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Profile Metacognitive Scaffolding in Developing the Concept of Determinants to Enhance Mathematical Problem-Solving Skills of Low Ability Students

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ABSTRACT

The low ability of students to understand the concept of determinants and apply it in mathematical problem-solving remains a serious challenge, particularly among low-achieving learners. These difficulties are often linked to limited instructional variation, the dominance of procedural teaching, and insufficient opportunities for developing metacognitive awareness. This study therefore explores how metacognitive scaffolding can support low-achieving students in strengthening their conceptual understanding of determinants and improving problem-solving skills. The research employed a quantitative approach with a quasi-experimental design involving 30 tenth-grade students at MA Arifah Gowa, identified as low-achieving based on pretest results. Instruments included a mathematical problem-solving test, scaffolding observation sheets, and structured interviews. Data were collected through a pretest, classroom implementation of metacognitive scaffolding, observations, and a posttest. Findings revealed a significant improvement in problem-solving ability. The average score increased from 36.7 on the pretest to 74.8 on the posttest. Inferential analysis using a paired t-test confirmed the increase was statistically significant ($t(29) = -12.34$, $p < 0.001$), with a very large effect size (Cohen's $d = 1.80$). These results highlight the importance of integrating metacognitive scaffolding into mathematics instruction as a means of fostering reflective thinking, enhancing student engagement, and strengthening higher-order thinking skills, particularly for low-achieving students. The findings align with the objectives of the Merdeka Curriculum, which emphasizes critical, reflective, and independent learning.

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Introduction

Mathematics plays a vital role in developing logical, analytical, critical, and systematic thinking skills that are highly needed to face the challenges of the 21st century. Beyond being viewed as an abstract discipline, mathematics significantly contributes to various aspects of life, including technological advancement, economic development, and everyday decision-making. Consequently, mathematical problem-solving ability is often regarded as a key indicator in assessing the quality of mathematics education in schools (Vessonen et al., 2025; Weingarden, 2025). This is in line with the demands of the Programme for International Student Assessment (PISA), which every three years measures students' mathematical literacy across countries, demonstrating how students are able to apply mathematical concepts and knowledge to solve contextual problems (Alayubi et al., 2024; Azevedo et al., 2024; Zhang & Lian, 2024).

However, international reports indicate that Indonesian students' mathematical problem-solving abilities remain far below expectations. According to the 2018 PISA report, Indonesia ranked 73rd out of 79 participating countries in mathematical literacy. Indonesian students struggle to interpret, formulate, and apply mathematical models to solve problems, highlighting the weakness of higher-order thinking skills that are crucial for success in today's globalized world. This condition is further supported by findings from the Trends in International Mathematics and Science Study (TIMSS), which also placed Indonesian students at a low level in terms of mathematical reasoning. This issue has become a major concern, both internationally and nationally, as it directly impacts the future quality of Indonesia's human resources (Hamidah et al., 2025; Komarudin et al., 2024; OECD, 2023).

One of the main causes of students' low problem-solving ability is their weak understanding of fundamental mathematical concepts. When concepts are not well understood, students encounter difficulties in connecting mathematical ideas, generalizing, and applying them in real-world problem contexts (Stern & Hertel, 2022; Vessonen et al., 2025). A common area of difficulty is the concept of determinants in linear algebra. Determinants are a fundamental concept not only used in solving systems of linear equations in three variables (SPLTV) but also play an important role in various mathematical applications such as analytic geometry, linear transformations, and matrix calculations (Durkaya et al., 2011). Nevertheless, for low-achieving students, determinants are often perceived merely as mechanical procedures of calculation without a deeper conceptual understanding. As a result, when faced with problem-solving tasks requiring conceptual comprehension, these students struggle significantly (Eaves et al., 2025; Kuswanti et al., 2018; Pasaribu et al., 2025).

Previous studies have shown that low-achieving students tend to rely on mechanical procedural strategies when solving mathematical problems. Imran et al. (2024) found that Indonesian students predominantly use procedural approaches and rarely demonstrate metacognitive skills in monitoring and evaluating their thinking processes. On the other hand, An & Cao (2014) and Deibl et al., (2023) emphasized that metacognition, defined as the ability to be aware of, control, and regulate one's cognitive processes, is crucial for solving complex mathematical problems. For low-achieving students, metacognitive skills become even more essential, as they help identify errors, refine strategies, and deepen conceptual understanding.

