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Mathematical Thinking Style as a Determinant of Mathematical Creativity of STEM Students

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Abstract

This study examined the influence of sex and mathematical thinking styles on the mathematical creativity among STEM students, particularly in the Philippine context. Guided by the mental self-government theory, this study sought to examine how sex and mathematical thinking styles predict students' mathematical creativity. Using correlational design, a total of 100 respondents participated in the study and employed stratified simple random sampling in the selection of the respondents. Data were collected using a contextualized instrument adapted from published international research, with face and content validity established through expert validation and pilot testing. Multiple linear regression with dummy coding for sex was used for analysis. The findings of the study revealed that mathematical thinking style is a significant predictor of mathematical creativity of STEM students, but not sex. For every unit increase in mathematical thinking style, there is a corresponding increase in the mathematical creativity of students. It was also revealed in the study that there is no difference in mathematical creativity between male and female students.

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1. Introduction

Mathematical creativity refers to the ability to explore problems from various perspectives, identify patterns, generate multiple solutions, and apply appropriate strategies to unfamiliar mathematical situations (Lu et al., 2025). Despite its importance, mathematics is still commonly perceived as one of the most difficult subjects, and many students view mathematical proficiency as an innate ability rather than a skill that can be developed (McClarty & Giacumo, 2025). These perceptions often result in low performance and a lack of persistence in mathematical tasks (Lamont et al., 2024). For example, recent studies emphasize that attitudes toward math, including fear of failure and fixed mindsets, significantly affect students' creativity and performance (Saefudin et al., 2022).

The significance of mathematical creativity lies in its role in developing problem-solving abilities, fostering innovation, and supporting learning in scientific and technical fields (Lu et al., 2025). Research has shown that engaging students in creative mathematical tasks boosts confidence, encourages flexible thinking, and improves academic performance (Velez & Thompson, 2022). Creativity enables learners to apply mathematical concepts to real-world situations, enhancing their sense of relevance and competence (Bicer, 2021). Therefore, developing mathematical creativity is not just an academic goal but also an essential foundation for personal and professional success in STEM-related fields.

Socially, mathematical creativity contributes to the advancement of mathematical thinking and innovation. As Li and Kim (2024) demonstrated, creative thinking activates brain regions associated with executive functions, showing how deeply rooted cognitive mechanisms support creative problem-solving in math. This aligns with findings by Rippon et al. (2023), who noted that nurturing creativity in the classroom environment—through open-ended problems and exploration—can empower

students to think more independently and innovatively. Educators who integrate creativity into instruction can better prepare students for the complexities of modern life and work, where innovation is increasingly valued (Saefudin et al., 2022).

Given its importance, this study examined a key factor that may influence mathematical creativity—mathematical thinking style. While research directly linking these two constructs is still limited, emerging theories suggest that creative mathematical thinking is closely related to how students cognitively process information and approach problems (Lamont et al., 2024). Students with positive mathematical dispositions are more likely to be motivated, resilient, and open to creative exploration (McClarty & Giacumo, 2025). Similarly, Ovat et al. (2024) found that positive attitudes toward mathematics significantly predict creativity, particularly in terms of fluency, flexibility, and originality in problem-solving.

Another dimension explored in this study is the influence of sex on mathematical creativity. Recent research presents mixed but evolving perspectives. While earlier findings often showed males outperforming females in spatial reasoning, more recent studies, such as Rippon et al. (2023), show negligible sex differences in creative mathematical output. This supports a more equitable understanding of mathematical creativity, suggesting that both males and females have equal potential to engage in and excel at creative mathematical thinking when given the right support and opportunities (Voyer et al., 2023).

The motivation for this study emerged from observations of poor performance in mathematics among senior high school (SHS) students. Many struggles with basic problem-solving and computation, which raises concern about their ability to develop mathematical creativity. To address this gap, the

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researchers examined how mathematical thinking style may influence students' creativity in math, and whether sex plays a role in this relationship. Given the limited local research on this topic, particularly among STEM students,

the study contributes to a deeper understanding of these factors and their educational implications.

