Pasundan Journal of Mathematics Education Volume 15, No. 2, 2025, pp. 102-115

Mathematical problem-solving ability of junior high school students in terms of self-directed learning

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Abstract

Self-directed learning (SDL) is a crucial factor that can significantly improve students' math problem-solving abilities (MPSA), particularly in 21st-century education, which emphasizes independence and critical thinking. This study aims to compare the math problem-solving abilities of junior high school students based on their self-directed learning categories. The research used a mixed-methods approach with a sequential explanatory design. It began with a quantitative phase, analyzing 82 eighth-grade students from one of the public junior high schools in West Bandung Regency through a problem-solving test and an SDL questionnaire. This was followed by a qualitative phase involving semi-structured interviews with three selected participants. The statistical results from the Welch test and Games-Howell post hoc analysis showed significant differences in math problem-solving abilities among students with high, moderate, and low SDL categories. The qualitative findings supported these results, indicating that students with high SDL were better at understanding problems, developing strategies, and reflecting independently on solutions. In contrast, students with low SDL displayed limitations in these areas. This study highlights the importance of adopting learning approaches that foster SDL in math education to enhance students' problem-solving skills comprehensively. It also provides a theoretical contribution toward developing more adaptive, student-centered math learning strategies tailored to individual needs in 21st-century education.

Keywords: mathematics learning, mixed-method, problem-solving skills, self-directed learning, sequential explanatory design.

How to Cite: Rami, D. R., & Achiaa, A. (2025). Mathematical problem-solving ability of junior high school students in terms of self-directed learning. Pasundan *Journal of Mathematics Education, 15*(2), 102-115. http://doi.org/10.23969/pjme.v15i2.34279

INTRODUCTION

Problem-solving ability is a crucial skill in 21st-century mathematics education, essential for preparing students to tackle real-world challenges. The National Council of Teachers of Mathematics (NCTM) has recognized problem-solving as one of the five process standards in mathematics learning because of its vital role in addressing real-life issues (Szabo et al., 2020). Thanheiser (2023) highlights that mathematics is not just about numbers but a way of thinking and solving problems by analyzing relationships and patterns. Therefore, meaningful mathematics learning should focus not only on the final answer but also on engaging in logical and exploratory thinking that actively develops problem-solving skills.

However, numerous previous studies indicate that the mathematical problem-solving abilities of junior high school students in Indonesia remain relatively low (Nur & Palobo, 2018; Indriana & Maryati,

http://doi.org/10.23969/pjme.v15i2.34279

2021; Setyaningsih & Firmansyah, 2022). Findings from these studies suggest that students struggle with understanding problem contexts, formulating logical solution strategies, and evaluating solutions thoroughly. Other studies by Resmiati & Hamdan (2019) and Widiastuti et al. (2018) further highlight students' weaknesses in interpreting information, choosing appropriate approaches, and reflecting on errors during the problem-solving process. This situation shows that students' cognitive and metacognitive potential have not been fully utilized in the mathematics learning process.

Various studies have explored factors affecting mathematical problem-solving abilities, including cognitive style, gender (Nur & Palobo, 2018; Yudiawati et al., 2021), learning motivation (Hafidz et al., 2019), emotional intelligence (Fuadi et al., 2015), problem-based learning (Kania et al., 2020; Yaniawati et al., 2019), learning strategies (Sari et al., 2019), and self-efficacy (Imaroh et al., 2021). One internal factor gaining more attention is self-directed learning (SDL), which is a student's ability to independently manage, motivate, and direct their learning process (Gibbons, 2002; Chee et al., 2011). According to Morris et al. (2023), SDL involves individuals taking the initiative, with or without assistance, to identify their learning needs, set goals, choose and apply learning strategies, and assess their learning outcomes.

SDL is important in math education because the subject requires independent thinking, exploring solutions, and perseverance when facing uncertainty (Loeng, 2020). Through SDL, students learn to recognize their strengths and weaknesses, allowing them to customize their strategies for solving math problems. The aspects of SDL, such as ownership of learning, self-management and monitoring, and extension of own learning, offer a solid framework for creating instruction that promotes self-reflection and learner independence (Chee et al., 2011).