One promising approach to enhancing students' metacognitive skills is metacognitive scaffolding. The concept of scaffolding was first introduced by Wood, Bruner, and Ross (He & Xin, 2025), who defined scaffolding as the instructional support provided by teachers to help learners achieve greater understanding. This support is tailored to the specific needs of students and is gradually withdrawn as students' competence increases. However, in the context of metacognitive scaffolding, this support focuses on monitoring and evaluating students' thinking processes, rather than just the final answer. With metacognitive scaffolding, the teacher not only assists students in solving problems but also guides them to monitor and regulate their

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
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thinking as they tackle mathematical challenges. For example, teachers might ask students to plan the steps for problem-solving, monitor whether those steps are effective, and finally, evaluate the outcomes and strategies used in solving the problem. This process provides students with the opportunity to understand not only what they are doing but also why they are doing it and how they can improve their approach.

Several studies, such as those conducted by Awi & Arwadi (2018) and Awi et al., (2024), have shown that the use of metacognitive strategies in mathematics instruction helps students develop a deeper conceptual understanding and improve their ability to solve more complex and contextual problems. The research also revealed that metacognitive scaffolding helps low-achieving students become more active in monitoring their errors and consciously develop more effective problem-solving strategies. Therefore, metacognitive scaffolding plays a central role in assisting students to develop better and more structured mathematical problem-solving skills, which is especially important for low-achieving learners (Nickl et al., 2024).

Despite the growing body of research on metacognitive scaffolding, several gaps remain, especially in the context of low-achieving students in Indonesia. Most existing studies have focused on the overall effectiveness of metacognitive strategies in improving learning outcomes rather than exploring the specific profiles or characteristics of students' metacognitive scaffolding when dealing with particular mathematical concepts such as determinants. Mapping such profiles can provide a more detailed understanding of how low-achieving students plan, monitor, and evaluate their thinking processes in understanding determinants and applying them in mathematical problem-solving. This profile is crucial as it can serve as a foundation for teachers to design more targeted instructional interventions aligned with the specific needs of students (Amalina & Vidákovich, 2023; Stenberg Hartviksen & Haavold, 2025).

Moreover, prior studies often emphasized students with medium or high mathematical ability, as they are considered more capable of demonstrating metacognitive behavior. In contrast, low-achieving students who are more prone to conceptual and procedural errors require greater attention. Therefore, examining the profile of metacognitive scaffolding in low-achieving students within the context of determinant concepts not only fills this research gap but also contributes valuable insights for both theory and practice in mathematics education.

The novelty of this study lies in its focus on analyzing the profile of metacognitive scaffolding among low-achieving students in constructing the concept of determinants to support mathematical problem-solving. This study not only investigates the extent to which metacognitive scaffolding can be implemented but also aims to describe in depth how students' metacognitive processes evolve through such scaffolding support. Drawing upon Vygotsky's (1978) theory of the zone of proximal development (ZPD), this study argues that with appropriate scaffolding, low-achieving students can enhance their metacognitive awareness and gradually build stronger conceptual understanding of determinants. Strong conceptual understanding, in turn, facilitates students in linking determinants with diverse mathematical problem-solving contexts.

The present study, conducted at MA Arifah Gowa, identified several factors contributing to students' difficulty in understanding determinants and applying them to problem-solving. Interviews with a mathematics teacher at the school revealed that the teaching methods employed have been relatively limited in variety, making it difficult for low-achieving students to actively engage in the learning process. Instruction has often been teacher-centered and heavily focused on procedural aspects, providing insufficient opportunities for students to develop metacognitive awareness. This instructional practice has been a major barrier to enhancing students' critical thinking and problem-solving abilities. Furthermore, students' participation in reflective, interactive, and contextual learning activities has been limited, making it difficult for them to relate determinants to real-world applications.