2. Materials and Methods

This study adopted a descriptive-correlational research design to explore the relationship among mathematical thinking style, sex, and students' mathematical creativity. A research design serves as the conceptual structure or blueprint for conducting research, guiding data collection, calculation, and interpretation (Bhatta, 2013; Devi, 2017). A descriptive design provides a snapshot of the current state of variables, aiming to systematically and accurately describe a population, situation, or phenomenon (McCombes, 2019), while also observing behaviors without manipulating them (Shuttleworth, 2008). In combination, the correlational design allows researchers to define and measure the degree of association between two or more variables and to make predictions based on existing data (Kalla, 2011; Creswell, 2012). Based on these perspectives, the integration of descriptive and correlational designs was identified as the most suitable approach for addressing the research questions concerning the degree and relationship of mathematical thinking style and sex on mathematical creativity. To further analyze these relationships, the study utilized regression analysis, a statistical technique that models the outcome variable as a function of one or more explanatory variables (Casella & Berger, 2002). This approach allowed the researchers to assess how variations in the predictors influenced the response variable, supporting both the generation of predicted values and inferences about associations. Within the context of this study, mathematical creativity was treated as the dependent variable, while mathematical thinking style and sex served as the independent variables.

This study involved 100 senior high school (SHS) students, composed of 50 male and 50 female STEM students enrolled in a higher learning institution in Davao City. Using simple random sampling, a technique that gives each member of the population an equal chance of being selected (Starnes et al., 2010), participants were chosen without bias to ensure fair representation. The researchers focused exclusively on STEM students, as their academic coursework aligns with mathematical and scientific competencies central to the study. Students from other strands were excluded to maintain content relevance and consistency with the study's objectives. Participants were officially enrolled SHS students at the time of data collection, actively participating in math-related subjects. Those who were not officially enrolled, who declined to participate, or who had known cognitive or behavioral diagnoses were excluded to reduce the risk of bias and preserve the internal validity of the study through well-defined inclusion and exclusion criteria.

Two sets of survey questionnaires were used to collect data from the respondents: the Mathematical Thinking Style Questionnaire developed by Ferri (2015) and the Mathematical Creativity Instrument designed by Mann (2005). To ensure validity, defined by Ghauri and Gronhaug (2005) as the extent to which the data accurately reflects the concept being measured, both instruments underwent expert review. The questionnaires were evaluated and revised by specialists in instrument construction to align with the cultural and academic context of the respondents. Reliability was established through pilot testing, consistent with Heale and Twycross

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(2015), who emphasized that reliable instruments must produce consistent results across time and items. Following Huck (2007), internal consistency was assessed using Cronbach's Alpha, the most widely accepted indicator of reliability. A minimum threshold of 0.70, as recommended by Whitley (2002) and

Robinson (2009), was used to determine acceptability. A five-point Likert scale was employed to effectively measure the respondents' levels of agreement, ensuring that the instruments used in the study were both valid and reliable for assessing mathematical thinking style and mathematical creativity.

3. Results

Table 1 shows the profile of the respondents, consisting of 100 STEM senior high school students. The respondents were evenly divided by sex, with 50 males and 50 females participating in the study.

Table 1. Profile of Respondents

Sex	Frequency
Male	50
Female	50
Total	100

Table 2 presents the level of mathematical thinking style among STEM students. The total mean score of 3.68 corresponds to a high descriptive level, indicating that the respondents often display characteristics related to mathematical thinking. Four items received very high ratings, six were rated high, and the remaining four were rated moderate. Items with very high ratings included *preferences for visual explanations* (4.44), *use of visual images to*

understand mathematics (4.31), *understanding variables and formulae* (4.26), and *using formulas in problem-solving* (4.20). High-rated items indicated preferences for group work, interaction during problem-solving, and focus on general issues. Moderate-rated items suggested that some students prefer to work mentally or independently or seek information rather than ask for help.

Table 2. Level of Mathematical Thinking Style of STEM Students

Indicator	SD	Mean	Descriptive Level
1. preferring visual explanation of teacher or sketches on the board	0.73	4.44	Very High
2. preferring geometry because a drawn figure can also be a possible selection	0.76	3.43	High
3. believing that visual images are helpful to understand mathematics	0.85	4.31	Very High
4. understanding that variables and formulae are helpful to understand mathematics	0.80	4.26	Very High
5. preferring to use a formula when solving a mathematical problem	0.89	4.20	Very High

