

Creative Self-efficacy in Mathematics and Choice of Science-oriented Classes (STEM) in Secondary School: The Role of Gender

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Abstract

This study explores the role of creative self-efficacy in mathematics in shaping students' choices of science, technology, engineering and technology (STEM) classes in secondary school, with a particular focus on gender differences. A sample of 185 eighth-grade students from the Mazovian Voivodeship in Poland completed measures of creative self-efficacy, creative personality traits, math skills, and school achievement. Results showed that boys reported higher creative self-efficacy in mathematics than girls, which was associated with a stronger preference for choosing STEM subjects. For girls, creative self-efficacy was primarily predicted by math grades, while for boys it was additionally linked to creative personality and math skills. The findings underscore the importance of targeted educational strategies to strengthen girls' confidence in their creative mathematical abilities and to reduce gender disparities in STEM pathways.

Keywords: Creative self-efficacy, gender differences, STEM education, mathematical skills, educational choices.

Poczucie twórczej skuteczności w matematyce a wybory klas o profilu nauk ścisłych (STEM) w szkole średniej: Rola płci

Streszczenie

Badanie analizuje rolę poczucia twórczej skuteczności w matematyce w kształtowaniu wyborów przedmiotów z obszaru STEM (nauka, technologia, inżynieria i matematyka) wśród uczniów szkół średnich, ze szczególnym uwzględnieniem różnic między płciami. Próba obejmowała 185 uczniów klas ósmych z województwa mazowieckiego, którzy wypełnili kwestionariusze dotyczące poczucia twórczej skuteczności, cech osobowości twórczej, umiejętności matematycznych oraz osiągnięć szkolnych.

Wyniki wykazały, że chłopcy charakteryzowali się wyższym poczuciem twórczej skuteczności w matematyce niż dziewczęta, co wiązało się z silniejszą preferencją wyboru przedmiotów STEM. U dziewcząt poczucie twórczej skuteczności było przede wszystkim przewidywane przez oceny z matematyki, natomiast u chłopców – dodatkowo przez cechy osobowości twórczej i umiejętności matematyczne. Uzyskane wyniki podkreślają znaczenie ukierunkowanych działań edukacyjnych mających na celu wzmocnienie pewności siebie dziewcząt w zakresie twórczych zdolności matematycznych oraz ograniczenie nierówności płci w wyborach ścieżek STEM.

Słowa kluczowe: Poczucie twórczej skuteczności, różnice między płciami, edukacja STEM, umiejętności matematyczne, wybory edukacyjne.

1. INTRODUCTION

Among the factors influencing educational choices and class profile in secondary school are both individual factors characterizing the student as well as environmental factors. These factors form a complex network of interdependencies, which include abilities, personality traits, motivations, family influence, and teacher actions (Meece et al., 1982; Mendick, 2005). Research indicates that educational decisions, particularly when choosing between STEM and the humanities, are often strongly related to students' gender. Early studies revealed that boys outperformed girls in math achievement (Benbow & Stanley, 1983; Fennema, 1974), with reasons for these differences attributed to sociocultural (Fennema & Sherman, 1977), cognitive (Fennema & Tartre, 1985), and biological factors (Schultheiss et al., 2005). However, recent trends show no differences in the achievements of girls and boys (Card & Payne, 2021; Golding et al., 2022), challenging these earlier assumptions. Despite this, boys tend to choose secondary schools and universities with a STEM focus, while girls are more likely to pursue education in the humanities (Card & Payne, 2021; Kahn & Ginther, 2017). The gender gap in technology skills is a global issue, making it crucial to understand the factors influencing these decisions. Research consistently finds that gender-normative ideas are prevalent in primary, secondary, and tertiary education, negatively affecting girls' STEM career choices (Goreth & Vollmer, 2022). Additionally, girls tend to have lower self-efficacy in STEM compared to boys (Goreth & Vollmer, 2022), with social and cultural factors contributing to the formation of gender stereotypes and the perception of STEM as a male-dominated field (Lane et al., 2022).

Conversely, extensive research confirms the relationship between school achievement and creativity (Gajda et al., 2017), including achievement in mathematics. It has been shown that with an increase in creativity levels, school achievement also increases (Gajda, 2016), with the strongest relationship identified in mathematical creativity (Gajda et al., 2017). Recently, mathematical creativity has been recognized as a crucial skill that should be encouraged in all students (Pelczer & Rodríguez, 2011). The essence of mathematics extends beyond finding the right answer; following algorithms and procedures represents only a small part of mathematical skills (Dreyfus & Eisenberg, 1996). However, research on mathematical creativity remains sparse (Leikin et al., 2009), further complicated by the lack of a coherent definition of mathematical creativity (Mann, 2005).

Therefore, this article aims to explore which factors characterizing male and female students may be related to their creative self-efficacy in math and their choice of STEM classes in secondary school. We focus particularly on math skills and achievements, as well as creative personality traits. While the relationship between mathematical skills and achievements and the choice of a STEM education profile seems evident and scientifically supported (Wang et al., 2013), no analyses, to our knowledge, simultaneously examine the effects of creative personality traits and creative self-efficacy together with the role of gender in educational decisions. Our goal is to answer the following questions: (i) Which factors are associated with creative self-efficacy in mathematics? (ii) Which factors are associated with STEM class choices in secondary school? and (iii) Do these factors differ for girls and boys?

