaching Efficacy and Beliefs (PTEB) and Teaching Outcome

Expectancy Beliefs (TOEB) regarding STEM education. Undstanding this relationship will help educators and researchers to see whether high self-efficacy and outcome expectancy teachers can mitigate students' STEM education anxiety and develop effective interventions that high self-efficacy and outcome expectancy teachers use, which will in turn lower students' anxiety about it and encourage positive attitudes and outcomes in STEM learning.

Method

Research design

A cross-sectional survey research design based on an offline questionnaire form was used to collect data and to investigate the relationship between secondary school students' anxiety towards STEM education and their teachers' self-efficacy beliefs and outcome expectancy. They provided their choices that best describe the perceptions of teacher self-efficacy and students' STEM education anxiety. The data for answering our research questions using statistical analysis.

Participants and Procedure

Based on the "convenience sampling method," data were collected from 200 secondary public school students and their 50 teachers from a public school in Bangladesh. However, responses from 165 students were retrieved and included in the analysis. There were 165 total students (80 male and 85 female) and 50 total teachers (39 male and 11 female) and the students were from tenth grade. The collection of data on the student participants was conducted during normal school days. Each participant received a briefing on the overall goals of the study and was asked to volunteer for it. The study adhered to the guidelines of the Helsinki Declaration and its later amendments or comparable ethical standards. The study was also approved by the Ethical Review Committee of the Department of Psychology, University of Dhaka, Bangladesh (PSY 23/03/029). Participants received assurances that their answers would be kept private and used exclusively for research. Verbal consent was obtained before the paper-based survey was conducted. The survey's components included an informed consent statement and a socio-demographic section, translated Bangla version of scales. Participants who were students answered questions on the mathematics, science, and spatial anxiety scales, and participants who were teachers answered items on the T-STEM Survey instrument's subscales measuring personal teaching efficacy and beliefs (PTEB), and teaching outcome expectation beliefs (TOEB).

Measures

Four questionnaires and a personal information form were utilized in the study to assess students' STEM-related anxiety. The Personal Information Form (PIF), Modified-Abbreviated Math Anxiety Scale (m-AMAS), Abbreviated Science Anxiety Scale (ASAS), Spatial Anxiety Scale (SAS), and T-STEM Survey were utilized for the evaluation in this study. According to researchers and educators, math anxiety is a significant obstacle to enrollment in and success in STEM fields (Picha, 2018) which is why the mathematics anxiety questionnaire was administered. It is expected that those who are anxious about science will avoid circumstances involving that subject by enrolling in fewer scientific courses and staying away from STEM-related jobs more frequently (Osborne et al., 2003) that’s why the science anxiety questionnaire was administered Students must also be able to understand and explain graphs, diagrams, and physical models that reflect visual-spatial representations for many abstract scientific processes and concepts. So, mastering spatial reasoning and thinking may boost STEM achievement and the number of people who choose to pursue STEM careers (Uttal & Cohen, 2012) that’s why a spatial anxiety questionnaire was administered. Science anxiety, Spatial anxiety, and Mathematics anxiety questionnaires were used to assess the STEM-related education anxiety of the students as a whole (Gonzalez et al., 2019). Additionally, the T-STEM Survey, which was administered by the Friday Institute for Educational Innovation in 2012, assessed the teaching efficacy, beliefs, and teaching outcome expectancy beliefs of educators.

The Personal Information Form (PIF) Student personal information includes age, class, gender, study hours, most recent academic performance, and academic background of parents. Regarding teachers, it encompassed a variety of aspects, such as gender, years of experience more.

The Modified-Abbreviated Math Anxiety Scale (m-AMAS): Modified-Abbreviated Math Anxiety Scale was used to measure students' math anxiety. The m-AMAS Carey et al., (2017) was based on the AMAS (Hopko, 2003). Carey et al. (2017) found strong reliability and validity in the m-AMAS in two UK trials with 7–12th graders. The m-AMAS factors affect negatively math achievement and exhibit strong internal consistency (Cronbach's alpha =.77–.88). It has 9 items and a 5-point Likert scale from 1 (low anxiety) to 5 (severe anxiety). Scores vary from 9 to 45. The final score was calculated by aggregating item ratings; higher scores indicate higher science anxiety.