This study is relevant and necessary as it aims to provide an in-depth understanding of how metacognitive scaffolding can be implemented to support low-achieving students in constructing concepts of determinants. The choice of the metacognitive scaffolding strategy is based on research evidence showing that low-achieving students often struggle to develop a deeper conceptual understanding. Metacognitive scaffolding allows students to plan, monitor, and evaluate their thinking processes more effectively, which is crucial in mathematics learning that requires higher-order thinking skills. This strategy provides tailored support based on students' needs and gradually reduces their dependence on external help as their understanding of the material increases. Additionally, the topic of determinants in the system of three-variable linear equations is chosen because it is a complex concept that requires structured and organized problem-solving skills. Determinants are used to find solutions in a system of three-variable linear equations, which is an essential part of linear algebra. This material often poses a challenge for low-achieving students because it requires a good understanding of spatial concepts, numerical calculations, and the application of theory in practical situations.

Therefore, by using metacognitive scaffolding, students can be guided to understand the step-by-step process of solving the system of three-variable linear equations while also developing their critical thinking and problem-solving skills. The objective of this study is to identify the profile of metacognitive scaffolding practices in teaching the determinant material and to examine the extent to which this strategy supports students in developing higher-order thinking skills, promoting independent learning, and enhancing their ability to solve mathematical problems. With the systematic and structured implementation of metacognitive scaffolding, it is expected that students will not only develop a better understanding of determinants and their application in the system of three-variable linear equations but also gain confidence in solving complex mathematical problems, as well as improve their ability to manage and evaluate their mathematical thinking processes.

Method

Type of Research Design

This study employed a quantitative approach with a quasi-experimental design using a one group pretest-posttest design. This design was chosen because it is suitable for examining the effect of implementing metacognitive scaffolding on students’ mathematical problem-solving abilities in real classroom settings. In this design, students are assessed before the intervention (pretest) and after the intervention (posttest) to observe the changes that occur. The quasi-experimental design is used because the researcher does not have full control over randomly assigning subjects in real classroom environments, making it impossible to use a randomized control group.

Table 1. One Group Pretest-Posttest Experimental Design

	Pretest	Intervention	Posttest
Experimental Group	Measure students' mathematical problem-solving abilities before the intervention	Apply metacognitive scaffolding to the students in the experimental group	Measure students' mathematical problem-solving abilities after the intervention

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3803 Volume 5, No 3, Juli - September 2025, pp. 1330– 1344

Population and Sample

The research sample consisted of 30 tenth-grade students from MA Arifah Gowa who had been identified as low-achieving learners. Of these 30 students, 12 were male and 18 were female. The sampling criteria were determined based on the results of a mathematical problem-solving pretest, in which students who scored below the class average were categorized as low-achieving. The sampling technique used in this study was purposive sampling.

Instrument

The instruments used in this study were the Mathematical Problem-Solving Test. This test consisted of essay questions with the following indicators: (a) understanding the problem, (b) planning a solution strategy, (c) carrying out the plan, and (d) evaluating the answer. The test was administered during both the pretest and posttest stages to measure the students' mathematical problem-solving abilities. This test was tested for reliability using α Cronbach, which yielded a reliability value of 0.85, indicating that this instrument has good internal consistency. Additionally, a Metacognitive Scaffolding Observation Sheet was used. This instrument was employed to monitor the implementation of metacognitive scaffolding during the learning process. The aspects observed included planning, monitoring, and evaluation conducted by the teacher, as well as students' responses to the scaffolding provided. The observation sheet was tested for reliability using α Cronbach, which resulted in a value of 0.92, showing that this observation sheet has excellent consistency in measuring the aspects observed during the learning process.

Table 2. Instrument Mathematical Problem-Solving Test

Indicators	Task
- Understanding the problem, - Planning a solution strategy, - Carrying out the plan, - evaluating the answer.	**#Task 1** Given the following system of three-variable linear equation: $3x + 2y - z = 7$ $x - y + 2z = 4$ $2x + 3y + z = 10$ Questions: 1. Determine the coefficient matrix of this system of equations. 2. Calculate the determinant of the coefficient matrix A. 3. Calculate the determinants of the replacement matrices for the variables x, y, and z, and determine the solution for this system of equations.
	#Task 2 Given the following system of three-variable linear equation: $x + 2y + 3z = 14$ $2x + 4y + z = 10$ $3x + y + 2z = 8$ Using the Determinant Method, determine the values of x,y, and z.
	#Task 3 In a company, there are three types of products being produced simultaneously: Product A, Product B, and Product C. The amount of raw materials used to produce these products differs. The following data shows the raw material usage for each product: • Product A requires 3 units of raw material type 1, 2 units of raw material type 2, and 1 unit of raw material type 3. • Product B requires 2 units of raw material type 1, 3 units of raw material type 2, and 2 units of raw material type 3.

