Received: 31 January 2024 | Accepted: 28 June 2024

DOI: 10.1111/bjep.12707

ARTICLE

the british psychological society
promoting excellence in psychology

The impact of math anxiety and self-efficacy in middle school STEM choices: A 3-year longitudinal study

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Abstract

Introduction: In today's world, which is progressively oriented towards science and technology and facing a growing demand for skilled professionals, it becomes essential to identify the factors that encourage individuals to pursue careers in STEM fields (Science, Technology, Engineering and Mathematics). Previous research has shown that affective-motivational factors, math performance and gender influence STEM occupational and academic choices in adulthood. However, few studies examined how these factors may influence STEM choices as early as middle school. This study aims to assess how math anxiety, math self-efficacy, math performance and gender influence STEM school choices during middle school.

Methods: We longitudinally assessed a group of 109 students (Year 6) over three school years, with measurements taken on three different occasions.

Results: Findings indicated that individuals who made an STEM school choice experienced lower math anxiety, higher self-efficacy and math performance and were predominantly male. Furthermore, the results indicated that both math anxiety in Year 7 and self-efficacy in Year 6 made the most substantial unique contributions to the STEM school choice.

Conclusion: Math anxiety and math self-efficacy seem to be both crucial in influencing middle school students' STEM choices, offering new perspectives for early interventions aimed at promoting more informed school choices.

KEYWORDS

academic choices, affective-motivational factors, gender differences, math anxiety, math performance, self-efficacy, STEM

INTRODUCTION

In our increasingly *mathematized* society, mathematical thinking plays a crucial role in supporting technical and scientific progress and understanding their dynamics (Keitel et al., 1993). Unsurprisingly, math performance is closely associated with improved educational and occupational outcomes (Bynner & Parsons, 1997; Rivera-Batiz, 1992), economic status (Gerardi et al., 2013; Gross et al., 2009) as well as individuals' physical and mental health (Furlong et al., 2016; Gross et al., 2009). Moreover, individuals with a strong mathematical education significantly contribute to the economic and social development of countries (Foley et al., 2017; Peterson et al., 2011). STEM (Science, Technology, Engineering and Mathematics) education is critical for enhancing a country's economy by preparing individuals and societies to confront future challenges. However, there is a noticeable shortage of trained professionals in STEM disciplines, as underscored by researchers and governments (Beilock & Maloney, 2015; European Commission, 2015; Henriksen, 2015).

Several authors highlighted that affective-motivational factors, math performance and gender are associated with career and academic STEM choices (Ahmed, 2018; Cribbs et al., 2021; Hembree, 1990). Yet, few studies longitudinally described and examined the unique contribution of these factors on STEM school choices during middle school years, which is a critical period for developing negative attitudes towards math and for defining individuals' occupational identity (Ahmed, 2018; Caviola et al., 2022; Namkung et al., 2019; Porfeli & Lee, 2012). In this context, the present study represents one of the first attempts to assess the role of affective-motivational factors (i.e., math anxiety and math self-efficacy), along with math performance and gender, in describing and predicting the STEM school choices of middle school students.

Math anxiety

Several studies highlighted the central role of affective-motivational factors in shaping individuals' learning experiences (Li et al., 2021; Namkung et al., 2019; Pizzie & Kraemer, 2017). Among these emotional factors, math anxiety (MA) has received extensive attention. MA can be defined as a specific form of anxiety toward math, namely *a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems* (Richardson & Suinn, 1972). In other words, MA can be described as a set of feelings encompassing tension, worry and apprehension for current and future situations involving math (Ashcraft & Moore, 2009; Carey et al., 2016; Núñez-Peña et al., 2013).

Extensive research indicates that MA may lead to two main adverse outcomes: poor math performance and math avoidance (Choe et al., 2019; Namkung et al., 2019; Pizzie & Kraemer, 2017). Particularly, MA detrimentally affects math performance, beginning in primary school (Cargnelutti et al., 2017; Pellizzoni et al., 2022; Rubinsten et al., 2018; Tomasetto et al., 2021) and peaking during middle school (Caviola et al., 2022; Namkung et al., 2019). Another negative consequence of MA is the tendency to avoid math-related activities (Ashcraft et al., 2007; Choe et al., 2019; Levine & Pantoja, 2021; Pizzie & Kraemer, 2017), which influences students' short and long-term education career trajectories and STEM choices (Ahmed, 2018; Meece et al., 1990; Pizzie & Kraemer, 2017). Further studies reveal that MA is associated with the avoidance of math tasks (Choe et al., 2019), effortful math study strategies avoidance (Cuder et al., 2023; Jenifer et al., 2022) and less interest in STEM educational pathways (Ahmed, 2018; Daker et al., 2021). This avoidance behaviour can perpetuate a feedback loop, where MA and avoidant behaviours are mutually reinforced (Carey et al., 2016; Choe et al., 2019; Geary et al., 2023). Recent research by Choe et al. (2019) proposed that student with MA may avoid math due to the perceived effortful costs associated with math engagement (Jenifer et al., 2022). For these reasons, MA is probably one of the most important predictors of reluctance to engage in math activities and in turn to pursue STEM pathways (Ahmed, 2018; Daker et al., 2021). Recent evidence has also indicated that MA is often associated with a lower sense of efficacy among students in math (e.g., Justicia-Galiano et al., 2017; Živković et al., 2023), emphasizing the importance of investigating MA, along with motivational factors.

