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Creative Problem-Solving Tasks and Mathematical Creativity: A Second-Order Construct Approach

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Abstract

This study responds to the increasing demand for pedagogical models that promote creativity in mathematics learning, yet few studies have holistically integrated both cognitive and affective dimensions of mathematical creativity. Despite extensive attention to cognitive aspects such as fluency, flexibility, and originality, research seldom links these elements with creative self-efficacy within a unified analytical framework. To address this gap, the present study investigates the effect of Creative Problem-Solving Tasks (CPST) on students' creative self-efficacy and creative thinking abilities in solving integer operation problems. A quasi-experimental design with a pretest–posttest non-equivalent control group was implemented, involving 60 seventh-grade students from two public junior high schools. Data were collected using a creative self-efficacy questionnaire and an open-ended mathematical creative thinking test. Results of independent sample t-tests revealed significant differences between the experimental and control groups in both creative self-efficacy ($t(58) = 11.56$, $p < .001$) and creative thinking ability ($t(58) = 5.22$, $p < .001$). Confirmatory factor analysis further supported the validity of mathematical creativity as a second-order construct encompassing cognitive and affective attributes. These findings demonstrate the potential of CPST to enhance students' confidence and promote creative mathematical thinking. The study contributes to theory development by conceptualizing an integrated model of mathematical creativity and offers practical implications for teachers and policymakers to design instructional strategies and curricula that nurture creative autonomy and divergent thinking in mathematics classrooms.

Keywords: creative problem-solving tasks; creative self-efficacy; integer operations; mathematical creativity; self-efficacy

Introduction

Mathematics education has long been criticized for prioritizing procedural mastery and rote memorization at the expense of students' creative problem-solving abilities. This concern has become increasingly relevant in both national and international contexts, as mathematics competence in the twenty-first century demands not only algorithmic proficiency but also the ability to reason creatively. Creative thinking, as articulated by Leikin and Pitta-Pantazi (2013), constitutes a central component of mathematical creativity, enabling learners to approach problems from multiple perspectives. Similarly, Meier et al. (2021) affirmed that creative thinking strongly correlates with students' problem-solving success, resilience, and capacity to adapt their knowledge across contexts. Following Torrance's model, mathematical creativity can be conceptualized through the three interrelated dimensions of fluency, flexibility, and originality key cognitive processes that underpin deep conceptual understanding and transfer of knowledge to authentic, real-world problem situations.

Empirical evidence, however, indicates that students' creative mathematical thinking remains underdeveloped. The PISA 2018 results demonstrated that Indonesian students scored below the OECD average in mathematical problem-solving and creative reasoning, ranking 72nd among 79 participating countries. Similarly, TIMSS 2019 revealed substantial difficulties among Indonesian students in tackling non-routine and open-ended problems. At the national level, a meta-analysis by Muhtadi, Assagaf, and Hukom (2022) showed that students' mathematical self-efficacy and creative problem-solving remain at moderate to low levels across regions, corroborating Purwati et al. (2025), who argued that self-efficacy plays a pivotal role in developing metacognitive regulation, emotional resilience, and persistence in mathematical problem solving. These findings highlight the necessity of addressing both cognitive and affective domains to cultivate holistic mathematical competence.

Self-efficacy, defined as an individual's belief in their capacity to succeed, is not fixed but can be strengthened through instructional models that encourage autonomy and active engagement. Research increasingly supports the positive influence of problem-based and project-based learning on students' self-efficacy and creative reasoning in mathematics and STEM education (Kwon et al., 2025; Zhang et al., 2023). Such approaches promote student participation, reduce anxiety, and foster intrinsic motivation (Ma, 2025). Furthermore, teacher self-efficacy has been found to predict their instructional creativity, which in turn enhances students' learning outcomes (Hayati et al., 2023). In addition, instructional models such as the Missouri Mathematics Project have demonstrated the potential to strengthen both creative thinking and self-efficacy simultaneously (Faradillah & Purwitasari, 2022).

Despite these developments, previous studies have largely examined the cognitive and affective components of creativity in isolation. Researchers have often focused exclusively on either creative thinking through measures of fluency, flexibility, and originality or on creative self-efficacy, examining its correlation with achievement, without recognizing the reciprocal relationship between the two. Consequently, the existing literature lacks an integrated framework that connects cognitive processes and affective dispositions within mathematical creativity, particularly in the context of problem-solving involving integer operations.