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6.	loving to learn and retain formulae	0.99	3.64	High
7.	preferring mathematical problems which are divided in several parts	0.89	3.42	High
8.	choosing to breakdown mathematical problems into smaller ones without looking at the problems as a whole	0.91	3.24	Moderate
9.	preferring to work on mathematical problems where one can focus on general issues rather than on specifics	0.80	3.46	High
10.	preferring to think through mathematical problems in the mind, without writing something down	0.98	3.00	Moderate
11.	having a preference to search information for solving a mathematical problem rather than ask	0.95	3.33	Moderate
12.	preferring to work alone on a mathematical problem	1.09	3.12	Moderate
13.	preferring to interact with others while solving a mathematical problem	0.96	3.68	High
14.	preferring to work in a group when solving a mathematical problem	0.86	3.96	High
Total Mean		0.43	3.68	High

Table 3 displays the level of mathematical creativity of the respondents. The overall mean of 3.60 suggests a high level of mathematical creativity among STEM students. All items were rated high except for one, which received a

moderate rating. Most items reflect the students' ability to generate ideas, take risks, display imaginative thinking, and adapt ideas creatively. Only the item relating to *finding humor in unusual situations* scored moderately (3.32).

Table 3. Level of Mathematical Creativity

	Indicator	SD	Mean	Descriptive Level
1.	demonstrating imaginative thinking ability	0.93	3.64	High
2.	having a sense of humor	0.91	3.74	High
3.	having the ability to come up with unusual, unique, or clever responses	0.83	3.50	High
4.	having an adventurous spirit or willingness to take risks	0.96	3.74	High
5.	having the ability to generate a large number of ideas of solution to problems or questions	0.91	3.42	High
6.	having a tendency to see humor in situations that may not appear to be humorous to others	0.91	3.32	Moderate
7.	having the ability to adapt, improve, or modify objects or ideas	0.82	3.85	High

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8. demonstrating intellectual playfulness, willingness to fantasize and manipulate ideas	0.87	3.72	Moderate
9. demonstrating a non-conforming attitude, not fearing being different	0.97	3.47	High
Total Mean	0.61	3.60	High

Table 4 presents the dummy coding applied to the variable sex. As a categorical variable, sex was transformed for statistical analysis, where female was coded as 0 (reference group) and male as 1.

Table 4. Coding for Dummy Variables

Categories of Original Variable		Dummy Variable Coding	
<i>Sex</i>		<i>Sex</i>	
Female	0	Reference Code	
Male	1		

Table 5 presents the Pearson product-moment correlation between the independent and dependent variable. The analysis revealed a strong, significant positive correlation between mathematical thinking style and mathematical

creativity ($r = .664, p = .000$). This indicates that students with a strong mathematical thinking style tend to demonstrate higher levels of mathematical creativity.

Table 5. Correlation between Variables

Pair of Variables			
Independent Variable	Dependent Variable	r-value	p-value
Mathematical Thinking Style	Mathematical Creativity	.664*	.000

Note. $P < .05$ indicates statistical significance

Table 6 shows the results of regression analysis. Mathematical thinking style significantly influences mathematical creativity ($B = .658, p < 0.05$), indicating that students with a strong mathematical thinking style tend to demonstrate higher levels of mathematical creativity. The model

is significant ($F = 13.220, p < .05$) and yields R^2 of .214, meaning 21.4% of the variance in mathematical creativity is explained by mathematical thinking style.

Table 6. Regression Analysis on Mathematical Thinking Style and Sex as Predictors of Mathematical Creativity

	Coefficients	Standard Error	t stat	p-value	
Intercept	1.112	0.487	2.280	0.024	Sig
MTS	0.658	0.129	5.064	1.95E-06	Sig
	R square	= 0.214			
	F value	= 13.220			
	p value	= 8.37E-06 ($p < 0.05$, significant)			

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6.1. The Regression Model

This study formulated three regression models: a general model, one for male students, and one for female students, to examine the influence of mathematical thinking style and sex on students' mathematical creativity. The findings show that male students have a slightly higher predicted mean score in mathematical creativity than female students by 0.132 units, but this difference is not statistically significant ($p > 0.05$), indicating that sex does not meaningfully influence creativity. In contrast, mathematical thinking style significantly predicts mathematical creativity, with each one-unit increase in thinking style associated with a 0.658 unit increase in creativity ($p < 0.05$). This suggests that students who exhibit stronger

mathematical thinking style are more likely to demonstrate higher levels of creativity. The overall regression model is statistically significant, confirming that a valid model can be constructed to explain variations in mathematical creativity, with mathematical thinking style emerging as the key influencing factor.

