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Review Article

Mathematical Critical Thinking Profile Of Students On Pisa Framework Space And Shape Content Questions Reviewed From Self-Efficacy

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ARTICLE INFO | **ABSTRACT**

The critical thinking skills of students in Indonesia are still low. This is attributed to teachers emphasizing solving mathematical problems with given formulas. Therefore, the PISA framework's space and shape content was used in this study to test students' abilities to identify similarities and differences in different objects, analyze the components of objects, and recognize different dimensions and representations. This research aims to describe and obtain students' cognitive knowledge at each stage of the mathematical critical thinking ability in working on PISA's space and shape content framework problems. The five indicators of mathematical critical thinking skills used are demonstrating problem understanding, explaining arguments according to mathematical concepts, using appropriate problem-solving methods, providing systematic modeling or explanations, and using alternative solutions in problem-solving. This qualitative research employed a grounded theory approach. Data were obtained through self-efficacy questionnaires, critical thinking ability tests on spatial geometry, and interviews. The self-efficacy questionnaire results were analyzed and categorized (high, medium, and low), with two students selected from each category as subjects. The research finding show that the indicator of using alternative solutions in mathematical problem-solving is not fulfilled in all three subject categories, which have high, medium, and low self-efficacy. Another aspect found in this study is the need for optimalization of reflective thinking for critical inquiry (contemplating) with effective communication among students or groups. This is necessary for identifying problems, detecting the correctness and errors of answers, and correcting them to draw accurate conclusions.

Keywords: Critical Thinking; Self-efficacy; PISA; FRISCO; Qualitative; Space and Shape.

Introduction

The ability to think will form intelligent students capable of solving every problem they face. It is related to the essence of education, which is to humanize highly potential human beings during the learning process as it involves direct interaction with students (Darma et al, 2015). Therefore, thinking skills encourage students to be skilled and have the disposition they need to face new challenges in the (Weinstein & Preiss, 2017), whether academically, personally, or morally (Wegerif et al., 2015; Keskin, 2015). Mathematics is one of the subjects that can cultivate high-level thinking skills, where students are required to find answers, use information, and explain arguments about problem solutions. It aligns with the statement by Kartin et al (Kartin et al., 2015) that mathematics can train critical, logical, systematic, and creative thinking.

Critical thinking is one of the high-level thinking skills, so students are expected to have good mathematical competence. However, in reality, the development of High Order Thinking Skills (HOTS) and High Order Mathematical Thinking (HOMT) in mathematics has not been optimal (Rusinah et al., 2017; Yuliati & Lestari, 2018; Gradini et al., 2022). As a result, Indonesian students' ability to identify new problems, solutions, or ideas to solve them and the flexibility of problem-solving procedures are still low (Marzuki et al., 2021), and they tend to focus more on memorizing mathematical concepts (Firdaus et al., 2015). It leads to students having difficulty constructing contemporary mathematics, where knowledge is created of students through reflection processes, both physical and mental actions (Moseley et al., 2005). Furthermore, the 2018 PISA (Program for International Student Assessment) study results showed that Indonesian students' mathematics proficiency score was 379, which is still below the OECD average of 489 (Schleicher, 2019).

The acquisition of those scores indicates that the mathematical ability of Indonesian students is deficient. The low PISA scores are due to Indonesian students' difficulty formulating everyday problems into formal expressions, understanding mathematical structures, applying mathematical information, evaluating results, and interpreting solutions (Jupri & Drijvers, 2016; Febrianti & Nurjanah, 2022). The factors causing students' errors in solving PISA questions are their low reasoning and creativity in solving and translating real-world contextual problems into mathematical form (Annizar et al., 2020). One of the PISA contents, namely the ability of students to solve geometry problems, especially in space and shape content, is crucial in developing critical thinking in real-life contexts (Pereira et al., 2022). Furthermore, students' comprehension of the provided PISA questions is still meager (Ismail, 2018). Therefore, considering the results of the PISA, Indonesian students are urged to reflect on themselves and improve their mathematical abilities. Fauzi & Abidin (Fauzi & Abidin, 2019) revealed that PISA questions demand problem-solving skills and reasoning abilities. A student can be said to effectively reason if they can apply their knowledge to new conditions they have never encountered before. This ability is commonly known as critical thinking.

Critical thinking ability is an activity stimulated by specific reasons and aimed at making decisions with an open mind and new evidence that influences ideas. Critical thinking activities include analyzing assumptions, identifying assumptions, problem-solving, evaluating arguments, supporting conclusions, and self-efficacy in making decisions and determining what needs to be done (Willingham, 2008; Basham et al., 2011). According to Zanthy (Zanthy, 2016) students' critical thinking abilities can be implemented in solving real-life mathematical problems. This is because students' critical thinking patterns can be organized, adjusted, and modified to arrive at appropriate problem solutions.

The reality in the field shows that students' mathematical critical thinking abilities indicate that the cognitive process in the evaluation aspect is 78%, self-regulation is 66%, interpretation is 52%, analysis is 56%, conclusion is 52%, and argumentation is 42% (Saputri et al., 2019). It is supported by the research results of Irawan et al. (Irawan et al., 2017), which stated that the average score of students in all aspects of critical thinking ability is still below 50%, specifically only 44.87%. This is further reinforced by the fact that students' critical thinking abilities in the overview aspect are still low (Setiana et al., 2020) and more focused on memorization processes (Setiana et al., 2016). Meanwhile, according to Tresnawati et al. (Tresnawati et al., 2017), their research findings, students still encounter difficulties in analyzing problems, relevant arguments, and cross-checking. The low level of students' mathematical critical thinking abilities is characterized by observable phenomena, including (1) inaccurate problem analysis; (2) difficulty in solving problems categorized as high-level (C4-C6); (3) suboptimal learning community; (4) lack of understanding of the relationships between concepts; (5) limited argumentation during discussions (Harjo et al., 2019).

According to Ennis (Ennis, 2011), critical thinking requires comprehensive knowledge and experience from various credible sources, allowing students to have self-efficacy in solving mathematical problems. Critical thinking involves a reflective process that addresses doubt, confusion, and self-efficacy to make decisions and find problem-solving strategies (Ennis, 1996; Sudarwinarti, 2019). Mathematical self-efficacy is crucial for students to avoid anxiety and uncertainty, leading to optimal results in solving mathematical problems (Rahmi et al., 2017; Sumarmo et al., 2018; Tresnawati et al., 2017). It, in turn, impacts students' confidence in their decisions and adaptability to the learning environment. The negative consequences of low self-efficacy levels will affect students, such as resorting to cheating because they are unsure of their ability to solve mathematical problems accurately (Hari et al., 2018).

Self-efficacy is self-confidence in one's ability to perform a particular role or task. Furthermore, Ennis (Lau, 2015) states that self-confidence is necessary to support critical thinking focused on deciding what to believe or do. Critical thinking is a disciplined intellectual process of actively conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered or generated through observation, experience, reflection, reasoning, or communication to guide belief and action (Nazemi, 2016).

Critical thinking enables students to discover truths and process information logically, allowing them to identify meaningful, irrelevant, or useless information (Amin et al., 2020; Setiana et al., 2021) to address various problems they encounter in social and personal life (Nuryanti et al., 2018). Some aspects of developing critical thinking skills include the ability to analyze and evaluate arguments, teaching students how to understand statements, follow and create logical arguments, solve problems, support the elimination of wrong paths, support conclusions, and focus on the right path (Willingham, 2008; Basham et al., 2011). The characteristics of critical thinking skills are related to (1) disposition (character); (2) criteria/standards; (3) reasoning; (4) interpretation; and (5) criteria application procedures (Alselah, 2020).

According to Glazer (Runisah et al., 2017), critical thinking conditions in mathematics should involve non-routine situations. Meanwhile, Beaumont (Beaumont, 2010) explains that learning provides opportunities for students to actively think through discovery, problem-solving, and discussion activities, which helps develop students' critical thinking abilities. According to Aizikovitsh-Udi & Cheng (Udi & Cheng, 2015), mathematical problems that involve thinking, analyzing, and synthesizing can stimulate students' critical thinking abilities. On the other hand, Anderson et al. (Richardo et al., 2018) reveal that characteristics of critical thinking students include seeking truth, being curious, analyzing problems, and thinking systematically. It is further supported by Romberg (Setiana et al., 2021), who suggests that to develop mathematical critical thinking, students should be given conflicting problems to construct knowledge while seeking truth and logical arguments. Appelbaum (Martyanti & Suhartini, 2018) state that students with critical thinking abilities engage in activities such as comparing, inducing, generating different ideas, proving, elaborating, connecting, analyzing, evaluating, and creating systematic schemes.