The Abbreviated Science Anxiety Scale (ASAS): To assess students' science anxiety, the Abbreviated Science Anxiety Scale (ASAS) developed by Ahmed M. Megreya, Dénes Szűcs, and Ahmed A. Moustafa was used. Internal ASAS factor consistency is good. Cronbach's alpha of .77–.88 confirmed the ASAS's two-factor structure (Megreya et al., 2021). In samples of Grades 7–10 students, the three science anxiety scores had well to sufficient reliabilities: 0.87–0.89 for the total score (Megreya et al., 2021). It has 9 items and a 5-point Likert scale from 1 (low anxiety) to 5 (severe anxiety). From 9 to 45, the total score was calculated by averaging the ratings for each question. Higher scores indicate higher science anxiety.

Spatial Anxiety Scale (SAS): The Lawton & Kallai, (2002) spatial Anxiety Scale was used to assess state-level spatial anxiety. The total score was calculated by aggregating item ratings; higher scores indicate stronger spatial anxiety. Scores between 8 and 40 re achievable. In a study with 120 college students, Lawton & Kallai, (2002) found that the SAS showed high levels of internal consistency (Cronbach's alpha =.81) and test-retest reliability (r =.83). The State-Trait Anxiety Inventory (STAI) and the Beck Anxiety Inventory (BAI) were also shown to have substantial correlations with the SAS, demonstrating convergent validity. The results of our reliability analysis indicated a Cronbach's alpha of 0.449.

Survey Instrument T-STEM Survey: Survey Instrument T-STEM developed by the Friday Institute for Educational Innovation (2012) was used for teachers to evaluate their self-efficacy for teaching; and their belief that teachers affect student learning. The survey measures several constructs on seven subscales, and for all constructs, Cronbach's alpha was calculated at 0.95 (Friday Institute for Educational Innovation, T-STEM Survey, 2009). The Personal Teaching Efficacy and Beliefs construct, which has 11 items, was translated into Bangla and used in the study to assess respondents' self-efficacy and confidence in teaching a specific STEM subject (Hamdani et al., 2024). The Teaching Outcome Expectancy Beliefs construct, which included nine items, assessed respondents' belief in the impact of teacher actions on student learning in the subject (Hamdani et al., 2024). A five-point Likert scale was used in the study to rate items on personal STEM teaching efficacy and outcome expectancy. Higher scores indicated higher levels of efficacy, and item analysis revealed internal consistency.

Data Interpretation

Results from the participants were included in the report. Statistical analyses (descriptive statistics, independent sample t-tests, and correlation analysis) of the data have been carried out with SPSS Statistics 20.0.

Result

Descriptive statistics and correlations

Descriptive statistics were conducted on 165 students to identify trends and distributions. The sample consisted of 51.5% female and 48.5% male students. The students' socioeconomic status varied, with 81.8% belonging to the middle class, 9.7% to the higher class and 8.5% to the lower class. Fathers' educational backgrounds ranged from uneducated (15.2%) to post-graduated (15.8%), while mothers' educational backgrounds varied from Secondary School Certificate (23%) to grade 1–10 (39.4%). According to students' self-report, 31.5% failed in Mathematics, 13.3% in Science, and 9.7% in Information and Communications Technology while 45.5% of the students claimed not to have any record of failure in the previous year. 45.5% of the participants reported studying more than 4-5 hours per day, 37.0% studied for 4-5 hours per day, and 17.0% studied less than 4-5 hours per day.

Table 1

Descriptive Statistics and Gender Differences in Mathematics, Science, Spatial Anxiety

Variables	*female(n=85)*		*male(n=80)*		*t*	*p*
	M	*SD*	*M*	*SD*		
Mathematics anxiety	20.64	4.667	20.78	5.011	0.185	.853
Science anxiety	20.40	4.433	20.05	4.682	-.493	.622
Spatial anxiety	20.04	3.231	19.71	3.67	-.600	.549

Table 1 presents descriptive statistics, including mean scores (*M*) and standard deviations (*SD*), along with gender differences in mathematics, science, and spatial anxiety scores. For mathematics anxiety, females scored 20.64 (SD = 4.667), while males scored 20.78 (SD = 5.011), and for science anxiety, females scored 20.40 (SD = 4.433), while males scored 20.05 (SD = 4.682), and for spatial anxiety, females scored 20.04 (SD = 3.231), while males scored 19.71 (SD = 3.67).

