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Comparative Effects of Problem-Based Learning, Creative Problem Solving, and Problem Posing on Junior High School Students' Mathematical Reasoning

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Abstract: Junior high school students in Indonesia consistently face systemic challenges in their mathematical reasoning skills, leading to consistently poor performance on international tests like PISA. This enduring educational disparity underscores an immediate need for pedagogical reforms that transcend rote memorization and promote approaches that foster cognitive adaptability. Our study was driven by the need to evaluate and compare the efficacy of three prominent student-centered frameworks: Problem-Based Learning (PBL), Creative Problem Solving (CPS), and Problem Posing, in enhancing students' reasoning outcomes. Our study utilized a quasi-experimental design featuring a post-test-only control group. The sample consisted of 93 seventh-grade students from Bandar Lampung. The data underwent statistical testing because the CPS group exhibited a non-normal distribution, as determined by preliminary normality testing (Sig. = 0.000). Therefore, the non-parametric Kruskal-Wallis Test was employed to ensure analytical integrity. The findings revealed a statistically significant disparity in reasoning achievement across the three experimental groups (Asymp.Sig. = 0.006). Detailed pairwise comparisons using the Bonferroni correction demonstrated that while PBL and CPS yielded comparable results (Adj.Sig. = 1.000), likely due to their shared reliance on structured problem-solving foundations, the Problem Posing model emerged as the most potent intervention. It significantly outperformed both PBL (Adj. Sig. = 0.007) and CPS (Adj. Sig. = 0.035). This superiority stems from the unique cognitive demands of problem-solving, which necessitate that students engage in thorough, divergent thinking and careful structural analysis of mathematical concepts. This model enhances metacognitive skills essential for advanced reasoning by transforming students' roles from problem solvers to creators. This study recommends problem posing as a core approach for educators aiming to improve students' mathematical reasoning.

Keywords: mathematical reasoning, problem posing, problem-based learning, creative problem solving.

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INTRODUCTION

Mathematics is a foundational discipline, essential for cultivating reasoning abilities and fostering systematic, logical, critical, and innovative thought processes, as well as the crucial problem-solving proficiencies demanded by the contemporary digital landscape (OECD, 2021). Recognizing this, educational paradigms perpetually adapt to incorporate teaching methodologies that effectively cultivate these cognitive attributes, especially during foundational stages such as junior high school. A strong understanding of math concepts is important for developing a logical, creative, and critical mind, which helps people deal with and solve problems in life (Maidiyah et al., 2021). Therefore, the cultivation of mathematical reasoning skills is paramount, as it underpins students' ability not only to understand abstract mathematical concepts but also to apply them in diverse real-world scenarios. Math now emphasises mathematical thinking rather than algorithms or methods (National Council of Teachers of Mathematics, 2000). Polya (1957) states that mathematical reasoning, drawing inferences from facts, premises, or information, is essential. This skill includes solving math problems, making guesses, and backing them up with proof (Lithner, 2007). Students' ability to comprehend abstract mathematical concepts and apply them in practical contexts is contingent on their cognitive processes, underscoring the significance of these skills for mathematical literacy.

Mathematical reasoning is a critical skill in the national curriculum; however, Indonesian pupils perform poorly, notably in Junior High School (Rauf et al., 2023). This condition often stems from conventional, teacher-centered learning practices that emphasize memorization of formulas and minimize opportunities for students to discuss, argue, or construct their own knowledge (Ginting, 2024). This phenomenon creates a gap between curriculum demands and actual student achievement in the field, especially in specific regions like SMPs in Bandar Lampung. To empower students' mathematical reasoning, we need innovative learning approaches that shift our focus from transferring to building knowledge. This absence of mathematical reasoning emphasizes the need to teach higher-order cognitive skills. These strategies should go beyond rote memory to help pupils grasp and analyze concepts.

