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Metacognitive Scaffolding in Problem-Based Learning: A Pathway to Developing Higher-Order Thinking Skills

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Abstrak

Kemampuan Berpikir Tingkat Tinggi (HOTS) siswa dalam pembelajaran matematika masih rendah, khususnya pada kemampuan menganalisis, mengevaluasi, dan mencipta. Penelitian ini bertujuan menguji pengaruh Problem-Based Learning yang diperkaya dengan scaffolding metakognitif (PBL-MS) terhadap peningkatan HOTS siswa. Penelitian kuasi-eksperimental dengan desain pretest–posttest control group *melibatkan 60 siswa kelas X SMA Negeri 15 Bandung yang dibagi ke dalam kelompok eksperimen (PBL-MS) dan kontrol (PBL). Data kemampuan HOTS dikumpulkan melalui tes tertulis berbentuk esai berdasarkan taksonomi Bloom revisi. Hasil penelitian menunjukkan bahwa peningkatan HOTS siswa pada kelompok PBL-MS berada pada kategori sedang (N-Gain = 0,51), sedangkan kelompok PBL berada pada kategori rendah (N-Gain = 0,30), dengan perbedaan yang signifikan (Sig. 2-tailed < 0,05). Temuan ini menunjukkan bahwa integrasi scaffolding metakognitif dalam PBL lebih efektif dalam meningkatkan kemampuan HOTS siswa.*

Kata Kunci*: PBL; scaffolding; metakognitif;* HOTS.

Abstract

Students' Higher-Order Thinking Skills (HOTS) in mathematics learning remain low, particularly in analyzing, evaluating, and creating skills, indicating the need for instructional strategies that can better support students' thinking processes. This study aimed to examine the effect of Problem-Based Learning enriched with metacognitive scaffolding (PBL-MS) on improving students' HOTS. A quasi-experimental study with a pretest–posttest control group design was conducted at SMA Negeri 15 Bandung, involving 60 tenth-grade students divided into an experimental group (PBL-MS) and a control group (PBL). HOTS data were collected using an essay-based written test developed based on the revised Bloom's taxonomy, covering analyzing, evaluating, and creating indicators. The results showed that the improvement in HOTS of students taught using PBL-MS was in the moderate category (N-Gain = 0.51), while students taught using PBL alone achieved a low category (N-Gain = 0.30). Statistical analysis indicated a significant difference between the two groups (Sig. 2-tailed < 0.05). These findings indicate that integrating metacognitive scaffolding into Problem-Based Learning provides a stronger effect on improving students' higher-order thinking skills.

Keywords: PBL; Metacognitive; Scaffolding; HOTS.

I. INTRODUCTION

In the context of 21st-century learning, higher-order thinking skills (HOTS) are one of the important competencies that students must have (Yen & Halili, 2015; Yulıanto et al., 2019; Kosasih et al., 2022). Consequently, HOTS has become a major concern in the formulation and development of educational curricula (İncirci & Howells, 2018; Hajaroh, 2021). HOTS or higher-order thinking skills are thinking skills that go beyond simply memorizing or understanding information. HOTS includes advanced cognitive processes such as analyzing, evaluating, and creating (Anderson & Krathwohl, 2001; Abraham et al., 2021). HOTS is an essential 21st-century competency that includes the skills of analyzing, evaluating, and creating, making it a major focus in curriculum development.

However, a number of studies indicate that students' HOTS are still at a low level and have not reached the expected standards (Saraswati & Agustika, 2020; Astria et al., 2025). This is supported by the results of interviews with mathematics teachers at SMA Negeri 15 Bandung, who expressed deep concern about students' HOTS. It is known that students often experience obstacles in carrying out processes such as differentiating, organizing, attributing, checking, critiquing, and creating (Syarifuddin et al., 2022; Sinaga, 2024; Desfita et al., 2025). Various studies and field findings show that students' HOTS are still low, with difficulties in performing complex thinking processes such as analyzing, evaluating, and creating.

One way to overcome students' low HOTS abilities is by using the Problem-Based Learning (PBL) model at various levels of education (Yulianti et al., 2020; Wicaktini et al., 2020; Dewi et al., 2025). The PBL model provides opportunities for students to be directly involved in solving real problems, encourages collaboration, and fosters independence in learning (Setyowidodo et al., 2018; Hardinata et al., 2023; Murti et al., 2024). However, the implementation of PBL alone does not automatically develop higher-order thinking skills without the support of appropriate learning strategies (Dhawo, 2019; Tâm, 2021; Sappaile et al., 2025). PBL effectively encourages the development of HOTS through real and collaborative problem solving, but it still requires the support of appropriate learning strategies for optimal results(Ismail et al., 2024).

