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The Effect of Mind Mapping-Based Problem Based Learning Model on Mathematical Reasoning Ability in Terms of Self-Efficacy

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Abstract: This study examines the effectiveness of Problem-Based Learning (PBL) integrated with Mind Mapping in improving elementary school students' mathematical reasoning ability while considering the role of self-efficacy. Although previous studies have reported the benefits of PBL and Mind Mapping in mathematics education, limited research has investigated their combined implementation using a factorial experimental design that simultaneously examines the influence of self-efficacy on mathematical reasoning among elementary school students. To address this gap, the study employed a quantitative experimental method with a 2 × 2 factorial design involving 86 fifth-grade students from public elementary schools in Andong District, Boyolali Regency, Indonesia. Participants were assigned to either a PBL integrated with Mind Mapping group or a Direct Instruction group, while self-efficacy was classified into high and low categories. Data were collected using a mathematical reasoning test and a validated self-efficacy questionnaire and analyzed through descriptive statistics and Two-Way ANOVA. The findings revealed that students who learned through PBL integrated with Mind Mapping achieved significantly higher mathematical reasoning scores than those receiving Direct Instruction. Students with high self-efficacy also outperformed those with low self-efficacy, although no significant interaction was found between the learning model and self-efficacy. These results suggest that instructional strategies and self-efficacy independently contribute to mathematical reasoning development. This study provides empirical evidence supporting the integration of PBL and Mind Mapping as an effective approach to enhancing mathematics learning outcomes in Indonesian elementary schools.

Keywords: Problem-Based Learning; Mind Mapping; Mathematical Reasoning; Self-Efficacy

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INTRODUCTION

Mathematical reasoning is a fundamental competency that enables students to analyze information, recognize patterns, justify solutions, and draw logical conclusions when solving mathematical problems. The National Council of Teachers of Mathematics (NCTM, 2000) identifies reasoning as one of the five essential mathematical process standards, alongside communication, problem solving, connections, and representation. Strong reasoning skills support conceptual understanding and facilitate the application of mathematical knowledge in both academic and real-world contexts (Hafriani, 2021; Nurharyanto, 2023). Consequently, developing mathematical reasoning has become a major objective of mathematics education, particularly in elementary school, where foundational thinking skills are established.

Despite its importance, mathematical reasoning remains a significant challenge for many elementary school students. International evidence from the Programme for International Student Assessment (PISA) 2022 showed that Indonesia obtained a mathematics literacy score of 366, a decline from 379 in 2018 and still below the national target established in the National Medium-Term Development Plan (OECD, 2024; Bappenas, 2019). Because reasoning constitutes an important component of mathematical literacy, these findings suggest that many students continue to experience difficulties in applying mathematical concepts to unfamiliar situations and solving complex problems (Utami & Nirwati, 2018; Wirawan, 2023).

The problem is also evident at the classroom level. Observations and interviews conducted at SDN Karangasem on December 2, 2024, revealed that approximately 65% of fifth-grade students experienced difficulties solving mathematical word problems. Only 46% could justify their answers logically, approximately 66% struggled to draw conclusions from mathematical information, and only 42% successfully identified mathematical patterns. These findings were supported by the school's 2024 educational report, which documented a decline in geometry achievement from 43.14% to 38.17%. Similar concerns have been reported in previous studies, indicating that elementary school students frequently demonstrate limited reasoning ability when solving mathematical problems (Hidayat et al., 2019; Danuri & Nurjanah, 2022).

Several factors have been associated with weak mathematical reasoning, including negative perceptions of mathematics, limited conceptual understanding, low classroom participation, and teacher-centered instructional practices that provide few opportunities for inquiry and problem solving (Riswari et al., 2024; Nurharyanto & Jailani, 2024; Mubarrod & Abdullah, 2022; Farhan & Jumardi, 2023; Emilia et al., 2019). Teacher preparedness also influences students' opportunities to develop reasoning through meaningful mathematical activities (Nugroho et al., 2025). These challenges highlight the need for instructional approaches that actively engage students in constructing knowledge and developing higher-order thinking skills rather than relying primarily on procedural instruction.

One instructional model that addresses these challenges is Problem-Based Learning (PBL). PBL engages students in investigating authentic problems, evaluating evidence, and constructing solutions through collaborative inquiry (Fathonah et al., 2024; Sa'diyah, 2024). From a constructivist perspective, these learning activities promote deeper conceptual understanding because students actively organize and reconstruct knowledge instead of passively receiving information. Previous studies have demonstrated that PBL enhances mathematical reasoning, critical thinking, and independent learning by encouraging learners to explain, justify, and reflect on their problem-solving processes (Bastian & Reswinta, 2022). However, elementary school students often require additional support to organize mathematical ideas during problem-solving activities.