This study examines and compares the efficacy of three constructivist learning models that have shown significant promise in enhancing Higher Order Thinking Skills (Arends, 2023). CPS, on the other hand, emphasizes the importance of structured stages in the problem-solving process to foster creativity and divergent thinking. This model teaches students how to generate different possible solutions and assess how likely each one is to be true. This helps them get better at making guesses and drawing logical conclusions (Treffinger et al., 2006). Problem Posing, on the other hand, is when students come up with problems or suggest them. This process not only deepens their understanding of mathematical concepts but also enhances their ability to analyze mathematical situations and formulate valid arguments (Nida Siregar et al., 2022; Rehman et al., 2023). This model is very good at helping students think about and analyze math information and test their understanding of concepts in depth. This is because students need to understand how concepts are put together before they can formulate a new, valid problem (Stoyanova & Ellerton, 1993).

Due to the shortcomings of conventional teaching methods, this comparative study examines the effects of Problem-Based Learning, Creative Problem Solving, and Problem Posing on junior high school students' achievement in mathematical reasoning (Pramasdyahsari et al., 2025).

These novel teaching strategies are crucial for fostering sophisticated mathematical thinking beyond justification (Breda et al., 2023). This aligns with the identified challenges Indonesian students face in applying creative thinking and adapting knowledge to novel contexts, as indicated by research on higher-order thinking in mathematics classrooms (Tanudjaya & Doorman, 2020). Theoretically, these three models provide a robust foundation for enhancing mathematical reasoning; however, comparative studies that explicitly evaluate the relative effectiveness of their final achievement outcomes within the same context, especially in the specific educational setting of SMPs in Bandar Lampung, remain scarce. This study seeks to rigorously compare the effects of Problem-Based Learning, Creative Problem Solving, and Problem Posing models on mathematical reasoning achievement, thereby filling a significant void in localized empirical evidence. This comparative analysis aims to elucidate the specific mechanisms by which each model cultivates unique aspects of mathematical reasoning, thus providing refined insights for curriculum development and instructional design (Selimi et al., 2025). Moreover, understanding which model most effectively cultivates higher-order thinking skills, especially within a particular demographic, can provide educators with evidence-based methods to enhance student outcomes (Ahmad et al., 2019). This comparative analysis is crucial for determining which pedagogical approach most effectively enhances students' critical thinking skills, a vital competency for addressing real-world challenges and future academic pursuits (Rehman et al., 2023). Problem-based learning and STEM education work well together because they help students learn more about math and science while also building important 21st-century skills like critical thinking, collaboration, communication, and problem-solving (Selimi et al., 2025). This integration is essential, as STEM education emphasizes developing critical thinking skills in mathematics (Priatna et al., 2020).

Each PBL model possesses distinct syntax and focal points: robust justification via real-world problems for PBL, innovation in solutions for CPS, and conceptual analysis through problem formulation for problem posing. Consequently, these variations are anticipated to yield divergent impacts on students' mathematical reasoning abilities. This study aims to elucidate the unique benefits of each model in enhancing various facets of mathematical reasoning, thereby facilitating a more refined understanding for educational application (Selimi et al., 2025). This study seeks to meticulously evaluate the diverse effects and provide empirical insights into the optimal application of each model to enhance specific facets of mathematical reasoning (Rehman et al., 2023; Syafrizal et al., 2020). This approach aligns with current education trends that prioritize student-centered learning and building 21st-century skills, such as problem-solving, reasoning, and critical thinking (Laine & Mahmud, 2022). Previous studies indicate that problem-based learning enhances critical thinking, problem-solving, logical reasoning, creativity, and decision-making skills, all of which are essential for mathematical success (Tursynkulova et al., 2023). In fact, project-based learning has been shown to improve students' ability to work together and make them feel better about math (Rehman et al., 2024). This comparative study is crucial for providing empirical evidence regarding the most effective model. These insights are especially important because there remains a strong demand for evidence in STEM education to support the adoption of new teaching methods over old ones (Selimi et al., 2025). For example, combining problem-based learning with STEM education has been shown to help students think critically and solve problems, both of which are critical for success in the 21st century (AlAli, 2024). This study aims to compare the efficacy of three prominent student-centered frameworks: Problem-Based Learning (PBL), Creative Problem Solving (CPS), and Problem Posing, in enhancing students' reasoning outcomes by using a quasi-experiment to compare the effectiveness of the PBL, CPS, and problem-posing models. The findings of this research are anticipated to yield substantial empirical contributions and practically validated recommendations for educators and curriculum policymakers in selecting the most effective learning model to demonstrably improve students' mathematical reasoning skills in the region. To achieve this, the study addresses the following research questions:

