MATHEMATICAL THINKING EXPERIENCE AS A KEY PREDICTOR OF STUDENTS' MATHEMATICAL CREATIVITY

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Mathematical creativity is a key goal of 21st-century mathematics education and is shaped by students' prior experience. Previous research has mainly examined group differences in creativity among students with different levels of mathematical thinking experience, but its predictive role remains unclear. This study involved 70 high school students and assessed their mathematical thinking experience and mathematical creativity. Results showed a significant positive correlation between the two constructs. Regression analyses further indicated that mathematical thinking experience significantly predicted overall creativity and its three dimensions, with slightly stronger effects on fluency and flexibility. These findings suggest that mathematical thinking experience may contribute to the development of mathematical creativity.

INTRODUCTION

Mathematical creativity is increasingly recognized as a key 21st-century competency and has become a central focus of international educational research (Leikin & Sriraman, 2022). Numerous studies and professional organizations have emphasized that mathematical creativity and cognitive flexibility are essential skills for students to meet future challenges (OECD, 2021), leading many countries to include creativity as a core objective in their mathematics curricula. In school mathematics, creativity is typically considered as relative creativity, reflected in students' fluency, flexibility, and originality (Leikin, 2009; Torrance, 1974). Relative creativity emphasizes its malleability and dynamic nature. Previous research suggests that students' prior learning experiences may play an important role in fostering creativity, which provides a rationale for investigating the relationship between mathematical thinking experience and students' mathematical creativity.

The development of mathematical creativity is widely recognized as a dynamic process that builds on learners' accumulated experiences rather than emerging spontaneously. Hadamard (1945/1954) described mathematical creativity as unfolding through preparation, incubation, illumination, and verification, with prior experience being particularly important during the preparation stage. Similarly, Krutetskii (1968/1983) suggested that inspiration often reflects the unconscious influence of previous experience, arising from prolonged prior thinking and the reprocessing of acquired knowledge. Ervynck (1991) also emphasized that original, non-algorithmic, insight-driven solutions depend on a cognitive context shaped by prior mathematical activity.

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Together, these studies indicate that students' prior experiences play a crucial role in supporting creative problem-solving in mathematics.

Consistent with this perspective, Guo & Shi (2012a, 2012b) proposed the concept of mathematical thinking experience, defined as the student's way of mathematics thinking accumulated from experiencing and understanding the processes of mathematics inductive reasoning and deductive reasoning. They further suggested that such accumulated experience can meaningfully contribute to the development of mathematical creativity. Building on this framework, our previous study (Li et al., 2025) empirically identified four dimensions of mathematical thinking experience: inductive reasoning, analogical reasoning, mathematical expression, and mathematical proof. It also showed that students with higher levels of experience outperformed their peers in overall creativity, fluency, flexibility, and originality, whereas significant differences between medium- and low-experience students were observed only in fluency and flexibility.

Although these studies highlight meaningful links between mathematical thinking experience and mathematical creativity, prior research has focused primarily on group-level differences. Evidence on whether mathematical thinking experience predicts individual creativity remains limited. Against this backdrop, the present study examines the relationship between mathematical thinking experience and students' mathematical creativity. In line with prior conceptual and empirical work, the study proposes the following hypotheses:

H1. Mathematical thinking experience is significantly and positively associated with students' mathematical creativity, including fluency, flexibility, and originality.

H2. Mathematical thinking experience significantly predicts students' mathematical creativity, including fluency, flexibility, and originality.

METHODOLOGY

Participants

A total of 70 second-year students (54 males, 16 females; ages 16 – 17) from a top-tier class in a key high school in Guangzhou participated in the study. All students completed both the mathematical thinking experience and creativity assessments.

Tasks and Data Collection

The tasks were adapted from our previous study (Li et al., 2025), retaining the original dimensions and scoring framework. Both assessments were administered separately in a classroom setting under standardized instructions. The mathematical thinking experience test consisted of four core components (inductive reasoning, analogical reasoning, mathematical expression, and mathematical proof), with a total score of 60 and a 90-minute duration. The mathematical creativity assessment comprised two probability-related open-ended problems, completed within a total of 40 minutes.

Students were encouraged to use both conventional and insight-allowing strategies. Creativity was evaluated using the Multiple Solution Tasks (MST) framework (Leikin, 2009), which evaluates fluency, flexibility, and originality. All responses were scored independently by two raters to ensure inter-rater reliability.