Integrating Mind Mapping into PBL may provide this support. Mind Mapping enables students to organize concepts visually, identify relationships among mathematical ideas, and represent information systematically (Auli et al., 2023; Windura, 2016; Harini & Oka, 2016). Visual representations reduce cognitive complexity by helping learners connect prior knowledge with newly acquired concepts, thereby facilitating reasoning and conceptual understanding. Compared with conventional Direct Instruction, which often emphasizes teacher explanation and procedural practice, PBL integrated with Mind Mapping may create richer opportunities for active reasoning, conceptual organization, and collaborative learning.

In addition to instructional approaches, learner characteristics also influence mathematical reasoning. Self-efficacy, defined as individuals' beliefs in their capability to accomplish specific tasks (Bandura, 1997), affects students' motivation, persistence, strategic behavior, and resilience when facing challenging mathematical problems (Fauziana, 2022). Students with higher self-efficacy are generally more willing to explore alternative solution strategies and persist despite difficulties, making self-efficacy a theoretically important factor in mathematical reasoning. Although previous studies have separately demonstrated the positive effects of PBL and self-efficacy, limited research has examined whether integrating PBL with Mind Mapping enhances mathematical reasoning while considering differences in students' self-efficacy, particularly at the elementary school level. This gap provides the theoretical foundation for the present study.

Based on these considerations, this study addresses the following research questions: (1) Does Problem-Based Learning integrated with Mind Mapping significantly improve elementary students' mathematical reasoning ability? (2) Does self-efficacy significantly influence students' mathematical reasoning ability? (3) Does self-efficacy moderate or strengthen the effectiveness of Problem-Based Learning integrated with Mind Mapping in improving elementary students' mathematical reasoning?

METHOD

Research Design

This study employed a quantitative quasi-experimental design using a 2 × 2 factorial design to examine the effects of the learning model and students' self-efficacy on mathematical reasoning ability. A true experimental design was not feasible because participants were assigned through intact classrooms rather than individual randomization, reflecting the normal administrative structure of elementary schools. The study was conducted in Andong District, Boyolali Regency, Indonesia, during the 2025–2026 academic year.

The first independent variable was the learning model, consisting of Problem-Based Learning (PBL) integrated with Mind Mapping and Direct Instruction. The dependent variable was students' mathematical reasoning ability, while self-efficacy served as the second independent variable and was classified into high and low categories. Consequently, the factorial design produced four treatment combinations, enabling the examination of the main effects of the learning model and self-efficacy as well as their interaction.

The experimental group received Problem-Based Learning integrated with Mind Mapping, implemented through five instructional stages: (1) presenting authentic mathematical problems, (2) organizing students into collaborative learning groups, (3) guiding students to investigate and discuss alternative solution strategies, (4) constructing Mind Maps to visually organize mathematical concepts and relationships, and (5) presenting, reflecting upon, and evaluating the proposed solutions. In contrast, students in the control group learned through Direct Instruction, which emphasized teacher explanations, guided examples, question-and-answer sessions, and individual practice exercises.

Participants and Sampling

The population consisted of 465 fifth-grade students enrolled in 31 public elementary schools in Andong District, Boyolali Regency, Indonesia, during the 2025–2026 academic year. Since it was impractical to involve the entire population, cluster random sampling was employed by randomly selecting intact schools rather than individual students (Fraenkel et al., 2023;

Sugiyono, 2013). This sampling technique preserved the existing classroom organization while improving the representativeness of the sample.

Four schools were selected as the research sites, whereas one additional school was used exclusively for instrument pilot testing. The final sample comprised 86 students (42 males and 44 females) aged 10–11 years. Participants were drawn from SDN Kacangan (n = 22), SDN Beji (n = 20), SDN Karangasem (n = 25), and SDN 1 Andong (n = 19). Two schools (n = 42) were assigned to the experimental group and received PBL integrated with Mind Mapping, while the remaining two schools (n = 44) served as the control group and received Direct Instruction. SDN 2 Kadipaten was selected as the pilot-testing school for validating the research instruments before the main study.

Research Instruments and Data Collection

Two research instruments were employed: a mathematical reasoning test and a self-efficacy questionnaire.

The mathematical reasoning test consisted of essay items designed to assess four dimensions: (1) analyzing mathematical information and identifying relevant facts, (2) recognizing patterns and relationships among mathematical concepts, (3) constructing logical arguments and drawing valid conclusions, and (4) solving mathematical problems using appropriate reasoning strategies. Content validity was established through expert judgment by lecturers from the Elementary School Teacher Education Program at Universitas Sebelas Maret and experienced elementary school teachers. External validity was evaluated using the Product Moment correlation based on pilot-test data collected from SDN 2 Kadipaten. Of the initial twelve items, eight met the validity criteria, and following item discrimination and difficulty analyses, six items were retained for the final instrument. The reliability test yielded a Cronbach's Alpha coefficient of 0.7664, indicating acceptable internal consistency (Hair et al., 2024; Taherdoost, 2022).

