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Analysis of Mathematical Critical Thinking Skills in Terms of Self-Efficacy

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ABSTRACT Mathematical critical thinking is an important skill in mathematics learning because it relates to students' ability to understand information, analyze problems, determine solution strategies, and evaluate results. This skill is also related to students' beliefs when dealing with mathematical problems. This study aimed to analyze students' mathematical critical thinking skills in terms of self-efficacy to gain an in-depth understanding. The study employed a qualitative phenomenological approach. The participants comprised 58 students from two Grade 10 classes at a public senior high school in North Jakarta. The researchers selected 11 students through purposive sampling based on the test and questionnaire results. Data were collected through a mathematical critical thinking skills test, a self-efficacy questionnaire, and interviews. The data were analyzed through data reduction, data presentation, and conclusion drawing. The results showed that students' mathematical critical thinking skills exhibited diverse characteristics across different self-efficacy categories. Students with very good skills and high self-efficacy were able to interpret information, construct mathematical models, determine strategies, and evaluate results accurately. Students with lower skills demonstrated limitations in constructing models, determining strategies, performing calculations, and drawing conclusions. Self-efficacy was reflected in students' beliefs, experiences, persistence, and responses when facing difficulties. However, the level of self-efficacy was not always directly proportional to mathematical critical thinking skills.

Keywords: mathematical critical thinking skills, self-efficacy, critical thinking analysis, mathematics education

INTRODUCTION

Mathematical critical thinking skills refer to an individual's cognitive ability to analyze problems in a structured manner, break down problem components, and reflect on thought patterns to formulate solution strategies and make appropriate decisions (Ariyani & Prasetyo, 2021; Wandira et al., 2022). Critical thinking skills in mathematics learning refer to students' ability to examine and solve mathematical problems (Prihatiningtyas & Rosmaiyadi, 2020). Accordingly, critical thinking in mathematics learning encompasses students' cognitive skills to examine, outline, and reflect on mathematical problems systematically to obtain accurate solutions. Mathematics learning is directly related to mathematical critical thinking skills because activities that involve analyzing problems and devising solution strategies can foster these skills (Damayanti et al., 2025).

Inadequate mathematics instruction often makes it difficult for students to think deeply because they have limited practice in solving mathematical problems and tend to memorize concepts without understanding their meaning (Kusumawati et al., 2022). In relation to this issue, the urgency of developing mathematical critical thinking skills has increased in accordance with changes to the curriculum in Indonesia, as outlined in the Ministry of Education, Culture, Research, and Technology Regulation No. 12 of 2024, Article 17, which states that critical thinking skills are part of the competencies for the Pancasila Profile Strengthening Project. Prajono et al. (2022) further argued that critical thinking skills could help students solve mathematical problems both in academic settings and in real-life situations. Thus, mathematical critical thinking skills should be a primary focus of mathematics learning.

The development of critical thinking skills also depends on students' motivation and confidence. According to Faiziyah & Priyambodho (2022), students' critical thinking skills in solving mathematical problems remain suboptimal. Empirical findings indicate that students' abilities vary across the indicators of mathematical critical thinking. Some students can only understand and identify information in a given problem, while others can analyze information, evaluate solutions, and draw conclusions. These findings indicate the need for learning approaches that support students' belief in their own abilities, or self-efficacy. Self-efficacy is important in applying critical thinking skills during mathematics learning because it strengthens students' confidence in facing mathematical challenges (Yustitia et al., 2025).

Self-efficacy (SE) is a psychological aspect that influences individual behavior, particularly when completing tasks and pursuing specific goals (Ridwan et al., 2023). According to Yang et al. (2024), self-efficacy refers to students' belief in their ability to complete tasks and achieve learning goals, which can be enhanced through sustained experience in facing various mathematical challenges. Accordingly, students with high self-efficacy believe that they are competent to analyze and solve mathematical problems. They generally demonstrate strong persistence, are not easily discouraged, and are willing to take risks when analyzing mathematical problems (Rahmawati & Nopriana, 2024). This view is supported by Ningsih & Hayati (2020), who state that students with high self-efficacy are confident that they can accomplish challenging tasks in their environment.

Studies of self-efficacy in mathematics learning generally organize measurement indicators into several dimensions. A study of self-efficacy among senior high school students by Sihombing et al. (2025) used three dimensions: magnitude, strength, and generality. The study showed that these dimensions could describe students' levels of self-efficacy in mathematics learning, with strength making the most prominent contribution. The use of these dimensions indicates that self-efficacy is not assessed only as high or low but can also be analyzed through students' beliefs about task difficulty, the strength of those beliefs, and their applicability across situations.

Previous studies have reported several relevant findings. Misbahudin (2019) found a significant relationship between self-efficacy and mathematical critical thinking skills among 11th-grade vocational high school students studying arithmetic sequences and series. This relationship was reflected in the students' performance on mathematics problems related to sequences and series, suggesting that self-efficacy can support the development of critical thinking skills in mathematics. This finding is supported by Aziz et al. (2023), whose study of junior high school students indicated that students' beliefs in their own abilities were associated with their ability to analyze, identify, solve, and evaluate mathematical problems comprehensively. Niswah & Agoestanto (2021), using a quantitative pre-experimental design, similarly found that students with high self-efficacy tended to meet more indicators of mathematical critical thinking skills than students with moderate or low self-efficacy.

Previous studies have shown a relationship between self-efficacy and mathematical critical thinking skills; however, a deeper understanding of the sources of self-efficacy is still needed. Studies in mathematics learning have used the dimensions of magnitude, strength, and generality, which were further elaborated into indicators to measure students' beliefs in their abilities. Bandura further explained that self-efficacy is formed through four sources: mastery experiences, vicarious experiences, social persuasion, and physiological states (Montillano et al., 2025). These sources describe how experiences of success or failure, observations of others' success, social support, and physiological and emotional conditions contribute to beliefs in one's own abilities.

Previous studies therefore indicate that self-efficacy is related to students' mathematical critical thinking skills. Nevertheless, these studies differ in educational level, subject characteristics, research method, and the sources of self-efficacy examined. Therefore, this study analyzed students' mathematical critical thinking skills in relation to self-efficacy to gain an in-depth and comprehensive understanding.

RESEARCH METHOD

This study employed a qualitative phenomenological approach because it focused on analyzing and comprehensively understanding the participants' experiences (Al Fauzi et al., 2024; Ibrahim & Robandi, 2020; Salmiati et al., 2025). In this context, phenomenology was used to explore students' mathematical critical thinking skills through the lens of self-efficacy.