1. Is there a significant difference in mathematical reasoning achievement among students taught using Problem Based Learning (PBL), Creative Problem Solving (CPS), and Problem Posing models?
2. Which of the three learning models is the most effective in improving students' mathematical reasoning achievement?

To address the research questions, the following hypotheses are formulated:

H_1: There is a significant difference in mathematical reasoning achievement among students taught through Problem-Based Learning (PBL), Creative Problem Solving (CPS), and Problem Posing models.

H_2: The Problem Posing model is significantly more effective than Problem-Based Learning (PBL) and Creative Problem Solving (CPS) in enhancing students' mathematical reasoning achievement.

METHOD

Participants

The research population encompassed all seventh-grade students (Grade VII) across Junior High Schools (SMPN) in Bandar Lampung, Indonesia, for the 2024/2025 Academic Year. The sample was selected using purposive sampling, with three parallel classes with equivalent initial characteristics to ensure a balanced baseline. To ensure a balanced baseline and to justify the equivalent initial characteristics of these groups, an analysis of students' prior mathematical achievement (based on their previous semester final grades) was conducted.

Table 1. Analysis of students' initial mathematical ability

Class	Number of Students	Mean Score	Standard Deviation
PBL	31	59.77	13.58
CPS	29	56.34	13.34
Problem Posing	33	56.97	14.17

Statistical testing using One-Way ANOVA on these initial scores yielded a p-value of 0.583 ($p > 0.05$), indicating no significant difference in mathematical ability among the three groups prior to the intervention. The use of a Posttest-Only Control Group Design was specifically chosen to eliminate testing effects or sensitization that can occur when students are exposed to a pretest, which might inadvertently influence their performance during the treatment and the final assessment. Given the empirical evidence of initial equivalence through prior achievement data, the posttest-only design is considered robust for evaluating the causal impact of the three pedagogical models.

The final participants consisted of 93 students divided into three groups: Class VII 1 (n=31) for the PBL treatment, Class VII 2 (n=29) for the CPS treatment, and Class VII 3 (n=33) for the Problem Posing treatment.

Research Design and Procedures

This study was structured as a quasi-experimental research, a method specifically selected to investigate causal relationships in an educational setting where full randomization is often impractical. The investigation employed a Posttest-Only Control Group Design, which allowed for a systematic comparison of student outcomes after the intervention without the potential bias of "testing effects" often associated with pre-tests. The primary objective of this framework was to evaluate and delineate the comparative impact of three distinct independent variables: Problem-Based Learning (PBL), Creative Problem Solving (CPS), and Problem Posing, against a single dependent variable: the students' mathematical reasoning ability. By isolating these three pedagogical frameworks, the study sought to identify which model most effectively facilitates the cognitive shifts necessary for high-level reasoning.

The implementation procedure followed a rigorous chronological sequence: (a) Group Assignment and Treatment: Each of the three parallel classes was assigned a specific pedagogical treatment. For several sessions, the groups were immersed in their respective learning environments, ranging from the authentic investigation of PBL and the creative solution-seeking of CPS to the conceptual deconstruction required by Problem Posing. (b) Pedagogical Consistency: During the treatment phase, the focus remained on shifting the classroom dynamic from a traditional "transfer of knowledge" to an active "construction of knowledge," ensuring that students in all groups were engaged in student-centered learning. (c) Final Assessment: Upon completion of the instructional period, a final assessment (posttest) was administered to all 93 participants. This posttest served as the primary data collection tool for measuring mathematical reasoning achievement across the different groups. (d) Comparative Analysis: The resulting scores were then subjected to statistical testing to determine whether variations in students' final reasoning proficiency were directly attributable to the specific learning model implemented.