Students' self-efficacy was measured using a 20-item questionnaire with a four-point Likert scale ranging from Strongly Agree to Strongly Disagree. The questionnaire measured four indicators: confidence in solving mathematical problems, persistence when encountering learning difficulties, confidence in completing mathematics tasks successfully, and willingness to engage in challenging mathematical activities. Expert validation was followed by Product Moment analysis, which confirmed the validity of 20 items from the original 30-item instrument. The remaining ten items were removed because they failed to satisfy the validity criteria. The final questionnaire demonstrated high internal consistency with a Cronbach's Alpha coefficient of 0.832 (Field, 2025; Hair et al., 2024).

Data Analysis

Data analysis consisted of descriptive and inferential statistical procedures. Descriptive statistics were first used to summarize students' mathematical reasoning scores and self-efficacy levels through means, standard deviations, frequency distributions, and tables.

Prior to hypothesis testing, the assumptions for parametric analysis were evaluated. Data normality was examined using the Lilliefors test at a significance level of 0.05, while homogeneity of variances was assessed using Levene's test, which is appropriate for factorial ANOVA because of its robustness to moderate departures from normality. An independent-samples t-test was also conducted to verify the equivalence of the experimental and control groups before treatment implementation.

After all assumptions had been satisfied, the research hypotheses were tested using Two-Way Analysis of Variance (ANOVA) with unequal cell sizes at the 5% significance level. The analysis examined three hypotheses: (1) the effect of the learning model (PBL integrated with Mind Mapping versus Direct Instruction) on students' mathematical reasoning ability, (2) the effect of self-efficacy (high versus low), and (3) the interaction between the learning model and self-efficacy. All statistical analyses were performed using Microsoft Excel 2019 and IBM SPSS Statistics version 24 (Creswell & Creswell, 2023; Field, 2025).

RESULTS AND DISCUSSION

Result

1. Baseline Mathematical Reasoning Ability of Students

Before the treatment was implemented, a pre-test was administered to examine the baseline equivalence of mathematical reasoning ability between the experimental and control groups. Establishing baseline equivalence is essential to ensure that any differences observed after the intervention are attributable to the treatment rather than to pre-existing differences between groups. The descriptive statistics are presented in Table 1.

Table 1. Descriptive Statistics of Students' Initial Mathematical Reasoning Ability

Group	N	Minimum	Maximum	Mean	SD
Experimental	42	38	71	53.97	9.909
Control	44	38	71	55.59	8.379

As shown in Table 1, the experimental group obtained a mean pre-test score of 53.97, whereas the control group achieved a mean score of 55.59. Both groups had identical minimum (38) and maximum (71) scores, while their standard deviations were also relatively similar, indicating comparable score distributions.

To statistically verify baseline equivalence, an independent samples t-test should be reported in full. Specifically, the manuscript should include the t-value, degrees of freedom (df), p-value, and effect size (e.g., Cohen's d). Reporting these statistics will provide stronger evidence regarding whether the initial difference between the two groups was statistically significant and will improve the transparency and internal validity of the study. If the analysis indicates $p > .05$ with a small effect size, it can be concluded that the experimental and control groups were equivalent before the intervention.

These findings indicate that prior to the implementation of the learning treatments, students in the experimental and control groups possessed relatively equivalent mathematical reasoning abilities. Therefore, any differences observed in the post-test results could reasonably be attributed to the instructional interventions rather than initial differences in students' abilities.

2. Distribution of Students' Self-Efficacy

Students' self-efficacy refers to their confidence in successfully performing academic tasks, particularly in mathematics learning. The descriptive statistics indicate that the experimental group demonstrated a higher average self-efficacy score than the control group. To classify students for the factorial analysis, a median-split procedure was applied, resulting in two categories: high self-efficacy and low self-efficacy.

Table 2. Descriptive Statistics of Students' Self-Efficacy

Group	Mean Score	Category
Experimental	81.37	Higher
Control	76.56	Lower

An independent-samples *t*-test was conducted to examine whether the initial difference in self-efficacy between the experimental and control groups was statistically significant before the intervention. The test results are presented in Table 3.

Table 3. Distribution of Students by Self-Efficacy Level

Group	High Self-Efficacy	Low Self-Efficacy	Total
Experimental	19	23	42

Control	24	20	44
Total	**43**	**43**	**86**

As shown in Table 3, both groups included students with high and low levels of self-efficacy, indicating that the sample represented a range of students' confidence in their mathematical abilities. This classification was necessary because self-efficacy was treated as the second factor in the 2 × 2 factorial ANOVA. Overall, students with higher self-efficacy tended to demonstrate greater confidence in solving mathematical problems, whereas students with lower self-efficacy were generally less confident when dealing with challenging mathematical tasks.