The research was conducted at a public senior high school in North Jakarta and involved 58 students from two classes. Participants were selected using purposive sampling based on criteria relevant to the research (Febrian & Jumadi, 2022). Based on the results of the mathematical critical thinking skills test and self-efficacy questionnaire, 11 students were selected to represent the mathematical critical thinking skill categories and high, moderate, and low levels of self-efficacy. The self-efficacy categories were based on the score ranges presented in Table 1. The 11 students were then interviewed to obtain more comprehensive information about their mathematical critical thinking skills in terms of self-efficacy.

Table 1. Self-Efficacy Questionnaire Score Ranges

Category	Formula
High	$M + 1SD < X$
Moderate	$M - 1SD \leq X < M + 1SD$
Low	$X < M - 1SD$

Data collection was conducted through several systematically organized stages, including instrument validity and reliability testing, followed by data interpretation and analysis. Based on the empirical validity and reliability tests, the mathematical critical thinking skills test and self-efficacy questionnaire were found to be valid and reliable and were therefore suitable for data collection. An overview of the research stages is presented in Figure 1.

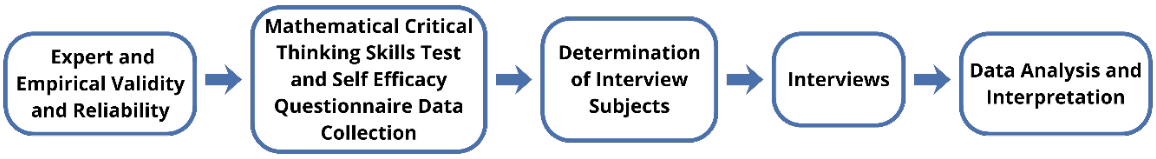

Figure 1. Research Implementation Procedures (Mahmud, 2025)

Mathematical critical thinking skills were assessed using an essay test. The self-efficacy questionnaire consisted of 28 items comprising positive and negative statements to identify students' levels of self-efficacy. Interviews were subsequently conducted to obtain more comprehensive data on how students understood, analyzed, and solved mathematical problems based on their levels of self-efficacy. The mathematical critical thinking instrument was developed based on the studies by Chaniago & Awalludin (2024) and Karim & Normaya (2015), while the self-efficacy instrument was based on the studies by Dzin & Lay (2021) and Sahin et al. (2024).

RESULTS AND DISCUSSION

Based on the results of the mathematical critical thinking skills test and self-efficacy questionnaire, 11 students were selected to represent combinations of mathematical critical thinking skill levels and self-efficacy categories. The categories of the interviewed students are presented in Table 2.

Table 2. Categorization of Student Interviews Based on Critical Thinking and Self-Efficacy

No.	Student Code	Mathematical Critical Thinking Skills Category	Self-Efficacy Category
1.	S1	Excellent	High
2.	S2	Excellent	Moderate
3.	S3	Good	High
4.	S4	Good	Moderate
5.	S5	Good	Low
6.	S6	Fair	High
7.	S7	Fair	Moderate
8.	S8	Fair	Low
9.	S9	Poor	High
10.	S10	Poor	Moderate
11.	S11	Poor	Low

Based on the results of the mathematical critical thinking skills test and self-efficacy questionnaire, 11 students were selected to represent different levels of mathematical critical thinking skills and self-efficacy, as presented in Table 2. The selected students were then asked to solve three problems as follows:

Problem 1. An airplane has seating capacity for no more than 48 passengers. Each first-class passenger is allowed to carry 60 kg of baggage, while each economy-class passenger is allowed to carry 20 kg. The airplane can carry a maximum total baggage weight of 1,440 kg. Based on the information above, identify and explain the information given in the problem.

Problem 3. A school field trip committee wants to rent two types of buses for 3 days. Type A buses can accommodate 30 passengers and cost Rp3,000,000, while Type B buses can accommodate 40 passengers and cost Rp4,500,000. The field trip will be attended by students from 8 classes, with 26 students in each class, 24 teachers, and 8 committee members. The maximum number of buses that can be rented is 7. Identify the variables and formulate the mathematical model, including the objective function and constraints.

Problem 5. A prospective student takes a university entrance examination. To be admitted, the student must obtain a mathematics score of at least 7 and a biology score of at least 6. The sum of both scores must be at least 13, and the biology score must be

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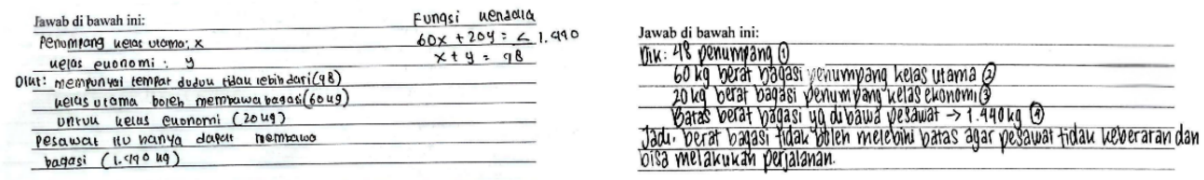
at least one point higher than the mathematics score. It is known that twice the mathematics score plus three times the biology score equals 30. Determine the mathematics and biology scores and whether the student is admitted.

The students' written responses and interview results were then analyzed to examine their mathematical critical thinking processes across different self-efficacy levels.

Students S1 and S2 (Excellent Mathematical Critical Thinking Skills, High and Moderate Self-Efficacy)



Jawab di bawah ini:
Penumpang kelas utama: x
kelas ekonomi : y
Dik: mempunyai tempat duduk tidak lebih dari (48)
kelas utama boleh membawa bagasi (60 kg)
untuk kelas ekonomi (20 kg)
pesawat itu hanya dapat membawa
bagasi (1.440 kg)
Fungsi kendala
$60x + 20y \leq 1.440$
$x + y = 48$

(a)

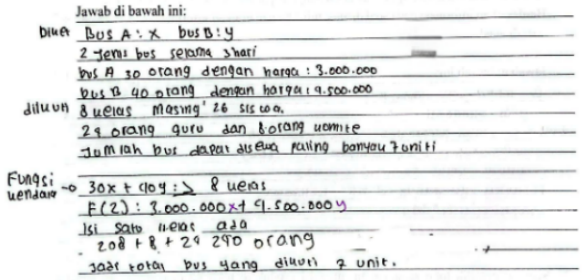
Jawab di bawah ini:
Dik: 48 penumpang (1)
60 kg berat bagasi penumpang kelas utama (2)
20 kg berat bagasi penumpang kelas ekonomi (3)
Batas berat bagasi yg dibawa pesawat → 1.440 kg (4)
Jadi. berat bagasi tidak boleh melebihi batas agar pesawat tidak keberatan dan bisa melakukan perjalanan.