Although the importance of promoting SDL in mathematics education is widely recognized, its implementation at the junior high school level remains inadequate. Several studies indicate that variations in SDL categories can explain differences in students' mathematical problem-solving abilities (Mayasari & Rosyana, 2019; Prabawanto, 2013). Hofmeyer (2016) even suggests that problem-solving is unlikely to happen without SDL. The findings of a study by Amaliyah et al. (2020) support this view, showing that applying SDL has a positive effect on students' mathematical problem-solving abilities.

However, studies that explicitly connect SDL categories to mathematical problem-solving ability, especially among junior high school students, are still quite limited (Hofmeyer, 2016; Resmiati & Hamdan, 2019). Previous research has mostly looked at these two variables separately without thoroughly exploring how they relate to each other, particularly within the problem-solving stages outlined by Polya (1973) and adapted by Prabawanto (2013) in the Indonesian education context. This gap highlights the need for studies that link SDL with problem-solving skills to develop more comprehensive and evidence-based teaching recommendations.

Therefore, this study aims to explore the differences in the mathematical problem-solving skills of junior high school students based on their SDL categories. The findings are expected to strengthen the theoretical foundation of the link between SDL and problem-solving. Additionally, they are intended to lay the groundwork for developing adaptive learning strategies that foster learning autonomy and improve critical thinking skills, which are highly relevant for addressing the challenges of 21st-century education (Szabo et al., 2020; Morris et al., 2023).

METHODS

This study used a mixed-methods approach with a sequential explanatory design. This design involves an initial phase of collecting and analyzing quantitative data, followed by a phase of gathering and examining qualitative data to explain better the quantitative findings (Creswell & Plano Clark, 2018). This method provided a comprehensive understanding of students' mathematical problem-solving abilities, especially regarding their self-directed learning (SDL) categories. The explanatory approach not only identifies significant differences but also explores the reasons and mechanisms behind these differences in the context of mathematics learning based on student autonomy. The sequential explanatory design is shown in the following figure.

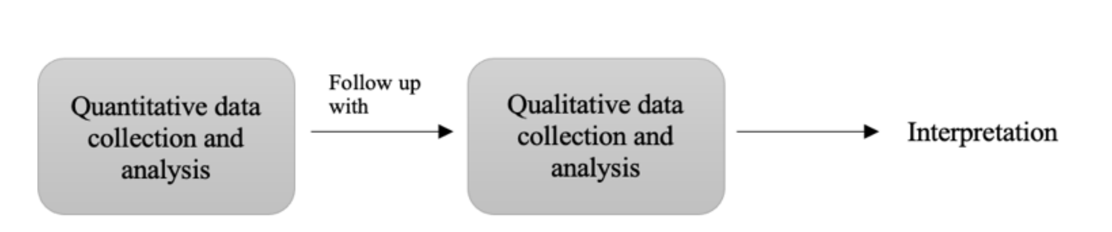
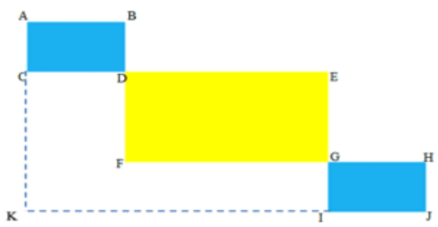


Figure 1. The Sequential Explanatory Design

This research was conducted at a public junior high school in West Bandung Regency. The population consisted of all eighth-grade students, and 82 students were randomly selected using a simple random sampling procedure through a computerized randomization process. This method was chosen due to the homogeneity of the population's characteristics, which forms the basis for its selection (Yaniawati & Indrawan, 2024). Afterward, in the qualitative phase, three students were purposively selected based on their SDL category (high, moderate, low) for in-depth analysis. Quantitative data collection took place over one month, while qualitative interviews were conducted over two weeks.

In the quantitative phase, data were collected using two main instruments: (1) a math problem-solving ability test and (2) an SDL questionnaire. The test included four essay questions designed to represent each indicator of problem-solving ability as proposed by Prabawanto (2013), with the solution process aligned with the steps outlined by Polya (1973). Before the test was run, it was piloted and evaluated for validity and reliability. Content validity was established through expert judgment involving a mathematics education lecturer, a mathematics teacher, and a psychology lecturer. The experts evaluated each item in terms of clarity, relevance, and alignment with the intended construct, and revisions were made based on their feedback. The empirical validity coefficients for the test items were as follows: Item 1 is 0.712 (high category), Item 2 is 0.893 (high category), Item 3 is 0.868 (high category), and Item 4 is 0.547 (moderate category). Reliability, measured with Cronbach's Alpha, with an alpha coefficient of 0.706, indicates high reliability. This math problem-solving test focused on the topic of the Pythagorean Theorem, as shown in the following table.