2. CREATIVITY IN MATH AND SCIENCE

Creativity in mathematics, and more broadly in science, has historically been marginalized, as mathematics is often viewed as a domain of rigid rules and correct answers rather than an area of imagination and invention. This perception is reinforced by educational practices that prioritize repetition and accuracy over inquiry, discovery, and experimentation (Grégoire, 2016). Yet research consistently shows that creative thinking is integral to mathematical learning and problem solving. It allows students not only to reach correct solutions but also to explore new strategies, discover patterns, and approach problems in original ways.

2.1 Defining and conceptualizing mathematical creativity

Mathematical creativity is most often conceptualized as a domain-specific ability to produce original, useful, and varied ideas. It comprises three components: fluency (generating many ideas), flexibility (adopting diverse perspectives or strategies),

and originality (producing novel approaches) (Kattou et al., 2013). Importantly, mathematical creativity is not limited to divergent thinking alone but also requires convergent processes. Divergent thinking supports the generation of multiple possibilities, helps students overcome fixation, and fosters openness to unconventional strategies (Haylock, 1987; Pehkonen, 1997). Convergent thinking, in turn, enables evaluation, selection, and refinement of solutions. Both are necessary: research shows that while convergent thinking predicts success in single-solution tasks, divergent thinking is essential in tasks requiring multiple solutions, and students with strong divergent skills can compensate for weaker convergent skills (de Vink et al., 2021). Thus, creativity in mathematics lies in the dynamic interplay between these two modes of thought.

This integrated definition is consistent with Polya's (1963) classic reflections, in which successful mathematical learning requires not only formal knowledge but also independence, originality, and "know-how". Similarly, Mann (2006) emphasized that the essence of mathematics extends beyond computation and algorithmic proficiency to include creativity and problem solving. Historical accounts, such as those of Hadamard (2020) and Poincaré (1913), underline that mathematical progress has always relied on creative leaps, moments of insight, and imaginative reasoning.

2.2 Empirical evidence and recent approaches

Empirical research further demonstrates that mathematical creativity contributes to performance and achievement. Hong and Aqai (2004) showed that students with high levels of mathematical creativity use more diverse and effective cognitive strategies than both high-achieving and average peers. Large-scale evidence from PISA 2012 confirmed that mathematical creativity is positively associated with student achievement (Sebastian & Huang, 2016). Moreover, Kattou et al. (2013) found that mathematical creativity is not only correlated with mathematical ability, but constitutes one of its subcomponents. These findings highlight that fostering creativity is not an optional enrichment but a core element of mathematical competence.

Recent literature illustrates the diversity of conceptual approaches in this area. A systematic review by Joklitschke et al. (2022) identified five main perspectives: creativity as fluency, flexibility, and originality; as divergent thinking; as a sequence of stages; as creative mathematical reasoning; and, as a construct defined by person, product, process, or behavior. Importantly, methodological innovation has followed theoretical development. Researchers increasingly use Multiple Solution Tasks (MSTs) to capture mathematical creativity in authentic contexts and apply tools such as eye-tracking to analyze phases of the creative process, including incubation (Joklitschke et al., 2022). These advances illustrate the growing sophistication in understanding and studying mathematical creativity.

Finally, creativity in mathematics depends not only on cognitive ability but also on motivational and contextual factors. According to Grégoire (2016), three elements play a central role: expertise (a deep understanding of mathematical concepts that enables creative application), original thinking (approaching problems from different angles and developing new strategies), and intrinsic motivation (enjoyment and persistence in tackling challenging tasks). Creating classroom environments that foster risk-taking, exploration, and tolerance for ambiguity helps students develop a creative style of thinking. Such environments, in which divergent and convergent processes are deliberately stimulated, may increase both students' mathematical performance and their confidence in their creative potential

3. GENDER DIFFERENCES IN CREATIVE SELF-EFFICACY

Self-efficacy refers to a person's belief in their ability to perform a specific action, with higher self-efficacy often leading to better performance (Bandura, 1977). Creative self-efficacy specifically refers to an individual's belief in their capability to generate creative outcomes. In the context of mathematics, creative self-efficacy describes a student's confidence in their ability to approach mathematical problems in innovative and original ways. However, the effectiveness of self-efficacy beliefs can vary depending on the level of measurement used. For example, research has not identified a clear pattern regarding different levels of self-efficacy beliefs (Haase et al., 2018), indicating a need for further studies to compare these measurement levels and explore any potential differences. Creative self-efficacy, on the other hand, is a psychological construct that has gained attention for its ability to measure a person's belief in their creative abilities. This belief, linked to actual creative competence, suggests that higher levels of creative self-efficacy can lead to better creative performance (Karwowski et al., 2018). Additionally, research consistently shows a positive relationship between creativity and creative self-efficacy beliefs (Haase et al., 2018). The potential antecedents of creative self-efficacy include creativity, general self-efficacy, and task performance, with studies addressing creative self-efficacy in various ways (Beghetto & Karwowski, 2017).

Students with higher mathematical abilities also exhibit higher self-efficacy in math, with slightly lower self-efficacy in language. Conversely, individuals with higher language skills have higher self-efficacy in language but not necessarily lower in math (Marsh, 1986). Given that self-concept ability is sensitive to changes in the frame of reference, it can be assumed that individuals with high mathematical abilities and average language skills will have higher self-efficacy in math compared to those with high abilities in both areas (Marsh, 1990; Wang et al., 2013).