The implementation of PBL can be enhanced through the integration of metacognitive scaffolding. Metacognitive scaffolding has been proven effective in helping students develop awareness and control over their thinking processes during problem solving (Talebi, 2025). Through step-by-step guidance tailored to students' needs, this scaffolding encourages students to reflect on their understanding, choose appropriate strategies, and critically evaluate their solution steps (Chomsriharat & Polyiem, 2024). The integration of metacognitive scaffolding in PBL will effectively improve HOTS by helping students manage, reflect on, and critically evaluate their thinking processes during problem solving.

Results Research by Kim & Hannafin (2011) shows that the integration of metacognitive scaffolding in PBL can improve learning effectiveness, especially in encouraging cognitive engagement and higher-order thinking skills in students (Kim & Hannafin, 2011). In addition, this approach also helps clarify abstract mathematical concepts through a process of reflection and better self-regulation, so that students not only solve problems but also understand the meaning of the solutions obtained (Suhendra & Nindiasari, 2025). The integration of metacognitive scaffolding in PBL has been shown to increase students' cognitive engagement and HOTS, while helping them understand mathematical concepts more deeply through reflection and self-regulation.

Based on this foundation, this study aims to explore the impact of implementing PBL enriched with metacognitive scaffolding (PBL-MS) in mathematics learning. In recent years, research on metacognitive interventions in mathematics learning has shown promising results, but the explicit combination of PBL and metacognitive scaffolding has been relatively rarely studied in depth (Wang et al., 2024; Sari et al., 2024).

Previous studies have also indicated that PBL can improve the quality of learning processes and outcomes, such as increased reflective thinking, complex problem solving, and deeper conceptual mastery (Annisa, 2023). Based on these findings, it can be assumed that the integration of metacognitive scaffolding in PBL not only increases the effectiveness of PBL itself but also contributes to the development of critical thinking skills, metacognitive awareness, and more meaningful learning outcomes. The integration of metacognitive scaffolding in PBL is also believed to encourage the development of critical thinking, increase metacognitive awareness, and produce more meaningful learning for students.

This study compares two learning approaches, namely PBL and PBL with metacognitive scaffolding (PBL-MS). The main difference between the two lies in the systematic support for students' thinking processes. In PBL, students work together to solve problems through open inquiry. Meanwhile, in PBL-MS, this process is reinforced with scaffolding that encourages students to set learning goals, monitor their understanding, and evaluate the effectiveness of their strategies, so that problem solving becomes more focused and meaningful (Valencia-Vallejo et al., 2019; Eticha et al., 2024).

Several studies have shown that metacognitive scaffolding has a positive impact on students' academic achievement and cognitive development. However, studies that specifically examine how metacognitive scaffolding in PBL can improve HOTS are still limited, especially in the context of mathematics learning. Therefore, this study aims to analyze the effect of applying metacognitive scaffolding in the Problem-Based Learning model on students' higher-order thinking skills.

II. METHOD

This quasi-experimental study was conducted at SMA Negeri 15 Bandung from May 23, 2025, to June 3, 2025, using *a pretest-posttest control group design.* A total of 60 tenth-grade students from SMA Negeri 15 Bandung participated in this study, divided into two classes: Class A as the experimental class and Class B as the control class, each consisting of 30 students. Both classes were taught by the same teacher, with class equivalence determined through testing students' mathematical abilities, which showed that both classes had equivalent ability levels.

The experimental class received treatment in the form of a combination of PBL and metacognitive scaffolding (PBL-MS), while the control class was taught using the PBL method without metacognitive scaffolding support. Data collection was conducted through tests designed to assess students' HOTS. These tests were administered at the end of scaffolding to evaluate the effectiveness of both learning methods. The data collection instrument was a written test consisting of eight questions, which measured eight main indicators of HOTS (analyzing, evaluating, and creating), namely:

1) Analyzing: -Differentiating, -Organizing, -Attributing.
2) Evaluating: -Checking, Critiquing
3) Creating: Generating, Planning, Producing (Anderson & Krathwohl, 2001)

Before being used in the study, this test was first piloted with 20 students from grade XI, a class not involved in the study, to determine its validity, reliability, and level of difficulty. To prevent leakage of test material, all answer sheets and questions were collected immediately after the pilot test was conducted.

The collected data were analyzed descriptively and inferentially. Descriptive statistics were used to calculate the mean, standard deviation, percentage, and highest and lowest scores. Meanwhile, inferential statistics, specifically the t-test, were used to test the hypothesis, which was done after all the analysis prerequisites were met.