According to Glazer (Harjo et al., 2019), critical thinking in mathematics refers to the ability and disposition to engage prior knowledge, mathematical reasoning, and cognitive strategies in generalizing, proving, or evaluating unfamiliar mathematical situations reflectively. During mathematics instruction in the classroom, teachers should facilitate students in developing critical thinking processes and encourage them to reflect on their abilities.

In this study, the steps used to develop mathematical critical thinking skills follow Bloom's taxonomy (Fink, 2003), which are as follows: (1) Step 1: Determine learning objectives; (2) Step 2: Teach through questioning; (3) Step 3: Practice before evaluating; (4) Step 4: Review, revise, and enhance; and (5) Step 5: Provide feedback and assess learning. As for the levels of human thinking according to Bloom's taxonomy (Anderson et al., 2001) that has been revised, they consist of six levels of thinking as follows:

Table 1. Aspects of Thinking Abilities

Thinking Aspect	Definition
Remember	Memory retrieval of relevant knowledge from long-term memory
Understand	Ability to formulate the meaning of learning messages and effectively communicate it in oral, written, and graphical forms
Apply	Ability to use procedures to solve problems
Analyze	Ability to break down a unit into its parts and determine how these parts are connected to the whole
Evaluate	Ability to make judgments based on specific criteria and standards
Create	Generating new ideas, products, or perspectives from a given event

Based on the explanation of Bloom's Taxonomy and Ennis's critical thinking elements, represented by FRISCO, the relationship between the two can be visualized as follows:

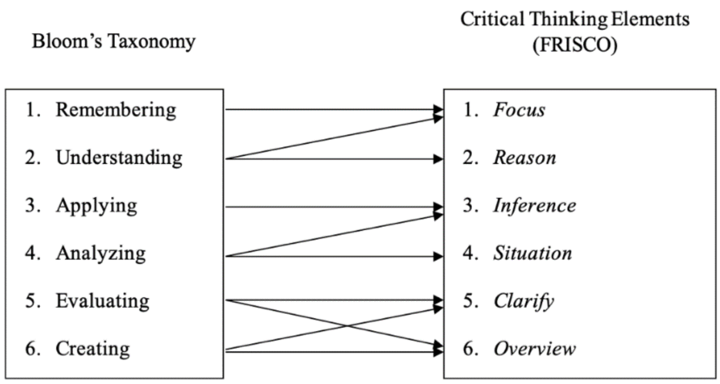

Figure 1. Relationship between Bloom's Taxonomy and Critical Thinking Elements (FRISCO)

Ennis (Ennis, 2018) explains that critical thinking is a process that enables us to make sensible decisions so that what we believe to be the best about truth can be done correctly. There are six essential elements to consider in critical thinking, which are acronyms as FRISCO:

Table 2. Mathematical Critical Thinking Ability Process (Ennis, 2018)

Aspect	Critical Thinking Skills	Sub Critical Thinking Skills
F (Focus)	Elementary Clarification (providing simple explanations)	Focusing on questions Analyzing arguments Asking and answering explanations or challenges
R (Reason)	The Basis for the Decisions (determining the basis for decision-making)	Adjusting to sources Observing and considering observation results
I (Inference)	Inference (concluding)	Deducting and considering deduction results Inducing and considering induction results Making and considering decision values
S (Situation) C (Clarity)	Advances Clarification (providing further explanations)	Defining terms and considering them Identifying assumptions
O (Overview)	Set strategy and tactic (setting strategies and tactics)	Determining actions Interacting with others

Referring to the opinion of Krulik & Rudnick (Pramarth et al., 2023), thinking skills consist of four levels: memorization (recall thinking), essential thinking, critical thinking, and creative thinking. Based on the levels of thinking above and the research development by Evendi et al (Evendi et al., 2022) on the levels of thinking up to critical thinking, they are as follows: (1) critical thinking level 0 (CT 0), which is the lowest level of thinking with indicators of memorization skills (recall thinking) consisting of almost automatic or reflexive skills; (2) critical thinking level 1 (CT 1) or also known as basic skills (essential thinking) with indicators of understanding concepts such as addition, subtraction, and their applications in problems; (3) critical thinking level 2 (CT 2) and critical thinking level 3 (CT 3) represent high-level thinking abilities. The criteria for CT 2 and CT 3, adapted from the indicators of critical thinking according to Ennis (Ennis, 2018), are the ability to: (1) formulate the main points of problems; (2) express existing facts; (3) select logical arguments; (4) detect bias from different perspectives; (5) draw conclusions.
According to Ennis, the theory of critical thinking used in this research is a modification of critical thinking ability through six critical thinking elements acronym FRISCO (Focus, Reason, Inference, Situation, Clarity, and Overview) (Ennis, 2018). It is further supported by the fact that indicators of critical thinking should provide many ideas, express new ways, develop ideas, and produce alternative answers (Ode & Darhim,, 2023). In this context, critical thinking ability is a reflective process aimed at assessing students' skills through analysis, evaluation, and inference to arrive at logical conclusions in problem-solving (Dwyer & Walsh, 2020). This research examines the relationship between self-efficacy and its potential to improve student's critical thinking in solving mathematical problems. Then, the mathematics problems focus on learning geometry based on aspects of space and shape following PISA recommendations.

Methods

This research is a qualitative study with a grounded theory approach aimed at discovering theories from understanding the phenomena that occur in the stages of students' critical thinking processes. Operationally, this research was conducted in several steps, referring to Creswell's theory (Sitorus & Masrayati, 2016): research initiation, data collection, data analysis, synthesis and research generation, and theory validation. In the research initiation stage, the researcher made several preparations, including determining the research location, preparing research instruments, and implementing them.

Research Sample

For determining the research location, the researcher obtained information from a mathematics teacher at SMP Ma'arif Kalibawang, Kulon Progo. The subjects of this research were 20 eighth-grade students from SMP Ma'arif Kalibawang, Kulon Progo.

Data collection

Instrumentation (sample of questions, scoring method, and psychometric properties (validity and reliability)). The research instruments used were self-efficacy questionnaires and tests based on PISA questions categorized as valid. The tests used in this research were two PISA open-ended questions. In addition, the researcher used Ennis' modified critical thinking indicators and interviews to complement the necessary data to measure students' level of critical thinking in mathematics. These subjects were given a questionnaire to measure their level of self-efficacy, which was then categorized according to Bandura's theory (2006), modified by Azwar (2013), as shown in Table 3 below.

Table 3. Categorization of Mathematics Self-Efficacy Levels

Category	Criteria
High	$X \geq (\mu + 1,0\sigma)$
Middle	$(\mu + 1,0\sigma) \leq X < (\mu + 1,0\sigma)$
Low	$X < (\mu - 1,0\sigma)$

Meanwhile, the questionnaire grid for students' mathematics self-efficacy is shown in Table 4 below:

Table 4. Self-Efficacy Questionnaire Grid

Aspect Measured	Indicators
Level	Students' confidence in facing given mathematical problems or tasks depends on their difficulty level.
Strength	Students' confidence in their competence to learn mathematics Students' confidence in their ability to solve mathematical problems or tasks
	Students' confidence in their effort to study mathematics
Generality	Students' belief in their ability to use mathematics to solve various problems

From the 20 students, different values were obtained based on the guidelines for categorizing the level of self-efficacy according to Table 1. The researcher selected six subjects representing high self-efficacy (2 students), moderate self-efficacy (2 students), and low self-efficacy (2 students). Data was collected using three methods: questionnaire filling, documentation, and in-depth interviews. The six students were then given a PISA test instrument to assess their critical thinking process based on the modified Ennis' critical thinking ability indicators. After completing the PISA test, the six students were interviewed according to critical thinking ability indicators related to the stages of problem-solving to clarify the implicit steps taken by the students.