As well as for Mathematics Anxiety, the t-test assuming equal variances (t = 0.185, *p* = 0.853) indicated no significant gender-based differences in mathematics anxiety scores. In the case of science anxiety, females had a mean score of 20.40 (SD = 4.433), whereas males had a mean score of 20.05 (SD = 4.682). Again, the gender difference was not statistically significant (t = -0.493, *p* = 0.622). For spatial anxiety, females had a mean score of 20.04 (SD = 3.231), and males had a mean score of 19.71 (SD = 3.677). The gender difference was not also statistically significant (t= -0.600, *p* = 0.549) here. For both Science and spatial Anxiety, the t-test demonstrated no statistically significant differences between male and female participants in science and spatial anxiety scores.

AMAS researchers proposed two criteria for categorizing people as having high or low mathematics anxiety. Participants scoring below 20 (9 to 19) have mild mathematics anxiety, while those scoring over 30 (31 to 45) have significant mathematics anxiety (Maloney et al., 2010). The mean mathematics anxiety (M = 20.70, SD = 4.823) found in this study was moderate. Based on the mean and standard deviation of the scale scores reported by Megreya et al., (2021) in their original study there are three criteria; Low science anxiety: scores from 9 to 18, Medium science anxiety: scores from 19 to 27, High science anxiety: scores from 28 to 45 (Megreya et al., 2021). The mean science anxiety score was 20.23 (SD = 4.545) in the present study which can be called medium. Some studies have used the following criteria to classify participants into low, medium, and high spatial anxiety groups: Low spatial anxiety: scores from 8 to 16, Medium spatial anxiety: scores from 17 to 24, High spatial anxiety: scores from 25 to 40. These criteria are based on the mean and standard deviation of the scale scores that Lawton, (1994) reported in her original study (Lawton, 1994). The mean spatial anxiety total score was 19.88 (SD = 3.448) here. This suggests that students, on average, experienced a relatively lower level of anxiety in spatial domains compared to mathematics and science. The lower standard deviation of 3.448 indicates less variability in spatial anxiety scores, and the variance of 11.888 reflects a relatively narrow distribution.

A sample of 50 teachers was involved, and different factors were looked at to identify their demographic and professional characteristics. Science and mathematics teachers each constituted 40.0% of the sample, while technology teachers made up 20.0%. Regarding gender, 78.05% of teachers were male, and 22.0% were female. Among the teachers surveyed, 94.0% belonged to the middle class, 4.0% belonged to the lower class, and 2.0% belonged to the higher class in terms of socioeconomic status. 54.0% of teachers had master's degrees, and 46.0% possessed honors/degree qualifications. Teaching experience varied among the educators. 38.0% had 21 or more than 21 years of teaching experience. Other experience categories included 11-15 years (20.0%), 6-10 years (18.0%), 0-5 years (16.0%), and 16-20 years (8.0%).

Table 2

Descriptive Statistics and Gender Differences for Teaching Efficacy and Beliefs and Teaching Outcome Expectancy

Variables	*female(n=11)*		*male(n=39)*		*t*	*p*
	M	*SD*	*M*	*SD*		
Teaching efficacy and beliefs	41.45	2.659	41.79	4.426	.242	.810
Teaching outcome expectancy	38.18	.4.094	34.82	4.116	-2.395	.021

Table 2 presents descriptive statistics, including mean scores (M) and standard deviations (SD), gender differences in teaching efficacy and beliefs, and teaching outcome expectancy. The study involved 11 females and 39 males. For teaching efficacy and beliefs, females had a mean score of 41.45 (*SD* = 2.659), while males had a mean score of 41.79 (*SD* = 4.426). However, in the case of teaching outcome expectancy, female teachers had a mean score of 38.18 (*SD* = 4.094), whereas male teachers had a mean score of 34.82 (*SD* = 4.116). An independent samples t-test was used to compare the mean of teaching outcome expectancy of male (n=39) and female (n=11) secondary school teachers. The gender difference was not statistically significant (t = 0.242, p = 0.810) for Teaching efficacy and beliefs. The t-test was statistically significant, with the mean teaching outcome expectancy of females (M=38.18, SD=4.) significantly higher, than the males (M= 39.74, SD=4.95), t=-2.395, p<.05, two-tailed.