Table 1. Mathematical Problem-Solving Ability (MPSA) Test Items

No	Indicator	Problem
1	Solving a closed mathematical problem inside a mathematical context	

		It is known that the ABCD and GHIJ rectangles have a length of 8 cm and a width of 6 cm. The DEFG rectangle has a length and width that are twice the length and width of the ABCD rectangle. If you are going to form an AKJ right triangle, then explain how to determine the length of AJ!
2	Solving an open-ended mathematical problem inside a mathematical context	It is known that two right triangles are different by one corresponding side. If the side of the triangle is 12 cm long, then sketch an approximate drawing and explain how to determine the lengths of the other sides, which must be integers!
3	Solving an open-ended mathematical problem outside a mathematical context	Samudra will build a fence for his land. The fence will surround a triangular area with a base of 12 meters and a height of 16 meters, made using iron wire and wood, as shown in the following picture.  The blue line represents iron wire, while the brown line represents wood. Sketch approximately two fence patterns of that size, then explain how long the wire needs to go around each fence pattern!
4	Solving a closed mathematical problem outside a mathematical context	Toni was on top of a 40-meter-high building. When he looked toward the sea, he saw two ships, let's call them Ship A and Ship B. Toni's distances from Ship A and Ship B were 50 meters and 104 meters, respectively. The positions of Ship A, Ship B, and the building where Toni was located were in a straight line. Make a rough sketch of the situation described! Then, explain how to find the distance between Ship A and Ship B!

Subsequently, the SDL questionnaire included 12 statement items using a semantic differential scale. This tool was created to assess students' SDL categories within the context of mathematics learning, based on the dimensions proposed by Chee et al. (2011). The questionnaire was validated by two experts, piloted, and tested for reliability. The reliability coefficient was 0.873, which is considered high. Based on these findings, this SDL questionnaire was deemed suitable for use in the study. The dimensions of SDL used in the research are listed in the table below.

Table 2. Dimensions of self-directed learning (SDL)

No	**Dimensions of *Self directed learning***	**Indicator**
1	*Ownership of Learning*	a) Students set their own learning goals b) Students identify study tasks to achieve their learning goals c) Students structure their learning process d) Students challenge themselves to achieve their learning goals e) Students set their learning standards

2	*Self-management and self monitoring*	a) Students ask relevant questions to help them learn b) Students explore every possible answer to make informed decisions c) Students plan their own learning d) Students set their own study time e) Students critically reflect on their learning by collecting feedback from teachers
3	*Extension of own learning*	a) Students apply what they have learned into a new context b) Students use skills that have been acquired outside of learning activities

The SDL categories (high, moderate, and low) were determined using calculations of the mean and standard deviation, following the methodology used by Muhammad et al. (2021). The criteria for SDL categorization are provided in the following table.

Table 3. SDL categories

Interval	Category
$x_i > (\underline{x} + s)$	High
$(\underline{x} - s) \leq x_i \leq (\underline{x} + s)$	Moderate
$x_i < (\underline{x} - s)$	Low

Notes :
x_i = student's SDL score
$\underline{x}$ = an average student's SDL score
s = the standard deviation of a student's SDL score

Next, the quantitative data were analyzed using One-Way ANOVA techniques to determine whether there are significant differences in mathematical problem-solving abilities among student groups with different SDL categories (Yaniawati & Indrawan, 2024). Subsequently, the qualitative stage was conducted through semi-structured interviews with students purposively selected from each SDL category (high, moderate, low), aiming to obtain narrative data that explain the statistical findings, especially the patterns that emerge from the quantitative analysis. This technique allows researchers to explore more deeply learning strategies, internal motivation, and students' challenges in solving math problems. Triangulation techniques were used to compare qualitative data with quantitative results to gain a more comprehensive understanding of SDL categories and problem-solving abilities (Yaniawati & Indrawan, 2024).