Table 5. Modified Indicators of Mathematical Critical Thinking based on Ennis' Theory

Indicator	**Modified Indicator of Critical Thinking**
Aspect: F (Focus)	
Understanding mathematical problems	Demonstrating understanding of the problem
Aspect: R (Reason)	
Explaining arguments according to factors in the learning process to make decisions and conclusions	Explaining arguments according to mathematical concepts
I (Inference)	
Making logical and accurate conclusions Selecting clear and appropriate reasons to support inferences	Selecting approaches and/or methods for problem-solving
S (Situation)	
Using all relevant information to the problem	Interpreting mathematical models and providing systematic explanations
C (Clarity)	
Systematic explanations and presenting conclusions Explaining terms in the problem Providing examples of similar cases to the problem	
O (Overview)	
Comprehensively check or cross-check	Using alternative problem-solving strategies or solutions

Data analysis

The data were analyzed qualitatively using a grounded theory approach. According to Glaser (Marzuki et al., 2021), the data analysis process consists of three stages: (1) data reduction, (2) data presentation, and (3) drawing conclusions or verification. The researcher synthesized the data to generate theory by identifying or refining core categories from all the data, defining relationships and data properties, and writing notes/memos within the theory. Theory generation was achieved through constant comparison of theoretical constructs and directed towards the relationship of each data.

The researcher tested the data validity by examining data credibility through source and technique triangulation (John et al., 2018). Source triangulation was used to verify data credibility by cross-checking student data. The data were then described and categorized into three types: same, different, and specific. Technique triangulation was done to verify the analysis results of the critical thinking ability test, which were then cross-checked through interviews. The researcher returned to the research field to collect data through observation and interviews to ensure the credibility of the obtained data. The researcher searched for relevant references to determine whether the data were valid.

Results

The analysis of the subject's mathematical critical thinking process used Ennis' modified critical thinking indicators and employed triangulation methods to test the data validity. Then, the step-by-step process of the subject's mathematical critical thinking in solving the PISA test instrument was explained. The details of this process are shown in Figure 2 below:

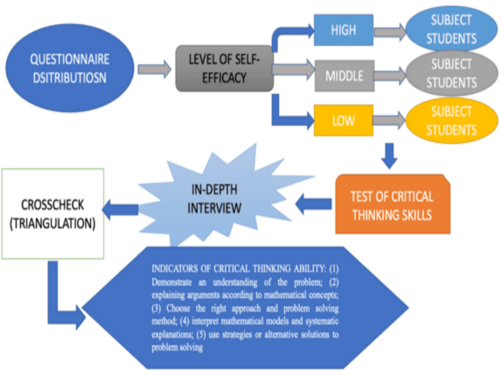

Figure 2. Data collection techniques for data analysis

The outcome of data analysis in which the self-efficacy questionnaire was administered to research participants to categorize each participant's self-efficacy level. The self-efficacy questionnaire given to the 20 students consists of twenty-two (22) statement items that include five indicators and takes approximately 40 minutes to complete. Based on the guidelines for categorizing self-efficacy levels, the research subjects were classified into high, moderate, and low self-efficacy levels.

Table 6. Categories of self-efficacy levels based on questionnaire results.

Score Interval	Frequency	Category
156 – 158	6 students	High
140 – 155	9 students	Moderate
130 - 139	5 students	Low

From the data in Table 6, it can be observed that out of 20 students, 30% have high self-efficacy, 45% have moderate self-efficacy, and 25% have low self-efficacy. Based on the self-efficacy classification, the researcher selected 6 (six) subjects representing each category. Students 1 and 2, hereafter referred to as S1 and S2, have high self-efficacy; students 3 and 4, S3 and S4, have moderate self-efficacy; and students 5 and 6, S5 and S6, have low self-efficacy. The next step involved giving these six subjects a critical thinking ability test consisting of two PISA framework questions, followed by conducting interviews as supplementary data to clarify the steps taken by the students based on the modified Ennis' critical thinking indicators.
The results of the question 1 solving process will be presented for each critical thinking ability indicator as follows:

Indicator 1. Demonstrating Understanding of the Problem.

S1's work demonstrates that the student can understand the problem well, as shown in Figure 3.

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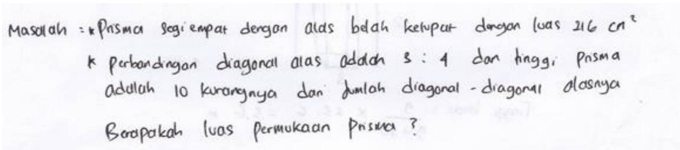


Figure 3. S1 in the Aspect of Demonstrating Understanding of the Problem

In Figure 3, the students listed the existing problems and ended with a question that needed to be solved. It indicates that the students can understand the problem well. In addition to S1, it turns out that S3 and S5 also presented the same thing, although it was written more briefly, as shown in Figure 4. (a), (b).

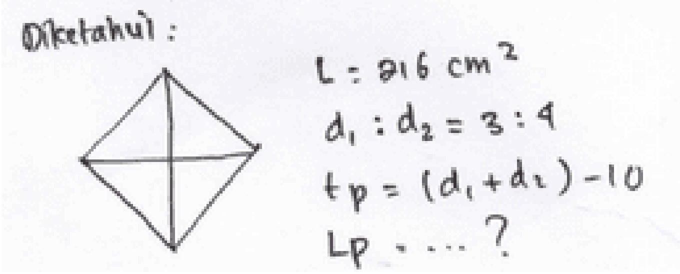


Figure 4. (a) S3

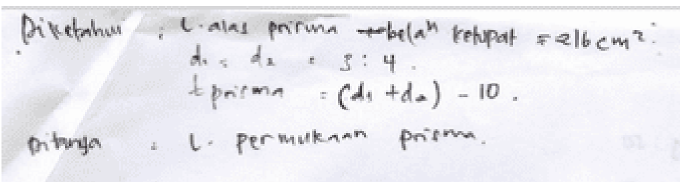


Figure 4. (b) S4

In Figure 4. (a) and (b), it can be observed that the students wrote the problems using mathematical symbols such as L for area, d for diagonal, tp for prism height, and Lp for surface area. An interesting observation can be made with S3, who used a rhombus to construct the known diagonal. Therefore, both S1 and S3 demonstrated a good understanding of the problem, even though the problems they wrote were brief. However, this differs from S5, which still lacks confidence in understanding the problem, as shown in Figure 5.

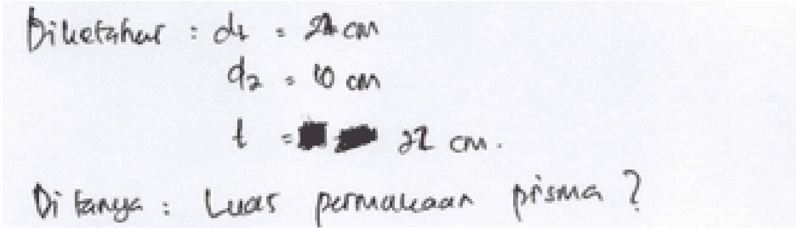


Figure 5. Aspect Understanding the Problem of S4

Figure 5 shows that S5 initially crossed out what was written, as they wanted to directly write the answer without stating the given problem. Additionally, S5 did not write down the known area of the prism and was not careful in writing down the known height, leading to some parts of their work being crossed out. Thus, it can be concluded that their ability to understand the problem is still not very good.

Indicator 2. Explaining arguments according to mathematical concepts

In the second indicator related to how students explain their opinions or ideas according to mathematical concepts, it is evident that S1 can do so well. It can be seen in Figure 6a.