Table 3 shows the correlation between three variables students' anxiety, teachers' teaching efficacy and belief, and teachers' outcome expectancy. There was a strong negative and statistically significant correlation between "Students' Mathematics Anxiety" and "Mathematics Teacher Teaching Efficacy and Belief" (r = -0.645, p < 0.01).

Table 3

Correlations between Students' Anxiety and Teachers' Teaching Efficacy and Belief and Teaching Outcome Expectancy

	1	2	3	4	5	6	7	8	9
Students' mathematics anxiety	1								
Students' science anxiety	.594**	1							
Students' spatial anxiety	.357**	.368**	1						
Mathematics teacher teaching efficacy and belief	-.645**	-.249	.393	1					
Mathematics teacher teaching outcome expectancy	-.444*	-.350	.283	.114	1				
Science teacher teaching efficacy and belief	-.257	-.450*	.128	.232	.071	1			
Science teacher teaching outcome expectancy	.038	-.462*	.140	.356	-.177	.466*	1		
Technology teacher teaching efficacy and belief	-.515	-.394	.689*	.144	.594	.309	.010	1	
Technology teacher teaching outcome expectancy	-.437	-.220	.737*	.570	.199	.228	-.345	.522	1

** Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

There was a moderate negative and statistically significant correlation between "Students' Mathematics Anxiety" and "Mathematics Teacher Outcome Expectancy" (r = -0.444, p < 0.05). There was a weak positive and statistically significant correlation between "Mathematics Teacher Teaching Efficacy and Belief" and "Mathematics Teacher Outcome Expectancy" (r =

0.114, $p < 0.05$), indicating that mathematics teachers who have higher teaching efficacy and belief tend to have slightly higher outcome expectancy. There was a negative and statistically significant correlation between "Students' Science Anxiety" and "Science Teacher Teaching Efficacy and Belief" ($r = -0.450$, $p < 0.05$). Similarly, there was a negative and statistically significant correlation between "Students' Science Anxiety" and "Science Teacher Outcome Expectancy" ($r = -0.462$, $p < 0.05$). There was a positive and statistically significant correlation between "Science Teacher Teaching Efficacy and Belief" and "Science Teacher Outcome Expectancy" ($r = 0.466$, $p < 0.05$). The correlation between "Students' spatial anxiety" and "Technology teacher teaching efficacy and belief" was negative and statistically significant ($r = -0.689$, $p < 0.05$). The correlation between "Students' spatial anxiety" and "Technology teacher outcome expectancy" was also negative and statistically significant ($r = -0.737$, $p < 0.05$).

Table 4

Multiple regression coefficients for Mathematics Teachers' PTEB and TOEB predicting students' Mathematics anxiety.

Variable	Unstandardized Coefficients		Standardized Coefficients	*tt*	***P**p*	Collinearity statistics	
	β	*Standard Error*	Beta			Tolerance	Variance inflation factor (VIF)
Constant	68.651	10.479		6.551	.000		
Mathematics teacher teaching efficacy belief	-.878	.237	-.602	-3.700	.002	.987	1.013
Mathematics teacher teaching outcome expectancy	-.341	.148	-.375	-2.306	.034	.987	1.013

Note: Outcome variable: Students' Mathematics anxiety score ($R^2 = .555$, Adj. $R^2 = .503$, $F (2, 17) = 10.62$, $p = 0.001$)

Table 4 represents the multiple regression coefficients for Mathematics Teachers' PTEB and TOEB predicting students' Mathematics anxiety. A statistically significant model for mathematics anxiety is revealed by the regression analysis, where teaching efficacy belief ($β = -0.602$, $p = 0.002$) and teaching outcome expectancy ($β = -0.375$, $p = 0.034$) have been found as significant predictors. The R-squared value of 0.555 shows that the model explains roughly 55.5% of the variation in students' mathematics anxiety scores. An adjusted R-squared value of 0.503 demonstrates the model's robustness when the number of predictors is taken into account. A statistically significant model for mathematics anxiety is revealed by the regression analysis ($F (2, 17) = 10.620$, $p = 0.001$).