3.1 Mixed empirical evidence on gender differences

Recent research suggests gender differences in the variability of creative self-efficacy. Variability analyses indicate a pattern of greater male variability: men show more variance than women in the overall distribution of creative self-efficacy scores, with men overrepresented at both the high and low extremes of the distribution. Additionally, mean comparisons suggest a pattern of male superiority, though with a small effect size (He & Wong, 2021a). In a nationwide sample of Poles, Karwowski et al. (2013) found that male superiority in creative self-efficacy stems from higher self-belief, evidenced by male students overestimating their creative abilities, while female students underrate theirs. Greater male variability is more likely in the figural domain of creativity, with larger effect sizes compared to the verbal domain. In the figural domain, men are consistently overrepresented in both the lower and upper regions, while in the verbal domain, greater male representation is observed in the lower regions but not in the upper regions (He & Wong, 2021b).

Gender differences in creative self-efficacy have been studied for decades with mixed results. Some research finds no significant gender difference in creativity test scores, creative accomplishments, and creative processes (Baer & Kaufman, 2008; Hora et al., 2021). Conversely, other studies report significant gender differences, favoring either males or females (He & Wong, 2011). To better explain these differences, researchers proposed the APT model of creativity (Baer & Kaufman, 2008), suggesting that gender differences in creative self-efficacy could be due to internalized gender roles and biases women hold against themselves regarding creativity. The observed gender gap in creative performance is comparable in size to gaps seen in self-esteem, talkativeness, leadership emergence, or initiation of negotiations. Furthermore, the lack of gender differences in creative test scores and accomplishments, alongside cultural influences, suggests that the overall gender difference in creative performance is small and contextually dependent (Hora et al., 2021).

3.2 Explaining gender disparities in mathematics self-efficacy

Gender differences also significantly impact self-efficacy in mathematics (Ghasemi & Burley, 2019). Girls generally have lower self-efficacy in mathematics than boys (Zander et al., 2020), attributed to factors such as higher levels of math anxiety (Else-Quest et al., 2010) and a lack of positive feelings and cognitive self-enhancement following test situations (Zander et al., 2020). This disparity can significantly impact academic performance and future career choices (Riegle-Crumb & King, 2010). Research shows that affective self-esteem explains girls' self-efficacy, while cognitive self-enhancement explains boys'. This lack of self-efficacy contributes to the underrepresentation of women in STEM fields and the gender gap index in education, economic participation, political representation, and health (Ghasemi & Burley, 2019). To bridge the gender gap in mathematics, it is crucial to understand the different factors contributing to self-efficacy in mathematics (Zander et al., 2020) and develop strategies to help both girls and boys achieve higher levels of self-efficacy in this subject.

4. THE GENDER GAP IN STEM PREFERENCES

Mathematics is a subject that can be intimidating and difficult for many students, yet it plays an integral role in many STEM-based university degree programs. Therefore, understanding the relationship between math skills, achievements, and the choice of a STEM education profile is crucial. A large dataset covering students admitted to Finnish universities from 2013 to 2015 demonstrated that the level of mathematics (basic/advanced/none) determined university admission (Kaleva et al., 2019). Furthermore, this dataset revealed that gender distributions in university degree programs varied depending on students' math skills. The authors investigated the connection between STEM subject choices, particularly the choice of mathematics in upper-secondary school and university admissions, examining the gender distribution in different university degree programs based on mathematics choices. Higher mathematics self-efficacy and STEM career knowledge were more prevalent among students with higher overall skills (Kaleva et al., 2019).

It is noteworthy that a high level of mathematical ability does not automatically translate to a preference for STEM-related majors. While girls and boys exhibit similar levels of mathematical ability, girls often show high ability in both mathematical and linguistic areas. A longitudinal study by Park et al. (2008) indicated that students with both mathematical and linguistic abilities were less likely to choose STEM-related majors and careers. Thus, gender plays a role in career choices, as students with high abilities in multiple fields have a broader range of study options.

4.1 Explanatory frameworks

Women significantly less often than men complete their education in STEM fields. National-level research in the United States and Canada shows that the gender gap in completing STEM studies accounts for nearly one-fifth of the wage gap between men and women entering the labor market (Card & Payne, 2021). The literature explains the lower frequency of STEM major selection by females through various factors: gender differences in cognitive ability, interests, professional preferences, valuing the STEM field, self-efficacy in STEM, and gender-related stereotypes (Eccles, 2009; Eccles et al., 1999; Wang & Degol, 2017). Two theories also explain the choice or avoidance of STEM majors: the expectancy-value theory (EVT) of Eccles et al. (1983) and having a specific mindset about mathematics (Dweck, 2006). According to EVT, women are less likely to pursue mathematics-related fields because they have lower expectations and place less value on mathematics and science than men.

Mindset theory suggests that women more often exhibit a fixed state of mind about mathematics, potentially leading to lower mathematical achievements (Wang & Degol, 2014).

4.2 The role of stereotypes and socialization

Gender stereotypes and the perceived lack of female role models in STEM also play a significant role (UNICEF, 2020). These factors can influence girls' decisions from an early age, making them less likely to pursue STEM courses in secondary school (Lane et al., 2022; Makarova et al., 2019). Additionally, research has found that girls associate math with the male gender, which can decrease their self-identification with the female gender. Gender-science stereotyping negatively affects female students' self-concept and interests, while exposure to male students pursuing STEM careers has the opposite effect (Makarova et al., 2019). Social gender stereotypes are powerful forces shaping the choices and interests of young girls. From an early age, girls are often pressured to conform to traditional gender roles and expectations, discouraging them from pursuing STEM fields. Even having friends with traditional gender norms can reinforce gender-stereotypical behavior and penalize non-conformity, especially in same-gender groups (van der Vleuten et al., 2018). This suggests that socialization is a crucial factor in determining girls' interests and behavior.