Math self-efficacy

Motivational factors play a central role in influencing student' learning experience (Usher & Pajares, 2009; Živković et al., 2023). One of the core motivational factors in math learning is math self-efficacy (SE) which can be defined as the set of beliefs regarding the ability to perform a specific task and achieve specific goals in math (Bandura, 1977, 1994), influencing how individuals feel, think, motivate themselves and behave during math-related tasks (Bandura, 1977; Lee, 2009; Marsh et al., 2019; Usher & Pajares, 2009). The development of SE beliefs begins as early as primary school (Joët et al., 2011; Živković et al., 2023) and is influenced by experiences with the discipline (Li et al., 2021), relationships with caregivers and peers (Ahn et al., 2017; Skaalvik et al., 2015), the cultural context (Ahn et al., 2016; Giofrè et al., 2020; Pellizzoni et al., 2020; Usher & Weidner, 2018) and negative emotions related to learning (Usher & Pajares, 2009).

Prominent theories on self-competence beliefs, such as the Control Value Theory (CVT, Pekrun, 2006) and the Expectancy-Value Theory (EVS, Eccles & Wigfield, 2020), suggest that expectations and perceived value of math and one's abilities influence math learning and engagement. In other words, positive beliefs about one's own efficacy in dealing with curricular demands can lead to increased involvement in math learning activities, which in turn enhances math performance (e.g., Galla et al., 2014; Schöber et al., 2018; Skaalvik et al., 2015). In addition, students with higher SE are generally more engaged in math-related activities (Du et al., 2021; Grigg et al., 2018; Rottinghaus et al., 2003). For example, higher SE in math not only fosters more positive emotional states (Du et al., 2021) but also promotes sustained engagement in the discipline (Martin & Rimm-Kaufman, 2015; Rottinghaus et al., 2003; Zhang & Wang, 2020), increased persistence (Czocher et al., 2020; Galla et al., 2014; Geisler et al., 2023; Multon et al., 1991) and reduces procrastination (Klassen et al., 2008). These efficacy beliefs in math are crucial not only for day-to-day engagement but also for significant life decisions and career choices, such as pursuing careers in STEM (see Eccles & Wigfield, 2020).

STEM choices

Building on the theoretical underpinnings of Control Value Theory and Expectancy-Value Theory, the interplay between MA and SE emerges as critical in shaping students' engagement with math (Ashcraft et al., 2007; Choe et al., 2019; Eccles & Wigfield, 2020). There is also evidence that students experiencing MA are likely to exhibit avoidant behaviour towards math (Ashcraft et al., 2007; Pizzie & Kraemer, 2017). On the other hand, students with higher SE beliefs are more likely to engage in math-related activities (Du et al., 2021; Grigg et al., 2018; Rottinghaus et al., 2003). These affective-motivational factors not only influence daily math approach and avoidance behaviour (Choe et al., 2019; Eccles & Wigfield, 2020; Pizzie & Kraemer, 2017) but also pivotal long-term decisions that affect educational and career trajectories in STEM fields. Indeed, several studies indicate that MA and SE are associated with interests in pursuing math courses (Betz & Hackett, 1983; Hembree, 1990; Huang et al., 2019) or future career aspirations in STEM fields (Chan, 2022; Eidlin-Levy et al., 2023). However, a limited number of studies evaluated how MA and SE are linked to STEM educational and occupational choices (Ahmed, 2018; Cribbs et al., 2021; Daker et al., 2021; Wang, 2013). For instance, a longitudinal study (Ahmed, 2018) showed that MA is negatively associated with STEM career choices in adulthood (Ahmed, 2018). Similarly, a study conducted on college students by Daker et al. (2021) indicated that MA was associated with the number of STEM courses the college students chose to take, controlling for math performance and gender. A study by Wang (2013) revealed that SE, assessed in high school, is indirectly associated with entry into college STEM courses. Recently, a study by Cribbs et al. (2021) showed that both MA and SE were associated with STEM career choices in college students. In other words, evidence suggests that MA and SE would be associated with young adults' career and educational choices, although their relative contribution to STEM choices has only been considered in one study (Cribbs et al., 2021).

Several theories have been proposed to explain the underrepresentation of girls in STEM education pathways. Recent evidence has shown that girls tend not to choose careers in STEM fields (Breda et al., 2023; Halpern et al., 2007; Huang et al., 2019; LeFevre et al., 1992; OECD, 2013). Research indicates that a complex interplay of factors contributes to this disparity, including for example societal norms and values (Guo, 2022), gender stereotypes (Makarova et al., 2019), math competence beliefs (Eccles & Wang, 2016) and learning preferences (Fisher et al., 2020). At the same time, a large body of research has indicated that girls typically report higher MA than boys (e.g., Devine et al., 2012; Doz et al., 2023; Giofrè et al., 2020; Hill et al., 2016; OECD, 2023). A recent international report (OECD, 2023) has also revealed a gender gap in math performance to the disadvantage of girls in Italy, which is the highest among all OECD countries. Therefore, further studies are needed to assess the contribution of gender in STEM school choices, considering other relevant variables such as MA, SE and math performance.

To sum up, the current literature suggests that affective-motivational constructs are associated with future occupational and college choices in STEM in adults (Ahmed, 2018; Cribbs et al., 2021; Wang, 2013). However, few studies assessed the role of MA and SE, along with math performance and gender on STEM school choices in middle school students. The Italian educational system offers an interesting opportunity to investigate how affective-motivational factors can shape students' school choices. During the last year of middle school, Italian students must choose which high school to enrol in for the following year. High schools in Italy are characterized by 5-year curricula that aim to prepare students for specific university courses and career paths (MIUR, 2023). For instance, national reports have shown that students in science-oriented high schools have better math performance (INVALSI, 2023) and are more inclined to pursue STEM university courses (AlmaLaurea, 2023). Unlike many countries, the Italian Ministry of Education primarily supports public schooling. This reflects the less pronounced disparities between public and private schools in Italy, as private schools are often seen as an alternative for those students who struggle in public schools. Focusing on middle school students is crucial since these students are particularly prone to developing negative attitudes towards math (e.g., Caviola et al., 2022; Namkung et al., 2019) and occupational identity begins to emerge (Ahmed, 2018; Porfeli & Lee, 2012). For these reasons, exploring the Italian educational context could be particularly important to comprehend the role of affective-motivational aspects and math performance in STEM choices as early as middle school. This significance is heightened in a country where gender differences in math performance are among the largest in the world (OECD, 2023).