The multiple regression analysis revealed that mathematical thinking style significantly predicted students' mathematical creativity, $F = 13.220$, $p < .05$, with $R^2 = 0.214$. This indicates that 21.4% of the variance in mathematical creativity explained by mathematical thinking style.

The regression equation for the general model is:

$$Y = 1.112 + .132 (\text{Sex}) + .658 (\text{MTS}) \quad \text{Model 1}$$

Where:

Y = predicted mathematical creativity
 Sex is dummy coded (0 = female, 1 = male),
 MTS = mathematical thinking style

A positive coefficient for MTS ($B = .658$, $p < 0.05$) suggests that students who exhibit stronger mathematical thinking style are more likely to demonstrate higher levels of mathematical creativity. On the other hand, sex ($B = .132$, $p > 0.05$) does not significantly influence mathematical creativity

To further explore how the relationship between mathematical thinking style and mathematical creativity may vary by sex, the dataset was stratified. This allowed for construction of two additional models: one for male students and another for female students.

Model for Male students ($\text{Sex} = 1$):

$$Y = 1.112 + .132 (1) + .658 (\text{MTS}) \quad \text{Model 2}$$

Model for Female students ($\text{Sex} = 0$):

$$Y = 1.112 + .658 (\text{MTS}) \quad \text{Model 3}$$

Comparing the two groups, it could be noted that there is difference between the two groups. Using Model 2 for male students, the mean mathematical creativity is 1.902 ($1.112 + .132 + .658$) while for female students the mean mathematical creativity is 1.77 ($1.112 + .658$). Rounding off to two decimal places, the descriptive equivalent for 1.90 is low while for 1.77 is very low. However, it could not be stated

that the mathematical creativity of male students is higher than the female students, as sex was not found to be a significant predictor of mathematical creativity. The models are significant as presented in Table 6. The presence of the three models signifies the rejection of the null hypothesis that no regression model can be crafted from the study.

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4. Discussion

4.1. Mathematical Thinking Style

STEM students in the study showed a high level of mathematical thinking style, often using visual aids like images and formulas to understand problems—supporting Ferri (2012) and Park and Brannon (2013), who emphasized that visual representations enhance understanding and creativity in mathematics. While most students preferred collaborative learning, some showed a preference for working independently, aligning with French et al. (2011) who found that gifted learners often favor

solitary study. These results support the findings of Luchavez and Caloc (2024), who concluded that enrichment programs and pedagogical preparedness significantly improve mathematical proficiency. Their study highlights the need for varied teaching strategies that include both collaborative and independent approaches. Providing flexible, enriched learning experiences helps support diverse thinking styles and enhances mathematical understanding among students.

4.2. Mathematical Creativity

The high rating for mathematical creativity implies that this ability is frequently exhibited by students, particularly in areas like imaginative thinking, risk-taking, and adaptability. This supports Sriraman's (2005) assertion that fostering creativity in mathematics classrooms is essential. Teachers play a critical role in encouraging risk-taking and creative expression, contributing to deeper understanding and improved mathematical performance (Mann, 2005). Similarly, Nadjafikhah et al. (2012) emphasize the value of interactive environments where students are free to explore ideas and learn from errors. A moderately rated item—relating to humor in unconventional situations—may be influenced by cultural differences in humor perception rather than a lack of creativity (Martin & Ford, 2018). These

findings echo the study of Obenza et al. (2024), who found that cognitive absorption—deep mental engagement in a task—significantly enhances learning outcomes, such as AI literacy, especially when shaped by individual factors like sex. Their conclusion suggests that sustained focus and immersion contribute to better cognitive performance. This parallels the role of deep engagement in mathematical tasks, where students who are mentally absorbed in creative problem-solving are more likely to demonstrate higher levels of mathematical insight. Encouraging creativity in math, like promoting cognitive absorption in AI, requires thoughtful, inclusive strategies that consider learner differences and provide supportive, exploratory environments.

4.3. Dummy Coding by Sex

To assess the influence of sex on mathematical creativity, dummy coding was applied by assigning a value of 0 to females (reference group) and 1 to males. This statistical method enables nominal variables to be included in regression analysis by converting categories into

binary variables (Salkind, 2010; Vashdi & Vigoda-Gadot, 2020). Through this coding, the study could measure the independent and combined effects of sex and mathematical thinking style on creativity.