5. METHOD

5.1 The present study

This study investigates the relationship between creative self-efficacy in mathematics and the choice of STEM-related classes in secondary school, with a particular focus on gender differences. The research aims to explore how creative personality traits and math skills contribute to students' decisions to pursue STEM education. We hypothesize that students with higher creative self-efficacy in mathematics are more likely to choose STEM classes, and that this relationship may differ between male and female students. The study utilized established measures of creative self-efficacy in math, creative personality traits, and mathematical skills. Additionally, students provided information about their math grades and their intended secondary school class profiles. By analyzing the data, we aim to identify key factors that influence creative self-efficacy in math and how these factors affect the choice of STEM classes in secondary school. Understanding these dynamics can provide valuable insights for educators and policymakers to support students in developing their creative potential and pursuing STEM education. Due to its cross-sectional and exploratory nature, this study does not allow for causal inferences about whether creative self-efficacy in mathematics actually determines STEM choices in the long term.

5.2 Participants and procedure

In the present study, 185 students participated, comprising 93 girls (Mage = 14.00, SD = 0.80) and 92 boys (Mage = 14.04, SD = 0.64) from the eighth-grade of primary school. Given the limited sample size and geographical scope, the presented results should be considered exploratory and interpreted with caution regarding generalizability. The study involved a random selection of respondents from five randomly chosen primary schools in the Mazovian Voivodeship. Participation required written consent from the students' parents or guardians, with the students providing oral, informed consent. All participants were informed that they could withdraw from the study at any time without providing a reason. The study was conducted following ethical standards in accordance with the guidelines of the American Psychological Association (2017), and approval was obtained from the ethics committee of Maria Grzegorzewska University. Data collection was conducted during classes with the teacher or after classes to avoid disrupting the established learning schedule.

5.3 Measures

5.3.1 Creative self-efficacy in math. The Creative Self-Efficacy in Math and Language Scale by Karwowski and colleagues (2015) was used to measure creative self-efficacy. The scale consists of twelve items, half of them pertaining to the field of mathematics and the other half to language. For the purposes of the study, only statements measuring creative self-efficacy in math were used. The task of the respondents is to estimate to what extent they would be able to cope with the task described in specific statements, on a scale from 0 to 100 percent. Examples of items relating to mathematics are: 'solving a mathematical problem in an original way' or 'discovering a new mathematical principle'. The scale has satisfactory psychometric properties (Gajda & Gralewski, 2021; Karwowski et al., 2015). In this study, the reliability of the math scale was $\alpha = 0.858$.

5.3.2 Creative personality traits. The creative personality scale from the Adjective Check List (ACL) (Gough, 1979) was used. The ACL is used to test various personality traits. The standard version contains 300 adjectives that a person must read and mark those that describe them well. For the purposes of the study, 30 adjectives loading the scale of creative and non-creative personality were selected, e.g., "imaginative", "curious". The ACL scale has good psychometric properties. The reliability of the creativity subscale in the present study reached the level of $\alpha = 0.687$.

5.3.3 Math skills. Mathematical skills were measured using the Mathematical Skills Test based on tasks included in the Eighth Grade Test sample sheets, which is an obligatory test for students completing their primary school education in Poland. The test consisted of 40 single-choice tasks with a cafeteria of four possible answers. Example task: For 10 months, Ola saved 80 PLN per month in a piggy bank. After that period, her mother added 200 PLN to Ola's savings. By what percentage did Ola's savings increase compared to the amount she had saved on her own? A. 20%; B. 25%; C. 50%; D. 40%. The task was to mark the correct answer after making the necessary calculations. The test covers the material students are required to learn during primary school. The reliability of the test was $\alpha = 0.885$.

5.3.4 Math grade and secondary school class profile. Students completed a short questionnaire in which they provided information about the average grade in mathematics (GPA) obtained in the semester preceding the study. In addition, they answered a question about their eventual choice of class profile in secondary school ("What was your average grade in mathematics last semester?" and "Which secondary school profile do you plan to choose?"). Specifically, students were asked whether they intended to choose a class with a humanities profile (predominance of language classes as well as history and social studies) or a STEM profile (predominance of math and science classes).

6. STATISTICAL ANALYSIS

All analyses were conducted using IBM SPSS Statistics 27. Descriptive statistics were calculated for all study variables. Pearson's correlation coefficients were used to examine associations between creative self-efficacy in mathematics, creative personality traits, math grades, and math test scores, separately for girls and boys. Chi-square tests were applied to analyze gender differences in class profile choices. Independent samples t-tests compared mean levels of the study variables between students declaring the STEM profile and the humanities profile. Multiple regression analyses were performed to identify predictors of creative self-efficacy in mathematics for girls and boys. Finally, UNIANOVA models tested the main and interaction effects of gender, GPA, and class profile on creative self-efficacy in mathematics. Effect sizes (Cohen's d , Cramér's V , partial η^2) were reported where applicable, and statistical significance was set at $p < .05$.