(b)

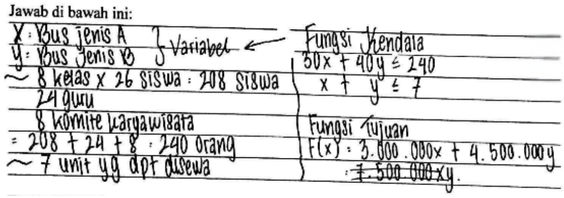
Figure 2. S1 and S2 Answers to Question 1

For question number one, which assessed the interpretation indicator, students S1 and S2 were able to explain the meaning of the problem clearly. This was supported by the interview with S1, who stated, "The problem provides information that the airplane has two classes, namely economy class and first class. First class passengers are allowed to bring baggage weighing up to 60 kg, while economy class passengers are only allowed to bring 20 kg. It is also stated that there are 48 seats on the airplane, which means that the airplane can accommodate only 48 passengers, and the airplane can carry a maximum baggage load of 1,440 kg". Similarly, S2 stated, "From question number one, it is known that the maximum passenger capacity of the airplane is 48 people. There are two types of classes on the airplane, namely first class and economy class. Regarding the baggage limit, first class passengers are allowed to bring up to 60 kg, while economy class passengers are only allowed to bring 20 kg. In addition, the total baggage that can be carried by the airplane is limited to a maximum of 1,440 kg".

The two student responses indicate that S1 and S2 were able to identify and explain the information provided in the problem appropriately. Their written answers also clearly show that both students understood the information contained in the problem.



(a)

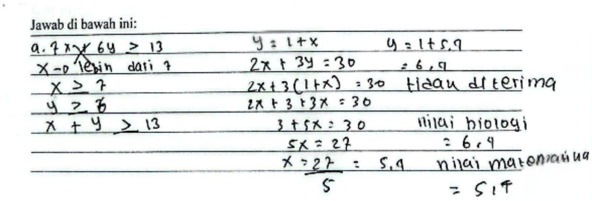


(b)

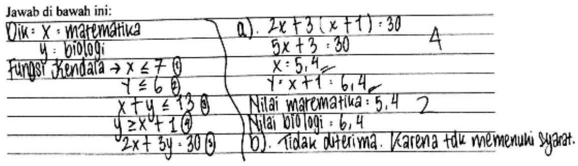
Figure 3. S1 and S2 Answers to Question 3

Findings from the interviews on question number three showed that students S1 and S2 were able to explain how to transform the information into a mathematical model. Both students explained that the first step in constructing the mathematical model was to define variables for Bus A and Bus B, then identify the number of passengers and buses before transforming the information into inequalities. In addition, both students used linear inequalities in two variables as a reference for constructing the mathematical model. Student S1 stated, "The material used as a reference is linear inequalities in two variables, to determine the variables and transform the information in the problem into inequalities". Student S2 also explained, "I constructed the mathematical model using the inequality material that had been taught previously, which involved determining the variables first and then transforming them into the objective function and constraint function inequalities".

In distinguishing between the objective function and the constraint functions, student S1 identified the constraint functions based on the requirements or conditions stated in the problem, while the objective function was associated with profit. Student S2 provided a more specific explanation by relating the terms "maximum profit" or "profit" to the objective function, while the terms "at most" or "at least" were used to identify the constraint functions. However, based on the written answer, student S1 still made an error when writing the constraint function model.



(a)



(b)

Figure 4. S1 and S2 Answers to Question 5

The findings from question number five showed that students S1 and S2 were able to explain the steps they used to solve the problem and obtain the final results. Both students explained that the solution began by transforming the information in the problem into a mathematical model, followed by using the substitution method to determine the mathematics and biology scores. Student S1 explained, "I transformed all the information into a mathematical model so that I could figure out how to determine the mathematics and biology scores" and chose the substitution method to obtain both values. Meanwhile, student S2 explained that after transforming the information into a mathematical model, the substitution method was chosen because the problem stated that the biology score had to be at least one point higher than the mathematics score. These statements indicate that both students were able to connect the information in the problem with the solution strategy they used.

When formulating a conclusion, students S1 and S2 obtained a mathematics score of 5.4 and a biology score of 6.4 and concluded that the student was not accepted into the university. Student S1 explained, "The student was not accepted because the mathematics score must not be less than 7", while S2 stated, "The student was not accepted because the mathematics score must not be less than 7 and the biology score must be at least one point higher than the mathematics score". These statements show that students S1 and S2 were able to relate the calculation results to the requirements stated in the problem and formulate an appropriate conclusion.

Based on the interview results related to self-efficacy, S1 and S2 showed relatively high levels of self-efficacy when faced with mathematical problems that had a level of difficulty similar to problems they had encountered previously. S1 and S2 tried to understand the meaning of the problem first before determining the most appropriate steps to solve it. In addition, when faced with lengthy or difficult problems, both students initially felt some doubt but continued to read and understand the problem gradually to determine an appropriate solution strategy.

Based on the test and interview results, students S1 and S2 demonstrated excellent mathematical critical thinking skills, as evidenced by their ability to understand problems, determine the required solution steps, and formulate logical conclusions. These abilities indicate that both students satisfied all the indicators used to measure mathematical critical thinking skills. Critical thinking involves not only obtaining the final answer but also examining information in depth, making connections between concepts, evaluating the accuracy of solution steps, and forming conclusions based on logical reasoning (Fauzi et al., 2020). The students' ability to apply previously learned knowledge shows that their thought processes were structured and systematic. Although student S1 demonstrated excellent ability, the student still made a mistake in writing the constraint function model. This condition indicates that even excellent critical thinking

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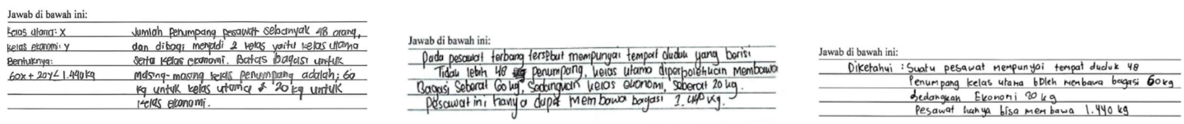
skills do not completely prevent students from making procedural mistakes in mathematical representation. It also shows that students can understand solution strategies but still make mistakes in writing mathematical models (Syarifuddin et al., 2025).

The high SE demonstrated by students S1 and S2 was evident in their persistence in solving problems, even when they initially felt uncertain upon encountering difficult mathematics problems. This indicates the presence of a "mastery experience" that strengthened the students' beliefs in their prior capabilities. The doubts that arose at the beginning of the task were also related to "physiological states," but both students continued thinking until they found a suitable solution. These conditions were consistent with findings indicating that experiences of success foster stronger self-efficacy in individuals' capacity to face and complete specific tasks (Makhmuuda et al., 2025). Furthermore, students with high SE tend to be more persistent and less likely to give up when solving mathematics problems (Zakariya, 2022).

