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THE PROBLEM-BASED LEARNING MODEL TO IMPROVE STUDENTS' CREATIVE THINKING ONTHE MATERIAL OF SIMILARITIES

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ABSTRACT

This study examined whether Problem-Based Learning (PBL) was associated with improved mathematical creative thinking in similarity among ninth-grade students. A quantitative pre-experimental one-group pretest-posttest design was used with 22 students in Grade IX-1 at SMP Negeri 1 Sukamakmur, Aceh Besar, selected through purposive sampling. Creative thinking was assessed through four essay problems covering fluency, flexibility, originality, and elaboration. Scores were analyzed descriptively and with a paired-samples t-test after checking the normality of score differences. The mean score increased from 31.53 on the pretest to 61.51 on the posttest, a mean gain of 29.97 points. All four indicators improved, with the largest gain in fluency. The paired-samples test showed a statistically significant within-group increase, $t(21) = 15.94$, $p < .001$, with a large standardized effect, Cohen's dz = 3.40. All 22 students obtained higher numerical scores, and 21 students (95.5%) moved to a higher descriptive creativity category. These findings indicate substantial improvement after PBL implementation. However, because the study used no control group, the result should be interpreted as strong within-group evidence rather than definitive causal proof. PBL can support creative mathematical thinking by engaging students in exploring, comparing, and explaining alternative solution strategies.

Keywords: problem-based learning; creative thinking; similarity; geometry; mathematics education

INTRODUCTION

Mathematical learning should develop more than procedural accuracy. Students also need to generate ideas, consider alternative strategies, connect representations, and explain why a solution works. These processes are central to mathematical creative thinking. Creative thinking in mathematics is commonly represented through fluency, flexibility, originality, and elaboration, although the expression of these dimensions depends on the task and students' prior knowledge (Hadar & Tirosh, 2019; Febrianingsih, 2022; Gunawan et al., 2022; Hanifah et al., 2024). When classroom tasks invite only one routine procedure, students have fewer opportunities to practice these forms of thinking.

Similarity is a geometry topic that requires students to coordinate visual information, proportional relationships, corresponding sides, and symbolic calculations. Recent studies show that students can experience conceptual and procedural difficulties when identifying similar figures, matching corresponding sides, applying similarity conditions, and visualizing geometric relationships (Solihah et al., 2025). Research on similarity problems also highlights the importance of proportional reasoning and flexible problem-solving processes rather than formula use alone (Putri et al., 2026; Tempola et al., 2026). These demands make similarity an appropriate context for investigating creative mathematical thinking.

Problem-Based Learning (PBL) places a meaningful problem at the beginning of learning and organizes learning around inquiry, discussion, explanation, and evaluation of possible solutions. In this model, students are expected to identify what is known, determine what needs to be learned, test ideas, and communicate their reasoning. This structure can create room for multiple solution paths and student-generated explanations (Hmelo-Silver, 2004; Savery, 2006). In mathematics education, PBL has been associated with improvements in problem solving, communication, critical thinking, and creative thinking across different levels and topics (Kardoyo et al., 2020; Umam et al., 2021; Kurniati & Sutiarso, 2021).

Empirical studies provide increasingly consistent support for this relationship. PBL has been reported to strengthen mathematical creative thinking in experimental, classroom, and meta-analytic studies (Yunita et al., 2020; Dewi & Harjono, 2021; Arifin et al., 2020; Annisah et al., 2023; Astria et al., 2023; Hidayah & Dwijanto, 2023; Ernita et al., 2024; Herlistiyanti et al., 2025; Arifin & Sidqi, 2025). Studies published in Algebra also show that PBL-based designs can support higher-order thinking through problem engagement and structured reflection (Alkamalia, 2025; Audila & Yusuf, 2025). These findings support the use of PBL, but they do not remove the need to examine how it performs in a specific classroom and mathematical topic.