Table 5 represents the multiple regression coefficients for Science Teachers' PTEB and TOEB predicting students' science anxiety. The regression analysis for science anxiety shows a marginally significant model (F (2, 17) = 3.371, p = 0.058), with teaching efficacy belief and teaching outcome expectancy both contributing to the model's explanatory power. The model explains approximately 28.4% of the variance in students' science anxiety scores, according to the R-squared value of 0.284. The adjusted R-squared (Adj. R^2 = 0.200) takes into consideration the model's explanatory power while taking the number of predictors into account. For science anxiety, the regression analysis shows a marginally significant model (F (2, 17) = 3.371, p = 0.058). Teaching outcome expectancy (β = -0.322, p = 0.183) and teaching efficacy belief (β = -0.300, p = 0.213) add to the model's explanatory power but are not statistically significant at conventional levels of significance.

Table 5

Multiple regression coefficients for Science Teachers' PTEB and TOEB predicting students' science anxiety.

Variable	Unstandardized Coefficients		Standardized Coefficients	*t*	*p*	Collinearity statistics	
	β	*Standard Error*	Beta			Tolerance	Variance inflation factor (VIF)
Constant	52.109	12.093		4.309	.000		
Science teacher teaching efficacy beliefs	-.330	.255	-.300	-1.294	.213	.783	1.278
Science teacher teaching outcome expectancy	-.504	.363	-.322	-1.389	.183	.783	1.278

Note: Dependent Variable: Students Science anxiety score (R^2 = .284, Adj. R^2 = 0.200, F (2, 17) = 3.371, p = 0.058)

Table 6

Multiple regression coefficients for Technology Teachers' PTEB and TOEB predicting students' spatial anxiety.

Variable	Unstandardized Coefficients		Standardized Coefficients	*t*	*p*	Collinearity statistics	
	β	*Standard Error*	Beta			Tolerance	Variance inflation factor (VIF)
Constant	59.38	11.082		5.359	.001		

Technology teachers' Teaching efficacy beliefs	-.482	.293	-.419	-1.647	.144	.728	1.374
Technology teachers' Teaching Outcome Expectancy	-.528	.259	-.518	-2.038	.081	.728	1.374

Note: Dependent Variable: Students' Spatial anxiety score (R^2 = .670, Adj. R^2 = 0.576, F (2, 7) = 7.118, *p* = 0.021)

Table 6 represents the multiple regression coefficients for Technology Teachers' PTEB and TOEB predicting students' spatial anxiety. For spatial anxiety, the regression analysis suggests a significant model (F (2, 7) = 7.118, p = 0.021). Teaching efficacy belief and teaching outcome jointly explain approximately 67% of the variance in students' spatial anxiety scores. Teaching efficacy belief (β = -0.419, p = 0.144) and teaching outcome expectancy (β = -0.518, p = 0.081) both have negative relationships with spatial anxiety, though the predictors are not statistically significant.

Discussion

Our first objective of the present study was to estimate secondary school students' STEM education anxiety, teachers' self-efficacy, and expectancy-value beliefs. The mean mathematics anxiety score was 20.64 (SD = 4.667) and AMAS researchers proposed categories for categorizing people as having high or low math anxiety. Low mathematics anxiety: scores from 9 to 18, Medium mathematics anxiety: scores from 19 to 27, High mathematics anxiety: scores from 28 to 45. (Maloney et al., 2010). The mean math anxiety was moderate in this study. Based on the mean and standard deviation of the Science anxiety scale scores reported by Megreya et al., (2021) in their original study there are three criteria (Megreya et al., 2021). These criteria are: Low science anxiety: scores from 9 to 18, Medium science anxiety: scores from 19 to 27, High science anxiety: scores from 28 to 45. The mean science anxiety score was 20.40 (SD = 4.433). Based on this norm, the mean Science anxiety can be called moderate. Studies have used the following criteria to classify participants into low, medium, and high spatial anxiety groups: Low spatial anxiety: scores from 8 to 16, Medium spatial anxiety: scores from 17 to 24, High spatial anxiety: scores from 25 to 40. These criteria are based on the mean and standard deviation of the scale scores reported by Lawton, (1994) in her original study (Lawton, 1994). The mean spatial anxiety total score was 20.04 (SD = 3.67). This suggests that students, on average, experienced a relatively lower level of anxiety in spatial domains compared to mathematics and science. Female teachers (M = 38.18, SD = 4.094) demonstrated significantly higher mean TOEB scores compared to male teachers (M = 34.82, SD = 4.116). At the same time, male teachers (M = 41.79, SD = 4.426) demonstrated higher mean PTEB scores compared to female teachers (M = 41.45, SD = 2.659). In previous studies, Klassen & Chiu, (2010) identified that female teachers had greater outcome expectancies in mathematics than male teachers and Bursal (2008) reported that female teachers had greater outcome expectancies in science than male teachers. This objective provided baseline data for the other objectives and allowed for comparing different groups of students and teachers.