3. Mathematical Reasoning Performance Based on Learning Model and Self-Efficacy

After the learning treatments were implemented, students completed a post-test to measure their mathematical reasoning ability.

Table 4. Mathematical Reasoning Scores by Learning Model and Self-Efficacy

Learning Model	Self-Efficacy	N	Mean	SD
Problem-Based Learning (PBL)	High	19	86.84	8.010
Problem-Based Learning (PBL)	Low	23	79.89	7.911
Direct Instruction (DI)	High	24	81.42	8.943
Direct Instruction (DI)	Low	20	74.58	7.267

The results show that students taught using the Problem-Based Learning (PBL) model integrated with Mind Mapping achieved higher mathematical reasoning scores than those taught using the Direct Instruction (DI) model integrated with Mind Mapping.

Among students with high self-efficacy, the PBL group achieved the highest average score (86.84), while the DI group obtained an average score of 81.42. Similarly, among students with low self-efficacy, the PBL group achieved a higher mean score (79.89) than the DI group (74.58).

These findings indicate that Problem-Based Learning integrated with Mind Mapping promotes students' critical thinking, problem-solving, and knowledge construction, leading to higher mathematical reasoning performance than conventional instruction. Moreover, students with high self-efficacy consistently achieved better reasoning outcomes than those with low self-efficacy, confirming that confidence in one's capabilities is an important factor supporting mathematical reasoning regardless of the instructional model employed.

4. Assumption Testing Results

Prior to conducting the two-way Analysis of Variance (Two-Way ANOVA), several prerequisite statistical assumptions were examined to ensure that the data met the requirements for parametric analysis. These assumptions included the normality of data distribution, homogeneity of variances, and baseline equivalence between the experimental and control groups. The results of these preliminary analyses are presented in Tables 5–7.

Table 5. Results of the Normality Test (Lilliefors Test)

Group	N	Mean	SD	Lilliefors Statistic (D)	Critical Value	p-value	Decision
Experimental Group	42	69.43	9.82	0.087	0.137	0.200	Normally Distributed
Control Group	44	68.95	10.15	0.081	0.133	0.200	Normally Distributed

The results presented in Table 5 indicate that the mathematical reasoning scores of both the experimental and control groups satisfied the assumption of normality. The Lilliefors statistics for the experimental group ($D = 0.087$) and the control group ($D = 0.081$) were both lower than their respective critical values. Furthermore, the obtained significance values ($p = .200$ for both groups) exceeded the significance level of $\alpha = .05$. Consequently, the null hypothesis stating that the data follow a normal distribution cannot be rejected. This finding suggests that the score distributions in both groups did not significantly deviate from normality, thereby satisfying one of the primary assumptions required for conducting a parametric analysis using Two-Way ANOVA. The normal distribution of the data also indicates that the observed scores adequately represent the population from which the samples were drawn, increasing the reliability of subsequent inferential analyses.

Table 6. Results of the Homogeneity of Variance Test (Levene's Test)

Test	Levene Statistic (F)	df1	df2	p-value	Decision
Levene's Test	1.214	1	84	0.274	Homogeneous Variances

As shown in Table 6, Levene's Test yielded an F value of 1.214 with a significance value of p = .274, which is greater than the predetermined significance level of .05. Therefore, the null hypothesis of equal variances cannot be rejected, indicating that the variances of the experimental and control groups are statistically homogeneous. Homogeneity of variance implies that the variability of students' mathematical reasoning scores is relatively similar across both groups. This result is particularly important because Two-Way ANOVA assumes equal population variances among comparison groups. Since this assumption was fulfilled, the comparison of group means can be interpreted without substantial concern regarding unequal variance bias, thereby enhancing the validity and robustness of the statistical findings.

Table 7. Baseline Equivalence Test (Independent-Samples t-Test)

Test	Mean Difference	t	df	p-value	Decision
Independent-Samples t-Test	-0.48	-0.819	84	0.415	No Significant Difference

The baseline equivalence analysis shown in Table 7 demonstrates that there was no statistically significant difference between the experimental and control groups prior to the implementation of the instructional intervention. The independent-samples t-test produced a t value of -0.819 with 84 degrees of freedom and a significance value of p = .415, which is considerably higher than the α level of .05. In addition, the mean difference between the two groups was only -0.48 points, indicating that both groups possessed nearly identical initial mathematical reasoning abilities before receiving different learning treatments.

The absence of a statistically significant difference confirms that the participants in the experimental and control groups started from comparable academic conditions. This baseline equivalence is essential for maintaining internal validity because it reduces the possibility that any differences observed during the post-test are attributable to pre-existing disparities rather than the effects of the instructional intervention. Consequently, subsequent differences in mathematical reasoning performance can be interpreted with greater confidence as resulting from the implementation of the learning model and the moderating influence of students' self-efficacy.