Addressing this gap, the present study proposes a unified model conceptualizing mathematical creativity as a second-order construct that incorporates both the cognitive dimensions of creative thinking and the affective dimension of creative self-efficacy (Baity, 2021; Bales & Estomo, 2022).

This theoretical integration posits that students' belief in their creative capability acts as a motivational driver that sustains cognitive engagement and risk-taking in solving non-routine mathematical problems. In turn, success in generating diverse and original solutions reinforces students' self-belief, forming a reciprocal dynamic between affective and cognitive dimensions. This model offers a more comprehensive explanation of mathematical creativity than existing unidimensional views, elucidating how confidence shapes students' fluency, flexibility, and originality in mathematical reasoning (Herianto et al., 2024).

Pedagogically, focusing on integer operations provides an appropriate and meaningful context for exploring this integration, as these topics are known to generate persistent conceptual and emotional obstacles for students (Hafizi & Kamarudin, 2020). Prior studies have reported frequent misconceptions in operations involving negative numbers due to incomplete conceptual understanding (Piasta et al., 2020; Rima et al, 2024). The study by Rima et al. (2024) revealed that many seventh-grade students systematically misunderstand addition and subtraction with negative integers, suggesting that these concepts remain cognitively demanding and abstract.

Integrating Creative Problem-Solving Tasks (CPST) within this context creates meaningful opportunities for developing both creative thinking and self-efficacy. CPST emphasizes open-ended, real-world mathematical problems that encourage divergent thinking, collaboration, and reflective evaluation (Ibrahim & Widodo, 2020; Ibrahim et al., 2023; Bicer et al., 2023). Its implementation typically involves stages of problem identification, idea generation, idea selection, and solution application, all of which stimulate cognitive flexibility and confidence.

Building upon these premises, this study aims to examine the effects of CPST on students' creative self-efficacy and creative thinking in solving integer operation problems while validating an integrated, second-order construct of mathematical creativity. The findings are expected to advance theoretical understanding of creativity in mathematics by linking its cognitive and affective dimensions and to offer practical implications for instructional design and curriculum development that foster confident, flexible, and original problem solvers in mathematics education.

Methods

This study adopted a quasi-experimental design with a pretest–posttest non-equivalent control group to investigate the effectiveness of the Creative Problem-Solving Tasks (CPST) approach in enhancing students' creative self-efficacy and creative thinking abilities in solving integer operation problems. The participants comprised 60 seventh-grade students purposively selected from two public junior high schools in North Luwu Regency, South Sulawesi: SMPN 3 Sabbang and SMPN 1 Baebunta. These schools were selected because they represent typical public junior high schools in the region, possess comparable academic standards, share similar sociocultural contexts, and were logistically accessible for collaborative research.

To minimize selection bias, the assignment of experimental and control classes was conducted in consultation with school administrators. One intact class from each school was chosen based on comparable average academic performance during the previous semester. The class from SMPN 3 Sabbang served as the experimental group, receiving instruction through CPST-based activities, while the class from SMPN 1 Baebunta functioned as the control group, receiving conventional teaching. Random assignment of students within the schools was not feasible due to administrative and ethical constraints; however, pretest analyses confirmed equivalent baseline characteristics between groups. Consequently, the design included one experimental group exposed to CPST and one control group following standard instruction.

Two validated instruments were employed to assess the affective and cognitive dimensions of mathematical creativity. The first instrument, a Creative Self-Efficacy (CSE) questionnaire, consisted of six items rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The items were adapted from established scales and reviewed by three experts in educational psychology and mathematics education to ensure construct validity. A pilot study conducted with 30 students outside the main sample produced a Cronbach's alpha coefficient of 0.82, indicating strong internal consistency. The second instrument was an open-ended Mathematical Creative Thinking Ability (CTA) test contextualized in integer operations, designed to measure fluency, flexibility, and originality. Student responses were scored using a rubric assessing (1) the number of distinct solutions generated, (2) the diversity of strategies employed, and (3) the uniqueness of solutions relative to peers. All responses were independently scored by two assessors, yielding an inter-rater reliability coefficient of 0.87, which indicated high scoring consistency.

The instructional intervention lasted for six weeks. During this period, the experimental group participated in CPST-based lessons twice weekly, designed to foster creative engagement through real-world contexts, open-ended tasks, and divergent thinking prompts that encouraged multiple solution strategies (Ibrahim et al., 2023; Bicer et al., 2023; Orakçı & Durnalı, 2022). The control group, on the other hand, continued standard instruction following the school's existing curriculum without any experimental modification.