	• Product C requires 4 units of raw material type 1, 1 unit of raw material type 2, and 3 units of raw material type 3. In a certain month, the total usage of raw material type 1 is 20 units, raw material type 2 is 17 units, and raw material type 3 is 19 units. Questions: 1. Write the system of linear equations that represents the raw material usage for each product. 2. Determine the coefficient matrix of this system of equations. 3. Calculate the determinant of the coefficient matrix A. 4. Calculate the determinant of the replacement matrices for variables A, B, and C, and determine how many units of products A, B, and C were produced based on the raw material usage.

Procedure

Data collection in this study was conducted through four main stages. First, a pretest was administered to measure students' initial mathematical problem-solving ability on the topic of determinants. Second, metacognitive scaffolding was implemented during instruction, where students were guided through activities of planning, monitoring the process, and evaluating the results. Third, observations were carried out simultaneously throughout the learning process to record the implementation of scaffolding and students' responses. Finally, a posttest was administered after the intervention to assess the improvement of students' problem-solving abilities compared to their pretest results. This study was conducted over 5 meetings, with each meeting lasting 3x45 minutes. During the first meeting, a pretest was conducted to measure the students' initial ability. From the second to the fourth meeting, metacognitive scaffolding was applied to guide students through the learning process. In the fifth meeting, a posttest was administered to measure the improvement in students' problem-solving abilities after the implementation of metacognitive scaffolding.

Analysis

Data were analyzed using a descriptive quantitative approach and inferential statistics through several steps. First, the mean scores of the pretest and posttest were calculated and compared to identify the improvement in students' problem-solving abilities. Next, a paired t-test was used to determine whether there was a significant difference between the pretest and posttest scores of the students. Effect size (such as Cohen's d) was calculated to assess the magnitude of the impact of metacognitive scaffolding on improving students' problem-solving abilities. Second, the improvement was examined based on specific problem-solving indicators, namely understanding the problem, planning a solution strategy, carrying out the plan, and evaluating the answer. This analysis was conducted using descriptive statistics to calculate the mean, standard deviation, and comparison between the problem-solving indicators. To further understand the generalizability of the results, a 95% confidence interval was calculated for each mean difference between the pretest and posttest. Third, the observation results were interpreted to provide an in-depth description of students' responses to the implementation of metacognitive scaffolding.

Research Findings

Description of Initial Ability (Pretest)

Before the intervention in the form of metacognitive scaffolding learning was applied, a pretest was administered to measure students' problem-solving ability on the topic of

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3803 Volume 5, No 3, Juli - September 2025, pp. 1330– 1344

determinants. Based on the analysis, the average score of the students was 36.7 out of a maximum of 100, with a score range of 25–50. This confirms that the research subjects belong to the low-ability category.

Table 3. The distribution of students' pretest results

Score Interval	Frequency	Percentage	Score Category
0-20	0	0	Very Low
21-40	18	60%	Low
41-60	12	40%	Moderate
61-80	0	0	High
81-100	0	0	Very High
	30	**100%**	

The data indicate that the majority of students fall into the low (60%) and moderate (40%) categories, with none reaching the high category. This condition reinforces the initial assumption that students experience difficulties in understanding the concept of determinants and applying them in problem-solving. When viewed by problem-solving indicators (Polya), the pretest results are presented in Table 4.

Table 4. The Pretest Result by Problem Solving Indicators (Polya)

Problem-Solving	Maximum Score	Average Score	Achievement Percentage
Understanding the Problem	25	12,3	49,2%
Planning a Strategy	25	8,7	34,8%
Implementing the Plan	25	9,1	36,4%
Evaluating the Answer	25	6,6	26,4%
Total	**100**	**36,7**	**36,7%**

From the Table 4, it is evident that the Evaluating the Answer indicator has the lowest achievement (26.4%), indicating that students are not yet accustomed to reviewing the steps and solutions they have obtained.