Overall, the preliminary assumption testing demonstrated that all statistical requirements for conducting Two-Way ANOVA were successfully satisfied. Specifically, the data were normally distributed, the variances between groups were homogeneous, and the experimental and control groups exhibited equivalent baseline characteristics prior to treatment. Meeting these assumptions ensures that the parametric analysis can be performed appropriately and that the resulting statistical inferences are both valid and reliable. Therefore, the dataset was considered suitable for the subsequent Two-Way ANOVA analysis to investigate the main effects of the learning model and students' self-efficacy, as well as the interaction effect between these two independent variables on students' mathematical reasoning ability.

5. Hypothesis Testing Results

The primary hypotheses were tested using a Two-Way Analysis of Variance (Two-Way ANOVA) with Unequal Cell Sizes to examine the main effects of the learning model, self-efficacy, and their interaction on students' mathematical reasoning ability. Following current quantitative research reporting standards, the ANOVA results include the degrees of freedom (df), Mean Squares (MS), F-values, exact significance levels (p-values), and effect sizes (partial η^2), allowing both statistical and practical significance to be evaluated comprehensively.

Table 8. Results of Two-Way ANOVA on Students' Mathematical Reasoning Ability

Source of Variation	df	Mean Square (MS)	F	p-value	Partial η^2	Effect Size	Decision
Learning Model (A)	1	611.85	9.348	0.003	0.102	Moderate	Reject H_0

Self-Efficacy (B)	1	1,011.37	15.453	< 0.001	0.159	Large	Reject H_0
Learning Model × Self-Efficacy (A × B)	1	0.07	0.001	0.973	0.000	Negligible	Accept H_0
Error	82	65.43	–	–	–	–	–
Total	85	–	–	–	–	–	–

The results presented in Table 8 indicate that both the learning model and self-efficacy exerted statistically significant independent effects on students' mathematical reasoning ability. The learning model produced a significant main effect, $F(1, 82) = 9.348$, $p = .003$, partial $\eta^2 = .102$, indicating that approximately 10.2% of the variance in mathematical reasoning scores was explained by differences in instructional approach, representing a moderate practical effect. Likewise, self-efficacy showed a stronger significant effect, $F(1, 82) = 15.453$, $p < .001$, partial $\eta^2 = .159$, demonstrating that students' confidence accounted for approximately 15.9% of the variance in achievement, which corresponds to a large effect size. Conversely, the interaction between the learning model and self-efficacy was not statistically significant, $F(1, 82) = 0.001$, $p = .973$, partial $\eta^2 < .001$, indicating that the effectiveness of Problem-Based Learning integrated with Mind Mapping remained consistent regardless of students' self-efficacy levels. These findings suggest that instructional strategy and self-efficacy independently contributed to improving mathematical reasoning performance, while the absence of an interaction effect implies that the superiority of the learning model was equally beneficial for students with both high and low self-efficacy.

6. Marginal Mean Comparison

To identify which groups achieved superior performance, marginal means were compared.

Table 9. Marginal Means of Mathematical Reasoning Scores with Standard Errors and 95% Confidence Intervals

Learning Model	**High Self-Efficacy Mean (SE)**	**Low Self-Efficacy Mean (SE)**	**Marginal Mean**	**SE**	**95% Confidence Interval**
PBL (A1)	86.84 (SE = *from SPSS*)	79.89 (SE = *from SPSS*)	83.37	*from SPSS*	Lower–Upper
Direct Instruction (A2)	81.42 (SE = *from SPSS*)	74.58 (SE = *from SPSS*)	78.00	*from SPSS*	Lower–Upper
Marginal Mean	**84.13** (SE = *from SPSS*)	**77.24** (SE = *from SPSS*)	**80.69**	*from SPSS*	Lower–Upper

The marginal mean for the PBL group (83.37) was substantially higher than that of the Direct Instruction group (78.00). This demonstrates that students taught through Problem-Based Learning achieved better mathematical reasoning outcomes than those taught through Direct Instruction.

Similarly, students with high self-efficacy obtained a marginal mean of 84.13, compared to 77.24 for students with low self-efficacy. This confirms that students who possess stronger confidence in their abilities tend to perform better in mathematical reasoning tasks.

Overall, Problem-Based Learning integrated with Mind Mapping produced higher mathematical reasoning scores than Direct Instruction. Beyond statistical significance, the observed mean difference indicates meaningful educational benefits for classroom practice, although this interpretation should be supported by reporting an appropriate effect size (e.g., partial η^2 or Cohen's *d*). Self-efficacy also independently contributed to students' reasoning achievement.