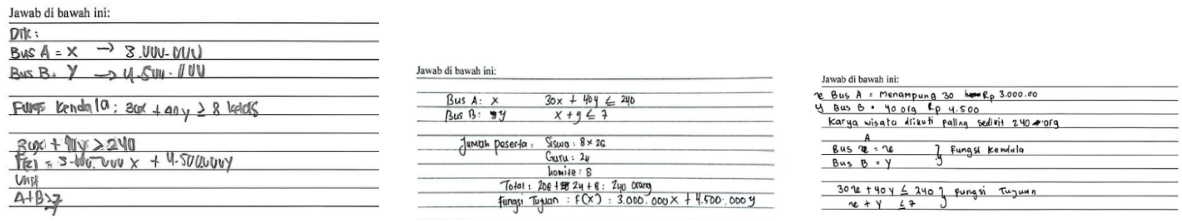
Students S3, S6, and S7 (Good and Fair Mathematical Critical Thinking Skills, High and Moderate Self-Efficacy)



(a) (b) (c)

Figure 5. S3, S6, and S7 Answers to Question 1

Based on their test answers, students S3, S6, and S7 demonstrated that they understood and could restate all the information listed in the questions. The students provided information on passenger capacity, flight class types, baggage allowances for each class, and the plane's maximum baggage capacity. The results of interviews with the three students, in which they stated, "Yes, I am certain that all the information mentioned explains the question," indicate that all three students believed the information they explained was present in the question.



(a) (b) (c)

Figure 6. S3, S6, and S7 Answers to Question 3

According to the test data findings for question number three, students S3, S6, and S7 constructed mathematical models systematically and accurately using the information

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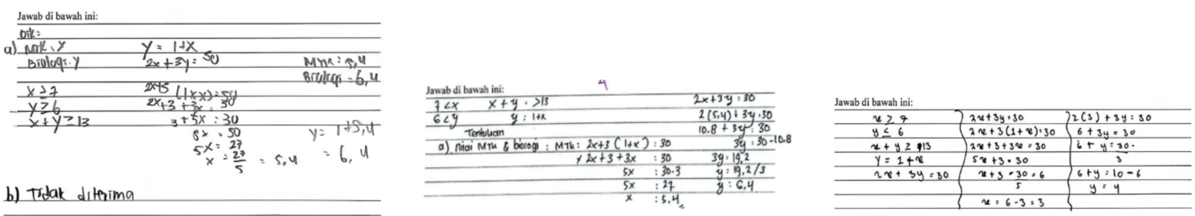
provided in the question. In the interviews, the three students explained that they converted the problem into a mathematical model by defining bus A as the variable x and bus B as the variable y, then identifying the number of field trip participants, the bus capacity, and the bus rental price. Next, the number of passengers was used to determine the constraint function, while the bus rental price was used to determine the objective function.

The three students also identified the relevant mathematical concept and explained the difference between the constraint functions and the objective function. Students S3, S6, and S7 explained that the material used was a system of linear inequalities in two variables, and the given question needed to be transformed into a mathematical inequality model first. The three students also explained that constraint functions were related to the requirements, limits, or conditions stated in the problem, while the objective function was related to profit. Student S3 stated, “If it discusses certain requirements, limits, or conditions, I use it as a constraint function. If it is used to determine profit, I use it as the objective function”. Student S6 explained, “The constraint function is used when there is information about a limit or requirement in the problem. If it is related to costs or profit, I include it in the objective function, but sometimes I am still not careful enough when distinguishing between them”. Similarly, student S7 explained, “If it is a requirement or there is a specific condition, I usually include it in the constraint function. If it is used to determine profit, I include it in the objective function”. Although the three students demonstrated an understanding of the steps involved in constructing a mathematical model, student S3 still made a minor mistake when writing the mathematical model, while student S6 still needed to review the answer because of occasional inaccuracy in distinguishing between the constraint functions and the objective function.



(a) (b) (c)

Figure 7. S3, S6, and S7 Answers to Question 5

Based on the test and interview results, students S3, S6, and S7 explained the solution strategy, constructed the mathematical model from the given information, and described the calculation steps to obtain the values of x and y. However, student S7 still made a mistake during the calculation process, resulting in inaccurate values of x and y. In the interviews, students S3, S6, and S7 were able to describe and explain why they used the substitution method because one variable could be substituted into the equation $2x + 3y = 30$. When formulating a conclusion, student S3 was able to relate the calculation results completely to the requirements stated in the problem. Student S3 stated, "I concluded that the mathematics score was 5.4 and the biology score was 6.4 based on the calculation results. Then I concluded that the student was not accepted because the mathematics score was 5.4, which was below 7, while the problem stated that the mathematics score must not be less than 7." Meanwhile, student S6 concluded the calculation results by stating, "From the calculation results, $x = 5.4$ and $y = 6.4$". Similar to student S6, student S7 only stated the calculation results without relating them to the requirements stated in the problem. Student S7 stated, "The conclusion is $x = 3$ and $y = 4$ because of the calculation". Thus, although students S3, S6, and S7 could explain the calculation results, only student S3 formulated a complete conclusion by stating the mathematics score, the biology score, and the decision that the student was not accepted into the university.

Based on the self-efficacy interview results, students S3, S6, and S7 showed a good level of belief in their abilities when solving mathematical problems with a level of difficulty similar to problems they had encountered previously. The three students explained that understanding the mathematical concepts was the basis of their belief in their ability to solve problems. Student S3 stated, "I am sure that I can solve the problem without looking at my notes when I have mastered the mathematical concepts", while student S7 explained, "I need to understand the mathematical concepts first. If I understand them, then I believe I can solve the problem". Student S6 also stated that they were "quite sure that I could solve it without looking at my notes if the problem was similar and I understood the solution steps". When facing lengthy or difficult problems, students S3, S6, and S7 continued to try to understand the problem before determining the solution method. This was reflected in the statement from student S3, who stated, "I would not feel doubtful or afraid, I would try to solve the problem first". Student S6 explained, "I would try to solve it first, so I would first remember which method to use, but if it was really difficult, I would answer the problem using the solution steps that I understood". Student S7 also stated, "First, I would not give up immediately, I would try to read and understand the problem first, then I would determine how to solve it. If the problem was really difficult and I did not understand it well, I would stop at the solution step that I understood". Although students S6 and S7 stated that when facing difficult problems they felt unable to solve, they would use a solution method they already understood, all three students continued to show effort to understand and solve the problems according to their abilities. These findings indicate that students S3, S6, and S7 had fairly good self-efficacy, as reflected in their beliefs and persistence when facing and solving mathematical problems.