Aims

The main aim of this study was to explore and predict factors influencing middle school students' (Year 6, Year 7 and Year 8) decisions to opt for STEM-focused high schools, considering affective-motivational factors, math performance and gender. Particularly, the research questions of the present study are twofold:

1. How do the levels of MA, SE and math performance differ among students who decide to enrol in STEM schools versus those who do not? Are there differences between boys and girls in STEM school choices? According to previous studies conducted on college students and young adults, we hypothesized that students who make an STEM school choice would have lower levels of MA (e.g., Ahmed, 2018; Daker et al., 2021), higher SE (Cribbs et al., 2021), higher math performance (Eidlin-Levy et al., 2023) and are predominantly male (Breda et al., 2023; Huang et al., 2019; LeFevre et al., 1992; OECD, 2013).
2. What unique contribution do MA, SE, math performance and gender make in predicting STEM school choices? This study emphasizes MA and SE due to their established links with math engagement (see Eccles & Wigfield, 2020) both in everyday math activities (e.g., Choe et al., 2019; Pizzie & Kraemer, 2017) and in long-term STEM choices in young adults (e.g., Ahmed, 2018;

Cribbs et al., 2021). Similarly, we also examined math performance and gender because previous literature highlights that high math achievers and males are more likely to show interest in STEM fields (Huang et al., 2019; Levy et al., 2021). However, we made no specific hypothesis for this research question. In fact, to date, few studies have been conducted to simultaneously assess the unique contribution of affective-motivational factors, math performance and gender, especially when considering middle school students. Results will shed new light on the relative contribution of these predictors on STEM school choice, providing useful insights for practitioners and policymakers.

The novelty of this study lies in its examination of STEM school choices during middle school, a period often overlooked in existing research. Prior studies have predominantly focused on the impact of MA and SE in students approaching critical decisions about college or careers (Ahmed, 2018; Cribbs et al., 2021; Wang, 2013) or have explored interests and vocational aspirations (Eidlin-Levy et al., 2023; Huang et al., 2019). Additionally, the longitudinal approach of the study over the course of three school years allows for capturing the contribution of affective-motivational aspects on STEM school choices over the first 2 years of middle school. Most of literature is in fact based on cross-sectional samples or, if longitudinal, considers a short time span (e.g., Cribbs et al., 2021; Eidlin-Levy et al., 2023). In this context, evidence has shown that middle school represents a critical period characterized by strong changes in emotional and motivational experience, including the development of an occupational identity (Ahmed, 2018; Caviola et al., 2022; Huang et al., 2019; Namkung et al., 2019; Porfeli & Lee, 2012).

METHODS

Participants

Participants in the study were students attending middle school who were longitudinally assessed on three measurement occasions (T1, T2 and T3) 1 year apart. Children under observation for suspected or established neurodevelopmental or specific learning disorders, or those who had not been in Italian school for at least 4 years, were not included in the study. The initial sample consisted of 111 children who had provided their STEM school choices. One student was excluded for responding randomly to the questionnaires, whereas another student was excluded for being an outlier in the math performance tasks, with an extremely low performance in all tasks. This resulted in a sample of 109 participants. Among the remaining participants, due to school absences, we tested $n = 97$ students at T1 ($\text{Mean}_{age} = 11.81$; $\text{Standard deviation}_{age} = .35$; Females = 45.36%), $n = 97$ students at T2 ($\text{Mean}_{age} = 12.85$; $\text{Standard deviation}_{age} = .35$; Females = 44.33%) and $n = 109$ children at T3 ($\text{Mean}_{age} = 13.93$; $\text{Standard deviation}_{age} = .36$; Females = 45.87%). The gender of each participant was obtained through questionnaires.

The socio-economic status of the participants' families was averaged using school records information. Participation in the research was bound by the approval of the project by the school principals of the schools involved. Informed consent and a data protection agreement form were signed by each parent or legal guardian, thereby authorizing their child's participation in the study. The study was approved by the Ethics Committee of the University of Trieste.

Procedure

The study was conducted over three longitudinal time periods (T1, T2 and T3), conducted in April and May of each middle school year through collective classroom assessments (see Figure 1). In other words, the evaluations started in Year 6 and occurred annually: T1 in Year 6, T2 in Year 7 and T3 in

Year 8. It is worth noting that in the Italian system, primary school consists of 5 years (Year 1 to Year 5). After primary school students are enrolled in the so-called middle schools (Year 6 to Year 8), while high school starts from Year 9 to Year 13. The administration of MA and SE questionnaires was conducted in a single session lasting approximately 20 min.

The second measurement occasion (T2) occurred 1 year later (Year 7), and consisted of two sessions, lasting 20 min each. In the first session, questionnaires were administered to measure MA and SE. The second session involved the evaluation of math performance and consisted of three tasks (i.e., the approximate calculation task, the math fluency task and the math inference task) taken from a standardized battery.

The third measurement occasion (T3) took place in the last year of middle school (Year 8) and involved the completion of a questionnaire regarding the students' school choice. This was a 5-min questionnaire administered by the teacher, following instructions from the research group.