The preliminary condition in Grade IX-1 at SMP Negeri 1 Sukamakmur showed low creative-thinking performance on similarity tasks. Students tended to rely on a limited procedure, had difficulty producing alternative solutions, and gave answers with insufficient detail. Therefore, the present study focused on the change in students' mathematical creative thinking after PBL was implemented in similarity learning. The study asked whether students' overall creative-thinking scores and the four indicators of fluency, flexibility, originality, and elaboration improved from pretest to posttest. Because the design used one group without a control class, the analysis emphasizes the magnitude and statistical significance of within-group change and avoids attributing the change exclusively to PBL.

RESEARCH METHODS

This study used a quantitative pre-experimental approach with a one-group pretest-posttest design. The design can be expressed as O1-X-O2, where O1 represents the pretest, X represents the PBL treatment, and O2 represents the posttest. The study was conducted during the even semester of the 2025/2026 academic year at SMP Negeri 1 Sukamakmur, Aceh Besar Regency. The participants were 22 students from Grade IX-1 selected purposively because the class met the study's instructional and data-collection requirements.

The main instrument consisted of four essay problems on similarity. Student responses were assessed using four indicators of mathematical creative thinking: fluency, flexibility, originality, and elaboration. The scoring rubric used a 0-4 scale for each response on each indicator. A score of 0 represented no relevant response, while higher scores reflected increasingly relevant, correct, varied, original, and detailed solutions. Each indicator had a maximum raw score of 16 across the four items. Indicator scores were converted to a 0-100 scale. The descriptive classification used five labels adopted in the original scoring framework: very creative, creative, moderately creative, less creative, and not creative (Febrianingsih, 2022).

Data analysis began with descriptive statistics for the pretest and posttest, followed by comparison of the four indicator means and the distribution of students across creativity categories. The individual score table in the original research report was recalculated to verify the reported means. The normality of paired score differences was examined with the Shapiro-Wilk test. Because the differences were normally distributed, a paired-samples t-test was used at alpha = .05. Cohen's dz was calculated as the mean paired difference divided by the standard deviation of the paired differences to describe the standardized magnitude of within-group change. The statistical analysis evaluates change within the observed class and does not by itself establish a causal effect because no control group was included.

RESULTS AND DISCUSSION

The descriptive results show a clear increase in students' mathematical creative thinking after the PBL learning sequence. The verified pretest mean was 31.53 and the verified posttest mean was 61.51, producing a mean increase of 29.97 points. The recalculation also corrected two arithmetic inconsistencies in the original summary table: the pretest elaboration mean is 30.68, not 28.97, and the overall posttest mean is 61.51, not 61.41. Table 1 summarizes the change for each creative-thinking indicator.

Table 1. Pretest and Posttest Scores by Creative-Thinking Indicator

Indicator	Pretest Mean	Posttest Mean	Increase
Fluency	31.25	70.45	39.20
Flexibility	34.94	53.98	19.03
Originality	29.26	57.39	28.13
Elaboration	30.68	64.20	33.52
Overall	31.53	61.51	29.97

Fluency showed the largest increase, rising by 39.20 points. This pattern indicates that students became more able to generate relevant solution ideas after the learning activities. Elaboration increased by 33.52 points, suggesting stronger ability to develop solutions with clearer details and reasoning. Originality increased by 28.13 points, while flexibility increased by 19.03 points. Although flexibility had the smallest gain, its posttest mean was still higher than its pretest mean. The pattern therefore shows improvement across all four dimensions rather than improvement in only one component.

Table 2. Distribution of Creative-Thinking Categories

Category	Pretest n (%)	Posttest n (%)
Very creative	0 (0.0)	1 (4.5)
Creative	0 (0.0)	10 (45.5)
Moderately creative	1 (4.5)	6 (27.3)
Less creative	5 (22.7)	4 (18.2)
Not creative	16 (72.7)	1 (4.5)
Total	22 (100)	22 (100)

The category distribution changed substantially. Before treatment, 16 of 22 students were classified as not creative and five were classified as less creative. After treatment, 10 students were classified as creative and six as moderately creative. One student reached the very creative category. All 22 students obtained higher numerical posttest scores than pretest scores. However, one student remained in the same descriptive category because the score increased from 12.50 to 32.81 without crossing the category boundary. Thus, 21 of 22 students, or 95.5%, moved to a higher category.