Data collection procedures involved administering both instruments as pretests and posttests. Preliminary statistical analyses were conducted to verify normality (using the Shapiro Wilk test) and homogeneity of variance (using Levene's test). Within-group changes from pretest to posttest were examined using paired-sample t-tests, while between-group differences in posttest performance were analyzed using independent-sample t-tests. All descriptive and inferential data analyses were carried out using SPSS version 25.

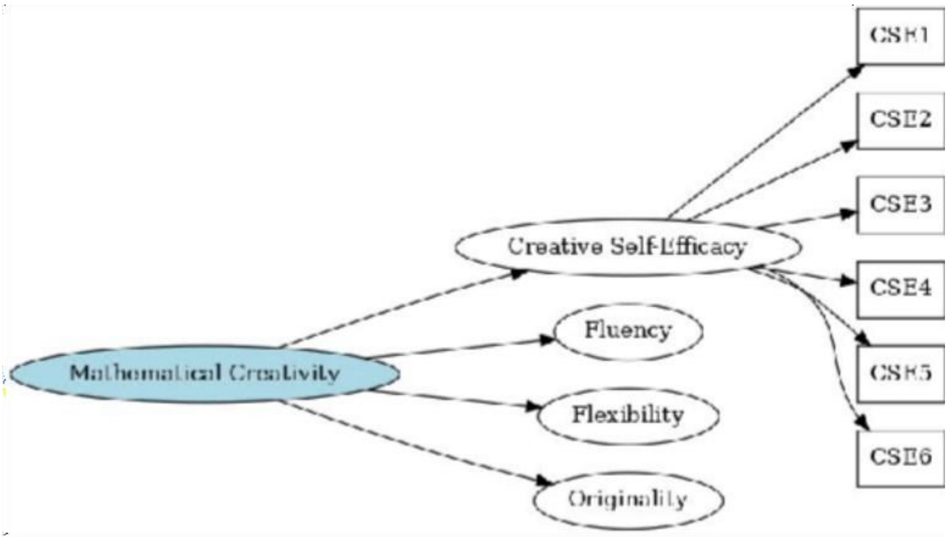

Figure 1. Model SEM Mathematical Creativity

To further substantiate the construct validity of mathematical creativity, Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) were employed to integrate both cognitive and affective dimensions into a second-order construct. These analyses were performed using AMOS version 24. Model adequacy was assessed through several widely recognized goodness-of-fit indices, including the Chi-square to degrees of freedom ratio ($\chi^2/df < 3$), Comparative Fit Index (CFI > 0.90), Tucker–Lewis Index (TLI > 0.90), Root Mean Square Error of Approximation (RMSEA < 0.08), and Standardized Root Mean Square Residual (SRMR < 0.08). According to recent methodological guidelines, these threshold values are considered appropriate for evaluating measurement models in educational research (Goretzko et al., 2024). The results indicated that all fit indices satisfied the established criteria, suggesting that the measurement model achieved satisfactory levels of validity and reliability.

Results and Discussion

This study involved 60 seventh-grade students divided into two groups: 30 students in the experimental group who received instruction through Creative Problem-Solving Tasks (CPST) and 30 students in the control group who received conventional teaching. The research utilized two instruments: (1) a Creative Self-Efficacy (CSE) questionnaire and (2) a Mathematical Creative Thinking Ability (CTA) test focused on integer operations. The CTA instrument was designed to assess three dimensions of creativity fluency, flexibility, and originality.

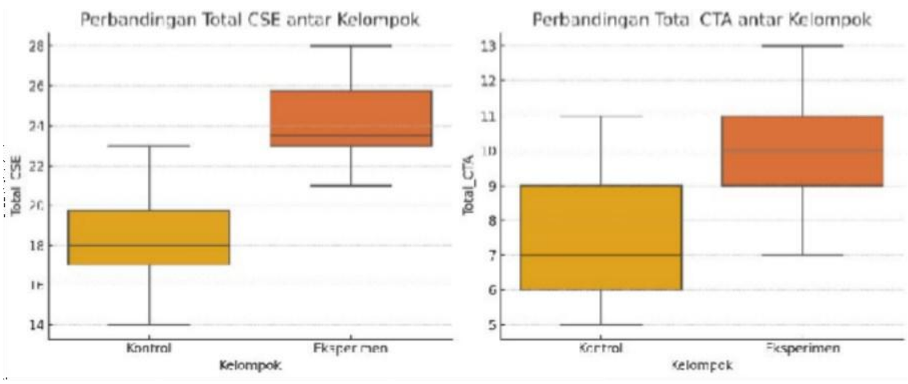

Figure 2. Comparison of Posttest Scores of Creative Self-Efficacy (CSE) and Creative Thinking Ability (CTA) between Experimental and Control Groups