Implementation of Metacognitive Scaffolding

After the pretest, learning was carried out using a metacognitive scaffolding strategy. The teacher implemented the steps of planning, monitoring, and evaluating in teaching the topic of determinants. This process was observed using an observation sheet.

Table 5. Observation Results of the Implementation of Metacognitive Scaffolding

Observed Aspects	Implementation Score	Average Score	Category
Planning	3,5	87,5%	Very Good
Monitoring	3,3	82,5%	Good
Evaluating	3,2	80,0%	Good
Total Average		**83,3%**	**Good**

Observation results showed that the implementation of metacognitive scaffolding was in the good category 83.3%. Teachers consistently guided students in planning solution strategies, monitoring the steps taken, and helping evaluate answers.

Description of Final Ability (Posttest)

After the treatment, students were given a posttest with the same indicators as the pretest. The analysis showed an average score increase to 74.8, with a range of 60–88. The distribution of posttest scores can be seen in Table 6.

Table 6. Distribution of Problem-Solving Ability Posttest Scores

Score Interval	Frequency	Percentage	Score Category
0-20	0	0%	Very Low
21-40	0	0%	Low
41-60	3	10%	Moderate
61-80	20	66,7%	High
81-100	7	23,3%	Very High
	30	**100%**	

Based on Table 6, it can be seen that most students are in the high 66.7% and very high 23.3% categories. The results of indicator are shown in Table 7.

Table 7. Average Posttest Scores by Problem-Solving Indicator

Problem-Solving	Maximum Score	Average Score	Achievement Percentage
Understanding the Problem	25	20,7	82,8%
Planning a Strategy	25	18,5	74,0%
Implementing the Plan	25	19,2	76,8%
Evaluating the Answer	25	16,4	65,6%
Total	**100**	**74,8**	**74,8%**

Improvements occurred in all indicators, especially in the aspect of evaluating answers, which was previously low 26.4% to 65.6%.

Inferential Statistical Analysis

To determine if the improvement in students' problem-solving ability was statistically significant, a paired t-test was conducted to compare the pretest and posttest scores. Before performing the paired t-test, assumptions of normality and homogeneity were tested. Shapiro-Wilk test was used to assess the normality of the pretest and posttest scores, and Levene's test was conducted to check for the homogeneity of variances between the pretest and posttest scores.

Shapiro-Wilk Test for Normality:

The Shapiro-Wilk test results indicated that both the pretest and posttest scores followed a normal distribution ($p > 0.05$), which satisfies the assumption of normality required for conducting the paired t-test.

Table 8. Result Test For Normality

Test	Pretest	Posttest
Shapiro-Wilk p-value	0.073	0.121

Since the **p-value** for both the pretest and posttest scores is greater than 0.05, we fail to reject the null hypothesis, meaning that the data is normally distributed.

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https://doi.org/10.51574/kognitif.v5i3.3803 Volume 5, No 3, Juli - September 2025, pp. 1330– 1344

Levene's Test for Homogeneity of Variance:

Levene's test was conducted to assess whether the variances of the pretest and posttest scores are equal (homogeneous). The results showed that the variances between the pretest and posttest scores were homogeneous ($p > 0.05$), which meets the assumption required for conducting the paired t-test.

Table 9. Result Test for Homogeneity of Variance

Levene's Test for Equality of Variances	F-value	p-value
Pretest vs Posttest	1.35	0.26

Since the p-value for Levene's test is greater than 0.05, we can assume that the variances between the pretest and posttest scores are homogeneous. After confirming normality and homogeneity of variance, the paired t-test was conducted. The results of the paired t-test are shown in the Table 10.

Table 10. Paired t-test Results

Variable	Mean Pretest	Mean Posttest	t-value	df	p-value
Problem Solving	36.7	74.8	-12.34	29	0.000

The results show that the difference between the pretest and posttest scores is statistically significant ($p < 0.05$), indicating that the intervention had a significant effect on students' problem-solving abilities.

Effect Size (Cohen's d)

To measure the magnitude of the effect, Cohen's d was calculated. The result of Cohen's d is 1.80, indicating a large effect size of the intervention.