RESULTS AND DISCUSSION

The SDL data analyzed in this study will be categorized into three categories: high, moderate, and low. The SDL data processed yielded an average of 68.95 with a standard deviation of 14.13, which is then used as the basis for categorizing SDL (Muhammad et al., 2021). The categories of SDL scores and student grouping are presented as follows.

Table 4. Categories and groupings of students based on SDL categories

Interval	Category	Total Students
SDL score > 83	High	13
55 ≤ SDL Score ≤ 83	Moderate	57
SDL Score < 55	Low	12

Before conducting a deeper analysis with qualitative data, a preliminary quantitative calculation involving statistical tests was performed to determine if there are significant differences in students' mathematical problem-solving abilities based on high, moderate, and low SDL. However, descriptive statistics are presented first as follows.

Table 5. Descriptive statistics of students' MPSA based on SDL categories

SDL Categories	Mean	Std. Dev	N
High	77,50	9,886	13
Moderate	61,23	15,038	57
Low	39,62	20,863	12

Next, normality and homogeneity tests were conducted. Since the data on students' mathematical problem-solving abilities were normally distributed but did not have homogeneous variances, an alternative test to the one-way ANOVA was performed, namely the Welch test or Brown-Forsythe test (Yaniawati & Indrawan, 2024). The results are presented as follows.

Table 6. Alternative ANOVA Test Based on SDL

Robust Tests of Equality of Means				
Mathematical Problem-Solving Abilities				
	Statistic[a]	df1	df2	Sig.
Welch	20.370	2	22.572	.000
Brown-Forsythe	17.662	2	22.610	.000
a. Asymptotically F distributed.				

From Table 6, it can be seen that the Welch Test or Brown-Forsythe Test shows a Sig. Value < 0.05, indicating that there is a significant difference in students' mathematical problem-solving abilities based on SDL categories. Next, a post hoc test (follow-up test) was conducted to determine which groups differ from each other. The post hoc test used is the Games-Howell Test. The Games-Howell Test is used when the data variances are not homogeneous (Yaniawati & Indrawan, 2024). The results of the post hoc test are presented in the following table.

Table 7. Post Hoc Test Based on SDL

	(I) Categories	(J) Categories	Mean Difference (I-J)	Std. Error	Sig.
Games-Howell	Low	Moderate	-21.613*	6.120	.008
		High	-37.885*	6.452	.000
	Moderate	Low	21.613*	6.120	.008
		High	-16.272*	3.480	.000
	High	Low	37.885*	6.452	.000
		Moderate	16.272*	3.480	.000

From Table 7, it is known that the overall Sig. Value < 0.05, indicating significant differences in mathematical problem-solving abilities among students with high, moderate, and low SDL. Students with high SDL in mathematics learning can form their own opinions and decisions, seek information from learning sources, plan independent learning strategies, face or solve problems, and assess the learning outcomes they achieve (Manaud et al., 2024; Lee & Chang, 2024; Bishara, 2021).

Next, the data were analyzed more thoroughly by conducting semi-structured interviews with students who were purposefully selected from each SDL category (high, moderate, low). Information about the three research subjects is presented in the following table.