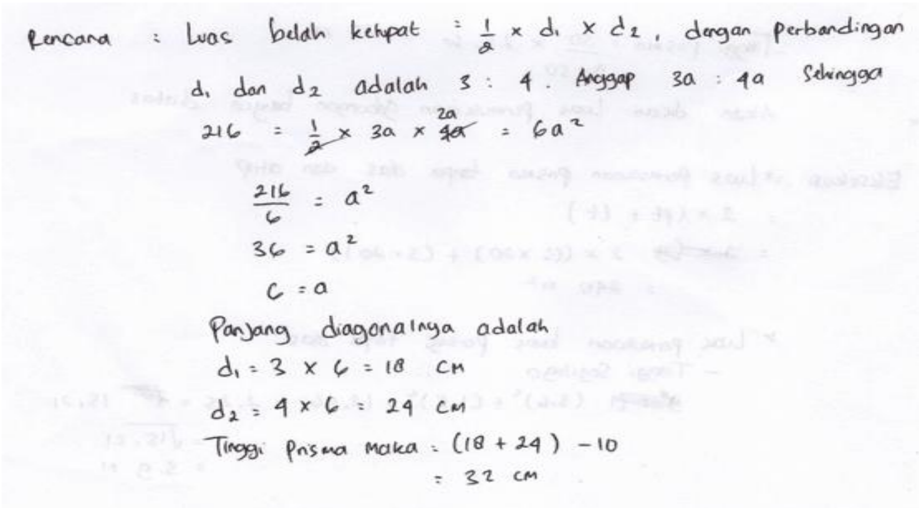


Figure 6a. S1 Arguments According to Mathematical Concepts

Figure 6a shows that S1 wrote a plan before solving the problem. In this case, S1 conducted an analysis of the comparison between the area of the rhombus and its diagonals, which allowed the student to find the value to determine the diagonal. Therefore, S1 can be said to have explained the argument under mathematical concepts very well. It differs from other students who solved the problem directly without conducting any data analysis beforehand. As for S3 and S5, they can be considered reasonable in the indicator of explaining arguments according to mathematical concepts. It can be seen in Figures 6b and 6c below:

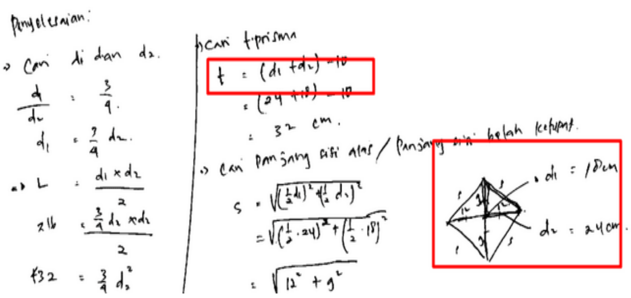


Figure 6b. S3 explains the argument

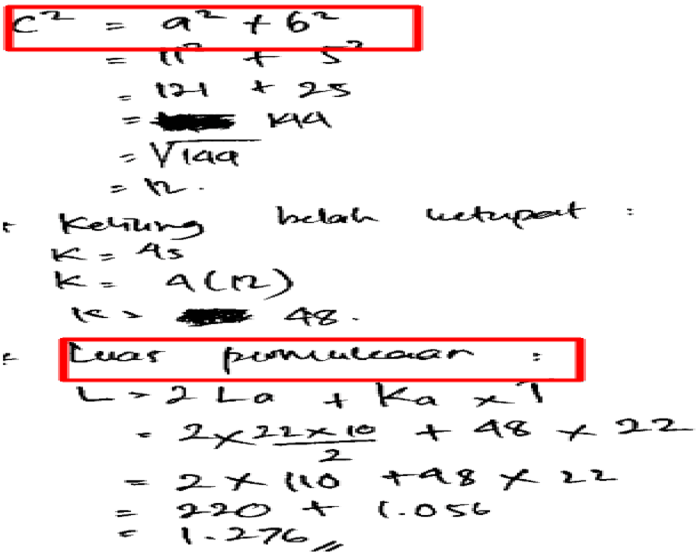


Figure 6c. S5 explains the arguments

Indicator 3. Selecting Approaches and Methods for Problem-Solving

The next indicator of critical thinking ability is selecting approaches and methods for problem-solving. In this case, S1 began by explaining the planned mathematical concept, followed by choosing the method for problem-solving, as shown in Figure 7.

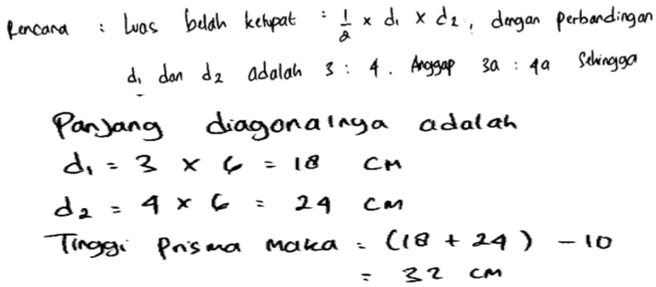


Figure 7. S1 Problem-Solving Method

Figure 7 shows that subject S1 has planned the problem-solving method. In this case, S1 wrote down the formula for the surface area of the prism without the base and roof, then determined the prism's surface area as the basis for calculating the building's area. Besides S1, subjects S3 and S5 also presented a similar approach, although in-depth interviews revealed some uncertainty, as seen in Figures 8 and 9 below:

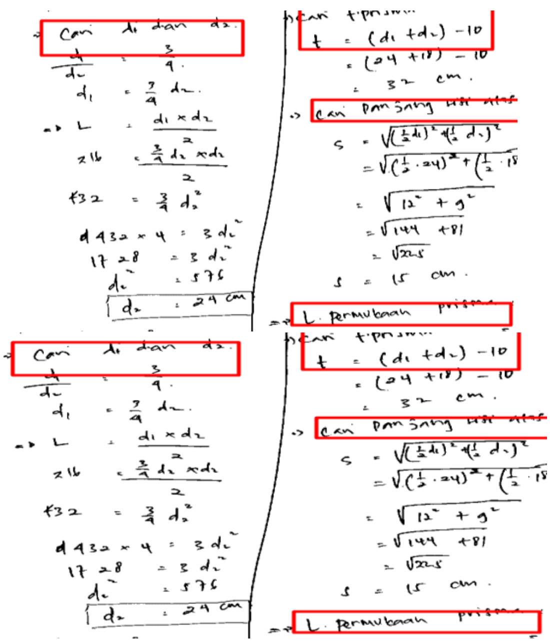


Figure 8. S3

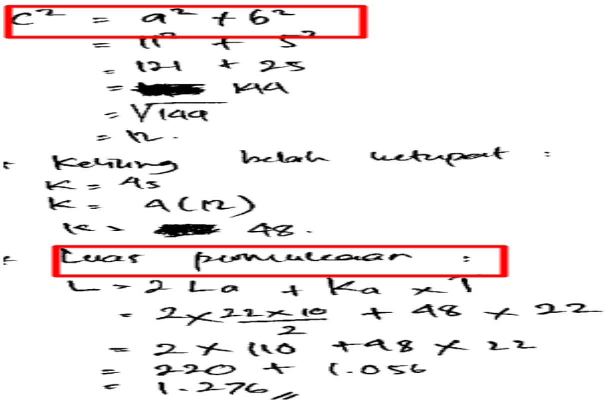


Figure 9. S5

On the other hand, the strategy used by S5 in determining the perimeter is not relevant in determining the surface area. It also resulted in an inaccurate surface area calculation. Therefore, it can be concluded that students with low self-efficacy cannot yet choose the appropriate problem-solving approach and strategy.

Indicator 4. Interpreting mathematical models and providing systematic explanations

In this indicator of critical thinking ability, S1 can interpret mathematical models well and provide systematic explanations, as seen in the work results in Figure 10 below.