7. RESULTS

7.1 Correlation analysis

Table 1 *Correlation analysis of the studied variables*

Variable	1. ACL_C	2. GPA	3. MATH	4. CSE_M
1. Creative personality (ACL_C)	—	.14	.27*	.22*
2. Math grade (GPA)	.18	—	.64**	.59**
3. Math test (MATH)	.19	.56**	—	.48**
4. Creative self-efficacy (CSE_M)	.48**	.51**	.49**	—

Note: Girls' results are shown above the diagonal, men's results are shown below the diagonal; * Significant correlation at the level of 0.05 (two-sided);

** Significant correlation at the level of 0.01 (two-tailed)

Table 1 shows that creative self-efficacy in math was closely linked to academic performance in both groups, but the pattern differed by gender. For girls, creative self-efficacy (CSE) was most strongly related to math grades and test results, while for boys it was shaped by both academic performance and creative personality. This suggests that boys' beliefs about their creative mathematical abilities draw on a broader set of factors than girls', whose self-efficacy appears more dependent on external validation through school achievement.

7.2 Class profile

To check whether there are significant differences in the number of girls and boys who prefer a specific class profile in secondary school, a chi-square analysis was performed. Its results are presented in Table 2.

Table 2 *Chi-square analysis for gender and choice of class profile*

Class profile	Girls (n = 61)	Boys (n = 47)	Total (N = 108)
STEM	29 (47.5%)	39 (83.0%)	68 (63.0%)
Humanities	32 (52.5%)	8 (17.0%)	40 (37.0%)

Note: The overall N=108 because some students did not answer the question about the declared class profile

Chi-square analysis confirmed significant gender differences in class profile choices. While girls were divided almost evenly between STEM and humanities, boys overwhelmingly preferred STEM. This highlights a persistent gender gap in educational aspirations, with boys more likely to pursue science-oriented pathways. In the next step, the differences between the average results obtained by boys and girls in creative self-efficacy, math skills test, creative personality traits, and math grade (Table 3) were analyzed.

Table 3 *Results of Student's t-test analysis by class profile for boys and girls*

Gender	Variable	STEM M	HUM M	t(df)	p
Girls	Creative self-efficacy (CSE_M)	60.61	47.69	2.30 (59)	.025
	Math test (MATH)	13.66	10.52	3.22 (59)	.002
	Math grade (GPA)	5.21	4.03	4.93 (57)	<.001
	Creative personality (ACL_C)	9.07	8.13	1.08 (59)	.283
Boys	Creative self-efficacy (CSE_M)	66.41	45.81	2.57 (45)	.013
	Math test (MATH)	12.06	9.50	1.66 (45)	.105
	Math grade (GPA)	4.95	4.13	2.31 (44)	.025
	Creative personality (ACL_C)	9.70	8.75	0.72 (43)	.478

Note: The overall N=108 because some students did not answer the question about the declared class profile

Students planning to pursue STEM classes consistently outperformed their humanities-oriented peers in creative self-efficacy, mathematics test scores and math grades, but not in creative personality. Among girls, those choosing STEM showed higher creative self-efficacy, math skills, and grades. For boys, significant differences emerged in creative self-efficacy and GPA, with STEM-oriented boys reporting stronger beliefs in their creative mathematical abilities. These findings confirm that educational aspirations are closely tied to both achievement and self-assessments, though the specific patterns differ by gender.

7.3 Creative self-efficacy in math

In the next step, possible predictors of creative self-efficacy in math were checked in the group of girls and boys. The results of the regression analysis are presented in Table 4.

Table 4 *Regression analysis of the studied variables*

Predictor	Girls β	p	Boys β	p
Creative personality (ACL_C)	.14	.112	.37	<.001
Math grade (GPA)	.47	<.001	.29	.005
Math test (MATH)	.16	.171	.24	.019

Note: Dependent variable: CSE_M, For girls: $F(3, 85) = 18.34$, $p < .001$, $R^2 = .39$. For boys: $F(3, 80) = 20.69$, $p < .001$, $R^2 = .44$

Regression analyses showed clear gender differences in the predictors of creative self-efficacy. For girls, math grades were the only significant predictor, suggesting that their confidence in creative problem solving relies heavily on external academic validation. For boys, creative self-efficacy was shaped by a broader set of factors, including creative personality, math grades, and test performance. This indicates that boys' self-assessment draws both on achievements and personal traits, whereas girls are more closely tied to formal school outcomes.

The results show that while the key predictor is the average grade in mathematics for girls, both creative personality traits and mathematical achievements have a significant impact for boys, which indicates a more comprehensive set of factors influencing their creative self-efficacy in math. For the group of girls, the most important factor is the average grade in mathematics, while for boys, the most important are creative personality traits. The obtained results highlight the differences in the processes influencing creative self-efficacy in math depending on gender, which may be important when designing educational programs supporting students' development. To check the interactive effect of GPA math and students' gender on creative self-efficacy, UNIANOVA analyses were conducted, introducing GPA and gender as constant factors into the model, and creative self-efficacy in math as the dependent variable (Table 5).