Our second objective was to see if there are differences in mean anxiety ratings between male and female students and between male and female teachers in Personal Teaching Efficacy and Beliefs (PTEB) and Teaching Outcome Expectancy Beliefs (TOEB) as some reports reported that girls are confident towards STEM education (Siddiqa & Braga, 2019). There were no significant gender differences in mathematics anxiety, science anxiety, or spatial anxiety scores between male and female students. Gender differences in math and science anxiety concerning STEM education have been investigated in several studies. However previous research conducted among elementary children, high school students, and non-STEM students showed that girls and women experience more math anxiety than boys and men do (Szczygieł, 2019). Female students report greater test anxiety and science evaluation anxiety than males, which negatively impacts their academic performance (Megreya et al., 2021). The relationship between gender and spatial anxiety is influenced by factors such as spatial skills and mental rotation capacity, according to Delage et al., (2021). In studies, females exhibited greater anxiety in spatial tasks, particularly in mental rotation, where they performed worse than males (Alvarez-Vargas et al., 2020).

In contrast to earlier studies that found higher levels of math, science, and spatial anxiety among girls and women, this study found no significant gender differences in students' anxiety about STEM education and our study findings support the previous policy papers' findings that girls are confident about STEM education in Bangladesh (Siddiqa & Braga, 2019). Multiple potential explanations exist for the lack of gender disparities in math, science, and spatial anxiety in this study. According to a (Canton et al., 2023) Júlio-Costa et al. study, there are no significant variations in math anxiety levels between boys and girls (Zeberio, 2023). In the study conducted by Özbuğutu, (2021), it was discovered that there was no statistically significant difference in the levels of anxiety experienced by male and female students on the occasion of attending scientific classes. As stated by Doz et al., (2023) Mathematics anxiety is influenced by cognitive and affective factors not solely determined by gender. Gonzalez et al., (2019) have shown that gender discrepancies in mathematics and science anxiety may be attributed to biases present in anxiety measurement instruments. Recent research has found that the presence of educational infrastructure has a significant impact on mathematics anxiety. Additional research has demonstrated that the gender difference in number line estimating is not significantly mediated by spatial anxiety (Tian et al., 2022). These support the evidence that external factors contribute to the levels of anxiety experienced (Lai & Lee, 2024). The difference in findings may arise from the sample's greater exposure to inclusive and supportive STEM environments, which may have closed the gender gap in anxiety.

In our study, it was also seen that among the 50 teachers, there were only 11 female STEM teachers and the findings support the policy paper which stated that quality female teachers who specialize in STEM are scarce, and, in rural areas where investment in education is lower, they are even harder to find (Siddiqa & Braga, 2019). Results of the present study show that there was a significant difference in TOEB among male and female teachers. Female teachers ($M = 38.18$, $SD = 4.094$) demonstrated significantly higher mean TOEB scores compared to male teachers ($M = 34.82$, $SD = 4.116$). Earlier research suggests that female teachers have higher outcome expectations than male teachers because they are less biased in their grading processes and have a better beneficial impact on female students' academic achievement (Rakshit & Sahoo, 2023). Klassen & Chiu, (2010) identified that female teachers had greater outcome expectancies in mathematics than male teachers. Another study found female teachers to have higher outcome expectations than male teachers in science, but not in mathematics and they also had higher levels of self-efficacy, which is linked to personal teaching efficacy (Rabab'h, 2023). Students evaluated female teachers more favorably when it came to their teaching methods and concluded that they had more favorable attitudes about teaching overall (Ward et al., 2020). Although there was no statistically significant difference in the outcome expectancies of male and female science teachers, male teachers may have slightly better personal scientific teaching efficacy scores (Hechter, 2011). As a result, it may be said that rather than gender disparities, female teachers' higher outcome expectations in science-related courses can be linked to their positive attitudes and strong self-efficacy beliefs.