Data Analysis

Descriptive statistics were computed for mathematical thinking experience and its four components, as well as for the total score and three dimensions of creativity (fluency, flexibility, and originality). Experience scores were converted to percentages to facilitate interpretation. Pearson correlations were computed between the Z-scores of mathematical thinking experience (total and component scores) and creativity (total and dimension scores). Finally, the total score of mathematical thinking experience was used as a predictor in regression analyses to examine its effects on overall creativity and its three dimensions.

RESULTS

Students' mathematical thinking experience and creativity performance

Table 1 summarizes students' performance on the mathematical thinking experience and creativity tasks. In the mathematicalvthinking experience assessment, students performed relatively well in inductive reasoning and analogical reasoning, but faced greater challenges in mathematical expression and proof, suggesting some difficulties in logical expression and proof. For creativity, students' performance showed variability across the three dimensions. Fluency, indicating the number of solution strategies generated across both tasks, showed that most students proposed one to two strategies per task. Flexibility, capturing variation among solutions, suggested that students struggled to produce distinctly different strategies. Originality, reflecting the ability to generate uncommon solutions, indicated that most students relied on conventional approaches, with relatively few demonstrating novel ideas.

Table 1: Descriptive statistics for mathematical thinking experience and creativity.

	Mean	*SD*
Mathematical thinking experience	48.95	12.70
Inductive reasoning	49.51	15.46
Analogical reasoning	60.45	14.15
Mathematical expression	43.75	18.77
Mathematical proof	36.98	26.12
Mathematical creativity	34.16	45.44
Fluency	2.53	1.40
Flexibility	20.03	9.66
Originality	3.69	4.68

Correlations between mathematical thinking experience and creativity

Table 2 presents the Pearson correlations among the total and component scores of mathematical thinking experience and creativity. As shown in the table, mathematical thinking experience was significantly and positively correlated with overall mathematical creativity (r = .37, p < .01) and its three dimensions: fluency (r = .45, p < .01), flexibility (r = .47, p < .01), and originality (r = .38, p < .01). These results indicate that higher levels of mathematical thinking experience are associated with stronger creativity.

Among the four components of mathematical thinking experience, inductive reasoning and analogical reasoning exhibited relatively stronger correlations with fluency (r = .41 and .46, both p < .01) and flexibility (r = .39 and .48, both p < .01), while mathematical expression showed a comparatively higher correlation with originality (r = .34, p < .01). In contrast, mathematical proof was weakly correlated with overall creativity and its three subdimensions and did not reach statistical significance.

Additionally, the three dimensions of mathematical creativity showed significant intercorrelations (r = .48 to .99), with the strongest association between fluency and flexibility, and the highest correlation observed between originality and overall creativity, consistent with previous studies (Leikin, 2009; Leikin & Zazkis, 2013). The four components of mathematical thinking experience also displayed significant intercorrelations (r = .25 to .86), suggesting that these components collectively form an integrated construct. Based on these relationships, subsequent regression analyses used the total score of mathematical thinking experience as a predictor to examine its explanatory contribution to mathematical creativity and its subdimensions.

Table 2: Pearson correlations among total and component scores of mathematical thinking experience and creativity.

		1	2	3	4	5	6	7	8
1	Mathematical thinking experience	1							
2	Inductive reasoning	.86**							
3	Analogical reasoning	.72**	.42**						
4	Mathematical expression	.59**	.39**	.37**					
5	Mathematical proof	.70**	.42**	.42**	.25*				
6	Mathematical creativity	.37**	.27*	.29*	.35**	.22			
7	Fluency	.45**	.41**	.46**	.23	.17	.48**		
8	Flexibility	.47**	.39**	.48**	.33**	.17	.62**	.85**	
9	Originality	.38**	.29**	.31**	.34**	.23	.99**	.53**	.63**