III. RESULT AND DISCUSSION

A. Research Results

This study aimed to analyze the effect of metacognitive scaffolding in the Problem-Based Learning (PBL-MS) model on students' Higher-Order Thinking Skills (HOTS). The study involved two groups: experimental (PBL-MS) and control (PBL).

1. Description of HOTS Data

The following are the average pretest and posttest HOTS scores of students in both groups:

Table 1.
Description of HOTS data

Group	N	Pre-test Average	`Posttest Average	N-Gain	Category
Experiment	30	8.23	20.57	0.51	Moderate
Control	30	8.90	15.97	0.30	Low

Table 1 shows that, descriptively, the distribution of students' HOTS pretest scores indicates that there is almost no difference. This means that there is likely no difference in HOTS between students who will receive PBL-MS and those who will receive PBL. Meanwhile, the posttest and N-Gain data show a difference. This will be tested statistically using inferential statistics.

2. Normality and Homogeneity Test of Pretests

Furthermore, a normality test is carried out to find out whether the data obtained comes from research subjects that are normally distributed or not. This normality test uses the Liliefors test at a real level. The normality test criterion is H0 accepted if sig > 0.05 and H0 are rejected if Sig < 0.05. The acceptance of H0 states that the research data come from normally distributed populations and vice versa. The following are the results of the normality test of control and experimental classes (see Table 2).

Table 2.
Pretest Normality test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Pretes_Kontrol	,133	30	,186	,957	30	,257
Pretes_Eksperimen	,147	30	,099	,942	30	,101
a. Lilliefors Significance Correction						

The Shapiro-Wilk test results show sig > 0.05, which means the research data come from normally distributed populations and vice versa.

Furthermore, a homogeneity test was carried out to find out whether the data of the two groups had homogeneous variances or not. The Bartlett Test conducted its homogeneity test at a significant level, with the criterion that if sig > 0.05 then the data of all two groups have the same (homogeneous) variance. Here are the results of the homogeneity test for the control and experimental groups (see Table 3).

Table 3.
Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Nilai_Pretes	Based on Mean	,039	1	58	,844
	Based on Median	,027	1	58	,870

The results of Levene's Test for Equality of Variances show that the Pre-test Score data has homogeneous (equal) variance between the control and experimental groups. This is confirmed by the significance value obtained of 0.844. Because the sig value is much greater than the significance level of 0.05, it can be concluded that there is no statistically significant difference in variance between the two groups. In other words, the assumption of variance homogeneity is fulfilled for the *pretest* data.

3. Hypothesis Test (t-test) for pretest

An independent t-test was used to determine the difference in students' initial HOTS scores between the experimental and control groups (see Table 4).

Table 4.
Hypothesis Test (t-test) pretest

	t-test for Equality of Means

							95% Confidence Interval of the Difference	
		t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai_Pretes	Equal variances assumed	-,986	58	,328	-,667	,676	-2,021	,687

Sig value = 0.328, meaning there is no difference in the initial HOTS of students who will receive PBL-MS and students who receive PBL.

4. Post-test Normality and Homogeneity Test

The research utilizes the Lilliefors test at a specified significance level to perform a normality test, which assesses whether the data obtained from the study participants follow a normal distribution. The decision-making process for this test is based on the significance value (sig): the null hypothesis (H0) is accepted if sig > 0.05, indicating the data come from a normally distributed population; conversely, H0 is rejected if sig < 0.05, meaning the data are not normally distributed. The subsequent section provides the specific results of this normality test for both the control and experimental classes in Table 5.

Table 5.
Postest Normality Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Postes_Kontrol	.134	30	,182	,948	30	,149
Postes_Eksperimen	,133	30	,185	,964	30	,381
a. Lilliefors Significance Correction						

Based on the results of the normality test, which uses the criterion of accepting the null hypothesis (H0) if the significance value (sig) is greater than 0.05, it can be concluded that the research data is normally distributed. Both the Control Class and the Experimental Class had sig values > 0.05, so it can be confirmed that the *post-test* data from both groups (control and experimental) came from a normally distributed population.

Furthermore, a homogeneity test was carried out to find out whether the data of the two groups had homogeneous variances or not. The Bartlett Test conducted its homogeneity test at a significant level, with the criterion that if sig > 0.05 then the data of all two groups have the same (homogeneous) variance. Here are the results of the homogeneity test for the control and experimental groups (see Table 6).

Table 6.
Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Postes Value	Based on Mean	.672	1	58	.416

The results of Levene's Test for Equality of Variances for the Post-test Score data show that the variance between the control group and the experimental group is homogeneous or the same. This decision is based on the significance value (sig) obtained of 0.416. Because this sig value is greater than the significance level of 0.05, it is concluded that the assumption of variance homogeneity is fulfilled for the *post-test* data.