Table 8. Data of Research Subjects

Number	Initial	SDL Categories
1	S1	High
2	S2	Moderate
3	S3	Low

Subject S1

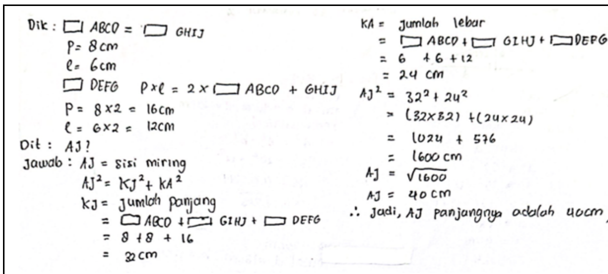


Figure 2. Test Result of S1 on Indicator 1

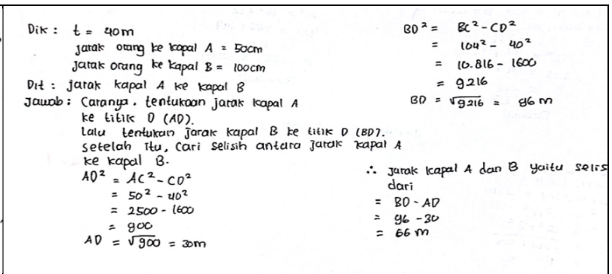


Figure 3. Test Result of S1 on Indicator 4

Based on Figures 2 and 3, S1 presents a correct, complete, and clear answer. Figure 2 shows the response to a closed problem in mathematics, while Figure 3 displays the answer to a closed problem outside mathematics. Both figures demonstrate that S1 can understand and solve closed mathematical problems easily. This aligns with the interview results with S1, which describe how he arrived at the answer, reflecting a deep understanding of problem-solving. S1 explains starting with how he comprehends the questions, identifying usable information, applying problem-solving methods, and rechecking the solutions. This is consistent with research by Muhammad et al. (2021) and Morris (2019), which indicates that students with high self-directed learning can understand problems, plan solutions, execute calculations as planned, and review their work results.

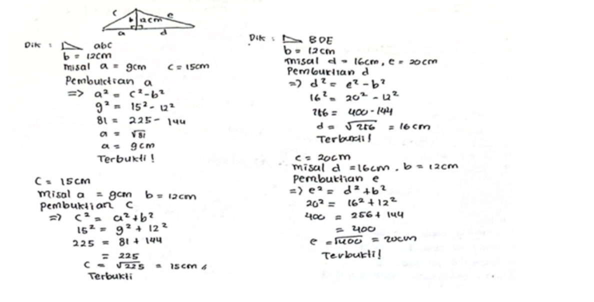


Figure 4. Test Result of S1 on Indicator 2

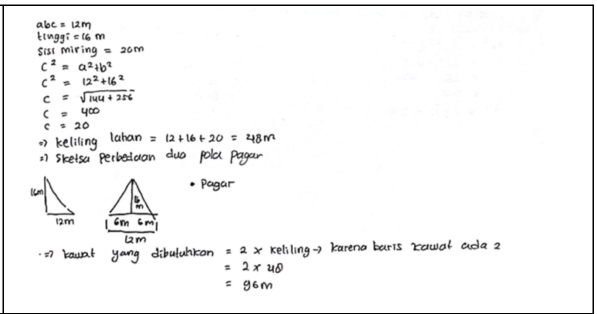


Figure 5. Test Result of S1 on Indicator 3

Based on Figure 4, S1 demonstrates an understanding of the given problem. Figure 4 is the solution to an open problem in mathematics. S1 not only followed the procedure correctly but also tried several combinations of triangle side lengths and tested their correctness using the Pythagorean theorem formula. This process demonstrates S1's capability to understand the problem, plan the solution steps, perform calculations, and verify the results by comparing the prediction with the final answer. As Zahrona & Chaniago (2021) stated, students with high self-directed learning (SDL) can meet the overall indicators of problem-solving ability. However, at the end of the task, S1 does not explicitly conclude what the solution is. The following is an excerpt from the interview between the researcher (R) and S1.

R: "*How did you get a solution to this problem*?"

S1: "*I tried some numbers that seemed to fit the sides... The problem is that he insists he has to be right-handed. So I checked using the Pythagorean theorem. If it fits, it means it is right. However, I did not write the conclusion because I thought I had already figured it out from the calculation*."

Figure 5 provides an answer to an open problem outside of mathematics, in which students are asked to analyze the need for the length of the fence (made of iron wire and wood) that surrounds the triangular land. S1 understood that this problem was related to the circumference of a triangle. His first step was quite systematic: he drew a sketch of the triangle, determined the oblique side using the Pythagorean theorem, and summed the lengths of all sides to find the circumference (12 + 16 + 20 = 48 meters). Students with high SDL can understand problems, take systematic steps, and answer questions (Li et al., 2021). Although S1 can present two models of fence sketches, he does not explain the possible circumference of the alternative fence shape (second pattern) that he made.