Instruments

The primary instrument used in this research was a posttest on mathematical reasoning. This instrument was administered to all three groups following the implementation of the respective learning models to collect quantitative data on students' final achievement and reasoning proficiency. The research instrument comprises four open-ended questions designed to evaluate mathematical reasoning skills. The specific details for each item are outlined below:

A total of 500 tickets, consisting of regular (Rp35,000) and VIP (Rp50,000) tiers, were sold for an art showcase, generating a total sum of Rp21,400,000. Based on this data, find the quantity of regular tickets purchased. Additionally, assess the total income generated from VIP sales if an extra 15 VIP tickets were added to the initial quota.

In light of the recent seasonal transition and the subsequent spread of the flu, David was asked to procure medicine and vitamins. His first purchase consisted of one strip of flu medicine and one vitamin tablet, totaling Rp16,000. A second purchase for his grandfather, involving two strips of flu medicine and one vitamin tablet, amounted to Rp28,000. Using a graphical approach, identify the unit price for both the flu medicine strip and the vitamin tablet.

Mr. Wayan operates a garment business that specializes in producing t-shirts and collared shirts. The facility operates on a 12-hour daily schedule. The production process requires one hour to complete a single t-shirt and two hours for a shirt, with respective production costs of Rp40,000 and Rp80,000 per unit. Given that the total daily expenditure reaches Rp480,000, determine the specific quantity of t-shirts and shirts produced within these operational and budgetary constraints.

A manufacturing plant operates two distinct production lines: Machine A, which yields 3 units per hour, and Machine B, which produces 5 units per hour. The plant manager recently received two conflicting production reports. The first report states that a total of 48 units were manufactured over a combined operational period of 12 hours. Conversely, the second report claims an output of 72 units within the same 12-hour timeframe. Are these two reports consistent with one another? Evaluate whether this problem yields a logical solution regarding the specific operational hours for both Machine A and Machine B.

To ensure objective and consistent measurement, the students' responses were evaluated using a structured, holistic rubric with a score range of 0 to 4 for each reasoning indicator. Each of the four questions was specifically mapped to evaluate all four indicators of mathematical reasoning: (1) Presenting mathematical statements, (2) Formulating conjectures, (3) Performing mathematical manipulation, and (4) Drawing conclusions. For instance, in Question 4, students are required to present the problem in a system of linear equations (Indicator 1), hypothesize whether the two reports are consistent (Indicator 2), solve the equations through substitution or elimination (Indicator 3), and finally deduce whether a logical solution exists to verify the reports' consistency (Indicator 4). The total score for each question is the sum of the scores across these four indicators, with a maximum possible score of 16.

Prior to its implementation, the test instrument underwent a pilot study to ensure its validity and reliability as a measurement tool. In terms of content validity, the instrument was deemed valid as the items align with both the learning objectives and the specific indicators of mathematical reasoning. Reliability analysis yielded a Cronbach's Alpha coefficient of r = 0.92, indicating a high level of internal consistency (Azwar, 2011). Furthermore, evaluations of item difficulty and discrimination power were conducted. All four test items fell within the 'moderate' difficulty category. Regarding discrimination power, Item 1 demonstrated a satisfactory level, Item 2 classified as excellent, while Items 3 and 4 were categorized as good.

Data Analysis

The data analysis followed a rigorous statistical hierarchy. Initially, normality and homogeneity of variance tests were conducted as prerequisites. While One-Way Analysis of Variance (ANOVA) was the a priori plan, the discovery that the CPS group data was not normally distributed led to the adoption of the Non-Parametric Kruskal-Wallis Test. To pinpoint specific differences between the models, the analysis was extended using Pairwise Comparisons with the Bonferroni correction, ensuring a precise identification of which pedagogical interventions yielded significantly different results.