Measures

Math anxiety

To measure MA, we used the Abbreviated Math Anxiety Scale (AMAS, Hopko et al., 2003; Italian version adapted by Caviola et al., 2017), a self-report questionnaire comprising nine items. Children were asked to think of themselves in various math-related situations and to rate their level of fear for each described event (e.g., 'thinking about the math test you will have to take tomorrow'). Responses were reported on a 5-point Likert scale (1 = very little fear, 5 = a lot of fear). The total score was calculated by summing the responses to the nine items, with scores ranging from a minimum of 9 to a maximum of 45. This instrument has demonstrated good internal consistency in our study according to Cronbach's Alpha reliability ($\alpha = .90$).

Math self-efficacy

Math SE was measured through the SE beliefs questionnaire (adapted from Di Giunta et al., 2013). The self-report questionnaire consists of five items in which participants are asked to indicate how good they feel they are at solving certain math tasks. Participants responded via a 5-point Likert scale (1 = not at all good, 5 = very good) and the total score was determined by the sum of the five items; thus, the minimum score obtainable could range from a minimum of 5 to a maximum of 25. The instrument appears to have good internal consistency in our study according to Cronbach's Alpha reliability ($\alpha = .77$).

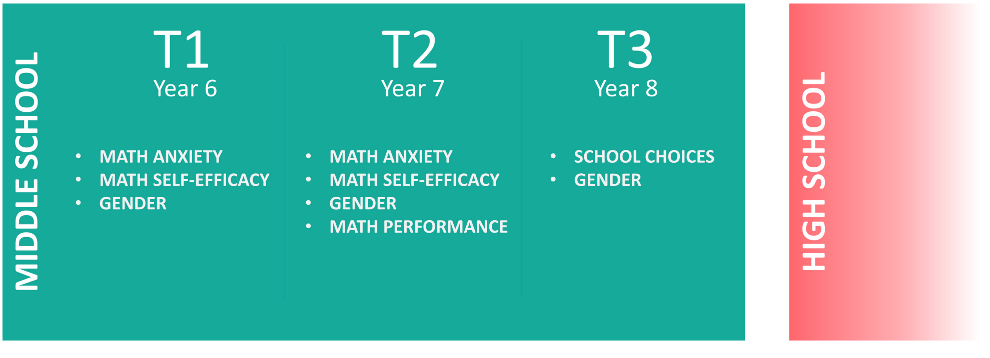

FIGURE 1 Graphical representation of the study procedure.

Math performance

Math performance was assessed through some tasks taken from the AC-MT-3 6–14 standardized battery (Cornoldi et al., 2020). Paper-and-pencil tests were administered collectively: the approximate calculation task, the math fluency task and the math inference task (see Figure 2). In the approximate calculation task (Figure 2a), participants were presented with 15 mathematical operations (additions, subtractions and multiplications) on the left side of the sheet. They were required to solve these mentally and circle the number closest to the result, choosing from three options.

In the math fluency task (Figure 2b), participants were given column operations (seven additions, five subtractions and three multiplications). They had to perform these operations (15 additions, 15 subtractions and 15 multiplications) and write down the correct results.

In the math inference task (Figure 2c), three different tasks were proposed. The first type involved operations (addition, subtraction and multiplication) presented with symbols replacing the numbers. Students had to identify the number corresponding to each symbol to solve the equation. The second type required students to complete operations (addition, subtraction, multiplication and division) that were presented with their results but missing the mathematical symbol (+, −, ×, ÷). They had to insert the correct symbol to complete the operation accurately. In the third type, for each item, two similar line operations (addition, subtraction, multiplication and division) were presented; the first was missing the result, and the second was complete. Students needed to determine the result of the first operation using the second as a reference, without performing the actual calculation.

Each correctly solved item was awarded one point, and the total score could range from 0 to 42 points. The test–retest reliability of the three tests according to the authors of the battery (Cornoldi et al., 2020) is good for the approximate calculation task ($r = .73$), the math fluency task ($r = .89$) and the math inferences task ($r = .69$).

STEM school choices

School choices were assessed through a self-report questionnaire administered to children in their last year of the middle school (Year 8). This questionnaire was given after children had already made their decisions to enrol in a specific high school. It is worth mentioning that all Italian children must make

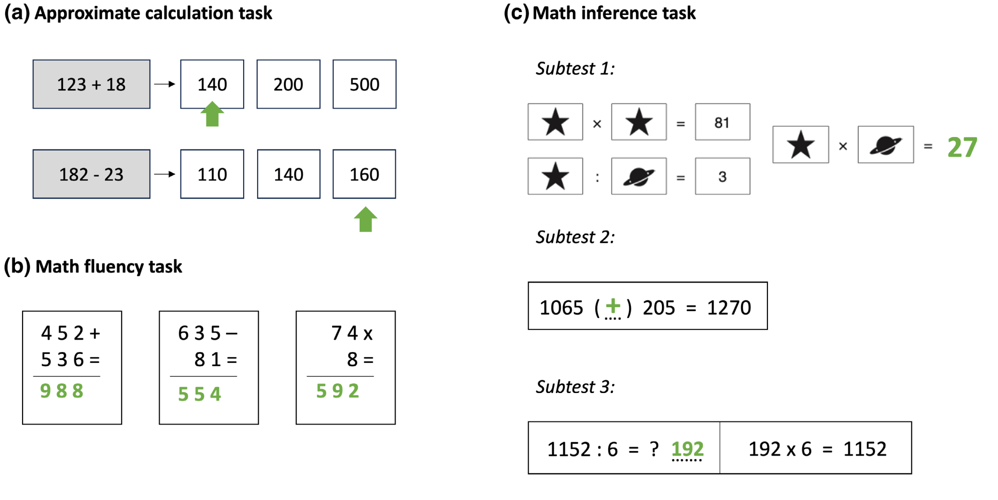

FIGURE 2 Graphical representation of paper–pencil tests used to assess math performance: Approximate calculation task, math fluency task and math inference task. Task solutions are shown in green.

their decisions typically by the end of January. Students were asked to specify the name of the high school and the chosen educational curriculum. Subsequently, the educational programs provided by the schools were used to calculate the number of hours dedicated to STEM subjects (e.g., mathematics, physics, chemistry, science) for each individual school; with higher scores corresponding to a higher number of hours dedicated to STEM subjects throughout high school years. Here again is important to note that the number of hours dedicated to STEM subjects can vary greatly in Italian high schools.