Figure 2 presents the comparison of posttest scores between the two groups. The left boxplot shows that the median CSE score for the experimental group was approximately 24.00, whereas the control group's median was around 18.27, indicating a substantial improvement in students' confidence following CPST instruction. The narrower interquartile range (IQR) in the experimental group suggests greater consistency in students' self-efficacy perceptions. A similar pattern is observed in the right boxplot, which displays the CTA results. The experimental group recorded a median CTA score of 9.70, compared with 7.53 in the control group, illustrating the positive impact of CPST on students' creative mathematical thinking across all assessed dimensions. Furthermore, the experimental group exhibited a wider overall score distribution, reflecting a broader range of creative performance and reinforcing the effectiveness of the intervention.

Descriptive Statistics

Table 1 shows that the data indicate that the experimental group consistently achieved higher average scores in both variables.

Table 1. Descriptive Statistics of Self Efficacy and Creative Thinking Ability

Group	Self-Efficacy (Mean ± SD)	Creative Thinking (Mean ± SD)
Experimental	24.00 ± 2.02	9.70 ± 1.56
Control	18.27 ± 1.82	7.53 ± 1.66

Paired Sample t-Test

Paired-sample t-tests were performed to analyze within-group improvements from pretest to posttest. In the experimental group, students' creative self-efficacy scores increased significantly from the pretest (M = 18.90, SD = 2.15) to the posttest (M = 24.00, SD = 2.02), $t(29) = 9.48$, $p < .001$. Likewise, their creative thinking scores rose substantially from the pretest (M = 6.10, SD = 1.43) to the posttest (M = 9.70, SD = 1.56), $t(29) = 8.12$, $p < .001$. These results demonstrate a significant and large improvement in both the affective and cognitive dimensions of mathematical creativity following CPST instruction.

In contrast, the control group exhibited only minor changes that were not statistically significant. Students' self-efficacy increased slightly from the pretest (M = 17.80, SD = 1.76) to the posttest (M = 18.27, SD = 1.82), t(29) = 1.12, p > .05, while their creative thinking scores improved marginally from the pretest (M = 7.20, SD = 1.48) to the posttest (M = 7.53, SD = 1.66), t(29) = 0.89, p > .05. These findings indicate that meaningful progress occurred only among students who participated in the CPST-based instruction, suggesting its greater effectiveness in fostering both confidence and creative mathematical thinking compared to conventional teaching.

Independent Sample t-Test

An independent-sample t-test was conducted to compare the posttest outcomes of the experimental and control groups in creative self-efficacy and creative thinking ability. The results indicated that students in the experimental group, who received instruction through Creative Problem-Solving Tasks (CPST), achieved significantly higher creative self-efficacy scores (M = 24.00, SD = 2.02) than those in the control group (M = 18.27, SD = 1.82), t(58) = 11.56, p < .001. A similar pattern was observed for creative thinking ability, where the experimental group (M = 9.70, SD = 1.56) outperformed the control group (M = 7.53, SD = 1.66), t(58) = 5.22, p < .001.

To evaluate the magnitude of improvement, normalized gain (n-gain) scores were calculated. The experimental group achieved an average n-gain of 0.62, indicating a moderate level of improvement, whereas the control group obtained an average of 0.10, reflecting only minimal progress. These findings, consistent with the results of the paired-sample t-tests, confirm that the observed gains were attributable to the CPST intervention rather than random variation, demonstrating the approach's effectiveness in enhancing both cognitive and affective dimensions of mathematical creativity.

Effect size analyses further substantiated the significance of these differences. The posttest comparison for creative self-efficacy showed a very large effect (Cohen's d = 2.98), and creative thinking ability also exhibited a large effect (Cohen's d = 1.35). Together, these results indicate that CPST not only yielded statistically significant improvements but also produced practically meaningful impacts on students' confidence and creative mathematical problem-solving performance.