RESULT AND DISCUSSION

H_1: The Comparative Impact of PBL, CPS, and Problem Posing on Mathematical Reasoning

This section presents an analysis of students' achievement in mathematical reasoning across the three learning models to address the first research hypothesis.

Pre-Analysis: Normality Testing

Before testing the hypothesis, a normality test was conducted using the Shapiro-Wilk method. The results are summarized in the following Table 2.

Table 2. Tests of normality

Treatment	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PBL	.106	31	.200*	.957	31	.236
Problem Posing	.297	28	.000	.729	28	.000
CPS	.122	33	.200*	.954	33	.176

The normality test indicates that the PBL (p = 0.236) and CPS (p = 0.176) groups are normally distributed ($p > 0.05$), whereas the Problem Posing group's data are not normally distributed ($p = 0.000 < 0.05$). Consequently, the assumption for parametric analysis (ANOVA) was violated. To ensure statistical validity, the analysis proceeded using a nonparametric approach with the Kruskal-Wallis test.

Hypothesis 1 Testing: Kruskal-Wallis Analysis

The Kruskal-Wallis test was performed to determine if there is a significant difference in the mean ranks of mathematical reasoning achievement among the three groups.

Table 3. Kruskal-Wallis test ranks

Treatment	N	Mean Rank
PBL	31	38.76
posing	28	59.80
CPS	33	42.48
Total	**92**	

Table 4. Test statistics

Test Statistics[a,b]	
	Value
Kruskal-Wallis H	10.315
Df	2
Asymp. Sig.	.006

Based on Table 4, the Asymp. Sig. value is 0.006, which is lower than the significance level of 0.05 (0.006 < 0.05). Therefore, the first hypothesis (H1) is accepted. This result confirms that there is a statistically significant difference in mathematical reasoning achievement among students taught using PBL, CPS, and Problem Posing models.

H_2: The Superiority of Learning Models in Enhancing Mathematical Reasoning

This section addresses the second research hypothesis by identifying which learning model yields the greatest improvement in students' achievement in mathematical reasoning.

Pairwise Comparisons (Post-Hoc Analysis)

Since the Kruskal-Wallis test in the previous section confirmed a significant difference, a *Post Hoc test using the Bonferroni procedure was conducted to examine* differences between specific pairs of models.

Table 5. Pairwise comparisons of models

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
PBL-CPS	-3.727	6.675	-.558	.577	1.000
PBL-Problem Posing	-21.046	6.958	-3.025	.002	.007
CPS- Problem Posing	17.319	6.857	2.526	.012	.035

The statistical data in Table 5 reveal two critical findings. First, there is no significant difference between the PBL and CPS models (Adj. Sig. = 0.1000 > 0.05), indicating that both models yield relatively similar outcomes in terms of students' mathematical reasoning. Second, and most importantly, the Problem Posing model shows a significant difference when compared to both PBL (Adj. Sig. = 0.007) and CPS (Adj. Sig. = 0.035). Consequently, the second hypothesis (H_2) is fully accepted. The evidence consistently points to Problem Posing as the most effective model for fostering achievement in mathematical reasoning among middle school students in Bandar Lampung.

Descriptive Data of Student Achievement.

The descriptive data of student achievement are presented in Table 6. Based on Table 6, descriptively, the group taught with the Problem Posing model had the highest mean score (78.65), followed by PBL (62.53) and the CPS group (66.41).

Analysis of Mathematical Reasoning Ability Indicator Profiles

In addition to evaluating total scores, an in-depth analysis was conducted for each mathematical reasoning indicator to assess the effectiveness of each learning model. The achievement levels for each indicator are

Table 6. Descriptive analysis of mathematical reasoning ability achievement

Class	Number of Students	Mean Score	Standard Deviation
PBL	31	62.53	21.52
Problem Posing	28	78.65	22.37
CPS	33	66.41	18.95

visualized in Figure 1, and statistical confirmation via the Kruskal-Wallis test was performed for each indicator to ensure the validity of these differences.