RESULTS

Preliminary analysis

Statistical analyses were conducted using *R* (R Core Team, 2023). Before examining the influence of affective-motivational factors, math performance and gender on STEM school choices, a cluster analysis was performed on the number of hours dedicated to STEM school subjects over the 5 years of high school. A clustering approach was selected because the literature lacks a clear definition of high schools that can be categorized as STEM. In the context of the Italian education system, high schools are known for their focus on either a more technical-scientific or a humanistic curriculum (MIUR, 2023). Furthermore, a preliminary analysis of the distribution of average weekly hours devoted to STEM subjects revealed a density approximating a bimodal, indicating a group of schools with higher STEM subject content and a group of schools with low STEM subject content (Hartigans' Dip test = .124; $p < .001$). The *Mclust* library (Scrucca et al., 2023) was used to conduct cluster analysis which identified a two-cluster solution as optimal (log-likelihood = −397.198, BIC = −817.943, LCI = −821.028) compared to a solution without clusters (log-likelihood = −431.336, BIC = −872.091, LCI = −872.091). A point-biserial correlation between the number of hours devoted to STEM subjects and the clusters obtained was found to be positive and strong ($r = .897$, $p < .001$). Students were therefore subdivided in two clusters. The first cluster was composed of students who had chosen schools with fewer weekly hours of STEM subjects ($n = 40$, $M_{\text{hours}} = 5.38$, $SD_{\text{hours}} = .52$) than the second cluster ($n = 69$, $M_{\text{hours}} = 9.78$, $SD_{\text{hours}} = 1.26$). Bivariate correlations between STEM school choices, MA (T1 and T2), SE (T1 and T2), math performance and gender are reported in Table 1.

Descriptive comparisons of STEM school choices

We used a chi-square test to assess differences between males and females in STEM school choice. The results showed significant differences in STEM school choice frequencies, $\chi^2(1) = 6.019$, $p = .014$, showing that 74% ($n = 44$) of males chose STEM schools (vs. 25%, $n = 15$). In contrast, females seemed to equally make STEM school choices (50%, $n = 25$) as non-STEM school choices (50%, $n = 25$).

To assess differences in affective-motivational factors and math performance on students' STEM school choices, we initially conducted a linear discriminant analysis (LDA) and then we evaluated model performance using ROC curves. Specifically, in the LDA, we considered the STEM school choice cluster as the response variable and included MA (T1 and T2), SE (T1 and T2), math performance and gender as predictors. The coefficients of linear discriminants are presented in Table 2. The model's performance, using ROC curves, indicated good predictive power (*AUC* = .811, *sensitivity* = .824, *specificity* = .576). Afterwards, we specified five analysis of covariance (ANCOVA) models to assess differences in affective-motivational factors and math performance based on students' STEM school choices. We placed STEM school choice (0 = non-STEM school choice; 1 = STEM school choice) as the fixed factor. In each model, we specified either MA (T1 and T2), SE (T1 and T2) or math performance as the independent variable, while placing participants' gender (0 = female; 1 = male) as the covariate. We used Cohen's *d* to calculate the effect size related to the observed differences, using Cohen's (1988) criterion for its interpretation: small effect $d = .20$, medium effect

TABLE 1 Bivariate correlations calculated between MA (T1 and T2), SE (T1 and T2), math performance and STEM school choice.

Variable	1	2	3	4	5	6
(1) MA (T1)						
(2) MA (T2)	.52**					
(3) SE (T1)	−.41**	−.43**				
(4) SE (T2)	−.30**	−.48**	.51**			
(5) Math performance	−.23*	−.38**	.31**	.53**		
(6) STEM school choice[a]	−.16	−.40**	.43**	.37**	.21*	
(7) Gender[b]	−.11	−.01	.12	.09	−.01	.25**

Abbreviations: MA, maths anxiety; SE, self-efficacy; STEM, Science, Technology, Engineering and Mathematics.

[a]0, non-STEM school choice; 1, STEM school choice.

[b]0, female gender; 1, male gender.

*$p<.05$. **$p<.01$.

TABLE 2 Descriptive statistics of affective-motivational factors and math performance related to STEM school choices.

	STEM school choice ($n=59$)		Non-STEM school choice ($n=31$)						
	M	SD	M	SD	CLD	F	p	p_{holm}	d
MA (T1)	21.22	4.38	22.77	4.90	.376	2.554	.113	.113	−.34
MA (T2)	19.64	5.27	24.26	4.57	−.658	18.487	<.001***	<.001***	−.92
SE (T1)	19.20	2.25	17.03	2.50	.599	21.604	<.001***	<.001***	1.00
SE (T2)	19.25	3.02	16.87	2.06	.275	14.489	<.001***	.001**	.83
Math performance	45.47	10.40	39.94	10.13	.042	4.281	.041*	.083	.44

Abbreviations: CLD, LDA coefficients; d, Cohens' d of the ANCOVA; F, F-test of the ANCOVA; M, mean; MA, maths anxiety; p, p-value; $p_{bonferroni}$, Bonferroni corrected p-value for multiple comparisons; SD, standard deviation; SE, self-efficacy; STEM, Science, Technology, Engineering and Mathematics.

*$p<.05$. **$p<.01$. ***$p<.001$.