Table 3. Paired-Samples Analysis of Overall Creative-Thinking Scores

Statistic	Result
Shapiro-Wilk test of paired differences	$W = 0.943$, $p = .229$
Mean paired increase	29.97 points
95% CI for mean increase	26.06 to 33.88
Paired-samples t-test	$t(21) = 15.94$, $p < .001$
Cohen's dz	3.40

The inferential result confirms that the increase was not only descriptive. The paired differences met the normality assumption ($p = .229$), and the paired-samples test indicated a statistically significant increase from pretest to posttest, $t(21) = 15.94$, $p < .001$. The 95% confidence interval for the mean increase ranged from 26.06 to 33.88 points. Cohen's dz of 3.40 indicates a very large standardized within-group change. This effect size should still be interpreted within the limits of a one-group design, because maturation, testing effects, and other classroom influences were not controlled.

The improvement is consistent with the learning mechanism proposed for PBL. PBL requires students to confront a problem, organize relevant information, propose strategies, compare ideas, and justify solutions. These activities align closely with the observed creative-thinking indicators. Generating several answers supports fluency, comparing different methods supports flexibility, constructing a less routine approach supports originality, and explaining a solution in detail supports elaboration (Hmelo-Silver, 2004; Savery, 2006). The large gain in fluency in this study is therefore plausible because classroom discussion and problem exploration create repeated opportunities to generate solution ideas.

The findings also agree with previous mathematics research. Meta-analytic evidence has reported positive effects of PBL on mathematical creative thinking (Yunita et al., 2020; Kurniati & Sutiarso, 2021; Ernita et al., 2024). Classroom studies likewise show gains in creative thinking when students solve open or contextual problems and communicate their reasoning (Dewi & Harjono, 2021; Umam et al., 2021; Annisah et al., 2023; Astria et al., 2023; Hidayah & Dwijanto, 2023). More recent studies continue to report that PBL can provide a productive structure for mathematical creative thinking (Herlistiyanti et al., 2025; Arifin & Sidqi, 2025). These converging findings strengthen the interpretation that the observed classroom improvement is educationally meaningful.

The similarity topic also helps explain why problem-based activity was useful. Similarity problems ask students to identify correspondence, coordinate ratios, interpret diagrams, and select procedures. Students may fail when they rely only on memorized rules or cannot connect visual and proportional information (Solihah et al., 2025; Wijaya et al., 2021; Widodo et al., 2021). Recent work on geometric similarity further shows that students differ in proportional reasoning and geometric thinking strategies (Putri et al., 2026; Tempola et al., 2026). A PBL environment can make these different strategies visible in discussion, allowing students to compare approaches and revise incomplete reasoning.

The result should not be generalized beyond the study conditions without caution. The sample included only 22 students from one class, the design did not include a comparison group, and the available research report did not provide separate validity and reliability coefficients for the creative-thinking test. Future studies should use a quasi-experimental or randomized comparison design, report instrument psychometrics, and examine whether gains persist after instruction. It would also be useful to analyze students' written strategies qualitatively to identify which PBL phases most strongly support fluency, flexibility, originality, and elaboration. Research in Algebra has similarly emphasized that the quality of problem engagement and reflection matters when PBL is used to develop higher-order thinking (Alkamalia, 2025; Audila & Yusuf, 2025).

CONCLUSIONS

The study found substantial within-group improvement in Grade IX-1 students' mathematical creative thinking after the implementation of Problem-Based Learning on similarity. The verified mean increased from 31.53 to 61.51, with a mean gain of 29.97 points. Fluency, flexibility, originality, and elaboration all increased. The paired-samples analysis confirmed a statistically significant increase, $t(21) = 15.94$, $p < .001$, with Cohen's dz = 3.40. All 22 students improved numerically, and 21 students moved to a higher descriptive creativity category. These results support PBL as a promising instructional approach for encouraging students to generate, compare, and explain mathematical solutions in similarity. Nevertheless, the absence of a control group means the findings should be interpreted as evidence of improvement during the PBL intervention rather than definitive proof that PBL alone caused the change.

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