5. Hypothesis Test (t-test) for postes

An independent t-test was used to determine the difference in HOTS achievement between the experimental and control groups (see Table 7).

Table 7.
Hypothesis Test (t-test) Post-test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai_Postes	Equal variances assumed	6.903	58	,000	4,600	,666	3,266	5,934

The results of the Independent Samples t-Test show that there is a statistically significant difference between the mean Postes scores of the control group and the experimental group. This decision is based on a sig value (2-tailed) of 0.000. Because this significance value is smaller than the significance level of 0.05, the Null Hypothesis (H0) is rejected, and the Alternative Hypothesis (H1) is accepted. In other words, the HOTS achievement of students who received PBL-MS is better than that of students who received PBL.

6. Normality and Homogeneity of N-Gain

The research utilizes the Lilliefors test at a specified significance level to perform a normality test, which assesses whether the data obtained from the study participants follow a normal distribution. The decision-making process for this test is based on the significance value (sig): the null hypothesis (H0) is accepted if sig > 0.05, indicating the data come from a normally distributed population; The subsequent section provides the specific results of this normality test for both the control and experimental classes (see Table 8).

Table 8.
N-Gain Normality Test

	Kolmogorov-Smirnov^{a}			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
N_Gain_Experiment	.084	30	.200*	.948	30	,150
N_Gain Control	.124	30	,200*	.967	30	,451
a. Lilliefors Significance Correction						

Based on the results of the normality test, which uses the criterion of accepting the null hypothesis (H0) if the significance value (sig) is greater than 0.05, it can be concluded that the research data is normally distributed. Both the Control Class and the Experimental Class have sig values > 0.05, so it can be confirmed that the *post-test* data from both groups (control and experimental) come from a normally distributed population.

Furthermore, a homogeneity test was conducted to determine whether the data of the two groups had homogeneous variances or not. The Bartlett Test conducted its homogeneity test at a significant level, with the criterion that if sig > 0.05, then the data of all two groups have the same (homogeneous) variance. Here are the results of the homogeneity test for the control and experimental groups (see Table 9).

Table 9.
Test of Homogeneity of Variance

		Levene Statistic	**df1**	**df2**	**Sig.**
Nilai_N_Gain	Based on Mean	3.522	1	58	.066
	Based on Median	3,519	1	58	.066

The results of Levene's Test for Equality of Variances for N_Gain data show that the variance between the control group and the experimental group is homogeneous or the same. This decision is based on a significance value (sig) of 0.066. Because the {Sig.} value is greater than the significance level of 0.05, it is concluded that there is no significant difference in variance between the N-Gain data of the two groups

7. Hypothesis Test (t-test) N-Gain

An independent t-test was used to determine the difference in HOTS scores between the experimental and control groups (see Table 10).

Table 10.
Hypothesis Test (t-test) N-Gain

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai_N_Gain	Equal variances assumed	6.027	58	,000	.20470	.03397	,13671	.27269

The results of the Independent Samples t-Test conducted on the N_Gain data show that there is a very significant difference in the increase in students' HOTS between the control group and the experimental group. This is confirmed by the significance value (Sig. 2-tailed) of 0.000. Because this significance value is less than 0.05, the Null Hypothesis (H0) is rejected, which means that metacognitive scaffolding in the Problem-Based Learning (PBL-MS) model given to the experimental group is proven to be more effective in improving students' HOTS compared to the control group.

In this study, the following is an example of a narrative lesson for 10th-grade high school mathematics on trigonometry that applies problem-based learning (PBL) and metacognitive scaffolding. The teacher displays a picture of a flagpole in the schoolyard and poses the question:

"A school official wants to know the height of a flagpole without having to climb it. If the observer is 10 meters from the pole and the angle of elevation is 30°, how can the height of the pole be determined?"

Based on this question, a lesson using the PBL-MS model will be developed, as shown in Table 11.