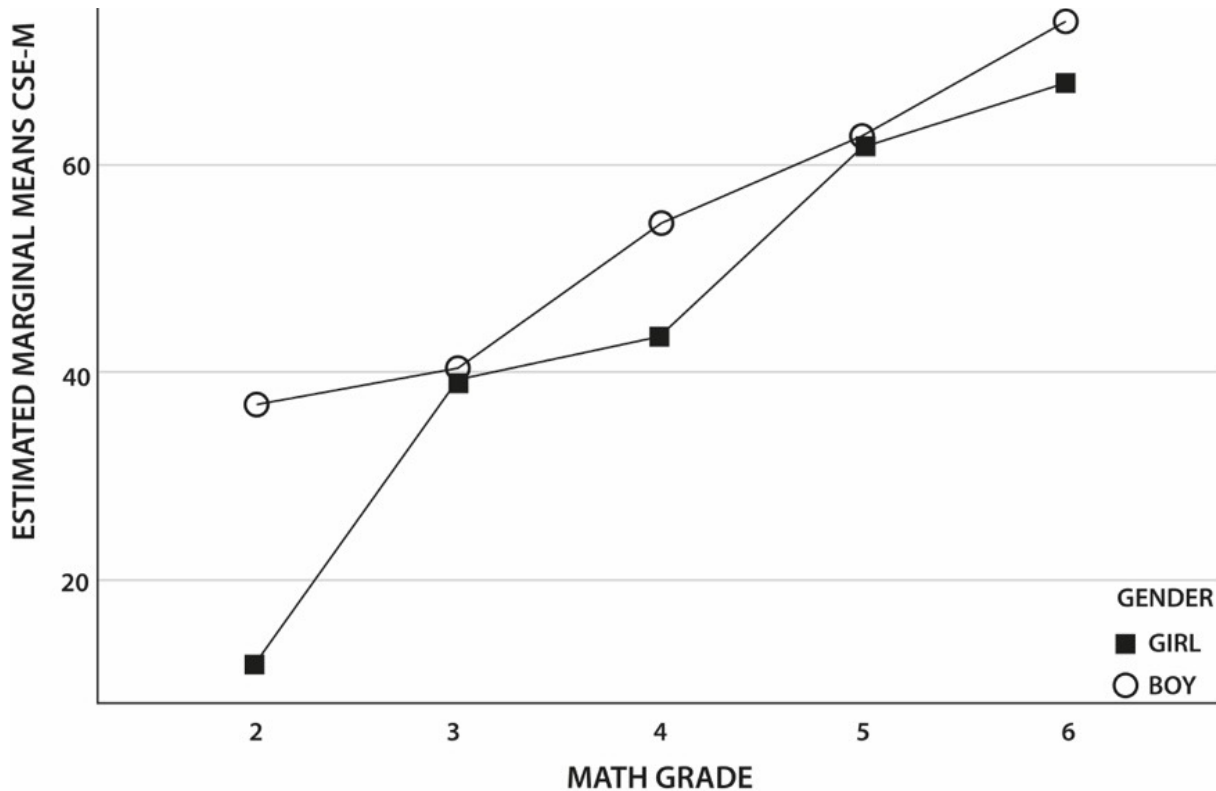
Table 5 *UNIANOVA results in testing the effect of gender interaction with math GPA on creative self-efficacy in math*

Source	F	p	Partial η^2
Gender	4.13	.044	.03
GPA	16.95	<.001	.29
Gender $\times$ GPA	0.85	.499	.02

Note: dependent variable: CSE_M, a. Model: $F(9, 164) = 7.96$, $p < .001$, $R^2 = .30$

Even though there was no significant interaction between variables, both GPA and gender turned out to be significant factors. Figure 1 shows the estimated marginal means of math CSE for girls and boys while achieving different math grades. Despite the lack of an interaction effect, a consistency can be seen in lower math CSE levels in the girls' group compared to the boys' group. The greatest differences in the level of this variable were identified when students obtained low grades in mathematics—girls with the lowest grades in mathematics have a much lower level of creative self-efficacy in math compared to boys with the same grades. These differences decrease with increasing math GPA, but they exist even when girls and boys obtain the highest grades. The obtained results indicate that both the average grade in mathematics and gender have a significant impact on the level of creative self-efficacy in math, which confirms that these factors should be considered independently of their mutual interactions. The lack of a significant interaction between gender and GPA suggests that the impact of average grades on creative self-efficacy is similar for girls and boys, although at a different base level. It was observed that girls with the lowest grades in mathematics are characterized by a significantly lower level of creative self-efficacy than boys with similar results. These differences decrease with increasing GPA but remain noticeable even at the highest grades.

Figure 1 *Estimated marginal means of CSE-M for girls and boys with different grades in math*



In the next step, a UNIANOVA analysis was performed for gender and students' planned class profile in secondary school as constant factors, and creative self-efficacy in math as the dependent variable (Table 6). Despite the lack of interaction between gender and class profile, a significant effect of class profile was observed in the constructed model.

Table 6 *UNIANOVA results in testing the effect of gender interaction with planned class profile on creative self-efficacy in math*