$d=.50$ and large effect $d=.80$. We corrected p-values for multiple comparisons using the Holm method (Shaffer, 1995). Results showed that there were statistically significant differences in SE measured at T1, $F(1,94)=21.604$, $p_{holm}<.001$, Cohen's $d=1.00$, in SE measured at T2, $F(1,94)=14.489$, $p_{holm}=.001$, Cohen's $d=.83$, and in MA measured at T2, $F(1,94)=18.487$, $p_{holm}<.001$, Cohen's $d=-.92$. No statistically significant difference between groups was found in MA measured at T1, $F(1,94)=2.554$, $p_{holm}=.565$, Cohen's $d=-.34$. Following the Holm correction, no statistically significant difference between groups has been detected for math performance, $F(1,94)=4.281$, $p_{holm}=.083$, $d=.44$.

Prediction of STEM school choices

Hierarchical logistic regression analysis

To assess the unique contribution of affective-motivational factors, math performance and gender on STEM school choice, we conducted five logistic regressions (Table 3) using STEM school choice as the dependent variable (0 = non-STEM school choice; 1 = STEM school choice). The first two models (Model 1 and Model 2) aimed to separately assess the effects of gender and math performance on STEM

TABLE 3 Logistic regression model outputs considering STEM school choice as dependent variable.

	Estimate	ME	SE	*z*	*p*	Pseudo R^2
Model 1						
Intercept	.000	–	.283	.000	1.000	.086**
Gender[a]	1.076	.246	.411	2.615	.009**	
Model 2						
Intercept	.596	–	.217	2.743	.006**	.249***
Math performance	.453	.100	.227	1.990	.047*	
Model 3						
Intercept	.139	–	.311	.447	.655	.291***
Gender[a]	.878	.191	.444	1.976	.048*	
Math performance	.484	.102	.233	2.076	.038*	
Model 4						
Intercept	.345	–	.367	.941	.347	.515***
MA (T1)	.093	.016	.290	.320	.749	
SE (T1)	.953	.169	.316	3.015	.002**	
Math performance	.378	.067	.268	1.408	.159	
Gender[a]	.758	.139	.504	1.504	.132	
Model 5						
Intercept	.415	–	.391	1.061	.288	.589***
MA (T1)	.435	.069	.340	1.280	.201	
SE (T1)	.811	.128	. 351	2.311	.021*	
MA (T2)	−.863	−.136	.363	−2.377	.017*	
SE (T2)	.367	.058	.358	1.024	.306	
Math performance	.053	.008	.310	.172	.863	
Gender[a]	.860	.139	.541	1.590	.112	

Abbreviations: MA, maths anxiety; ME, marginal effects; *p*, *p*-value; pseudo-R^2, Nagelkerke pseudo-R^2; SE, self-efficacy; SE, standard error; STEM, Science, Technology, Engineering and Mathematics; *z*, *z*-value.

[a]0, female gender; 1, male gender.

*$p<.05$. **$p<.01$. ***$p<.001$.

school choices. Subsequently, in Model 3, gender and math performance were simultaneously regressed on the dependent variable to determine their unique contribution. In Model 4, MA and SE measured at T1 were introduced to assess their contributions while controlling for the effects of gender and performance. Finally, in Model 5, we introduced MA and SE measured at T2 while controlling for predictors at T1, gender and math performance. To enhance models' interpretability, we have also reported the marginal effects in Table 3. These effects estimate how the probability of choosing a STEM school changes with a one-unit change in the predictor variable, holding all other variables constant. Effect sizes were estimated using the Nagelkerke pseudo-R^2, allowing us to estimate the variance explained by the model to that of a null model.

In Model 1, we included gender as the only predictor. The model was found to be statistically significant, but with limited predictive power, $\chi^2(1)=7.083$, $p=.008$, $R^2=.086$. Specifically, the result showed that gender had a significant positive effect, $B=1.076$, $SE=.411$, $p=.009$, that is, males had a higher propensity to choose STEM schools. In other words, being male resulted in a $B=1.076$ increase in the log-odds of choosing a STEM school.

In Model 2, we included math performance as the only predictor. The model was found to be statistically significant, with a moderate predictive power, $\chi^2(1)=20.714$, $p<.001$, $R^2=.249$. Specifically, the result showed that math performance had a significant positive effect on STEM school choices,

$B = .453$, SE = .227, $p = .047$. In other words, one-unit increase in math performance predicted a $B = .453$ increase in the log-odds of choosing a STEM school.

In Model 3, we entered gender and math performance simultaneously. The model was found to be statistically significant with moderate predictive power $\chi^2(2) = 24.715$, $p < .001$, $R^2 = .291$. In particular, the result showed that both genders, $B = .878$, SE = .444, $p = .048$ and math performance, $B = .484$, SE = .233, $p = .0378$ had a significant positive effect on the STEM school choice. In other words, being male resulted in a $B = .878$ increase in the log-odds of choosing an STEM school. Furthermore, one-unit increase in math performance predicted a $B = .484$ increase in the log-odds of choosing a STEM school.

In Model 4, we included MA and SE measured at T1, math performance and gender in the model. The model was statistically significant with good predictive power, $\chi^2(4) = 47.547$, $p < .001$, $R^2 = .515$. Results showed that SE measured at T1, $B = .953$, SE = .316, $p = .002$, but not, was positively predictive of STEM school choice. In other words, one-unit increase in SE measured at T1 predicted a $B = .953$ increase in the log-odds of choosing a STEM school. Neither MA measured at T1, $B = .093$, SE = .290, $p = .749$, math performance, $B = .378$, SE = .268, $p = .159$, nor gender, $B = .758$, SE = .504, $p = .132$, predicted STEM school choice, after controlling for SE at T1.