Correlation Analysis

The Pearson correlation analysis, as presented in Table 2, revealed a significant positive association between creative self-efficacy (CSE) and creative thinking ability (CTA). Overall, CSE demonstrated a moderate correlation with total CTA scores (r = 0.42, p < .05). Further examination of the three dimensions of creative thinking showed strong positive correlations with fluency (r = 0.69, p < .01), flexibility (r = 0.65, p < .01), and originality (r = 0.66, p < .01). All correlations were statistically significant at the 0.05 or 0.01 level, providing robust evidence that students' confidence in their mathematical abilities is closely associated with their capacity to generate multiple ideas, employ diverse strategies, and produce original solutions in problem solving.

Table 2. Pearson Correlation Results

Variable	Correlation with CSE	Correlation with CTA

Fluency	0.20	0.69
Flexibility	0.37	0.65
Originality	0.28	0.65
Total SE	—	0.42

Interestingly, fluency emerged as the most dominant dimension, exhibiting the strongest correlation with overall mathematical creativity. This finding reinforces the central role of students' capacity to generate multiple solutions as a foundational process for cultivating both flexibility and originality (Leikin & Pitta-Pantazi, 2013). It suggests that the breadth of idea generation facilitates strategic adaptability and the development of unique solution paths. These results emphasize the pedagogical value of instructional models such as Creative Problem-Solving Tasks (CPST), which encourage exploration, learner autonomy, and engagement with open-ended mathematical problems. Such approaches not only increase the number of ideas students generate but also nurture their ability to shift strategies and produce original solutions (Ibrahim & Widodo, 2020).

Discussion

The findings of this study empirically support and extend those of Bicer et al. (2023), who demonstrated that the implementation of Creative Problem-Solving Tasks (CPST) in mathematics instruction can substantially enhance students' creative self-efficacy (CSE) and creative thinking ability (CTA). In this study, students in the experimental group who received CPST-based instruction exhibited marked improvement across all three cognitive dimensions of creativity fluency, flexibility, and originality as well as in their confidence to solve integer-related problems. In contrast, no comparable patterns were observed among the control group students who were taught through conventional methods, underscoring the pedagogical value of CPST as an effective and innovative approach to fostering mathematical creativity.

The mechanisms underlying these improvements can be attributed to the distinctive nature of CPST activities, which consistently engage students in open-ended mathematical exploration. During lessons on integer operations, for example, students modeled "debt and credit" scenarios using number lines, counters, and contextualized word problems. One student noted, "I never thought using the number line backwards could explain negative numbers, but it makes sense." Such experiences illustrate how CPST promotes fluency by stimulating idea generation, flexibility by encouraging shifts between multiple representations, and originality by inspiring students to design unique solution strategies. Classroom observations also revealed that students exhibited greater confidence in articulating ideas and a reduced fear of error, signaling strengthened creative self-efficacy. These dynamics highlight how CPST simultaneously cultivates cognitive exploration and affective reinforcement, thereby making mathematics learning both intellectually engaging and emotionally empowering.

Grounded in social cognitive theory, these findings align with Bandura's (1997) assertion that self-efficacy functions not only as a predictor of academic achievement but also as a motivational force sustaining persistence and the willingness to engage with complex tasks. Within the context of mathematics learning, students with stronger creative self-efficacy are more likely to embrace intellectual risk-taking, employ diverse strategies, and sustain engagement when solving challenging problem. In line with this view, Purwati et al. (2025) found a strong positive correlation between self-efficacy and creative thinking ($\rho = 0.849$, $p < .001$), emphasizing that instructional designs aimed at strengthening students' confidence are directly linked to improvements in their creative mathematical performance. Specifically, when applied to integer operations, CPST was shown to mitigate common misconceptions such as errors in adding and subtracting negative numbers by allowing learners to explore and compare multiple representations (e.g., number lines, color-coded counters, and financial contexts). Thus, CPST not only enhances students' creative abilities but also directly addresses the conceptual challenges inherent to integer concepts.

The observed correlation between CSE and CTA reinforces the conceptualization of mathematical creativity as a second-order construct that integrates both cognitive and affective dimensions (Haavold, 2016; Bicer et al., 2023). This integrated model underscores the reciprocal relationship between students' confidence and their creative performance an interdependence that cannot be fully understood when each construct is examined separately. Confidence empowers students to take cognitive risks, while success in generating original solutions further strengthens their belief in their creative potential, creating a positive feedback loop that sustains long-term creative growth in mathematics learning.