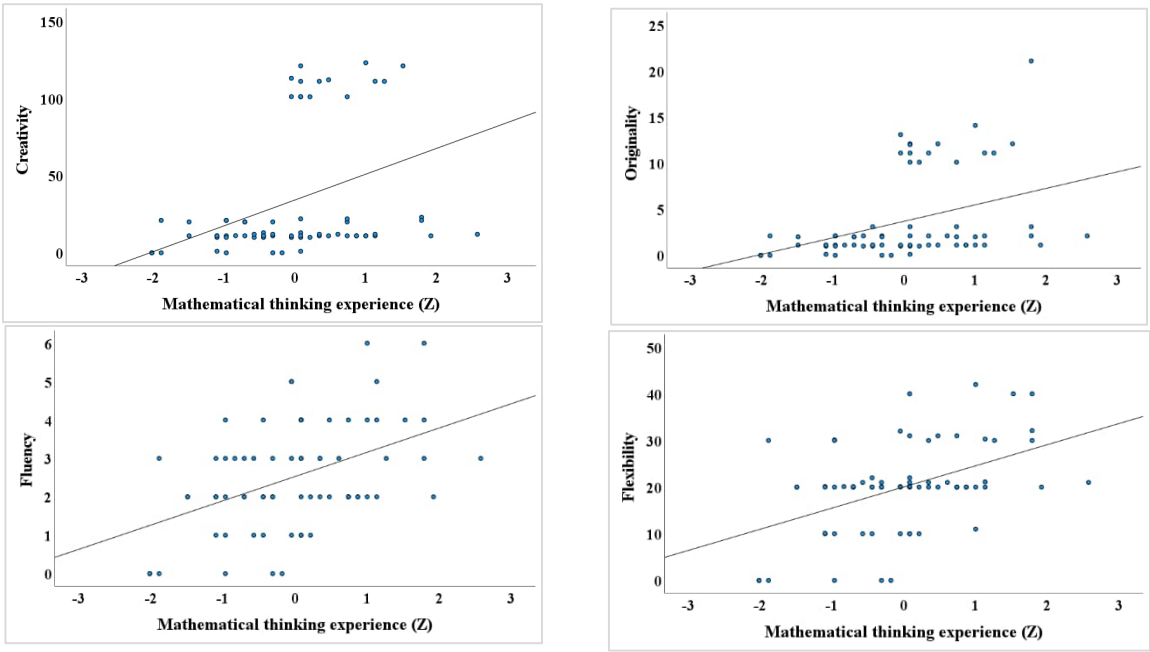
Predictive role of mathematical thinking experience on creativity

Regression analyses (Table 3) indicated that mathematical thinking experience significantly and positively predicted overall mathematical creativity as well as its three dimensions. Specifically, it predicted overall mathematical creativity (β = 0.368, t = 3.263, p = .002), explaining 13.5% of the variance (R^2 = 0.135). Regarding the dimensions, the predictive effect was stronger for fluency (β = 0.451, t = 4.167, p < .001) and flexibility (β = 0.469, t = 4.378, p < .001), which explained 20.3% and 22.0% of the variance, respectively, while the effect on originality was also significant (β = 0.382, t = 3.409, p = .001), accounting for 14.6% of the variance (R^2 = 0.146). These results suggest that mathematical thinking experience contributes not only to overall mathematical creativity but may have a slightly stronger influence on fluency and flexibility than on originality, suggesting its key role in supporting creative performance in mathematics.

Table 3: Regression models predicting mathematical creativity from experience.

	B	*β*	*t*	*p*	R^2
Mathematical creativity	16.717	0.368	3.263	.002	0.135
Fluency	0.632	0.451	4.167	<.001	0.203
Flexibility	4.530	0.469	4.378	<.001	0.220
Originality	1.788	0.382	3.409	.001	0.146

Figure 1: Scatterplots of mathematical creativity and its dimensions against experience.



The scatterplots in Figure 1 further illustrate these relationships. Each plot shows a positive association between mathematical thinking experience and overall creativity as well as its three dimensions. These visual patterns support the regression findings, suggesting that students with higher levels of mathematical thinking experience tend to demonstrate higher creativity, particularly in fluency and flexibility.

Case illustration: differences in creativity by mathematical thinking experience

In Task 2, low-experience students typically followed a single approach, such as exhaustively listing all combinations, demonstrating limited fluency, flexibility, and originality. In contrast, high-experience students observed the numerical distributions and patterns across the columns, drew analogies with prior combinatorial problems, and generated multiple solution strategies (fluency). They flexibly switched among exhaustive, structural analysis, and analogy-based strategies (flexibility), and further identified incremental values to propose non-obvious selection strategies, indicating overall higher creativity (originality).This example shows that mathematical thinking experience, through processes of observation, analogy and expression, supports higher levels of fluency, flexibility, and originality in creative problem solving.