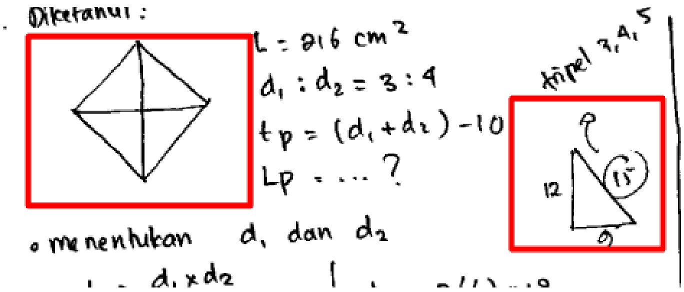


Figure 10. Illustration of Mathematical Model

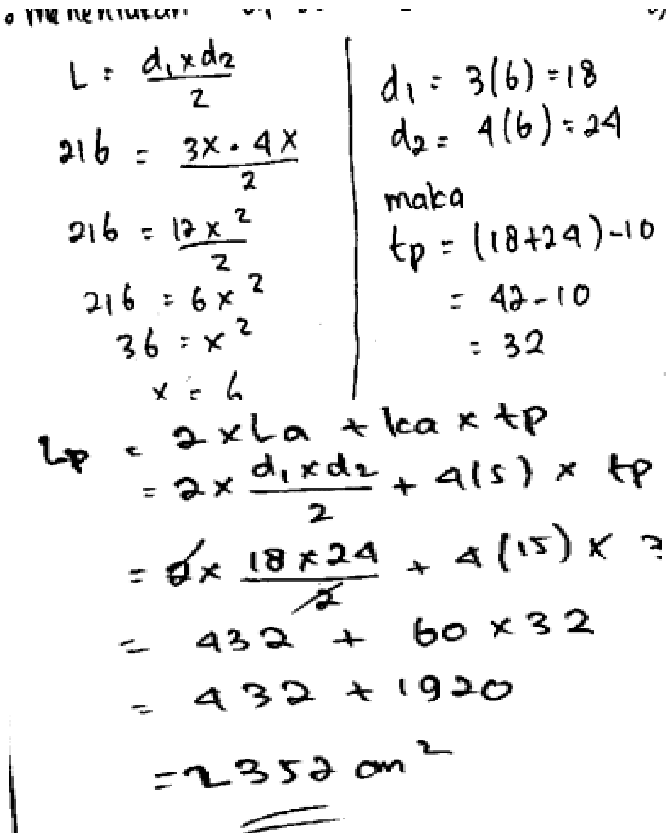


Figure 11. Problem-Solving Method of S1

Figure 10 shows that S1 models the mathematics by visualizing geometric shapes, while in picture 11, S1 executes the problem well. However, in the final step, S1 still made an error. The correct outer surface area should be 2,353 cm2, but it was written as 6,272 cm2. It is unfortunate because all the critical thinking processes of the students were good, but there was a lack of accuracy in the final result obtained. Therefore, it can be concluded that S1, who has high self-efficacy, still lacks the accuracy of the final result.
Next, in the systematic stage of problem-solving, S3 first determines d_1 and d_2 to find the height of the prism. It can be seen in Picture 12.

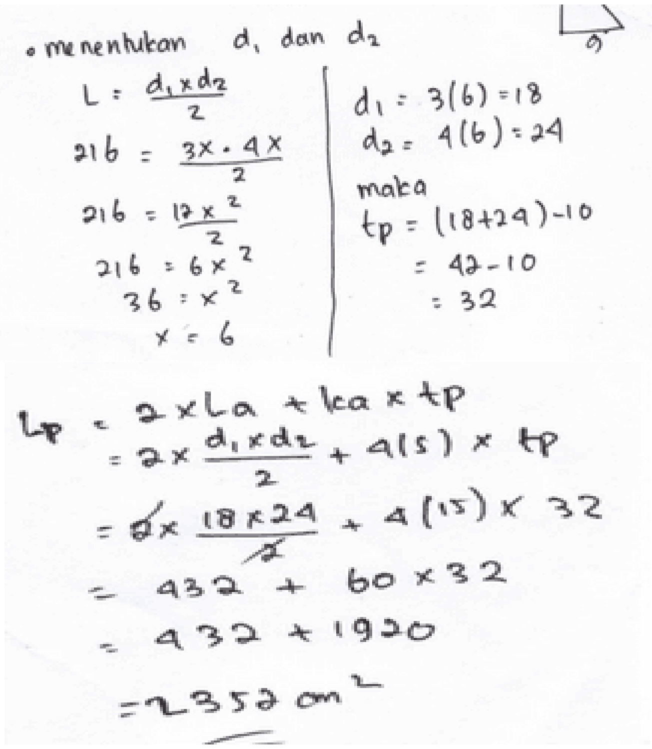


Figure 12. Solution of S3

Based on Figure 12, it can be seen that S3 can determine the value of x concisely and clearly to find the height of the prism subsequently. S3 chose this strategy to solve the given problem. The final result obtained by S3 is correct, which is 2.353 cm2. This approach is also used by S5, as shown in Figure 13.

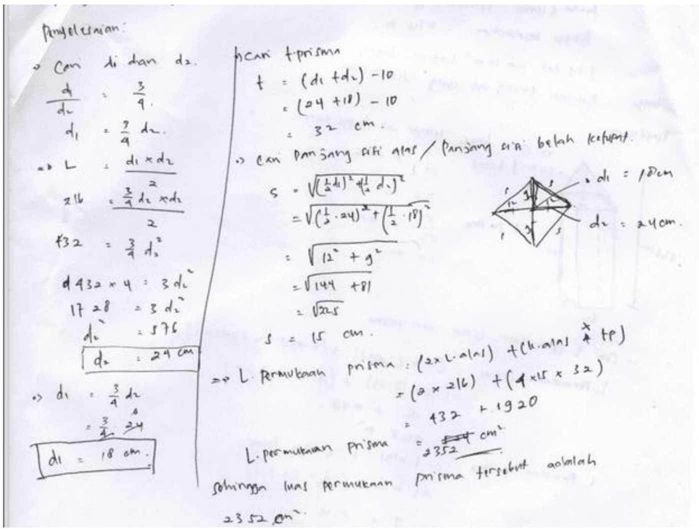


Figure 13. Problem-Solving of S3

Figure 13 shows the systematic approach used by S3 in problem-solving. The strategy starts by determining the diagonal to find the height of the prism. Next, they find the required surface area. In this case, S3 illustrates a kite to indicate the difference in the length of the diagonals. Furthermore, the result obtained by S3 is also accurate, with a surface area of 2.352 cm2. Thus, it can be concluded that students with moderate self-efficacy can solve problems accurately. The problem-solving process differs for S5, as presented in Figure 14.

Figure 14. Problem-Solving Systematic of S5

The work of S5 shows a less accurate systematic problem-solving approach. The student should have first found the values of the diagonal and height to determine the surface area.

Indicator 5. Using alternative strategies or solutions for problem-solving

In the final stage, all students wrote their final results. Although only S3 and S5 obtained accurate results, S1's were still less accurate. Based on the S1, S3, and S5 interview results, the students generally used formulas as presented in the mathematics textbook. It can be seen in the following figures 15a, 15b, and 15c:

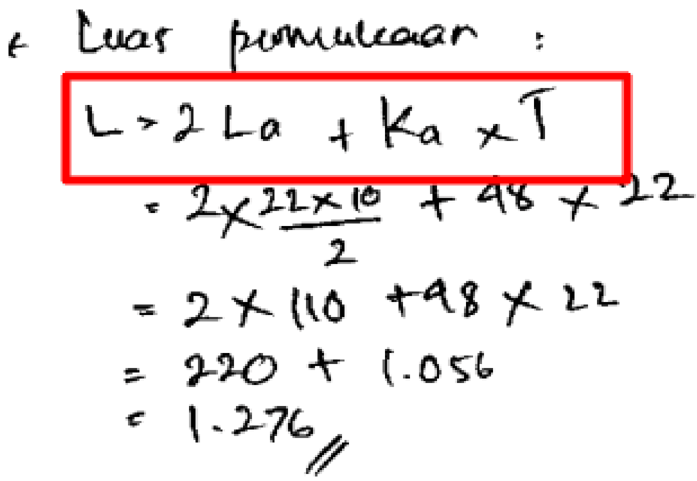


Figure 15a. S5

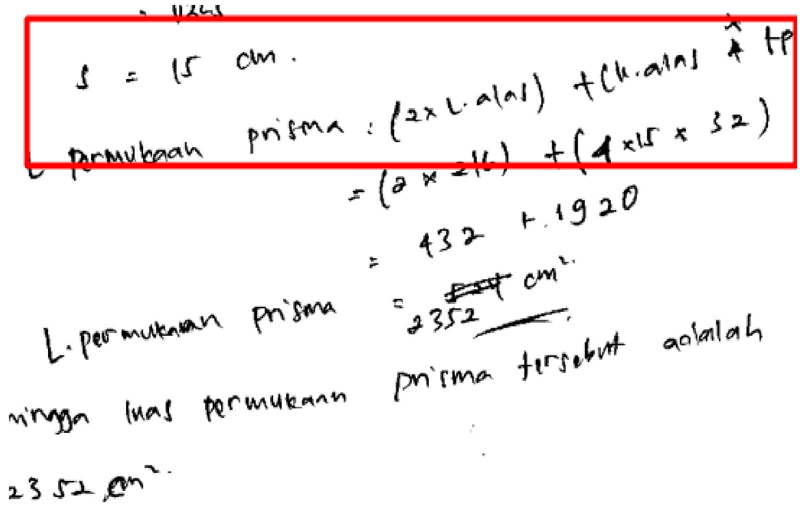


Figure 15b. S3

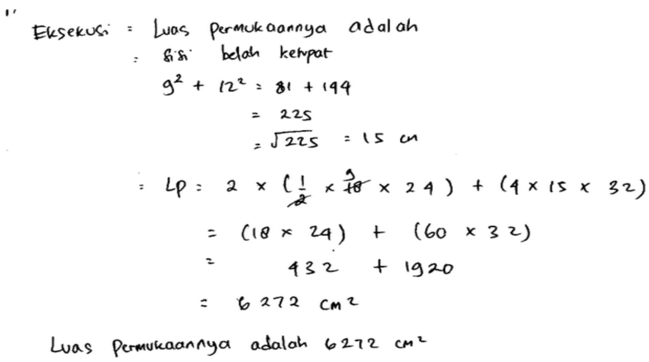


Figure 15c. S1

It can be said that S1 has tried several alternative solutions, although the results obtained are less accurate. Unlike S1, S3, and S5 have not utilized alternative solutions in mathematical problem-solving based on the critical thinking ability indicators. The interview results with S1 revealed that the lack of time was the reason, S3 felt confident in their answer, and S5 mentioned that only that formula was frequently taught by the teacher. Based on the analysis of the critical thinking ability test in mathematics for question number 2, it was found that:

Indicator 1: Demonstrating Problem Understanding

The work of S2 shows that the student can present a good understanding of the problem, as shown in Figure 16.

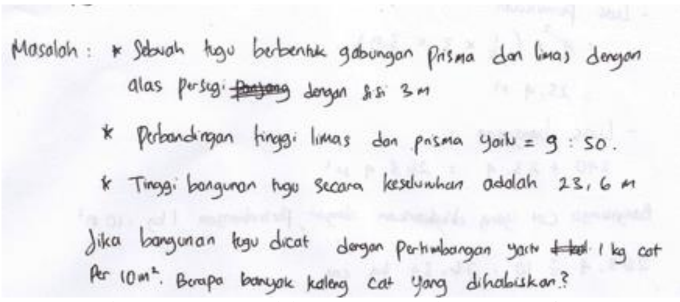


Figure 16. Problem Comprehension of S2

In Figure 16, the student registers the problem with a concluding question that needs to be solved. Additionally, S2 is attentive because when registering the existing problem, there is crossed-out writing where it should be a square, so the notation "persegi panjang" (rectangle) is corrected. It indicates that the student understands the problem well as they read it carefully. Furthermore, the same is done by S4 in Figure 17.

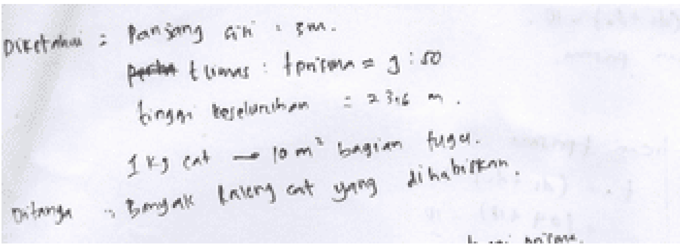


Figure 17. Problem Comprehension of S4

In Figure 17, S4 has written the existing problem, but the critical point is that the problem about the monument, which consists of a prism and a pyramid, is not mentioned, and the problem question is incomplete, stating that the building only will be painted. Therefore, the description of the problem written by S4 is still incomplete. S6 also does the same in Figure 18.

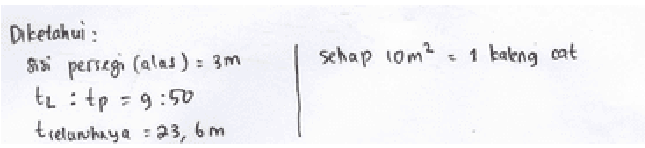


Figure 18. Problem Comprehension of S6

Figure 18 shows that the problem description written by S6 is almost the same as S4 and lacks clarity about the problem to be solved because there is no problem question. However, S4 and S6 have at least written down the existing problem, even though it is incomplete. In contrast, in the work of S6, there is no mention of the existing problem. Therefore, based on the analysis of test documents and interview results, it can be concluded that students with high self-efficacy (S2) have a high ability to understand the problem, students with moderate self-efficacy (S4) have a moderate ability to understand the problem, and students with low self-efficacy (S6) have a low ability to understand the problem. However, this will be further analyzed in the subsequent indicators of S6's work.

Indicator 2. Explaining arguments according to mathematical concepts

The second indicator related to how students organize data and select relevant information shows that S2 and S4 can do it well. It can be seen in Figure 19.

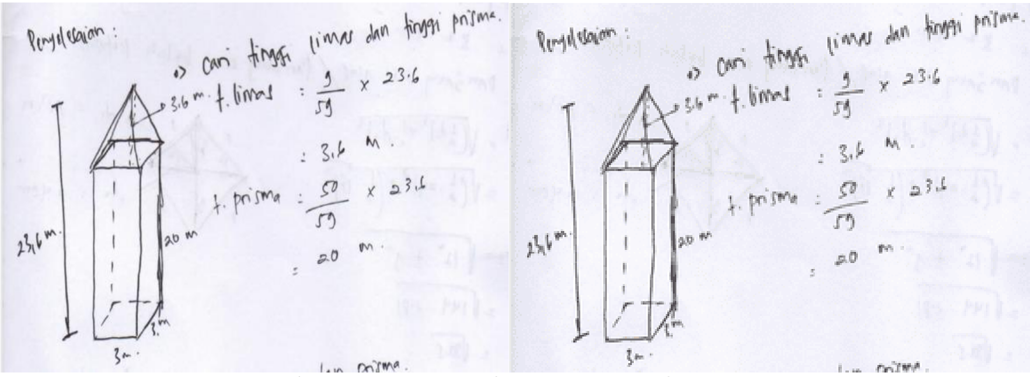


Figure 19. S2 and S4 Organize the Data

Picture 19 shows that S2 and S4 write a plan before solving the problem. In this case, S2 and S4 illustrate the shape of the monument according to the given problem, write down each known detail from the question, and then proceed to find the height of the pyramid and the height of the prism before calculating the surface area of the monument to determine the amount of paint needed to color the monument. It indicates that S2 and S4 can effectively argue with the selection and organization of mathematical concepts. In addition to S2 and S4, S6 follows the same steps before solving the problem, as presented in Figure 20.

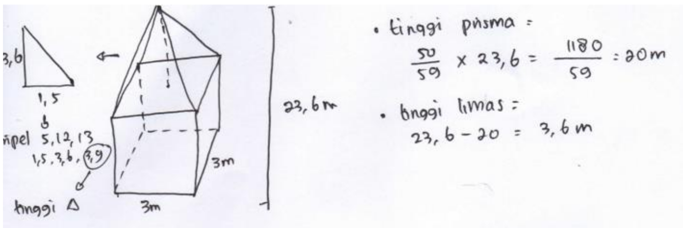
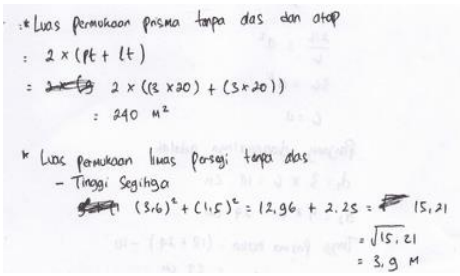


Figure 20. S6 explains the argument for the mathematical concept

In Figure 20, it can be seen that S6 also does the same as S2 and S4, starting with creating an illustration of the monument and then finding the heights of the prism and pyramid. However, the method used to find the pyramid's height differs by subtracting the height of the prism already found from the overall height. It also leads to the exact correct solution as S2 and S4. Therefore, it can be concluded that S2, S4, and S6 can plan and process mathematical concepts effectively.

Indicator 3. Selecting an Approach and/or Problem-Solving Method

The next indicator of critical thinking ability is selecting an approach and problem-solving method. In this regard, S2 begins by organizing the data and executes the problem-solving process, as shown in Figure 21.