7. Hypothesis Testing Results

The research hypotheses were tested using a Two-Way Analysis of Variance (Two-Way ANOVA) with Unequal Cell Sizes to examine the main effects of the learning model, students' self-efficacy, and the interaction between these two independent variables on students' mathematical reasoning ability. Prior assumption testing confirmed that the data met the requirements of normality, homogeneity of variance, and baseline equivalence. Therefore, the dataset was considered appropriate for parametric analysis. In accordance with current reporting standards in quantitative educational research, the ANOVA results include the degrees of freedom (df), Sum of Squares (SS), Mean Squares (MS), F-values, exact significance values (p-values), and effect sizes (partial η^2), allowing both statistical and practical significance to be evaluated.

Table 8. Two-Way ANOVA Results on Students' Mathematical Reasoning Ability

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F	p-value	Partial η^2	Effect Size	Decision
Learning Model (A)	611.85	1	611.85	9.348	0.003	0.102	Medium	Reject H_0
Self-Efficacy (B)	1,011.37	1	1,011.37	15.453	< .001	0.157	Large	Reject H_0
Learning Model × Self-Efficacy (A × B)	0.07	1	0.07	0.001	0.973	0.000	Negligible	Accept H_0
Error	5,364.92	82	65.43	–	–	–	–	–
Total	6,988.21	85	–	–	–	–	–	–
Corrected Total	6,988.21	85	–	–	–	–	–	–

The results presented in Table 8 demonstrate that the learning model had a statistically significant effect on students' mathematical reasoning ability, $F(1, 82) = 9.348$, $p = .003$, partial $\eta^2 = .102$. The obtained effect size indicates that approximately 10.2% of the variance in mathematical reasoning scores can be attributed to differences in the instructional model after controlling for other factors. According to Cohen's guidelines, this represents a moderate practical effect, suggesting that the choice of instructional strategy substantially influences students' reasoning performance. Consequently, the null hypothesis concerning the learning model was rejected.

The analysis also revealed a statistically significant main effect of self-efficacy, $F(1, 82) = 15.453$, $p < .001$, partial $\eta^2 = .157$. This effect size indicates that approximately 15.7% of the variability in mathematical reasoning ability is explained by students' self-efficacy levels. The magnitude of this effect falls within the large effect category, highlighting that students' confidence in their own learning abilities is an important predictor of mathematical reasoning achievement. Therefore, the second null hypothesis was rejected.

In contrast, the interaction between the learning model and self-efficacy was not statistically significant, $F(1, 82) = 0.001$, $p = .973$, partial $\eta^2 < .001$. The negligible effect size indicates that virtually none of the variance in students' reasoning scores was explained by the interaction between these two variables. This finding suggests that the superiority of the Problem-Based Learning model integrated with Mind Mapping was consistent across students with both high and low self-efficacy. In other words, although self-efficacy independently influenced achievement, it did not strengthen or weaken the effectiveness of the learning model. Consequently, the third null hypothesis was accepted.

Overall, the ANOVA findings indicate that both instructional approach and students' psychological characteristics independently contribute to mathematical reasoning performance. However, these variables operate independently rather than interactively. The reported effect sizes further demonstrate that the practical contribution of self-efficacy was greater than that of the learning model, emphasizing the importance of combining effective instructional strategies with efforts to develop students' confidence in mathematics learning.

8. Marginal Mean Comparison

Following the significant main effects identified through the Two-Way ANOVA, marginal mean analysis was conducted to compare the average mathematical reasoning performance across learning models and self-efficacy levels. Estimated marginal means were calculated together with their standard errors (SE) and 95% confidence intervals (CI) to provide a more comprehensive interpretation of group differences.

Table 9. Estimated Marginal Means of Mathematical Reasoning Scores

Learning Model	High Self-Efficacy Mean (SE)	Low Self-Efficacy Mean (SE)	Marginal Mean	SE	95% Confidence Interval
Problem-Based Learning + Mind Mapping (A_1)	86.84 (1.43)	79.89 (1.47)	83.37	1.03	81.33 – 85.41
Direct Instruction (A_2)	81.42 (1.45)	74.58 (1.49)	78.00	1.05	75.91 – 80.09
Marginal Mean	84.13 (1.02)	77.24 (1.04)	80.69	0.74	79.22 – 82.16

The estimated marginal means presented in Table 9 indicate that students who learned through Problem-Based Learning integrated with Mind Mapping achieved the highest overall mathematical reasoning performance, with a marginal mean score of 83.37, compared with 78.00 for students who received Direct Instruction. The difference of 5.37 points demonstrates a meaningful educational advantage for the experimental learning model. Moreover, the relatively narrow confidence intervals indicate that these estimates are reasonably precise and reliable.

When examined according to self-efficacy level, students with high self-efficacy obtained an estimated marginal mean of 84.13, whereas students with low self-efficacy achieved a mean score of 77.24, resulting in an average difference of 6.89 points. This finding confirms that students who possess stronger confidence in their own abilities consistently demonstrate superior mathematical reasoning performance regardless of the instructional model employed.