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4.4. Correlation

A significant positive correlation was found between mathematical thinking style and mathematical creativity, leading to the rejection of the null hypothesis. This aligns with findings by Khorri et al. (2013) and Ayllon et al. (2016), who reported that students with stronger

mathematical thinking skills tend to be more creative problem solvers. These cognitive processes foster creative engagement by requiring students to form conjectures and consider multiple perspectives when addressing mathematical tasks.

4.5. Influence

Regression analysis revealed that mathematical thinking style significantly influences mathematical creativity, while sex does not. These findings are in line with Lince (2016), who stated that mathematical thinking directly enhances problem-solving abilities and creative expression, and Zaenuri et al. (2019), who emphasized the importance of cultivating logical, critical, and creative thinking through mathematics education. On the other hand, the absence of a significant effect from sex supports

research by Permatasari et al. (2020), Baer and Kaufman (2008), and Matud et al. (2007), all of whom found minimal or no differences in creativity between males and females, particularly in educational settings. Sex does not exert a significant influence on creativity, as its development is primarily shaped by educational opportunities, available resources, and sociocultural support rather than by biological determinants (Baer & Kaufman, 2008; Baer, 2015).

4.5. Regression

Three regression models were developed: a general model, a model for male students, and a model for female students. All models demonstrate that mathematical thinking style significantly predicts mathematical creativity. In the general and male-specific models, a slight increase in creativity is associated with male students, but the effect is statistically insignificant. In the female-specific model, the predicted creativity scores rely solely on mathematical thinking style. These findings

support Sternberg's (1988) Self-Government Theory (SGT), which proposes that students use different thinking styles to manage learning tasks. Kirton's (1970) framework further explains the link between creative problem-solving and thinking preferences. Overall, while male students scored slightly higher in predicted creativity, the difference is negligible, reinforcing the notion that creativity is more influenced by cognitive style than by sex.

5. Conclusions and Recommendations

5.1 Conclusions

The study concludes that mathematical thinking style significantly influences mathematical creativity, affirming its critical role in shaping students' ability to generate original, imaginative, and adaptive mathematical responses. STEM students demonstrated a high level of both mathematical thinking style and

creativity, with a particular preference for visual representations and collaborative problem-solving. While sex was initially examined as a potential influencing factor, it did not emerge as a significant predictor of mathematical creativity, aligning with the gender similarities hypothesis. The regression models

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developed for male, female, and combined groups confirm that mathematical creativity is primarily driven by thinking style rather than sex. These results emphasize the importance of

nurturing cognitive strategies over gender-based assumptions in promoting mathematical creativity among students.

5.2. Recommendations

1. Schools and local education authorities should develop curriculum that prioritize tasks that promote visual reasoning, collaborative learning, and open-ended problem solving to strengthen students' cognitive strategies. Professional development programs should be provided to equip teachers with the skills to foster multiple thinking styles, utilize technology effectively, and implement gender-neutral pedagogical approaches.
2. Teachers should incorporate multiple forms of representation in instruction, such as visual models, graphs, and symbolic reasoning, to accommodate diverse cognitive preferences and enhance flexibility in problem-solving. Collaborative learning should also be encouraged through group activities and peer discussions, as these provide opportunities for students to exchange ideas and develop adaptive strategies.
3. Future studies should include larger and more diverse samples across multiple schools or regions to validate the generalizability of the models and further explore the moderating role of sex and other sociocultural variables in mathematical creativity.

6. Limitations

While this study employed rigorous sampling and validated instruments, several limitations should be acknowledged. First, the findings have limited generalizability, as data were collected from a single private school in Davao City with a relatively small sample size. Second, the study relied on self-reported data, which may be

subject to social desirability or recall bias. Third, the cross-sectional design limits the ability to infer causal relationships between mathematical thinking style, sex, and mathematical creativity. Future research may benefit from longitudinal or experimental designs to establish causal pathways and enhance external validity.

Author Contributions:

This paper was collaboratively authored by two researchers, each contributing according to their area of expertise. Mr. Fuentes took the lead in developing the introduction, methodology, results, and discussion, as well as interpreting the findings. Prof. Amago was responsible for the critical editing and refinement of the manuscript.

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Informed Consent Statement:

Informed consent was obtained from all subjects involved in the study.

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The authors declare no conflict of interest.

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