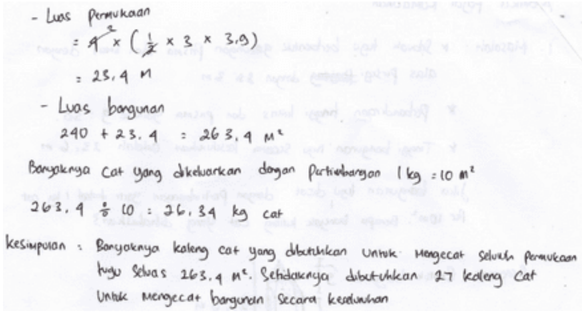


Figure 21. The strategy of S2 in Problem-Solving

Figure 21 illustrates the steps taken by S2 to solve the problem. S2 starts by calculating the surface area of the prism without the base and top, then proceeds to calculate the surface area of the square pyramid without the base. When calculating the surface area of the pyramid, S2 first looks for the critical information, which is the height of the triangle, to find the surface area of the pyramid. After that, S2 adds up the calculated surface areas to obtain the surface area of the monument. Once the surface area is known, the final step is determining the paint required based on the given condition of 1 kg per 10 m². Therefore, the total surface area obtained is divided by 10. The final result indicates that 26.34 kg of paint is needed, or rounded to 27 kg. In the conclusion step, S2 writes the conclusion of the problem solved, stating that 27 kg of paint is required to color the monument. It demonstrates that S2 can successfully solve the problem from start to finish. Additionally, S4 successfully solves the problem, as presented in Figure 22.

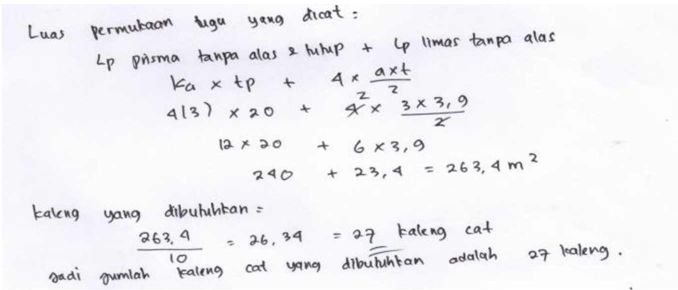


Figure 22. The strategy of S4 in Problem-Solving

S4 solves the given problem by directly calculating the surface area of the monument to be painted using the formula for the surface area of the prism without the base and top plus the surface area of the pyramid without the base. The result obtained by S4 is the same as S2, which is 27 kg of paint cans needed to paint the monument. In the final part, S4 concludes the problem by stating that 27 paint cans are required. It demonstrates that S4 also can solve problems effectively, just like S2. However, unlike S2 and S4, S6 makes a mistake in solving the problem, as shown in Figure 23.

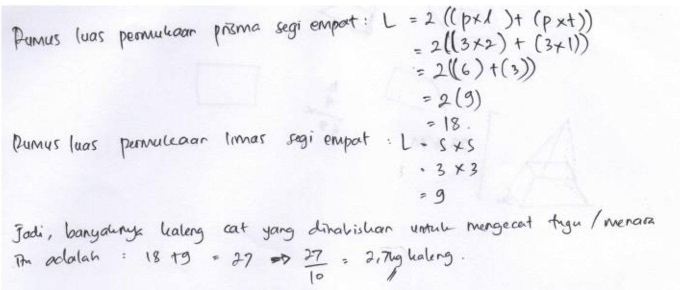


Figure 23. The strategy of S6 in Problem-Solving

In the problem-solving strategy, S6 also made errors in determining the surface area of the prism and pyramid. It is consistent with the mistakes made in the previous steps, where S6 did not write down the given problem and organize the data correctly, leading to incorrect problem-solving. Thus, it can be concluded that S6 cannot solve problems effectively. The interview results with subject S6 showed they needed to know the total surface area to calculate the paint used.

Indicator 4. Interpreting Mathematical Models and Systematic Explanations

Regarding the indicator of critical thinking ability in interpreting mathematical models, both S2 and S4 can be considered reasonable. It is evident in Figures 24 a and 24 b below:

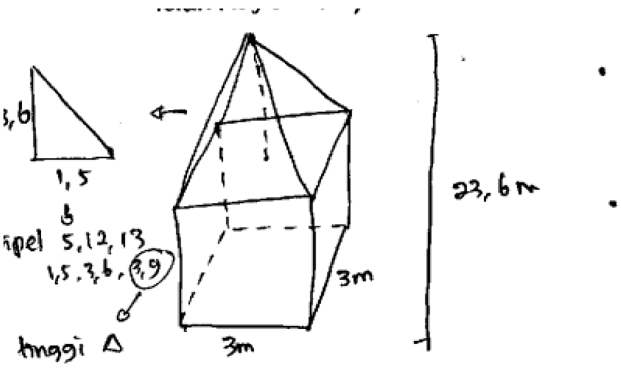


Figure 24a. illustration of S2's drawing

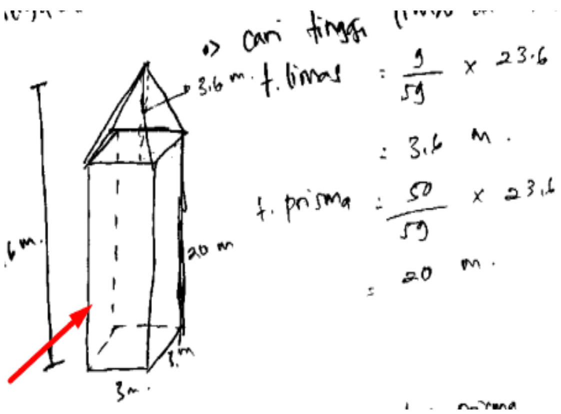


Figure 24b. illustration of S4's drawing

It is reinforced by the systematic explanation of mathematical problem-solving, as shown in Figures 24c and 24d below:

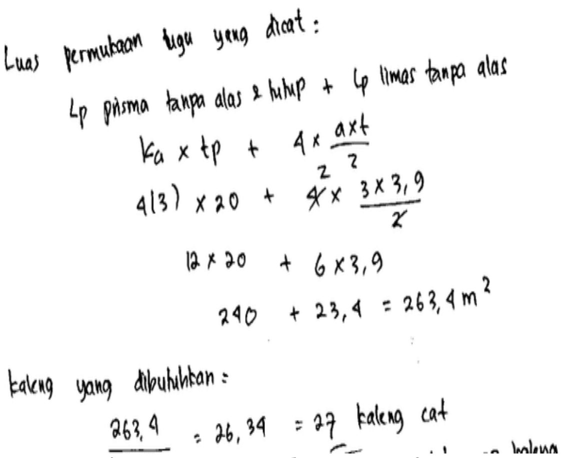


Figure 24c. explanation of S2

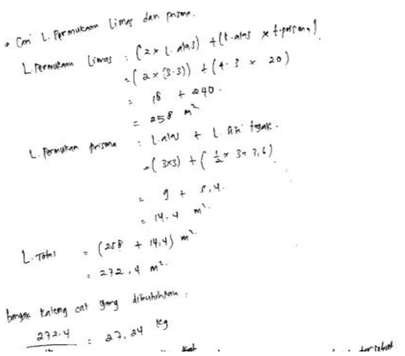


Figure 24d. explanation of S4

Unlike S6, which only illustrated the Monument in Figure 25a.