Based on the test and interview results, students S3, S6, and S7 demonstrated mathematical critical thinking skills ranging from good to fair. This was evident in their ability

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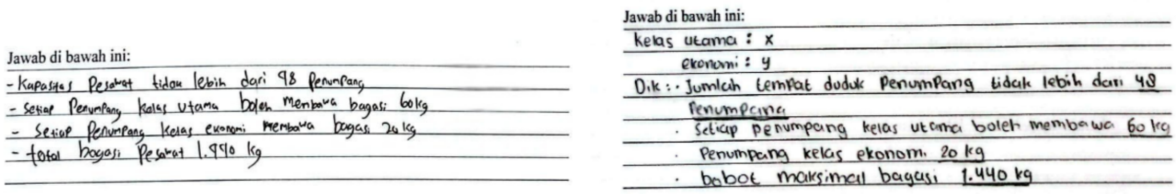
to identify and understand information, construct mathematical models, determine solution strategies, and form conclusions based on the results obtained. These findings indicate that all three students achieved the four indicators of mathematical critical thinking skills. Nevertheless, several mistakes remained, including student S3's incorrect mathematical model, student S6's lack of precision in distinguishing between constraint and objective functions, and student S7's calculation error. Additionally, the SE interview results showed that all three students held fairly strong beliefs in their ability to solve mathematical problems and continued striving to understand the problems when facing difficulties. These conditions indicate the presence of a "mastery experience" that supported students' beliefs in their abilities and enabled them to persist in solving the problems. These findings indicate that students with high SE tend to demonstrate perseverance and are not easily discouraged when solving mathematical problems (Septhiani, 2022).

Students S4 and S5 (Good Mathematical Critical Thinking Skills, Moderate and Low Self-Efficacy)


Jawab di bawah ini:
- Kapasitas Pesawat tidak lebih dari 98 penumpang
- Setiap Penumpang kelas utama boleh membawa bagasi 60kg
- Setiap Penumpang kelas ekonomi membawa bagasi 20 kg
- total bagasi Pesawat 1.990 kg

Jawab di bawah ini:
kelas utama : x
ekonomi : y
Dik : · Jumlah tempat duduk Penumpang tidak lebih dari 48 Penumpang
· Setiap penumpang kelas utama boleh membawa 60 kg
· Penumpang kelas ekonomi 20 kg
· bobot maksimal bagasi 1.440 kg

(a) (b)

Figure 8. S4 and S5 Answers to Question 1

Based on the students' written answers, S4 and S5 clearly explained the information presented in the problem. Both students identified information about passenger capacity, baggage limits for first class and economy class, and the airplane's maximum baggage capacity. When asked whether their explanations had covered all the information in the question, students S4 and S5 stated, "All the information in the problem has been explained completely". This statement indicates that both students believed that their explanations had covered all the information required in the question.

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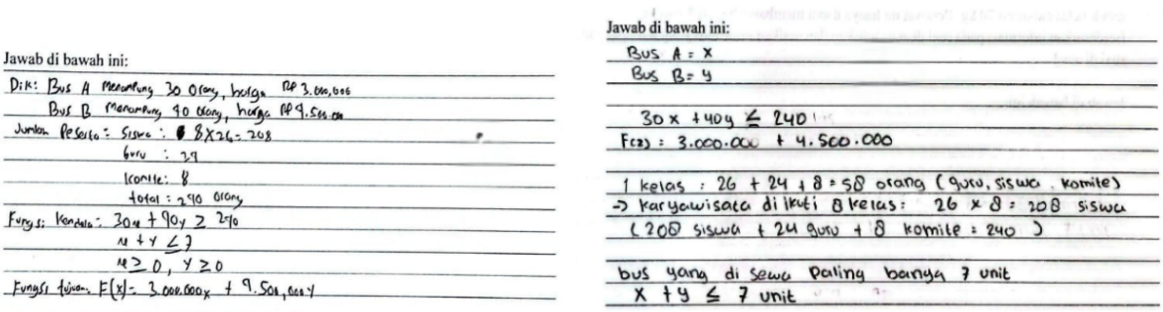

Jawab di bawah ini:

Dik: Bus A menampung 30 orang, harga Rp 3.000.000
Bus B menampung 40 orang, harga Rp 4.500.000
Jumlah Peserta: Siswa: 8 × 26 = 208
Guru: 24
Komite: 8
total: 240 orang
Fungsi: Kendala: $30x + 40y \geq 240$
$x + y \leq 7$
$x \geq 0,\ y \geq 0$
Fungsi tujuan: $F(x) = 3.000.000x + 4.500.000y$

Jawab di bawah ini:

Bus A = x
Bus B = y

$30x + 40y \leq 240$
F(x) : 3.000.000 + 4.500.000

1 kelas : 26 + 24 + 8 = 58 orang (guru, siswa, komite)
→ karyawisata di ikuti 8 kelas: 26 × 8 = 208 siswa
(208 siswa + 24 guru + 8 komite = 240)

bus yang di sewa paling banyak 7 unit
$x + y \leq 7$ unit

(a) (b)

Figure 9. S4 and S5 Answers to Question 3

Based on the test and interview data obtained from question number three, students S4 and S5 were able to explain how to construct a mathematical model based on the information provided in the question. Both students explained that constructing the mathematical model involved defining variables for Bus A and Bus B, identifying information about the bus capacity and the number of field trip participants, and then transforming the information into inequalities. Students S4 and S5 also explained that the bus rental price was used to determine the objective function, while information about the bus capacity and the number of participants was used to determine the constraint functions. Both students used the learning material on systems of linear inequalities in two variables as a reference for constructing the mathematical model. Student S4 stated, "The material is a system of linear inequalities in two variables", while student S5 stated that the student used "linear inequalities in two variables and how to transform the information in the question into a mathematical model".

In distinguishing between the constraint functions and the objective function, student S4 identified limitations or requirements, such as maximum or minimum quantities, as the constraint functions, while information used to determine profit was identified as the objective function. Student S5 also distinguished between the constraint functions and the objective function based on information that represented requirements and information used to obtain the final result. At the end of the statement, student S5 stated, "Sometimes I still need to check again so I do not mix them up". The interview results showed that students S4 and S5 understood the basic process of constructing a mathematical model and the difference between the constraint functions and the objective function, although student S5 still needed to check the answer again to avoid confusing the objective function with the constraint functions.