Our last objective was to explore the relationship between students' anxiety regarding STEM education and their teachers' Personal Teaching Efficacy and Beliefs (PTEB) and Teaching Outcome Expectancy Beliefs (TOEB) regarding STEM education. The correlation between teachers' PTEB and TOEB with their students' mathematics, science, and spatial anxiety was significant, and found that the relationships between PTEB and TOEB among science teachers and students' anxiety about science, between PTEB and TOEB among technology teachers and students' spatial anxiety, between PTEB and TOEB among mathematics teachers and students' anxiety about mathematics; these were negatively correlated. There is a significant relationship between students' anxiety levels and their teachers' teaching self-efficacy and outcome expectancy attitudes has been provided by a prior study of Indrawati et al., (2021).

High PTEB and high TOEB among math teachers were associated with low math anxiety among the students. The same type of results was found when we saw the association between PTEB and TOEB among science teachers with students' science anxiety and between PTEB and TOEB among technology teachers with students' spatial anxiety. The results of our investigation showed that anxiety related to mathematics was significantly significant, explaining 55.5% of the variation. The multiple regression analysis results suggest that teachers' PTEB and their TOEB are important factors influencing students' mathematics anxiety. When teachers have higher efficacy beliefs and expect positive outcomes, students tend to experience less mathematics anxiety. Additionally, there were significant negative connections between mathematics anxiety and teaching efficacy belief and teaching outcome expectancy. A study (Benden & Lauermann, 2023) found a negative relationship between instructors' self-efficacy perceptions and students' math fear. This relationship showed that when teachers were more confident in their ability to teach mathematics, students experienced less arithmetic dread. Teachers who believe in themselves can establish supportive learning environments and help students manage anxiety (Zay & Kurniasih, 2023). Furthermore, teachers with a high level of self-efficacy may be able to effectively explain and demonstrate ways of dealing with arithmetic fear and this self-efficacy of their teachers can help students to establish their own self-efficacy beliefs and lessen their anxiety levels (Ervia et al., 2024). According to Hendral & Hidayati, (2023), instructors with a high level of self-efficacy in mathematics are more confident in their ability to assist pupils in overcoming whatever fears they may have. Students can benefit from a supportive and motivating learning environment that is fostered by teachers who have higher outcome expectancy to teach mathematics and students' math fear may be reduced by the teacher's positive attitude and confidence (Yorulmaz et al., 2021). Thus, teachers' personal outcome expectancy beliefs play an important role in reducing students' mathematics anxiety by fostering a pleasant and supportive learning environment (Zanabazar et al., 2023).

According to our present study, science anxiety was marginally significant, accounting for 28.4% of the variance in students' science anxiety scores. The multiple regression analysis results suggest that while there might be a slight relationship between science teachers' beliefs and students' science anxiety, the evidence is not strong enough to conclude that PTEB and TOEB are significant predictors and Science anxiety was inversely related to instructional efficacy belief and outcome expectancy. Previous studies have shown that teachers' attitudes and self-efficacy beliefs affect students' science anxiety. More specifically, students with better professor self-efficacy had reduced science anxiety (Arnado et al., 2022). This confidence can create a pleasant teaching climate and minimize students' anxiety about science (Alkhateeb & Alkhateeb, 2022). Furthermore, when teachers have strong self-efficacy and outcome-anticipation beliefs, they are more inclined to take chances, embrace challenges, and attempt new ways of teaching science. This can generate a supportive and engaging learning environment that minimizes students' anxiety (Kiziltepe & Kartal, 2022).

Based on our findings, the spatial anxiety model explained 67% of the variation. Their strong explanatory power was demonstrated by the considerable negative associations between teaching efficacy belief and result expectancy. The multiple regression analysis results suggest that while there is a significant relationship between technology teachers' beliefs and students' spatial anxiety, the specific contributions of PTEB and TOEB to this relationship are not clear-cut. Other factors, or perhaps an interaction between PTEB and TOEB, might be driving the overall model significance. Demirkol et al., (2022)found that students' spatial anxiety is mostly driven by their efficacy beliefs, rather than their attitudes, STEM education self-efficacy, or expectancy-value beliefs. Teachers' outcome expectancy beliefs reduce students' spatial anxiety (Burte et al., 2020). High-self-efficacy teachers who believe they can help students learn are more likely to remain longer, focus on academics, and give feedback (Turk et al., 2011). This positive attitude regarding their teaching abilities and expected outcomes can provide a helpful and encouraging environment for students, reducing spatial task anxiety (Mji & Arigbabu, 2012). Thus, teachers with high outcome anticipation and confidence in their teaching may reduce students' spatial anxiety and improve learning conditions (Rocha et al., 2022). Another example of how technology can enhance spatial skills and reduce spatial anxiety is provided by (Rocha et al., 2022) O'Sullivan et al. (2021). They described a project that aimed to bridge the gap between spatial skills instruction and a technology education program for first-year students in Ireland. They found that students who received an online intervention that blended spatial skills training with technology education showed significant improvements in their spatial skills, as well as increased confidence and motivation in learning about technology. In addition, they proposed that technology can promote feelings of happiness and support from others, which might act as a counterbalance to the negative consequences of spatial anxiety.