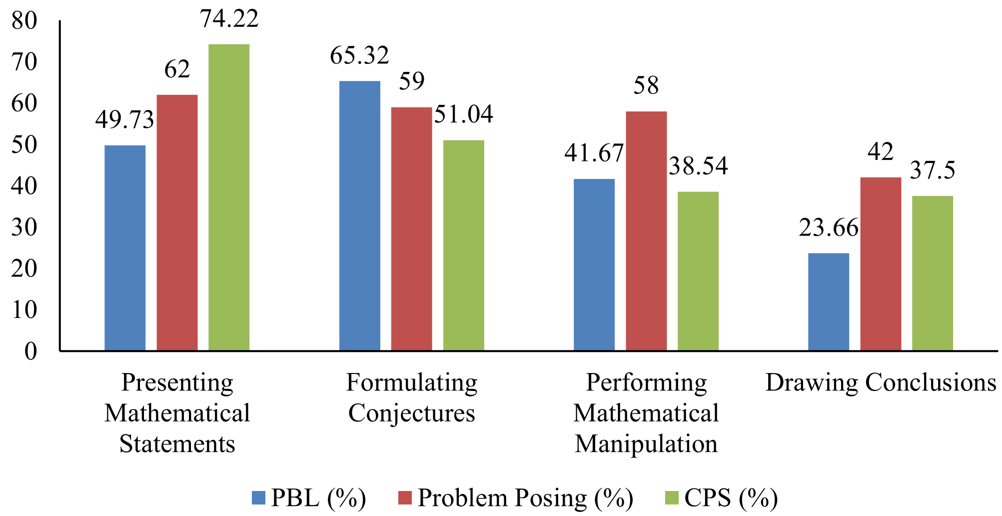

Figure 1. Achievement analysis of mathematical reasoning ability indicators

To provide a comprehensive understanding of the effectiveness of each learning model, separate statistical analyses were conducted for each indicator of mathematical reasoning using the Kruskal–Wallis test, followed by post hoc pairwise comparisons.

Indicator 1: Presenting Mathematical Statements

This indicator measures students' ability to present mathematical ideas or statements in a formal and systematic manner.

Presenting Mathematical Statements

The Kruskal-Wallis test for this indicator yielded an *Asymptotic Significance* of .000, confirming significant differences among the models. The post-hoc analysis reveals that CPS is the most superior model, achieving 74.22%. It significantly outperforms both PBL (Adj. Sig = .000) and Problem Posing (Adj. Sig = .004). This suggests that the CPS framework is particularly effective in enhancing students' ability to formalize and communicate mathematical ideas.

Table 7. Kruskal-Wallis test results of mathematical reasoning achievement

Indicators	Kruskal-Wallis Test	Pairwise Comparisons		
		PBL-Problem Posing	PBL-CPS	Problem Posing-CPS
Presenting Mathematical Statements				
Asymptotic Sig.	.000			
Std. Error		6.954	6.672	6.853
Adj. Sig.		.015	.000	.004

Formulating Conjectures				
Asymptotic Sig.	.000			
Std. Error		6.830	6.648	6.930
Adj. Sig.		.010	.000	.251
Performing Mathematical Manipulation				
Asymptotic Sig.	.000			
Std. Error		6.660	6.842	6.942
Adj. Sig.		.314	.000	.000
Drawing Conclusions				
Asymptotic Sig.	.000			
Std. Error		6.660	6.942	6.842
Adj. Sig.		.000	.000	.306

Formulating Conjectures

For the second indicator, the test also showed a significant difference (Asymp. Sig = .000). Descriptively, PBL achieved the highest score at 65.32%. While PBL is significantly better than CPS (Adj. Sig = .000), there is no significant difference between PBL and Problem Posing (Adj. Sig = .251). This indicates that both PBL and Problem Posing are equally effective in stimulating students' initial predictive thinking.