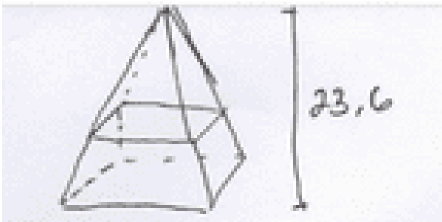


Figure 25a. S6 Organizes the Data

Figure 25a shows that S6 attempted to illustrate the existing problem by depicting the monument. However, the drawn image is inaccurate, as S6 only illustrated a pyramid cut in the middle to resemble a combination of a pyramid and a pyramid base, which is not the required illustration. Additionally, S6 did not write down other known information about the problem because S6 did not first write down the problem. Moreover, S6 did not determine the height of the prism and pyramid, an essential step in solving this problem. Thus, it can be concluded that S6 has not been able to explain arguments according to mathematical concepts, particularly in organizing and processing available data properly. It can be seen in Figure 25b below:

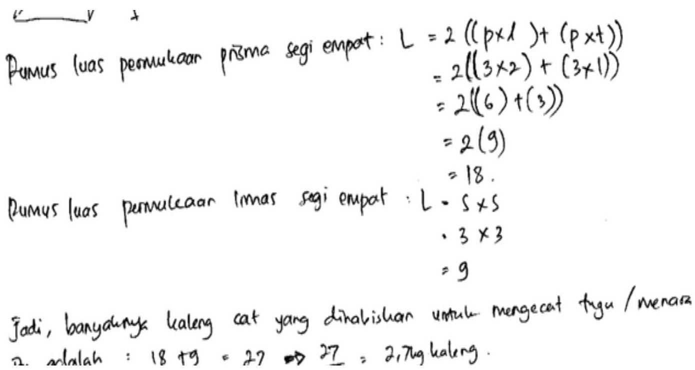


Figure 25b. Problem-Solving Methodology of S6

Indicator 5. Using Alternative Problem-Solving Strategies or Solutions

In the final stage, all students wrote their final results, with only S2 and S4 obtaining accurate results, while S6's result was still less accurate. Based on the interview results with S2, S4, and S6, the students still relied on formulas in their problem-solving approach. It can be seen in Figures 26a, 26b, and 26c.

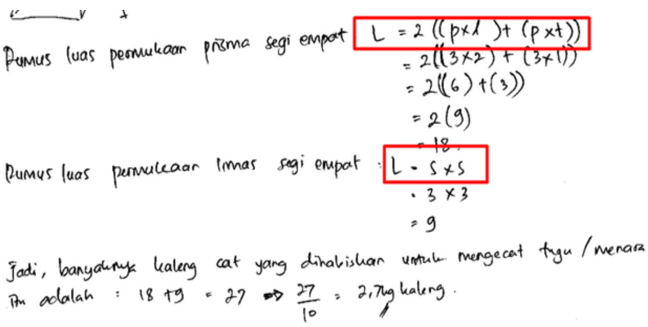


Figure 26a. S6

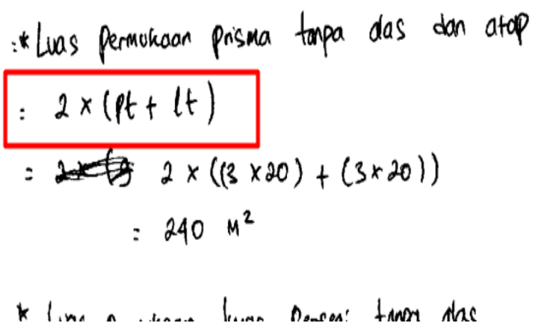


Figure 26b. S4

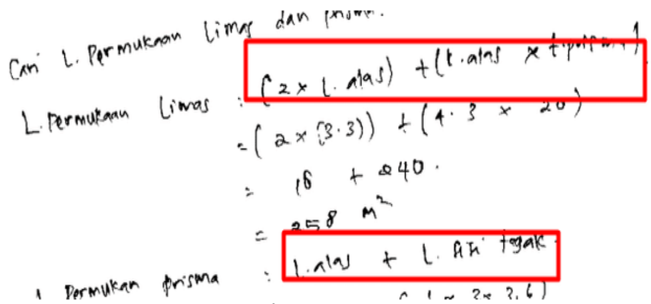


Figure 26c. S2

It can be said that S2, S4, and S6 have not yet fulfilled the indicator of critical thinking ability, which is using alternative solutions in solving mathematical problems. Based on the test documentation, both S2, S4, and S6 still mainly focused on using mathematical formulas from the available math textbooks. Although it can be seen that S2 made some modifications in the solution steps, the value for L (length) of the base is still L alas=2 (p x l), just like what was written by S4 and S6.

In summary, the qualitative analysis of the critical thinking ability test documentation can be presented in the following Table 7:

Table 7. Results of Grouping Critical Thinking Ability Indicators

Modified Critical Thinking Indicators		Subjects					
		S1	S2	S3	S4	S5	S6
1.	Demonstrates understanding of the problem	√	√	√	√	√	√
2.	Explains arguments based on mathematical concepts	√	√	√	√	√	√
3.	Chooses an approach and/or problem-solving method	√	√	√	√	-	-
4.	Interprets mathematical models and provides systematic explanations	√	√	√	√	√	-
5.	Uses alternative strategies or solutions in problem-solving	√	-	-	-	-	-

Discussion

The results of the qualitative data analysis using the grounded theory research approach method indicate that some subjects with high self-efficacy levels (S1 and S2), moderate self-efficacy levels (S3 and S4), and low self-efficacy levels (S5 and S6) show that several indicators of critical thinking abilities have not been fulfilled. In this study, critical thinking ability consists of five indicators: (1) demonstrating an understanding of the problem; (2) explaining arguments based on mathematical concepts; (3) using appropriate problem-solving methods; (4) providing systematic modeling and explanations; and (5) using alternative solutions in problem-solving. The level of self-efficacy is used as one aspect to help describe and analyze the fulfillment of these critical thinking indicators. By conducting checks or cross-referencing the work results, it is beneficial to ensure that the answers are correct. This step will also determine whether the obtained solutions can be accepted as problem-solving or need re-evaluation due to potential inaccuracies that make the answers unreliable (AlMarwani, 2020).

While reviewing concepts and problem-solving steps, students admitted that while checking the answers to the given test questions, they found several writing errors and immediately corrected them. Although the errors were unrelated to the concepts, the students were satisfied with their work and considered it complete. The in-depth interviews further confirmed the test and questionnaire analysis results, which indicated that most students did not fulfill the overview aspect in the indicator of comprehensive cross-checking or providing alternative solutions. Some factors contributing to these constraints were identified: (1) lack of motivation among students to complete the problem-solving process, leading to a tendency to be reluctant to recheck their work; (2) students' overconfidence in their answers, assuming that the written responses must be correct; and (3) limited time available for students to review their answers from beginning to end.

The process of fostering and developing critical thinking first requires understanding students' knowledge to search for mathematical concepts, explore ideas or concepts to obtain solutions, make informed decisions, find alternative solutions, and reflect on the problem using previous thought processes. Furthermore, interaction among students through effective communication is essential. It aligns with Zulkardi and Jurnaidi's (Jurnaidi & Zulkardi, 2014) research, which concluded that interviews with five students in the field test class revealed that, in general, PISA mathematical reasoning questions could prompt students to think when solving problems critically. However, some students still face challenges in understanding concepts and problem-solving. Supported by Dolapcioglu & Doğanay (Juniarti & Renda, 2018) that the understanding that critical thinking in mathematics not only involves knowing and using knowledge to achieve the correct solution but also understanding, interpreting, exploring various ways to find solutions, and reflecting on the benefits of mathematics in everyday life.

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Conclusion

Based on the description of the results of data analysis and research discussions regarding critical thinking abilities concerning self-efficacy in solving mathematical problems using the PISA framework, it can be concluded that students with high self-efficacy fulfill 4 (four) indicators of critical thinking ability clearly and accurately: showing understanding of the problem, explaining arguments according to mathematical concepts, using appropriate problem-solving methods, and modeling or providing systematic explanations. However, they have not yet met the indicator of using alternative solutions in mathematical problem-solving. On the other hand, students with moderate self-efficacy fulfill 4 out of 5 indicators of critical thinking ability. The indicator not met at this level of self-efficacy is using alternative solutions in mathematical problem-solving. As for subjects with low self-efficacy, they fulfill clear and relevant indicators in understanding the problem and explaining arguments according to mathematical concepts, as they write down what is known in the problem briefly and mention the information needed to solve the problem. The student's also attempt to provide a systematic explanation, although it is not yet accurate. Based on the analysis of the mathematics test results using the PISA framework, the indicator of critical thinking ability, which is using alternative strategies or solutions in problem-solving, is still not accurately and relevantly fulfilled. The fifth indicator's condition, which is not met as expected, may warrant further research related to efforts in fulfilling and improving the five indicators of critical thinking skills, namely the optimization of reflective thinking for critical inquiry (contemplating) with effective communication among students or groups. This is essential for identifying problems, detecting the correctness and errors of answers, and correcting them to draw accurate conclusions.

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STATEMENT OF CONFLICT OF INTEREST

The authors state that the study was conducted without any commercial or financial relationship that could be construed as a potential conflict of interest.

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