According to the policy paper by the Echidna Global Scholars Program, Teachers of secondary education are largely unmotivated and lacking in support, and teacher quality and infrastructural challenges keep students from reaching their full potential (Bracke & Corts, 2012) (Scherer & Siddiq, 2019). Furthermore, according to this paper, various reasons compound the issue of teachers' lack of confidence in their ability and outcome expectations. For instance, teachers are overburdened with teaching multiple subjects across various ages and lack adequate resources and Bangladesh spends only 2 percent of the gross domestic product on education—the second-lowest level in South Asia—teachers' inability to support themselves with their salaries alone is unsurprising (Khajehpour, 2011) (World Bank, 2019). This leaves little time for the extracurricular activities that students desire, like STEM clubs or science and technology fairs that can alleviate STEM anxiety (Scherer & Siddiq, 2019). Our findings also show that teacher-related factors like PTEB and TOEB negatively influence students and thus provoke STEM education anxiety in secondary education of Bangladesh. Secondary school students' STEM education anxiety can negatively impact academic performance, motivation, and career decisions and factors such as teachers' self-efficacy and expectancy-value views can influence students' anxiety.

Limitations

The study conducted in Bangladesh on the teacher's self-efficacy and outcome expectancy in STEM education has potential limitations. Firstly, a standardized measure of these components is not available in the Bangladeshi context, as their definition, operationalization, and measurement can have different meanings and outcomes. Secondly, the study was conducted in rural school, which may limit access to STEM education opportunities, affecting the motivation and achievement of students. Additionally, our measurements of STEM anxiety may not have taken into account the particular causes and gender-specific expressions of anxiety, such as interest, self-confidence, and performance expectations. Furthermore, the age range or educational level that our research concentrated on may not accurately represent the gender disparities that start or become more pronounced in later phases of the STEM pipeline. Further research is required on the teaching efficacy and outcome expectancy of teachers to gain more insights into these factors.

Practical implications & Conclusion

Despite these limitations, the findings have several theoretical and practical implications. Theoretically, the relationship between emotional and motivating factors and teachers' and students' involvement in STEM education can aid in understanding the interactions between personal and contextual variables. This relationship has the potential to identify gaps in STEM education literature and practice in Bangladesh and other developing countries. In application, this relationship can aid in the development of efficient interventions and policies to improve the quality and equity of STEM education, evaluate diverse programs and curricula, and foster a positive STEM culture for student and teacher growth.

According to this study, teachers who are more confident and motivated to teach STEM subjects have students who are less anxious and fearful of learning these subjects. This statement highlights the need for future research to explore various aspects of the STEM education domain. It raises questions about the instructional strategies implemented by high-performing teachers, the difficulties that teachers face during implementation, and how these challenges can be tackled. In addition, to gain a better understanding of the relationship between STEM education anxiety and efficacy among diverse groups, future studies should investigate the moderating effects of other variables such as gender, socioeconomic status, ethnicity, location and school type. This could aid in the development of interventions and activities that reduce students' anxiety while also increasing teachers' teaching efficacy and expectations. The study indicated a negative association between teachers' beliefs and students' success in STEM subjects. The results of this study hold significant implications for future STEM education initiatives and programs in underdeveloped countries like Bangladesh. However, there are still disparities between rural and urban areas, as well as issues with teacher education programs. To develop interventions that can reduce students' anxiety and improve instructors' perspectives, future studies should investigate the causal processes, mediators, and moderators. This research will contribute to increased chances for successful STEM education in Bangladesh and other similar countries.

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