Theoretically, these findings suggest that mathematics instruction must extend beyond procedural accuracy to intentionally nurture divergent thinking. In line with constructivist and metacognitive perspectives, CPST offers a pedagogical environment that supports reflection, experimentation, and self-regulation. Through engaging with complex, open-ended problems, students are encouraged to monitor their reasoning processes, evaluate strategy effectiveness, and build self-awareness regarding their problem-solving approaches key elements of higher-order mathematical thinking.

Furthermore, CPST aligns well with task value theory and principles of autonomous motivation in mathematics education (Niu et al., 2022). By allowing students to explore problems, select strategies, and evaluate outcomes independently, CPST enhances perceived task relevance and intrinsic motivation two crucial factors in sustaining mathematical engagement over time. Students perceive the learning task as personally meaningful, which, in turn, promotes deeper cognitive investment and persistence in solving complex problems.

From a practical standpoint, these results emphasize the pivotal role of teachers in fostering classroom environments that reward creativity and embrace the learning potential embedded in error-making. Effective implementation of CPST requires teachers to act not merely as content deliverers but as facilitators who orchestrate exploration, discussion, and self-reflection. As noted by Orakçı and Durnalı (2022), teacher support for student autonomy is critical in promoting both self-efficacy and creative thinking. To implement CPST effectively, teachers can: (a) integrate real-world contexts, such as financial or debt-credit scenarios, when modeling integer operations; (b) employ visual tools like number lines and colored counters to represent negative quantities; (c) organize small-group discussions that encourage idea exchange and multiple strategy generation; and (d) provide formative feedback emphasizing creativity and reasoning rather than correctness alone. These strategies ensure that CPST remains both theoretically grounded and instructionally practical.

Finally, the integration of CPST into mathematics instruction not only strengthens students' creative problem-solving skills in integer operations but also builds an affective foundation essential for long-term mathematical literacy. This research advances existing scholarship by empirically validating the second-order construct of mathematical creativity in the underexplored domain of integer operations. Practically, it offers a viable instructional framework for Indonesian mathematics education, addressing persistent learning difficulties through adaptable, student-centered pedagogy. Collectively, the study contributes to both theoretical advancements in understanding the interplay between cognitive and affective dimensions of creativity and to the practical design of holistic, transformative instructional models in mathematics education.

Conclusion

This study provides empirical evidence that the implementation of Creative Problem-Solving Tasks (CPST) significantly enhances students' creative self-efficacy (CSE) and creative thinking ability (CTA) in the context of integer operations. The results reveal that CPST strengthens both the affective and cognitive dimensions of mathematical creativity, improving students' confidence, fluency, flexibility, and originality in problem solving. The confirmatory factor analysis supported the conceptualization of mathematical creativity as a second-order construct that integrates belief in one's creative potential with the ability to generate, adapt, and refine mathematical ideas. These findings affirm that CPST promotes deeper engagement with mathematical concepts by encouraging exploration, risk-taking, and reflection during problem-solving activities. Consequently, CPST can be viewed as an effective pedagogical model that supports the development of mathematically confident and innovative learners who can apply creative reasoning across diverse problem contexts.

Despite its contributions, this study carries certain limitations that warrant careful consideration. The research was conducted with a relatively small sample drawn from two public junior high schools in North Luwu Regency, which may limit the generalizability of the findings. Moreover, the study focused solely on integer operations, a relatively specific mathematical domain, and did not examine the long-term sustainability of creative skill development over time. Future research is recommended to expand the scope of CPST implementation across different mathematical topics, grade levels, and cultural contexts, as well as to employ longitudinal designs that capture the durability of its effects. Further studies could also incorporate qualitative methods such as classroom observations, interviews, or learning trajectory analyses to explore how CPST shapes students' cognitive processes and dispositions in real classroom settings. The results of this study have significant implications for teachers, curriculum developers, and policymakers in designing instructional frameworks that intentionally integrate affective and cognitive aspects of creativity, thereby fostering a more holistic and enduring approach to mathematics education.

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Conflicts of Interest

The authors declare that there is no conflict of interest concerning the publication of this manuscript. This research was conducted independently and was not influenced by any external funding or institutional pressure that could potentially affect the objectivity of the findings. All ethical considerations, including informed consent, voluntary participation, and the anonymity of student participants, were upheld throughout the research process. Furthermore, the authors affirm that there are no issues related to plagiarism, research misconduct, data fabrication or falsification, duplicate publication or submission, and redundancies. The study adhered to ethical standards applicable to educational research involving human participants.

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