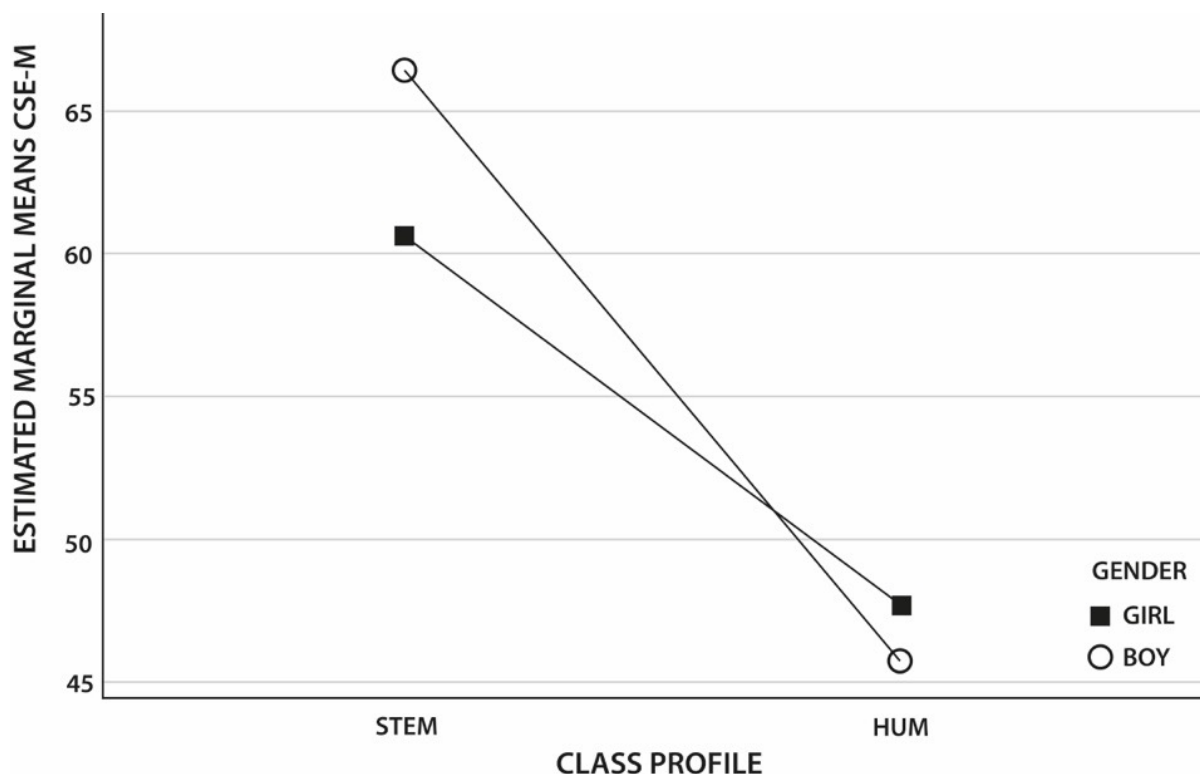
Source	F	p	Partial η^2
Gender	0.16	.694	.00
Class profile	11.35	.001	.10
Gender × Class profile	0.60	.442	.01

Note: dependent variable: CSE_M, a. Model: $F(3, 104) = 5.50$, $p = .002$, $R^2 = .14$

The significant effect of class profile indicates that students' choice of the STEM or humanities profile is associated with differences in the level of creative self-efficacy in math. Students choosing the STEM profile show higher levels of creative self-efficacy in math compared to students choosing the humanities profile, which may be due to the greater exposure to the demands associated with mathematical thinking in STEM profiles. These results indicate the need to support students choosing humanities profiles in developing their creative mathematical self-efficacy in order to reduce the differences resulting from educational choices.

The graphical representation of the obtained results is shown in Figure 2. The creative self-efficacy in math of girls choosing classes with a science profile is lower than that of boys who also chose this profile. On the other hand, boys choosing classes with a humanities profile are characterized by lower creative self-efficacy in math than girls choosing this profile.

Figure 2 *Estimated marginal means CSE-M for girls and boys choosing different class profiles in secondary school*



8. DISCUSSION

The research presented in this article highlights the intricate interplay between creative self-efficacy, mathematical skills, and gender in shaping educational choices, particularly the preference for STEM classes in secondary school. This discussion further explores these findings, examining their implications for educational practice and policy.

The study confirms significant gender differences in creative self-efficacy in math, with boys generally exhibiting higher levels of self-efficacy than girls. This disparity is consistent with previous research indicating that boys often have greater confidence in their creative abilities, which can influence their educational and career choices (He & Wong, 2021a). The reasons for these differences can be traced to social and cultural factors, including gender stereotypes and differential encouragement from teachers and parents (Ghasemi & Burley, 2019; Zander et al., 2020). These differences may stem from deeply rooted psychological and sociocultural mechanisms. From an early age, girls often encounter stereotypes positioning mathematics as a predominantly male domain, which can negatively impact their self-perception and confidence in their abilities (Foley, 2016). Socialization processes, including differential parental expectations, gendered educational practices, and teachers' implicit biases, further reinforce these stereotypes (Solbes-Canales et al., 2020). Girls frequently receive less encouragement to pursue mathematics-related activities outside the classroom and may internalize societal messages that undervalue their mathematical potential (Rhodman, 2024). In contrast, boys are more often exposed to positive feedback regarding their analytical and mathematical skills, boosting their confidence and fostering higher creative self-efficacy (Pajares, 1996). Recognizing these deeper cultural and social influences is essential for designing targeted interventions aimed at reducing gender disparities in STEM fields.

It is noteworthy that girls' creative self-efficacy in math is strongly correlated with their academic performance, specifically their math grades. This suggests that external validation through grades significantly impacts girls' confidence in their mathematical and creative abilities. In contrast, boys' creative self-efficacy is influenced not only by their grades, but also by their creative personality traits and actual math skills. This indicates a broader range of influences on boys' self-efficacy, encompassing intrinsic traits and external achievements. Similar findings have been reported by Zander et al. (2020), who noted that girls often exhibit lower self-efficacy in mathematics due to higher levels of math anxiety and lower cognitive self-assessment.

These findings underscore the importance of fostering a supportive environment that boosts girls' confidence in their creative abilities, particularly in math. Educational interventions could include providing consistent positive feedback and reinforcement from teachers, emphasizing effort and improvement rather than just achievement. This approach can help girls develop a growth mindset, which is crucial for building self-efficacy (Dweck, 2006). Introducing female role models in STEM

fields can inspire girls and provide tangible examples of successful women in these areas (Lane et al., 2022). Programs that connect students with female scientists, engineers, and mathematicians can help counteract stereotypes and broaden girls' perceptions of their potential careers. Additionally, incorporating creative problem-solving tasks into the math curriculum can enhance all students' creative self-efficacy. These activities should encourage divergent thinking and allow students to explore multiple solutions to problems, thereby fostering a creative approach to mathematics (Hong & Aqui, 2004).