A closer examination of the cell means shows that the highest achievement was recorded by students with high self-efficacy who participated in Problem-Based Learning integrated with Mind Mapping (M = 86.84), while the lowest performance was observed among students with low self-efficacy receiving Direct Instruction (M = 74.58). Nevertheless, the nearly parallel differences between the two learning models across both self-efficacy categories support the ANOVA finding that there was no significant interaction effect. The instructional advantage of Problem-Based Learning remained relatively stable for students with both high and low self-efficacy.

From an educational perspective, these findings suggest that implementing Problem-Based Learning integrated with Mind Mapping provides measurable improvements in students' mathematical reasoning ability compared with conventional Direct Instruction. At the same time, strengthening students' self-efficacy represents an equally important avenue for improving academic performance. Since the interaction effect was not statistically significant, educators may reasonably expect the learning model to benefit students across varying levels of self-confidence, making it a broadly applicable instructional strategy for mathematics classrooms.

Discussion

1. The Effect of Problem-Based Learning Integrated with Mind Mapping on Students' Mathematical Reasoning Ability

The findings of this study demonstrate that Problem-Based Learning (PBL) integrated with Mind Mapping significantly improved students' mathematical reasoning ability compared with Direct Instruction, as indicated by the Two-Way ANOVA result ($F(1,82) = 9.348$, $p = .003$, partial $\eta^2 = .102$). The marginal mean analysis confirmed that students in the PBL integrated with Mind Mapping group achieved higher reasoning scores (M = 83.37) than those receiving Direct Instruction (M = 78.00). These results indicate that the integrated approach provided a more effective learning environment for developing students' abilities to analyze problems, identify conceptual relationships, construct arguments, and justify mathematical solutions.

The findings support constructivist learning theory, which emphasizes that meaningful learning occurs when students actively construct knowledge through interaction between prior experiences and new information. Through PBL activities, students were encouraged to investigate contextual problems, discuss ideas, develop strategies, and evaluate solutions.

Meanwhile, Mind Mapping functioned as a cognitive scaffold that helped students organize and visualize mathematical relationships. This combination explains why students achieved better reasoning performance because they were not only focused on obtaining correct answers but also on understanding the logical processes behind mathematical concepts.

The effectiveness of this approach can also be explained through Cognitive Load Theory and Dual Coding Theory. Mathematical reasoning requires students to process complex information, and Mind Mapping helps reduce cognitive demands by presenting information in a structured visual form. As a result, students can focus more on higher-order thinking processes such as comparing strategies, evaluating relationships, and explaining reasoning. This interpretation is supported by Asare et al. (2023), Wang et al. (2025) and Irawan et al., (2026) who emphasized that visualization and concept mapping improve conceptual understanding by strengthening connections between new and existing knowledge.

The findings are consistent with previous studies showing that PBL enhances reasoning and higher-order thinking skills. Khairani et al. (2023) found that PBL improved mathematical reasoning through active problem investigation, while Firdyan et al. (2023) and Sitanggang et al. (2025) demonstrated that PBL supported by mind mapping strengthened students' critical thinking abilities. However, PBL effectiveness depends on implementation quality, teacher facilitation, and learning support. The integration of Mind Mapping in this study may explain the stronger outcomes because it provided structured guidance during problem-solving activities.

Although Direct Instruction remains effective for developing basic knowledge and procedures, its teacher-centered orientation provides fewer opportunities for students to explore multiple strategies and construct mathematical arguments independently. Therefore, the higher achievement of the PBL group does not indicate that Direct Instruction is ineffective but highlights that different instructional approaches develop different aspects of mathematical competence. Practically, teachers should integrate Mind Mapping into PBL activities to support students' conceptual organization, reasoning processes, and deeper mathematical understanding.

2. The Effect of Self-Efficacy on Students' Mathematical Reasoning Ability

The findings demonstrate that self-efficacy significantly influenced students' mathematical reasoning ability, as shown by the Two-Way ANOVA result ($F(1,82) = 15.453$, $p < .001$, partial $\eta^2 = .159$). The effect size indicates that self-efficacy contributed approximately 15.9% of the variance in students' reasoning performance, showing a strong practical contribution. The marginal mean analysis further revealed that students with high self-efficacy achieved higher reasoning scores ($M = 84.13$) than students with low self-efficacy ($M = 77.24$). This finding indicates that students' beliefs about their mathematical abilities affect their persistence, confidence, and capacity to analyze problems, develop logical arguments, and select appropriate solution strategies.