Based on the analysis of the answers and interviews of undergraduate students from Figures 4 and 5, it shows that students with high self-directed learning (SDL) are capable of making their own decisions to solve problems and designing problem-solving strategies on their own initiative. This reflects the characteristics of active and responsible students in the learning process, as expressed by Hofmeyer (2016), that students with high SDL tend to form their own opinions and decisions, seek learning sources proactively, design independent learning strategies, face challenges, and evaluate their learning outcomes reflectively. However, although undergraduate students demonstrate strong independence in solving routine or structured problems, they still face difficulties in solving open-ended problems. Open-ended problems require high cognitive flexibility, such as the ability to think analogically and reactive flexibility; these problems do not have a single correct answer, thus demanding creativity and the ability to manage uncertainty (Cui et al., 2023). This may occur because students are not accustomed to being trained to solve open-ended problems. Therefore, more targeted learning strategies are needed to train students in handling open-ended problems within the context of mathematics learning.

Subject S2

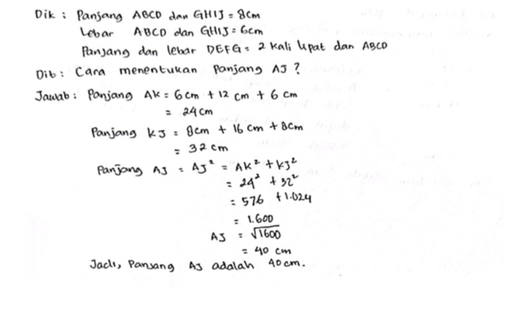


Figure 6. Test Result of S2 on Indicator 1

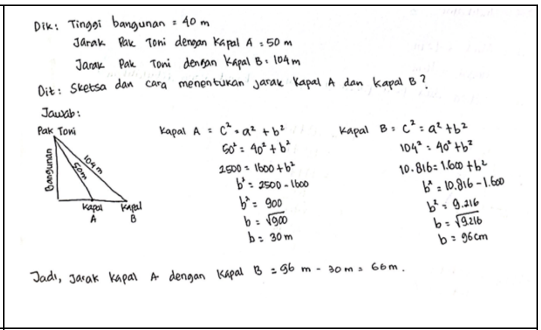


Figure 7. Test Result of S2 on Indicator 4

Subject S2 has fairly good mathematical problem-solving abilities, especially in closed-ended questions that are familiar. This is evident in Figures 6 and 7, where the subject can understand the information, determine the appropriate formula, and solve the problem systematically. For example, in Figure 6, the subject correctly uses the Pythagorean theorem to solve the problem. In Figure 7, they can read the context of the boat situation and depict it in the form of a triangle before performing calculations. This aligns with Zahrona & Chaniago (2021), who state that students with limited problem-solving skills can only meet indicators such as understanding the problem, planning the problem-solving process, and implementing solutions. Furthermore, this is supported by the following interview results.

R: "*How do you solve problem number 1*?"

S2: "*I first noticed there was a triangle, then I knew the lengths of two sides, so I remembered the Pythagorean formula. I wrote it out using the Pythagorean theorem, entered the numbers, and kept calculating until I found the hypotenuse*."

R: "*Why are you sure it is the right formula to use*?"

S2: "*The problem is that the shape of the triangle is right-angled, so you must use Pythagoras*."

R: "*After you find the solution, how can you be sure that your answer is correct*?"

S2: "*I will double-check and recount to make sure*."

The statement reflects that Subject S2 has a sufficiently systematic procedural approach. They show initiative to verify results even in a simple form (recalculating). For multiple-choice questions, S2 can complete them well. This is because multiple-choice problems rely more on spatial working memory and retrieving previously known information, usually having one correct solution, and the problem-solving process is more structured (Cui et al., 2023).