Performing Mathematical Manipulation

The analysis confirms a significant difference in this dimension (Asymp. Sig = .000). Problem Posing led this indicator with a score of 58%. The pairwise comparison shows that Problem Posing significantly outperforms CPS (Adj. Sig = .000), but it does not differ significantly from PBL (Adj. Sig = .314). This implies that constructing original problems provides a strong foundation for mastering mathematical procedures and manipulations.

Drawing Conclusions

The final indicator also shows significant variation (Asymp. Sig = .000). Problem Posing achieved the highest, at 42%. The statistical data reveal that Problem Posing is significantly superior to PBL (Adj. Sig = .000). However, the difference between Problem Posing and CPS is not statistically significant (Adj. Sig = .306). This suggests that Problem Posing is a robust model for developing logical deduction, although its impact on this specific indicator is comparable to that of the CPS model.

Similarity of Impact between PBL and CPS

The statistical analysis revealed no significant disparity in achievement between the PBL and CPS groups (Adjusted Significance = 1.000). This lack of a substantial difference can be attributed to several critical factors. First, both models share core similarities in their pedagogical frameworks; they are founded on contextual problem-based learning, in which students participate in collaborative problem-solving and the practical application of mathematical principles.

Beyond these structural similarities, observations during classroom implementation revealed that the specialized "creative" stages of CPS specifically divergent and convergent thinking tended to overlap significantly with the standard problem-solving phases in PBL. Junior high school students often prioritized finding the correct logical procedure over exploring a wide variety of original ideas. Consequently, the *Idea Finding* phase in CPS functioned similarly to the *Developing Solutions* phase in PBL, leading to nearly identical cognitive activations in practice.

Furthermore, the research instrument utilized in this study primarily assessed formal mathematical reasoning indicators, such as logical manipulation and deductive accuracy. Because the test was not specifically designed as a creativity-based assessment, it may have been less sensitive to the divergent-thinking benefits unique to the CPS model. Although CPS is theoretically associated with enhanced divergent thinking and creative reasoning processes (Murwaningsih, 2022; Reza et al., 2024), the empirical data in this study reveal that its mean achievement (66.41) did not surpass that of the Problem Posing model (78.65). This discrepancy suggests that while CPS may foster ideational fluency, such cognitive activation does not automatically translate into higher formal mathematical reasoning scores, particularly when assessed through structured reasoning indicators.

Superiority of Problem-Posing Cognitive Mechanisms

The finding that the Problem Posing model yielded significantly superior achievement compared to both PBL and CPS, as evidenced by the statistically significant differences and its highest descriptive mean, is supported by the activation of unique High-Order Thinking Skills (HOTS) cognitive mechanisms. There are three primary reasons for this superiority.

Deep Structural Analysis and Concept Construction. The Problem Posing activity requires students to create new problems or alter existing ones, which exceeds the cognitive demands of conventional problem-solving tasks in PBL or CPS. While the CPS model excels specifically in the Presenting Mathematical Statements indicator (74.22%), the Problem Posing model demonstrates a more balanced and robust influence across the more complex reasoning stages. To pose a valid problem, students must rigorously analyze the problem's structure, identify the interrelationships among variables, and fully understand the mathematical conditions. This deep deconstruction of concepts ensures a more stable mastery of reasoning than models that focus only on solving pre-defined problems. This shows that students must analyze the structure of problems, determine how variables are related, and fully understand the mathematical conditions before they can propose a new valid problem (Darhim et al., 2020; Kul & Celik, 2020; Wang et al., 2022).

Intense Activation of Metacognitive Abilities. The Problem Posing model strongly activates students' metacognitive abilities, the awareness and regulation of their own thinking processes. To formulate a solvable problem, students must reflect on their existing knowledge and evaluate how different mathematical ideas are interconnected. This reflective process helps students recognize their knowledge deficiencies and significantly strengthens their conceptual understanding, thereby enhancing deductive reasoning. Global empirical findings consistently indicate that Problem Posing significantly enhances creativity and cognitive flexibility, which are crucial elements of adaptable mathematical reasoning (Akben, 2018; Çelik & Arslan, 2022; Chiu & Yang, 2024).