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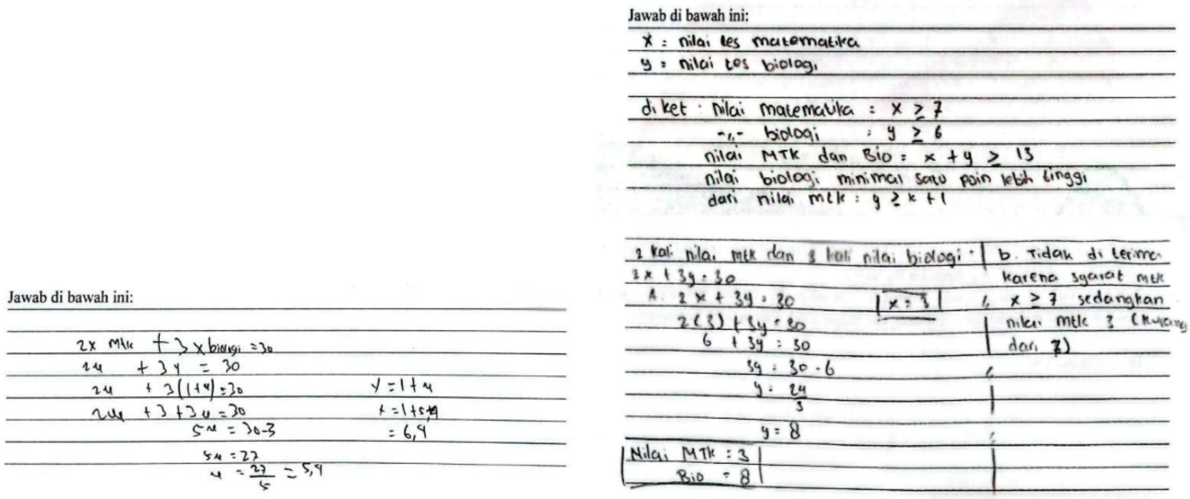

(a) (b)

Figure 10. S4 and S5 Answers to Question 5

The test and interview data from question five showed that students S4 and S5 solved the mathematical problem by presenting the solution steps and obtaining the calculation results. Both students began by identifying the given information and transforming it into equations, then used the substitution method to determine the values of x and y. Student S4 explained, "First, I looked at the information given in the problem, then I changed it into an equation such as 2x+3y=30. After that, I looked for one of the variables that could be substituted into the equation to find the values of x and y". Student S5 also explained, "First, I determined the mathematical model, then after transforming it, I found the value of x and obtained x = 3. Then, I substituted the value of x into the equation 2x+3y=30 to find the value of y and obtained y = 8". Student S5 still made a mistake during the calculation process and had difficulty explaining one of the steps used to determine the value of x. In formulating a conclusion, student S4 stated only, "The student was not accepted because the mathematics score was low", while student S5 formulated a conclusion and related the answer to the requirements stated in the question. Student S5 stated, "My conclusion was that the mathematics score was 3 and the biology score was 8 based on the calculation results. Another conclusion was that the student was not accepted because the scores did not meet the required minimum". Thus, although the calculation results for student S5 were still inaccurate, student S5 was able to formulate a more complete conclusion, while student S4 stated only the final conclusion based on the calculation results.

Based on the interview results, the level of self-efficacy of students S4 and S5 was reflected in their beliefs and persistence when facing difficulties in solving mathematical problems. Student S4 showed a high level of belief when facing problems with a difficulty level similar to problems encountered previously because the student still remembered the solution steps and how to construct the mathematical model. Student S4 stated, "I believe I can solve it if the type of problem is almost the same because I usually still remember the solution steps and how to construct the mathematical model from problems I have solved before". When facing lengthy or difficult problems, student S4 also continued to try to understand the problem before determining the solution, as stated, "Usually, I do not immediately panic or feel doubtful. I try to reassure myself that I can solve it by reading and examining the problem carefully first". Meanwhile, student S5 showed a lower and more limited belief in the ability to solve problems. Student S5 stated, "I will try to answer it first to find the solution. But if I become confused and do not know how to solve it, I will not continue and will answer based on what I have already written". Nevertheless, when facing lengthy or difficult problems, student S5 still tried to read and understand the problem first before writing the solution steps gradually. This was reflected in the statement from student S5, "At first, I do not immediately answer the problem. Instead, I read and understand it first, then when I understand it, I write down the given information and the solution steps one by one". These findings indicate that student S4 had a stronger belief when facing problems similar to those encountered previously, while student S5 still had limited belief when experiencing difficulties in determining the solution steps.

The findings from the self-efficacy interviews align with Bandura's theory that successful experiences in solving mathematics problems can strengthen an individual's self-efficacy in solving similar problems (Özcan & Kültür, 2021). Previous research has found that mathematical self-efficacy is related to students' confidence in solving problems, their persistence when facing challenges, and the effort they invest in completing mathematical problems (Street et al., 2022).

The abilities of students S4 and S5 showed that both students had achieved all indicators of mathematical critical thinking. Their ability to understand information and construct mathematical models demonstrated that they could identify information and analyze problems to determine the appropriate mathematical concepts (Salahuddin & Ramdani, 2021). Student S4 performed better in terms of the accuracy of solution strategies and calculation steps, while student S5 was more precise in interpreting the conclusions from the results obtained. However, student S5 was not yet fully able to explain the strategies used in the solution steps accurately. This finding aligns with previous research indicating that students can apply mathematical problem-solving strategies but cannot systematically explain the thought processes underlying those steps (Astuti et al., 2026).

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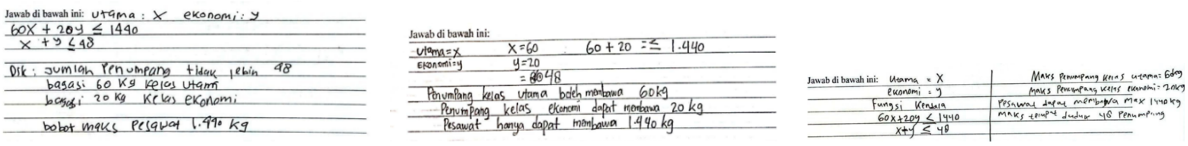
Students S8, S10, and S11 (Fair and Poor Mathematical Critical Thinking Skills, Moderate and Low Self-Efficacy)



(a) (b) (c)

Figure 11. S8, S10, and S11 Answers to Question 1

Based on the test and interview findings from question number one, students S8, S10, and S11 were able to restate the information provided in the problem. The three students identified information about passenger capacity, flight classes, baggage limits for each class, and the airplane's maximum baggage capacity. Students S8, S10, and S11 stated that "the information I explained already covered the statements provided in the question". Nevertheless, based on their test answers, the three students were still not fully accurate in identifying the information because they considered that the information provided in the question needed to be transformed into a mathematical model.