Table 11. Result of Cohen's

Effect Size (Cohen's d)	Value
Cohen's d	1.80

This large effect size suggests that the scaffolding metacognitive intervention had a strong impact on improving students' problem-solving abilities.

Discussion

The findings of this study provide a comprehensive picture of the effect of applying metacognitive scaffolding on improving the problem-solving skills of low-ability students in mathematics, specifically on the topic of determinants. Overall, the results indicate a significant increase in students' average scores from the pretest to the posttest. This improvement was not only evident in the total achievement scores but also across each of Polya's four problem-solving indicators: understanding the problem, devising a plan, carrying out the plan, and evaluating the solution.

At the initial stage, the pretest results revealed that the average score was only 36.7 out of 100, with the majority of students falling into the low 60% and medium 40% categories. None of the students reached the high or very high categories. This confirms that the subjects of the study were consistent with the intended criteria of students with low mathematical ability. More specifically, the lowest achievement was observed in the indicator of evaluating the solution (26.4%), which indicates that students were not accustomed to reflecting on their chosen steps and solutions. This finding aligns with previous studies Gusti et al. (2021) and Mukuka et al. (2023), which emphasized that one of the most common weaknesses of students in mathematical problem-solving lies in their metacognitive ability, especially in monitoring and evaluating the problem-solving process. Thus, the low pretest scores can be understood as a reflection of students' limited ability to regulate their own thinking processes.

The implementation of metacognitive scaffolding was introduced as an intervention to address these weaknesses. The instructional process emphasized three main components: planning, monitoring, and evaluating. Observational data showed that the implementation of scaffolding was conducted at a good level (83.3%). Teachers consistently guided students in designing problem-solving strategies, monitoring their steps, and evaluating their answers. The success of this approach can be explained through Vygotsky's (1978) theory of the Zone of Proximal Development (ZPD), where scaffolding serves as external support that helps students move beyond their actual developmental level to achieve higher potential. Within this framework, metacognitive scaffolding provides students with a systematic thinking structure, enabling them not only to solve problems technically but also to develop awareness and control over their own thought processes (Dassa et al., 2024; Haataja et al., 2019; Menekse et al., 2025).

Following the treatment, the posttest results showed a highly significant improvement. The average score increased to 74.8, with most students falling into the high (66.7%) and very high (23.3%) categories. No students remained in the low or very low categories. Statistical analysis further confirmed that this improvement was not due to chance. The Shapiro-Wilk and Levene's tests showed that the data met the assumptions of normality and homogeneity, making the use of a paired t-test appropriate. The paired t-test results indicated a statistically significant difference between the pretest and posttest scores ($t = -12.34$, $p < 0.001$), confirming that the intervention had a real impact on students' problem-solving abilities. Moreover, the effect size (Cohen's $d = 1.80$) was categorized as large, suggesting that metacognitive scaffolding had a strong and meaningful impact on students' mathematical performance.

The improvement in the indicator of understanding the problem (from 49.2% to 82.8%) was also particularly significant. This suggests that metacognitive scaffolding helped students identify relevant information more carefully, distinguish between facts and assumptions, and clearly define the problem. Such improvement is crucial, as understanding the problem is the foundation for subsequent steps in problem-solving. Without adequate comprehension, strategies and solutions are unlikely to be effective.

More specifically, all four of Polya's indicators showed notable improvement. The indicator of evaluating the solution, which had previously scored only 26.4%, rose to 65.6%. This result indicates that students began to develop the habit of reflecting on their steps and solutions—a core aspect of metacognitive skills. This is consistent with Flavell (Hasan, 2020), who emphasized the role of metacognition in directing individuals to assess, regulate, and control their own thinking processes. The improvement in the indicator of understanding the problem (from 49.2% to 82.8%) was also particularly significant, suggesting that metacognitive scaffolding helped students identify relevant information more carefully, distinguish between facts and assumptions, and clearly define the problem. Similarly, the indicators of devising a plan (74.0%) and carrying out the plan (76.8%) showed substantial progress. Through scaffolding, teachers not only provided technical guidance but also encouraged students to consider alternative strategies and select the most appropriate ones. These findings supportSaputra et al. (2024) and Talib et al. (2024), who reported that metacognitive scaffolding in mathematics instruction enhances students' ability to formulate questions, plan strategies, and evaluate their own work.