Intrinsic Motivation and Cognitive Ownership. Affective and motivational factors also play a critical role. Because students feel a sense of "ownership" over the problems they create, their cognitive effort is driven by intrinsic motivation rather than external instruction. This enhanced engagement encourages students to think critically and deeply, ensuring that their created problems are mathematically valid and logical. Such high-level engagement is a vital factor in the development of long-term mathematical reasoning skills (Hutajulu et al., 2019; Saha et al., 2024; Schoenherr, 2024).

In conclusion, although CPS achieved the highest descriptive mean, the substantial variability in its data and the non-parametric statistical results confirm that the Problem Posing model provides a more consistently effective impact. Its superiority lies in the ability to integrate critical analysis, metacognitive reflection, and intrinsic motivation through problem creation, resulting in statistically more reliable mathematical reasoning achievement than the PBL and CPS models.

Despite the significant findings, this study acknowledges several limitations. First, the use of a posttest-only control group design, while effective in preventing testing effects, does not allow direct measurement of students' initial baseline progression. Second, the non-normal distribution in the CPS group data necessitated a non-parametric approach, which, although statistically robust, may offer lower power than parametric tests. Lastly, the study was conducted within a specific geographic and demographic context in Bandar Lampung; therefore, the generalizability of these results to different educational settings or higher grade levels should be interpreted with caution. Future research should consider longitudinal designs or the inclusion of pre-test measures to further validate these pedagogical impacts.

CONCLUSION

To create or change problems, students have to analyze the structure of the problems, determine how the variables are related, and consider different situations. This activity directly stimulates the formulation of conjectures and the drawing of logical conclusions, which is the essence of reasoning. Based on the analysis of the quasi-experimental research results using the Posttest Only design, this study concludes that there is a significant difference in students' achievement in mathematical reasoning among the tested treatment groups (Kruskal-Wallis Test, Asymp. Sig. = 0.006). Compared to both the Problem Based Learning (PBL) and Creative Problem Solving (CPS) models, the Problem Posing learning model yielded superior mathematical reasoning achievement.

The Problem Posing model demonstrated functional superiority as it statistically differed significantly in final mathematical reasoning achievement compared to PBL (Adjusted Sig. = 0.007) and CPS (Adjusted Sig. = 0.035). This advantage is confirmed by: (i) The Problem Posing model explicitly incorporates critical analysis and metacognitive reflection. Difficult tasks help students learn how variables relate to one another and how they affect one another. This process improves the ability to formulate hypotheses and draw logical conclusions, which are essential to reasoning. (ii) The Problem Posing process enhances students' sense of ownership over the material and the learning process, which in turn increases intrinsic motivation. This motivation encourages the deep, critical thinking efforts necessary to achieve high mathematical reasoning competence.

Convergent Effect of PBL and CPS Models. No significant difference in mathematical reasoning achievement was found between the groups taught using the PBL and CPS models (pairwise comparison test, Adjusted Sig. = 1.000), despite CPS showing the highest mean. This convergence of effects is attributed to the fundamental similarity in the problem-based pedagogical basis of the two models. Both emphasize contextual problem-solving and real-world application, which train similar reasoning domains. The lack of specific exploitation of the Creative elements within CPS during field implementation may lead to reasoning achievement comparable to that produced by PBL. The problem-posing model excels in synthesising critical analysis, metacognitive reflection, and intrinsic motivation via problem-creation tasks, leading to statistically superior mathematical reasoning compared to the PBL and CPS models.

DECLARATION IF GENERATIVE AI USAGE INI THE WRITING PROCESS

During the writing of this manuscript, the authors employed Gemini (Google AI) to assist with language refinement, proofreading, and improving the structural coherence of the discussion. The authors have reviewed and edited the content generated by this tool and assume full responsibility for the content of the published article.

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