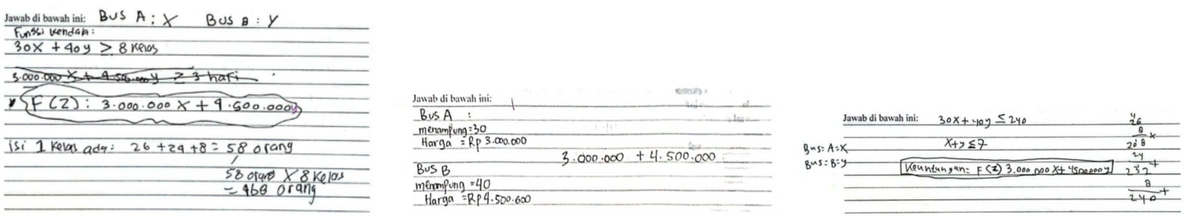


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Figure 12. S8, S10, and S11 Answers to Question 3

The test and interview data for question three showed that student S8 could explain the process of constructing the mathematical model by defining variables, transforming the information into inequalities, and identifying the information used in the mathematical model. Student S8 explained, "First, I defined Bus A as x and Bus B as y. After that, I transformed the information into a mathematical model using the method that had been taught before. I transformed the number of passengers on Bus A and Bus B into inequalities. Then, I also included the bus rental prices in the mathematical model, which are usually used to determine the profit. Finally, I calculated the total number of passengers from the number of students, teachers, and field trip participants. I obtained a total of 468 participants". However, the test results showed that student S8 still made a mistake when writing the mathematical model. Meanwhile, students S10 and S11 could not yet explain how to transform the information into a mathematical model. Student S10 stated, "Actually, I did not transform it into a mathematical model

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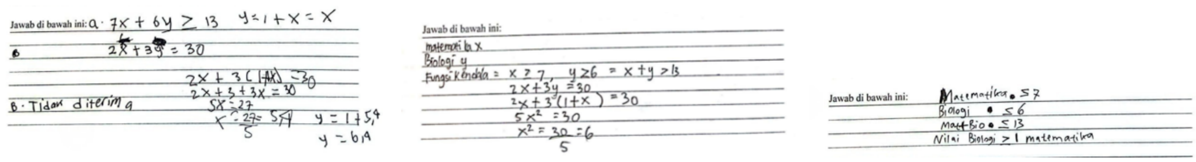
here. I only described some of the information given in the problem because at that time I was still trying to understand how to transform it into the model". Meanwhile, student S11 explained that the mathematical model was constructed after asking a friend. The following is an excerpt from the interview: "Actually, I am still confused about how to explain the process of transforming the information into a mathematical model. So, at first, I definitely defined Bus A as x and Bus B as y, then I calculated the total number of people participating in the field trip from 8 classes, 24 teachers, and 8 committee members. For the other parts of the mathematical model, I asked a friend".

The three students used the learning material on inequalities as a reference to solve the problem and transform the information into a mathematical model. In distinguishing between the constraint functions and the objective function, student S8 understood that information related to price or profit was used as the objective function. Students S10 and S11 had difficulty distinguishing between the two functions. Student S10 stated, "I usually look at the numbers and the information given in the problem. But sometimes I am still confused about which one is the constraint function and which one is the objective function". Student S11 explained, "I can still work on transforming the problem into inequalities. But when I am asked to distinguish between them, I am still confused because they have almost the same form". These findings indicate that student S8, who had fairly good mathematical critical thinking skills, was able to identify the learning material used and distinguish between the constraint functions and the objective function, while students S10 and S11, who had lower mathematical critical thinking skills, still experienced difficulties in distinguishing between the constraint functions and the objective function.



(a) (b) (c)

Figure 13. S8, S10, and S11 Answers to Question 5

The test and interview data regarding the solution to question number five showed similarities between students S8 and S10, as both had not fully understood how to solve question number five and therefore asked their friends for help in determining the solution steps. Student S8 stated, "Actually, I solved this problem by asking my friend for help. After I transformed the requirements regarding the scores into a mathematical model, I asked my friend about the method that should be used". Student S10 also stated, "For question number five, I asked my friend how to solve it, and I followed the method used by my friend". Nevertheless, based on the test results, student S10 still made a mistake during the calculation process. In formulating a conclusion, student

S8 was able to conclude that the student was not accepted because the mathematics test score was less than 7. However, the conclusion was still incomplete because it did not include the mathematics and biology scores. Meanwhile, student S10 was not able to formulate a conclusion because the student felt that the solution was not yet complete, as stated, "I do not know the conclusion because I feel that the problem I worked on was not finished". In contrast, student S11 only described some of the information provided in the problem because the student did not yet know how to solve question number five. This was supported by student S11, who stated, "I do not really know how to solve it or how to determine the first step, so I was still confused and only wrote down some of the information provided in the problem".

Based on the self-efficacy interview results, students S8 and S10 showed a moderate level of belief in their ability to solve mathematical problems with a level of difficulty similar to problems they had encountered previously, while student S11 showed a lower level of belief in their ability. Student S8 stated that the student believed they could solve problems without looking at notes when they had mastered the formula or solution method, although they still needed time to determine the appropriate steps. Meanwhile, student S10 stated, "I do not think I can solve it without my notes because I need to practice first before solving it", and student S11 explained, "I do not really believe I can, because I usually forget the steps quickly". When facing lengthy or difficult problems, student S8 tended to seek help from friends and review the learning material, while student S10 waited for help from friends and stopped when unable to determine the solution steps. Student S11 also experienced fear or confusion when facing lengthy problems, which affected the belief in their ability to solve the problem, as stated, "Usually, I immediately feel scared or confused when I see a long problem. That is what makes me less certain that I can solve it". These findings indicate that students S8 and S10 had a moderate level of belief that was influenced by their understanding of the material and previous practice, while student S11 showed a lower level of belief and was more easily affected by the difficulty of the problem. This was also reflected in the test results, where student S11 was unable to continue solving question number five and only wrote down some of the information provided in the problem.

The findings from the self-efficacy interviews show that students with moderate and low levels of self-efficacy still experience uncertainty when facing mathematical problems they consider difficult and tend to require assistance from others. Low self-efficacy can make students less confident in determining solution strategies and more dependent on others' help when working on complex mathematical problems (Fatmasari et al., 2022).