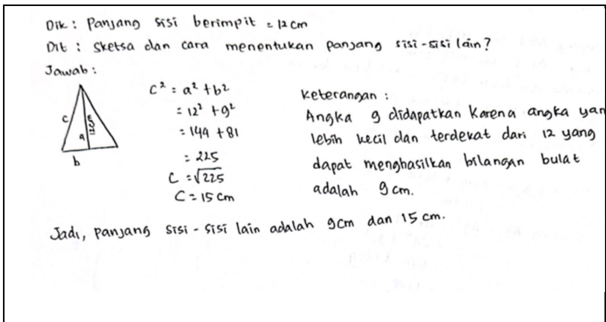


Figure 8. Test Result of S2 on Indicator 2

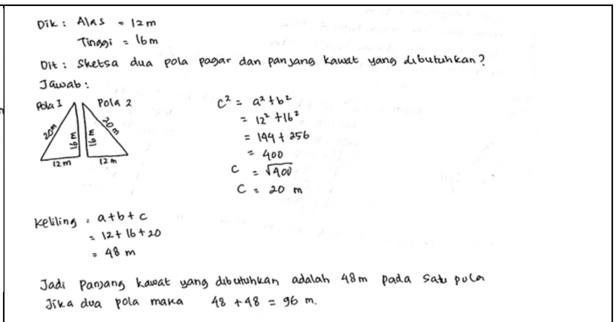


Figure 9. Test Result of S2 on Indicator 3

The difficulty of the S2 subject is reflected in students' answers, which are still not precise in addressing the problems in indicator 2 (Figure 8) and indicator 3 (Figure 9). Both of these problems are part of the open-ended mathematical task. In indicator 2, students draw a triangle and use the

Pythagorean theorem, but their choice of side lengths is less logical based on the theorem. Although they can complete the calculations correctly, their decision-making process is neither logical nor systematic. In indicator 3, students can describe the shape of the triangle and calculate the circumference of the fence wire. However, they have not yet reached the reflective stage to verify whether their procedures are appropriate for the problem. This aligns with the research by Millah (2021) and Lubis et al. (2023), which states that students with moderate SDL only meet a few problem-solving indicators.

Subject S3

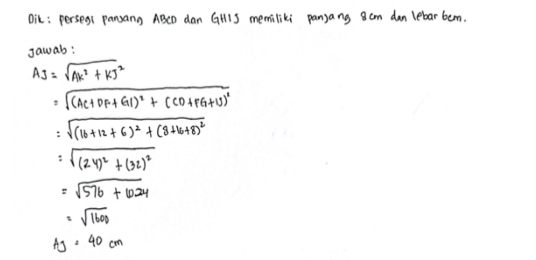


Figure 10. Test Result of S3 on Indicator 1

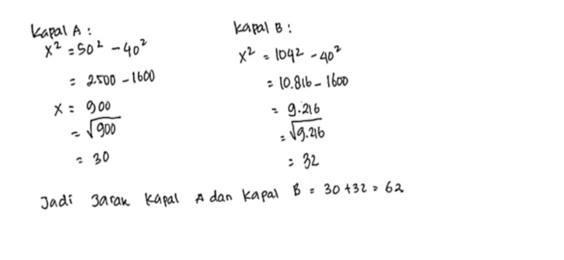


Figure 11. Test Result of S3 on Indicator 4

In Figure 10, S3 correctly solves the problem of calculating the slanted side of the triangle. He demonstrates a good understanding of Pythagorean formulas and shows thoroughness in his calculations. This suggests that S3 has solid procedural understanding when the information in question is fully and clearly conveyed. Consistent with the interview results, S3 stated, "*The problem is clear. There is already a length and width measurement. So enter it into the formula*." This suggests that students often rely on experience with similar questions and are not accustomed to taking initiative or exploring new or open-ended problems. Similarly, Zahrona & Chaniago (2021) noted that students with low SDL only meet the basic indicators of understanding the problem. Meanwhile, in Figure 11, students demonstrate their initial ability to model real-world situations with mathematics. However, the modeling process remains imprecise. For example, when calculating the distance between two ships, students can set up equations but struggle to apply the concept of Pythagoras thoroughly. This aligns with Muhammad et al. (2021), who found that students with low SDL often do not fully meet problem-solving requirements indicators.