Taken together, the improvement across all indicators demonstrates that metacognitive scaffolding is effective in fostering students' thinking awareness and self-regulation. This is particularly important for low-ability learners, who often struggle to organize problem-solving

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3803 Volume 5, No 3, Juli - September 2025, pp. 1330– 1344

steps and tend to give up when faced with complex tasks. Scaffolding provided them with systematic guidance that structured their thinking process, thereby boosting their confidence in tackling mathematical problems.

Beyond cognitive gains, the observed improvements can also be linked to motivational aspects. Instruction using metacognitive scaffolding, which emphasizes students' active involvement in planning, monitoring, and evaluating, likely enhanced their intrinsic motivation. According to self-determination theory (Ambarwati & Wahyuni, 2023; Hasan, 2020), involving students in decision-making and self-assessment fosters autonomy, competence, and social relatedness, which in turn strengthens learning motivation. Supporting this, student interviews revealed that they felt more confident and motivated when they had opportunities to monitor and evaluate their own learning processes.

These findings carry important implications for mathematics education. First, metacognitive scaffolding has proven effective in supporting low-ability learners to enhance their problem-solving skills, a competency often considered part of higher-order thinking skills and traditionally seen as challenging to achieve. Second, the approach aligns with the objectives of the Indonesian Merdeka Curriculum, which emphasizes independent learning, reflection, and critical thinking. Thus, this study recommends that teachers integrate metacognitive scaffolding into regular classroom practice. From a theoretical perspective, the results strengthen the view that mathematics education should not only focus on mastering concepts and procedures but also on developing students' awareness and control of their thinking processes. This aligns with Flavell's concept of metacognition, which highlights the importance of monitoring and regulation in successful learning. Therefore, metacognitive scaffolding can be seen as a crucial strategy for bridging the gap between cognitive and metacognitive skills, particularly in the context of mathematical problem-solving (Kuswanti et al., 2018; Nuralam et al., 2023).

It should also be noted, however, that the success of metacognitive scaffolding heavily depends on the consistency and skill of teachers in delivering appropriate support. Teachers must be able to adapt scaffolding to students' individual needs and gradually reduce assistance as students develop independence. Consequently, effective implementation of this strategy requires teacher training and a strong understanding of metacognitive principles.

Conclusion

The findings of this study demonstrate that the implementation of metacognitive scaffolding had a significant and powerful effect on improving the problem-solving abilities of low-ability students in learning the concept of determinants. The average score increased from 36.7 on the pretest to 74.8 on the posttest, with most students shifting from the low and moderate categories to the high and very high categories. Inferential analysis confirmed that this improvement was statistically significant, as indicated by the paired t-test ($t(29) = -12.34$, $p < 0.001$), while Cohen's $d = 1.80$ reflected a very large effect size. Improvements were consistently observed across all of Polya's problem-solving indicators, with the evaluation stage showing the most substantial progress, suggesting that scaffolding effectively trained students to reflect on their strategies and solutions. Beyond cognitive gains, the intervention also fostered confidence, active engagement, and intrinsic motivation, as students became directly involved in planning, monitoring, and evaluating their learning. Therefore, metacognitive scaffolding not only enhances mathematical problem-solving skills but also cultivates metacognitive awareness and self-regulation, aligning strongly with the objectives of the Merdeka Curriculum in promoting critical, reflective, and independent learning. Nevertheless, this study is limited by its relatively small sample size, focus on a single topic (determinants), and short duration, which restrict the generalizability and long-term conclusions of the findings. Future research should therefore involve larger and more diverse samples, apply scaffolding to other mathematical domains, and adopt longitudinal approaches to examine the sustainability of students' metacognitive skills over time.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

A. conceptualized the research idea presented and collected the data. The other Four authors (S., M.A.N., N.N and M.N.H.) actively contributed to the development of the theory, methodology, data organization and analysis, discussion of the results, and approval of the final version of the work. All authors confirm that they have read and approved the final version of this manuscript. The percentage contributions for the conceptualization, drafting, and revision of this paper are as follows: A.: 30%, S.: 20%, M.A.N.:20%, N.N.:20% and M.N.H.: 10%.

Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, [A], upon reasonable request.

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