Suggested practical recommendations for teachers:

Provide consistent positive feedback – emphasize effort, improvement, and creativity in math problem solving rather than only correct answers.

Use female role models in STEM – introduce students to stories, guest speakers, or case studies of successful women in STEM fields.

Incorporate creative problem-solving tasks – include open-ended math problems that allow for multiple strategies and solutions, encouraging divergent and convergent thinking.

Foster a growth mindset – explicitly teach students that mathematical ability and creativity can be developed with practice and persistence.

Create supportive classroom environments – promote risk-taking, exploration, and tolerance for mistakes as part of the learning process.

Mentorship and peer support – organize mentoring programs where older or more advanced students, especially girls, can inspire and support younger peers in STEM learning.

The significant gender gap in the choice of STEM vs. humanities classes is a critical issue that has been studied for years, and new developments in gender economics are changing our understanding of the math gender gap and reshaping policy as a result. This gender gap is particularly problematic in terms of future labor market outcomes, as women tend to choose degrees with lower average earnings than men (Bertrand, 2018). While much of the literature on the gender gap in mathematics has focused on precollege populations (Morán-Soto & González-Peña, 2022), the gender gap in self-efficacy and math anxiety must be addressed to reduce gender differences in achievement (Bertrand, 2018). Research has shown that there is a gap between males and females in terms of mathematics performance with males having an advantage in mathematical problem solving and females having an advantage in arithmetic and calculus. Additionally, males have been found to perform better in math-fact retrieval than females (Pina et al., 2021).

The study shows that boys are more likely to choose STEM classes, while girls prefer the humanities. This gap can perpetuate gender disparities in STEM fields and contribute to broader societal inequalities. To address this, schools and policymakers should consider strategies such as designing curricula that integrate STEM subjects with real-world applications and creative projects. This can make STEM subjects more appealing to girls and help them see the relevance of these fields to their interests and future careers (Eccles & Barber, 1999). Establishing mentoring programs where older students or professionals' mentor younger girls in STEM can provide guidance, support, and encouragement. Mentors can help demystify STEM subjects and careers, making them more accessible (Guenaga et al., 2022). Interventions aimed at younger students can be particularly effective. Encouraging girls to engage with STEM subjects early on can help build a foundation of interest and confidence that will carry through to secondary school and beyond (Meece et al., 1982).

Despite the significant findings, this study has several limitations that should be acknowledged. First, the sample size was relatively small ($N = 185$) and drawn from a single region of Poland, which limits the generalizability of the results. Post hoc sensitivity analyses indicated, however, that with the achieved sample sizes, the regression models had sufficient power ($\geq .80$) to detect small-to-medium effects, while smaller effects may have remained undetected. Second, the cross-sectional design restricts causal inference regarding the relationships between creative self-efficacy, mathematical skills, and educational choices. Future studies using longitudinal designs would allow for examining how these variables interact over time and whether changes in self-efficacy predict actual STEM-related educational decisions. Finally, the reliance on self-reported measures of creative self-efficacy and personality traits may have introduced response biases, as students could either overestimate or underestimate their abilities. Addressing these limitations in larger, multi-site, longitudinal projects will be crucial for strengthening the robustness and generalizability of the findings.

This study opens several avenues for future research. One area that warrants further investigation is the longitudinal impact of creative self-efficacy on STEM choices and achievements. Longitudinal studies could provide insights into how creative self-efficacy develops over time and how it influences long-term educational and career outcomes. Additionally, exploring the role of socio-cultural factors in shaping creative self-efficacy and STEM preferences could yield valuable insights. Understanding how cultural norms, family expectations, and peer influences interact with individual traits to impact educational choices can help develop more targeted and effective interventions.

In conclusion, addressing gender disparities in creative self-efficacy and STEM choices requires a multifaceted approach that includes supportive educational practices, role models, and early interventions. By fostering an environment that

encourages all students, particularly girls, to develop confidence in their creative and mathematical abilities, we can help close the gender gap in STEM fields and promote a more inclusive and equitable educational landscape. Future research should continue to explore these dynamics to inform policies and practices that support all students in reaching their full potential.

9. CONCLUSIONS

The exploratory analysis provides noteworthy findings regarding the performance of creative mathematics self-efficacy in students' secondary school STEM class enrollment decisions, especially registering notable gender differences. Boys were consistently found to have higher mathematics creative self-efficacy than girls, with both internal creative dispositions and educational external successes playing a role. Girls, however, had mathematics creative self-efficacy based primarily on external sources of validation through academic achievement. These findings underscore the necessity for rigorously targeted educational interventions to address gender disparities in STEM education. Creative self-efficacy in girls can be promoted through interventions, including positive and sustained feedback, introduction to engaging female role models, and the inclusion of creative problem-solving activities within mathematics courses. Understanding and overcoming more entrenched cultural and social determinants, such as gender stereotypes and differential socialization practices, remain critical to ensuring a more inclusive and equitable STEM education environment. Subsequent research with longitudinal designs and more extensive, geographically representative samples would further clarify the paths of creative self-efficacy and STEM selection through time, contributing valuable information to teaching strategies and policy making.

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