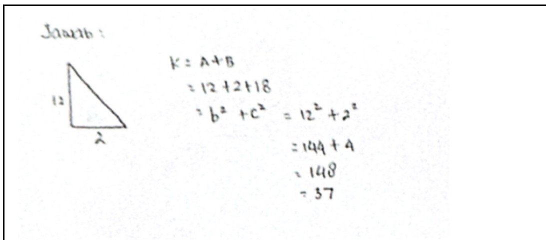


Figure 12. Test Result of S3 on Indicator 2

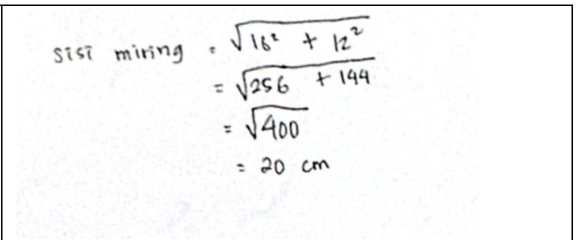


Figure 13. Test Result of S3 on Indicator 3

In indicators 2 and 3, students are expected to develop their strategies, create sketches, and explain their thinking process. Although students attempt to solve the problem by counting sideways (Figures 12 and 13), they fail to provide the necessary explanation or justification. The sketch is incomplete, and students only apply formulas without demonstrating a logical connection to the information in the problem. The results of the S3 interview also showed that when solving problems 2 and 3, S3 said the word "*confused*" more than three times. The student's lack of preparation in building strategies and justifications indicates they do not yet have strong metacognitive control. Low SDL fails to meet the full troubleshooting indicators (Lubis et al., 2023; Muhammad et al., 2021; Amaliyah et al, 2020).

Based on the results of the quantitative and qualitative data analysis presented, it can be concluded that there are differences in mathematical problem-solving abilities among students with different SDL categories. Students with high SDL demonstrate fulfillment of all problem-solving indicators, including understanding the problem, designing strategies, carrying out calculations, and verifying and reflecting on the solutions obtained, both in closed and open problems (Muhammad et al., 2021; Zahrona & Chaniago, 2021). However, there are still some minor difficulties in solving open-ended problems. Meanwhile, students with moderate SDL tend only to be able to solve closed problems and some indicators of open problem-solving, especially in planning and implementation aspects, but lack in reflective and logical decision-making aspects (Millah, 2021; Lubis et al., 2023). Students with low SDL generally can only meet initial indicators, such as understanding the problem, and have difficulty developing strategies, evaluating solutions, and justifying the procedures used (Amaliyah et al., 2020).

This difference can be seen in the characteristics of SDL itself. Students with high SDL demonstrate strong learning initiative, independence, and reflective skills, making them more prepared to handle both closed and open problems, although they still struggle with non-routine questions due to a lack of practice (Shadiev & Aksal, 2024; Tanudjaya & Doorman, 2020). Students with moderate SDL can manage information and show some reflection but still depend on guidance, making it easier for them to solve routine problems compared to open-ended ones that require flexibility (Wong & Kan, 2022). Meanwhile, students with low SDL exhibit inadequate learning management skills and lack confidence in the absence of teacher guidance, and possess minimal reflective abilities, leading to significant challenges at almost every stage of problem-solving (Bhandari et al., 2020).

The findings of this study provide practical implications for teachers in enhancing students' self-directed learning (SDL) as a foundational skill for mathematical problem-solving. Teachers need to consistently integrate learning approaches that encourage learning initiative, such as problem-based learning (Zahrona & Chaniago, 2021), and the use of digital media (Chee et al., 2011; Lee & Chang, 2024; Shadiev & Aksal, 2024). Additionally, teachers should also get students accustomed to open-ended questions (Tanudjaya & Doorman, 2020; Cui et al., 2023). Through these steps, teachers not only enhance mathematical skills but also prepare students with the basic independence in learning necessary to tackle the challenges of 21st-century education.

CONCLUSION

This study's findings indicate that students' mathematical problem-solving abilities differ based on SDL categories. Students with high SDL excel at understanding problems, developing solutions, applying strategies, and reflecting on their results. However, they still encounter difficulties with open-ended questions. Students with low SDL often struggle to create strategies, organize information, and justify their solutions logically. Interview results support these findings, showing that students with high SDL are motivated, control their own learning, and are skilled at solving math problems. In contrast, students with low SDL rely more on specific question details and demonstrate limited reflective thinking and independent decision-making. These findings theoretically reinforce the view that self-directed learning fosters metacognitive awareness and independent reasoning in mathematics. Therefore, this research emphasizes the crucial role of SDL in enhancing middle school students' math problem-solving abilities. Consequently, teachers and math curriculum designers are encouraged to adopt methods that promote independent learning, such as problem-based learning, practicing open-ended questions, and using media that foster exploration, particularly within the context of 21st-century skills education. Future research is recommended to employ experimental or longitudinal approaches to further examine the causal relationship between SDL and mathematical problem-solving performance.

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