In Model 5, we also included MA and SE at T2 as well as all the other predictors included in previous models. The model was statistically significant with good predictive power, $\chi^2(6) = 57.06$, $p < .001$, $R^2 = .589$, which was the highest compared to all previous models. The results showed that only SE measured at T1, $B = .811$, SE = .351, $p = .021$, and MA measured at T2, $B = -.863$, SE = .363, $p = .017$, were predictive of STEM school choice. In other words, a one-unit increase in SE at T1 and MA at T2 predicted an increase of $B = .811$ and a decrease of $B = -.863$, respectively, in the log-odds of choosing an STEM school. No statistically significant effects were found for MA measured at T1, $B = .435$, SE = .340, $p = .201$, SE measured at T2, $B = .367$, SE = .358, $p = .306$, math performance, $B = .053$, SE = .310, $p = .863$ and gender, $B = .860$, SE = .541, $p = .112$.

Dominance analysis

In order to further assess the unique contribution that the predictors have on STEM school choices, we conducted a dominance analysis. This procedure is particularly suitable when examining the contribution made by each variable with respect to the dependent variable, especially when predictors are expected to be correlated with each other (Azen & Budescu, 2003). Dominance analysis is a statistical procedure for assessing how much each variable contributes to the variance of the dependent variable, evaluating them both independently and in conjunction with other combinations of predictors (Budescu, 1993).

We first specified a full logistic regression model by placing the STEM school choices (0 = non-STEM school choice, 1 = STEM School choice) as the dependent variable, and MA (T1 and T2), SE (T1 and T2), math achievement and gender (0 = female; 1 = male) as predictors. Nagelkerke pseudo-R^2 was used to indicate the additional contribution of each predictor when introduced to a subset model. We then assessed the average dominance of each predictor. Dominance analysis output and the average contribution of each predictor are shown in Table 4.

Dominance analysis progresses from examining the relationship between the dependent variable and a single predictor (Level 0) to reaching the full model, which evaluates the Nagelkerke pseudo-R^2 of all predictors within the same model (Level 4). Results showed that SE measured at T1 made the largest average unique contribution to STEM school choices (average $R^2 = .114$), followed by MA measured at T2 (average $R^2 = .096$), SE measured at T2 (average $R^2 = .072$) and MA measured at T1 (average $R^2 = .054$). Results revealed that math achievement (average $R^2 = .038$) and gender (average $R^2 = .024$) explained on average only a modest proportion of the variance.

TABLE 4 Dominance analysis results are considering as dependent variable STEM school choices.

Predictor	Nagelkerke pseudo R^2 Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Average
SE (T1)	.359	.216	.146	.102	.072	.049	.114
MA (T2)	.325	.174	.105	.070	.055	.054	.096
SE (T2)	.301	.151	.079	.040	.019	.009	.072
MA (T1)	.201	.110	.073	.049	.029	.014	.054
Math achievement	.206	.085	.035	.011	.001	.000	.038
Gender[a]	.064	.031	.025	.022	.021	.022	.024

Note: Predictors are sorted according to their average unique contribution to STEM School choices.

Abbreviations: MA, maths anxiety; SE, self-efficacy; STEM, Science, Technology, Engineering and Mathematics.

[a]0 = female gender, 1 = male gender.

DISCUSSION

The general aim of the present study was to describe and predict the STEM school choices of middle school students, considering affective-motivational factors (i.e., MA and SE), math performance and gender. While prior research has primarily focused on high school students and adults, exploring the influence of affective and motivational factors (Ahmed, 2018; Cribbs et al., 2021; Daker et al., 2021; Wang, 2013) as well as math performance and gender (Breda et al., 2023; Huang et al., 2019), this study provides fresh insights into the factors describing and predicting STEM school choices during the transitioning from middle to high school (Years 6–8 in the Italian school system). This period is in fact critical for the development of negative attitudes towards math (Caviola et al., 2022; Namkung et al., 2019) and for the formation of an occupational identity (Ahmed, 2018; Porfeli & Lee, 2012).

The first aim of the present study was to describe the differences in affective-motivational factors, math performance and gender between those who made an STEM school choice and those who did not. Results showed statistically significant differences in affective-motivational factors and gender was associated with an STEM school choice. As for affective-motivational factors, children who made an STEM school choice showed lower MA at T2, although no statistically significant differences were observed in MA measured at T1. From a theoretical point of view, it is well known that experiencing MA leads students to avoid situations and activities in which math is involved, during everyday activities (Choe et al., 2019; Pizzie & Kraemer, 2017) or when a school or work career choice needs to be made (Ahmed, 2018; Cribbs et al., 2021; Daker et al., 2021). This result aligns with other studies conducted on adults, suggesting that MA influence STEM choices (Ahmed, 2018; Cribbs et al., 2021), even after controlling for gender and math performance (Daker et al., 2021). Furthermore, this pattern of results also aligns with Ahmed's (2018) longitudinal study, which indicates that the effects of MA play a prominent role when evaluated in a time period close to the STEM choice. As for motivational aspects, our results showed that students who made a STEM school choice had statistically significantly higher levels of SE at both T1 and T2. This outcome agrees with evidence indicating that SE is one of the most powerful predictors of STEM choices in college and future careers (Cribbs et al., 2021; Wang, 2013). Evidence shows that individuals with positive SE beliefs are usually more engaged in situations involving math, showing more positive emotions, greater perseverance and better math performance (Du et al., 2021; Eccles & Wigfield, 2020; Galla et al., 2014; Klassen et al., 2008; Martin & Rimm-Kaufman, 2015). The results considering math performance suggest that math performance may not be associated with STEM school choices after controlling for multiple comparisons. However, it should be noted that corrections for multiple comparisons lead to a reduction in the statistical power of the tests, which may explain the marginal significance observed for math performance. This appears to be particularly likely considering studies that have found small or non-significant effects for the association between math performance and STEM school choices. For instance, a study by Daker et al. (2021) found no association between math performance and STEM course participation. Additionally, results indicated that being male was positively associated with an STEM school choice. This finding is consistent with existing literature, which suggests that girls are less likely to make STEM choices (Huang et al., 2019; LeFevre et al., 1992; OECD, 2013).