The analysis of the test and interview data shows that the mathematical critical thinking skills of students S8, S10, and S11 ranged from fair to poor. Although they could identify information in the questions, all three students still struggled to meet the indicators for

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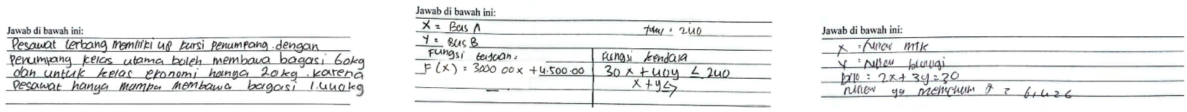
analysis, evaluation, and inference. This was evident from inaccuracies in transforming information into mathematical models, mistakes in the calculation process, and an inability to draw conclusions consistent with the solution results. These findings indicate that mathematical critical thinking skills are demonstrated not only through an understanding of given information but also through the ability to analyze problems, evaluate solution steps, and form logical conclusions based on the information obtained. These findings align with previous research suggesting that students with low levels of mathematical critical thinking often struggle to construct mathematical models, determine solution strategies, and explain the rationale behind the solution steps they select and implement to solve mathematical problems (Nurpratiwi & Setianingsih, 2021).

Student S9 (Poor Mathematical Critical Thinking Skills, High Self-Efficacy)



(a) (b) (c)

Figure 14. S9 Answers to Questions 1, 3, and 5

In the interpretation question, student S9 explained the information provided and showed that the explanation was consistent with the information presented in the question. Student S9 explained that the airplane had a capacity of 48 passengers, with a baggage limit of 60 kg for first class and 20 kg for economy class, and a maximum baggage capacity of 1,440 kg. When asked whether the information was complete, student S9 stated, "Yes, I have explained all the information in the problem completely". This statement indicates that student S9 identified the relevant information in the question and believed they had explained it completely.

Based on the test and interview data for question three, student S9 was able to construct and explain how to form the mathematical model based on the given information. Student S9 stated, "First, I defined Bus A as x and Bus B as y. Then, I calculated the total number of people participating in the field trip from 8 classes, with 26 students in each class, then added 24 teachers and 8 committee members. After that, I wrote the information from the problem in mathematical form according to the information provided". The interview excerpt shows that student S9 first defined the variables, calculated the total number of field trip participants, and then transformed the information in the problem into a mathematical model. Student S9 also identified inequalities as the learning material used as a reference for constructing the mathematical model because it was the most recently studied material. However, student S9 still experienced difficulty distinguishing between the constraint functions and the objective function, as stated by student S9, "Actually, I still get confused when distinguishing between them.

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What I know is that if there is a limit on the number or a minimum or maximum requirement, I just transform it into an inequality". This indicates that student S9 understood the basic process of constructing a mathematical model and the learning material used as a reference, but still had difficulty distinguishing between the constraint functions and the objective function.

Based on the test results and interview findings, student S9 was unable to complete question number five because of limitations in determining an appropriate solution strategy. Student S9 explained, "When working on the test, I skipped question number five because I found it difficult to answer and had not yet thought about which method to use, so I tried to solve the other questions first and worked on question number five when the test submission time was approaching". This condition led student S9 to prioritize solving the other questions before returning to question number five. As a result, based on the written answer, student S9 only wrote down some of the information provided in the problem without continuing the solution process to obtain the final answer.

Based on the questionnaire and interview data, student S9 exhibited a fairly high level of confidence when facing mathematics problems with characteristics and difficulty levels similar to those solved previously. This confidence arose because the student still recalled the formulas and solution steps learned previously. When faced with lengthy or difficult problems, student S9 tried to remain calm by working on easier problems before returning to solve the mathematics problem using familiar methods, even if the final calculations were incorrect. This situation reflects aspects of mastery experience and physiological states, including beliefs formed through prior successful experiences and the ability to manage emotional states when facing tasks.

Student S9 was categorized as having poor mathematical critical thinking skills. Student S9 was able to explain and identify information in the problems and translate it into mathematical models. However, student S9 still struggled with the evaluation and inference stages, as evidenced by their inability to fully solve problem number five. In addition, student S9 chose to work on other problems first because they found it difficult to determine the solution steps. These findings indicate that their ability to determine solution strategies and make logical decisions based on information remained suboptimal. This aligns with findings that students with low mathematical critical thinking skills tend to fulfill only some critical thinking indicators and often experience difficulties with evaluation and inference because they are accustomed to solving procedural mathematics problems (Anggraini et al., 2022).

High self-efficacy does not always correspond to strong mathematical critical thinking skills. Self-efficacy reflects an individual's belief in their own ability rather than their actual ability. Therefore, students may feel confident that they can solve mathematics problems but still struggle with problems that require in-depth analysis, evaluation, and inference. Previous research has also shown that high self-efficacy does not always reflect students' mathematical critical thinking skills because self-efficacy can develop from previous success in solving procedural problems (Endika et al., 2025).

CONCLUSION AND RECOMMENDATION

Mathematical critical thinking skills viewed in terms of self-efficacy varied across the different categories. Students with very good mathematical critical thinking skills and high self-efficacy were able to interpret information, construct mathematical models, determine solution strategies, and evaluate results accurately. Students with good mathematical critical thinking skills and either high or moderate self-efficacy were able to understand the information and construct solutions, although some errors were still found in writing mathematical models, performing calculations, and formulating conclusions. Students with good mathematical critical thinking skills and low self-efficacy also demonstrated an understanding of the concepts and solution steps, but their limited belief in their abilities when facing difficulties made them more likely to stop the solution process. In the fair mathematical critical thinking skills category, students with moderate self-efficacy were able to identify information and use appropriate concepts but still experienced difficulties in constructing mathematical models and distinguishing between the constraint functions and the objective function. Students with low self-efficacy showed limitations in sustaining the solution process when facing difficult problems. Meanwhile, students with poor mathematical critical thinking skills and high self-efficacy continued to show confidence and persistence when facing problems but still experienced difficulties in determining appropriate strategies and obtaining correct solutions. Students with low self-efficacy showed limitations in both the solution process and their belief in their abilities when facing mathematical problems.

Overall, self-efficacy was reflected in the way students solved mathematical problems, particularly in their belief in their abilities, use of previous experiences, persistence when facing difficulties, and responses during the problem-solving process. However, the level of self-efficacy did not always correspond to mathematical critical thinking skills. Students with high self-efficacy could demonstrate poor mathematical critical thinking skills, while students with lower self-efficacy could still demonstrate fairly good mathematical critical thinking skills. Therefore, gaining an in-depth understanding of students' mathematical critical thinking skills requires not only examining their written solutions but also considering their beliefs, experiences, and responses throughout the problem-solving process.

Based on these conclusions, mathematical critical thinking skills can be developed by providing students with more opportunities to engage actively in critical thinking activities, particularly analysis, evaluation, and inference, which still present challenges for some students. In addition, improving self-efficacy requires gradual experiences of success, positive reinforcement, and opportunities for students to explain their reasoning and problem-solving strategies. As a result, students will not only believe in their abilities but will also be able to demonstrate their mathematical critical thinking skills more effectively when solving mathematics problems.

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Author Contribution Statement: ASR: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. BH: Methodology, Validation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration.

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