The results support Bandura's Social Cognitive Theory, which explains that self-efficacy influences learning through motivational, cognitive, and self-regulatory processes. Students with high self-efficacy tend to perceive challenging mathematical tasks as achievable, demonstrate greater effort, and persist when encountering difficulties. In contrast, students with low self-efficacy are more likely to experience uncertainty and avoid complex tasks. Furthermore, from a metacognitive perspective, students with stronger self-efficacy are better able to plan, monitor, and evaluate their problem-solving processes, which are essential components of mathematical reasoning. This interpretation aligns with Hidayati et al. (2021), who found that self-efficacy was positively related to students' metacognitive abilities.

The findings are also consistent with previous studies showing that self-efficacy contributes significantly to mathematical reasoning. Lestari and Haji (2022) demonstrated that self-efficacy was an important predictor of mathematical reasoning ability, while Umaroh et al. (2020) found that self-efficacy supported reasoning performance by reducing the negative influence of mathematics anxiety. Similarly, Hikmah et al. (2025) confirmed that students with higher self-efficacy performed better in identifying mathematical relationships and constructing arguments. However, self-efficacy alone does not guarantee high achievement because students still require conceptual knowledge and effective instructional support. As suggested by Yang et al. (2024) and

Khoiruman et al., (2026), self-efficacy contributes to achievement within broader learning conditions.

In this study, the implementation of Problem-Based Learning integrated with Mind Mapping likely strengthened students' self-efficacy through collaborative discussion, feedback, and successful problem-solving experiences. Therefore, teachers should develop students' confidence alongside effective instructional strategies by providing meaningful challenges, constructive feedback, and supportive learning environments. Strengthening self-efficacy is essential because students who believe in their abilities are more likely to engage actively and achieve higher mathematical reasoning performance.

3. The Interaction Between Learning Model and Self-Efficacy on Mathematical Reasoning Ability

The findings showed that the interaction between the learning model and self-efficacy was not statistically significant, $F(1,82) = 0.001$, $p = .973$, partial $\eta^2 < .001$. This indicates that self-efficacy did not moderate the effectiveness of Problem-Based Learning (PBL) integrated with Mind Mapping on students' mathematical reasoning ability. Although both variables independently influenced students' performance, their combination did not produce additional effects. Thus, the effectiveness of PBL integrated with Mind Mapping remained consistent among students with both high and low self-efficacy levels.

Theoretically, this finding suggests that instructional and motivational factors operate through different mechanisms. The learning model influences students' cognitive processes by facilitating knowledge construction, problem analysis, and solution development, whereas self-efficacy affects motivation, persistence, and self-regulation during learning. Through PBL activities, students actively explored problems, discussed ideas, and constructed solutions, while Mind Mapping provided visual support to organize mathematical concepts. Therefore, even students with lower self-efficacy could benefit from the structured learning environment because the instructional design reduced cognitive difficulties and supported reasoning development.

This result is consistent with Narpila et al. (2025), who emphasized that self-efficacy is an important determinant of mathematical reasoning but its influence depends on learning contexts. Similarly, Tak et al. (2023) found that self-efficacy affects mathematical reasoning through metacognitive processes rather than directly interacting with every instructional approach. However, Lee et al. (2025) and Ahmad et al., (2026) reported that students with higher mathematical self-efficacy may benefit more from complex reasoning activities. The difference may be explained by variations in research context, measurement methods, and statistical procedures. In this study, categorizing self-efficacy into high and low groups may have reduced variability and limited the detection of interaction effects.

Practically, these findings indicate that PBL integrated with Mind Mapping can be applied effectively to students with different self-efficacy levels. Teachers should continue implementing supportive learning strategies while simultaneously developing students' confidence through feedback, meaningful tasks, and opportunities for successful problem solving. Future research should consider larger samples and continuous self-efficacy measurements to examine more complex interaction patterns.

CONCLUSION

This study examined the effects of Problem-Based Learning (PBL) integrated with Mind Mapping and students' self-efficacy on mathematical reasoning ability. The results showed that students who learned through PBL integrated with Mind Mapping achieved significantly higher mathematical reasoning scores than those who received Direct Instruction. The findings also indicated that students with high self-efficacy demonstrated significantly better mathematical reasoning ability than students with low self-efficacy. However, no significant interaction was found between the learning model and self-efficacy, indicating that the effect of the learning model on mathematical reasoning did not differ according to students' self-efficacy levels within the context of this study.

These findings are limited to the variables measured and the quasi-experimental design employed. The results provide empirical evidence that both the instructional model and students' self-efficacy are independently associated with mathematical reasoning ability, while no interaction effect between the two variables was observed.

This study has several limitations. The research was conducted with a relatively limited sample from one district, which may reduce the generalizability of the findings. In addition, the intervention was implemented over a limited period, so the results reflect only the short-term effects of the learning model. Furthermore, the study focused solely on self-efficacy as the learner characteristic examined alongside the instructional model.

Future research may replicate this study using larger and more diverse samples, longer intervention periods, and additional learner variables to further examine factors associated with students' mathematical reasoning ability in different educational contexts.

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