The second aim of the present study was to assess the longitudinal unique contribution of MA, SE, math performance and gender in predicting STEM school choices. Results from logistic models unveiled that MA, measured at T2, and SE, measured at T1, were the main predictors of STEM school choices. Similarly, dominance analysis revealed that MA measured at T2, and SE measured at T1 made the largest average contribution in predicting school STEM choices, followed by SE measured at T2, MA measured at T1, math performance and gender. These findings suggest intriguing developmental patterns linking affective-motivational factors in predicting STEM school choices. On the one hand, MA seems to play a crucial role when measured in temporal proximity to making the STEM school choice, aligning with the findings by Ahmed (2018) in adults. Conversely, as early as Year 6, SE appears to be a positive predictor of STEM school choice. In this sense, SE may be a central construct in fostering positive emotional states towards math (Du et al., 2021; Martin & Rimm-Kaufman, 2015; Usher & Pajares, 2009); however, future studies are needed to further investigate the role of this construct in STEM choices. Intriguingly, logistic regressions and dominance analysis showed that gender and math performance had a limited role in predicting STEM school choice once accounting for the effects of all the other predictors (including MA and SE). This result aligns with a study by Daker et al. (2021), in which math performance and gender did not predict STEM course participation, after accounting for the effects of MA. Notably, MA and SE appear crucial in predicting middle school students' STEM school choices. Future observational and interventional studies should carefully evaluate their impact, offering fresh insights into adolescents' vocational behaviour.

Limitations

Some limitations should be considered. For a start, a larger sample of children, encompassing different contexts and Italian regions, would enable the examination of interregional differences and variations between different cultures, enhancing the study's generalizability to a broader context. Additionally, an important limitation of our study is the correlational research design, which limited the assessment of causal relations between the variables we considered. Consequently, our results should be taken with caution in terms of their capacity to make causal generalizations or propose interventions to promote STEM school choices. Also, affective-motivational and performance variables were only assessed in Years 6 and 7. Including a longer time frame, while also taking a longitudinal approach, could probably provide a better insight into the impact of these variables in the long run. Finally, the study did not consider the influence of other factors such as parents, peers, and teachers; which can also have an impact on math performance (Semeraro et al., 2020) and on future career choices (Wang & Degol, 2013). Future studies should also investigate whether the distinction between STEM and non-STEM schools depends not only on curricular factors but also on other aspects, such as the schools' human and economic resources and the neighbourhoods in which they are located.

CONCLUSION

In a world increasingly shaped by mathematical knowledge and a growing demand for skilled professionals in technological-scientific fields, identifying factors that encourage educational pathways in STEM fields is crucial for an advanced society (Beilock & Maloney, 2015; European Commission, 2015;

Henriksen, 2015; Keitel et al., 1993). To the best of our knowledge, this study is the first to investigate the combined role of affective-motivational factors, math performance and gender on STEM school choices. The results seem to indicate that affective-motivational factors and gender are associated with students' choices in STEM education. However, when the unique contribution of these factors is considered, it becomes clear that MA and SE are crucial predictors of STEM school choices. Notably, our findings reveal that SE positively predicts STEM school choices as early as in Year 6. From Year 7 onward, MA seems to start predicting STEM school choices.

In light of these findings, future studies should focus on the role of affective-motivational factors in STEM choices, particularly in middle school years (Years 6–8 in the Italian school system). This period seems to be crucial for the establishment of occupational identity (Ahmed, 2018; Porfeli & Lee, 2012) and the emergence of negative attitudes towards math (Caviola et al., 2022; Namkung et al., 2019). Further investigations should carefully assess whether the enhancement of positive affective-motivational factors can promote STEM school choices. As suggested by the results of the present study, these factors seem relevant in predicting STEM choices, more so than other factors, including math performance and gender. Consequently, researchers should evaluate the efficacy of activities aimed at mitigating negative attitudes towards math (Passolunghi et al., 2020), making STEM educational pathways an accessible opportunity for a growing number of students.

AUTHOR CONTRIBUTIONS

Alessandro Cuder: Conceptualization; methodology; writing – review and editing; writing – original draft. **Sandra Pellizzoni:** Conceptualization; methodology; writing – review and editing; writing – original draft. **Miriana Di Marco:** Investigation; methodology. **Claudia Blason:** Investigation; methodology. **Eleonora Doz:** Investigation; validation; methodology. **David Giofrè:** Supervision; writing – review and editing. **Maria Chiara Passolunghi:** Supervision; writing – review and editing.

ACKNOWLEDGEMENTS

We acknowledge financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender no. 104 published on 2 February, 2022 by the Italian Ministry of University and Research (MUR), funded by the European Union—NextGenerationEU—Project Title: Cognitive & emotional pathways to hidden STEM: longitudinal and intervention studies fostering higher educational choices—CUP D53D23009660006—Prot. 2022FZ595K—Grant Assignment Decree No. 1016 was adopted on 7 July, 2023 by the Italian Ministry of University and Research (MUR). Open access publishing facilitated by Universita degli Studi di Trieste, as part of the Wiley - CRUI-CARE agreement.

CONFLICT OF INTEREST STATEMENT

None of the authors have a conflict of interest to disclose.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Cuder, A., Pellizzoni, S., Di Marco, M., Blason, C., Doz, E., Giofrè, D., & Passolunghi, M. C. (2024). The impact of math anxiety and self-efficacy in middle school STEM choices: A 3-year longitudinal study. *British Journal of Educational Psychology*, *94*, 1091–1108. https://doi.org/10.1111/bjep.12707