Figure 2: Task 2 - Multiple solutions generated by students

Task-2 (2024 China National College Entrance Examination, Paper I, Q14)

In a 4×4 grid table as shown in the figure, each cell contains a unique number. You need to select 4 grids, ensuring that exactly one grid is chosen from each row and each column. How many different ways are there to make such a selection? What is the maximum possible sum of the four selected numbers among all valid selections?

11	21	31	40
12	22	33	42
13	22	33	43
15	24	34	44

Solution 1:Enumeration method

List all 24 possible cases and compute the sum for each. The maximum sum is 15 + 21 + 33 + 43 = 112.

Solution 2:Insight solution-Determinant method

By performing row and column transformations on the numbers in the 4 × 4 grid, the maximum achievable sum is 15 + 21 + 33 + 43 = 112.

11	21	31	40
12	22	33	42
13	22	33	43
15	24	34	44

1	1	1	0
2	2	3	2
3	2	3	3
5	4	4	4

0	0	0	-1
0	0	1	0
0	-1	0	0
1	0	0	0

Solution 3:Insight solution-Arithmetie sequence

If each column of the table follows an arithmetic sequence with a common difference, then all valid selections yield the same sum. Observing the grid, we see that each column has one term adjusted by ± 1, determining the four selected numbers.

11	21	31	40
12	22	33	42
13	22	33	43
15	24	34	44

11	21	31	41-1
12	22	32+1	42
13	23-1	33	43
14+1	24	34	44

DISCUSSION

This study aimed to investigate the relationship between high school students' mathematical thinking experience and their mathematical creativity, as well as the predictive role of such experience. Consistent with our hypotheses, the results confirmed that mathematical thinking experience was significantly associated with creativity (H1) and significantly predicted students' mathematical creativity, including fluency, flexibility, and originality (H2). Stronger predictive effects were observed for fluency and flexibility than for originality, indicating that students with richer

mathematical thinking experience are more capable of generating multiple solution strategies and switching flexibly among them. These results support the perspectives of Hadamard (1945/1954), Krutetskii (1968/1983), and Ervynck (1991), who emphasized that creativity depends on accumulated knowledge and experience, particularly insights gained from sustained engagement in mathematical activity.

Analysis of the four components of mathematical thinking experience revealed differential associations with creativity. Inductive and analogical reasoning significantly predicted students' fluency and flexibility. Specifically, inductive reasoning may help students extract patterns, generate conjectures, and explore novel solutions. Analogical reasoning may facilitate knowledge transfer across contexts, allowing students to connect seemingly unrelated concepts and generate diverse problem-solving strategies. This observation is consistent with previous research showing that inductive reasoning supports the discovery of new mathematical patterns and innovative ideas (Assmus & Fritzlar, 2022; Eraky et al., 2022), while analogy facilitates cross-domain connections and creative problem solving (Lee & Sriraman, 2011; Singer & Voica, 2022). Mathematical expression was more strongly associated with originality and creativity, suggesting that expressing mathematical ideas allows students not only to externalize existing thoughts but also to develop new structured understandings and innovative insights (Eraky et al., 2022). In contrast, mathematical proof was not significantly associated with creativity or its dimensions. This may be because high school instruction often emphasizes formulaic or imitative proofs, focusing on the validity of conclusions rather than exploration, which limits opportunities for conceptual reconstruction, strategy discovery, and innovation.

In this study, the predictive effects of mathematical thinking experience on fluency and flexibility were stronger than those on originality, reflecting differences in students' performance across the three creativity dimensions. Specifically, prior work (Li et al., 2025) showed that high-experience students outperformed their peers across all creativity dimensions, whereas medium- and low-experience students differed significantly only in fluency and flexibility, with no notable difference in originality. These results align with prior findings (Leikin, 2009; Leikin & Lev, 2013), indicating that fluency and flexibility are dynamically interconnected, while originality, as a relatively distinct aspect of creativity, is less affected by moderate variations in experience. Overall, these observations support the view that components of mathematical thinking experience, especially inductive and analogical reasoning, have a stronger impact on fluency and flexibility, whereas developing originality may require a higher threshold of accumulated experience.

In summary, this study demonstrates that mathematical thinking experience plays a key role in students' mathematical creativity, particularly in enhancing fluency and flexibility. Based on these findings, teachers can provide students opportunities to develop fluency, flexibility, and originality through open-ended problems, non-routine

tasks, inductive and analogical reasoning exercises, as well as structured mathematical expression and exploratory proof activities, offering practical classroom guidance.

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