Table 10.
Mapping of Metacognitive Scaffolding and Student Activities

Metacognitive Phase	Type of Teacher Scaffolding	Examples of Scaffolding Questions	Students' Cognitive & Metacognitive Activities	Indicators of Thinking Processes
Planning	Activation of prior knowledge and strategy planning	“What information is known from this problem?” “Which trigonometric concept is relevant?” “What steps will you take first?”	Identifying given and required information Determining relevant concepts (sin, cos, tan) Formulating a solution plan	Students are able to explain the rationale for concept selection Students construct a sequence of solution steps
Planning	Problem representation	“How can this problem be represented in the form of a triangle?”	Constructing a right-triangle sketch based on the context	The sketch is consistent with the problem situation and angle of elevation
Monitoring	Strategy clarification	“Why did you use tangent instead of sine?”	Explaining the appropriateness of the chosen concept based on the position of the angle and sides	Logical and conceptually consistent arguments in trigonometry
Monitoring	Error detection	“Are the positions of the angle and sides correct?” “Are the units appropriate?”	Rechecking calculation steps Correcting conceptual or procedural errors	Students perform self-correction
Monitoring	Reinforcement of awareness of thinking processes	“Does this step bring you closer to the solution?”	Reflecting on the effectiveness of the steps being applied	Students are able to explain their progress toward the solution
Evaluating	Solution reflection	“Is the obtained answer reasonable?”	Evaluating the final result based on the problem context	Logical and contextualized answers
Evaluating	Strategy reflection	“If the problem is modified, would the same strategy still apply?”	Comparing the applied strategy with alternative strategies	Students are able to generalize the strategy
Evaluating	Reflection on learning difficulties	“Which part was most difficult and how did you overcome it?”	Identifying learning difficulties and the strategies used to address them	Self-awareness of strengths and weaknesses in thinking

B. Discussion

Studying mathematics is an important means of honing human thinking skills, particularly higher-order thinking skills (HOTS), which include the dimensions of analysis, creativity, and evaluation (Hujjatusnaini, 2022). HOTS are essential 21st-century competencies that go beyond mere memorization or comprehension, and are a key focus in curriculum development (Anderson & Krathwohl, 2001; Pasani & Suryaningsih, 2021).

Despite its importance, a number of studies and observations, including at SMA N 15 Bandung, consistently indicate that students' HOTS are still at a low level, as reflected in mathematics scores that are often the lowest compared to another subject. This condition requires teachers to actively determine innovative learning models that can support students in improving their higher-order thinking skills.

Therefore, to optimize the potential of PBL in developing HOTS, the integration of Metacognitive Scaffolding is crucial. Metacognition—thinking about how one thinks—includes the skills of planning, monitoring, and evaluating cognitive processes (Valencia-Vallejo et al., 2019).

By adding *metacognitive scaffolding* interventions, teachers can explicitly train students to:

1. Plan problem-solving strategies before starting.
2. Monitor their progress and adjust strategies during project work.
3. Evaluate the effectiveness of the solutions produced.

This integration aims to produce a learning model that not only involves students in projects (PBL) but also equips them with mental tools to control cognitive processes, thereby directly improving students' thinking and creativity skills and becoming a more certain path to achieving higher HOTS levels.

However, it should be noted that the effectiveness of scaffolding is also influenced by student readiness and teacher facilitation skills. Therefore, teacher training in applying metacognitive scaffolding is an important component in the successful implementation of this strategy.

Metacognitive scaffolding is effective because it guides students to plan, monitor, and evaluate their thinking processes, thereby promoting higher-order cognitive engagement (C4–C6) and deeper conceptual understanding, yet its implementation in real classrooms is challenged by time constraints, students' limited reflective habits, teachers' pedagogical expertise, and classroom heterogeneity.

The results of the study show that the application of metacognitive scaffolding in problem-based learning (PBL-MS) significantly improves students' higher-order thinking skills. This is in line with Flavell's (1979) opinion that metacognition allows students to be more aware of how they think and learn, enabling them to make more appropriate decisions in solving complex problems. Also, the results of research Enfiyostuti et al., (2022) explains that metacognitive intervention (in the form of *scaffolding*) helps students think reflectively when solving problems, which is an important prerequisite for HOTS.

However, it should be noted that the effectiveness of scaffolding is also influenced by student readiness and teacher

facilitation skills. Therefore, teacher training in applying metacognitive scaffolding is an important component in the successful implementation of this strategy.

IV. CONCLUSION

This study proves that PBL-MS has a significant impact on students' higher-order thinking skills. The results show that the application of PBL-MS can improve students' HOTS, with variations in impact depending on the classroom context in which it is applied. This study makes an important contribution to the field of mathematics education by confirming that PBL-MS is an effective method for developing students' higher-order thinking skills (HOTS). For future research, it is recommended that other researchers further explore the application of PBL-MS in various learning contexts and examine its impact on other aspects of student learning outcomes.

` Future studies should explore PBL integrated with metacognitive scaffolding in other mathematical topics and examine its long-term effects on students' metacognitive regulation and problem-solving transfer. Also, schools should provide specific training on questioning techniques for teachers before attempting PBL-MS.

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