Students' Critical Thinking Ability in Solving Controversial Mathematical Problems Seen from Computational Thinking

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Abstract

The mathematical critical thinking ability and computational thinking skills are crucial to be developed in order to enhance students' problem-solving skills, especially for students at the Center of Excellence Vocational High School who are expected to possess advanced skills for entering the professional world. This research aims to describe the mathematical critical thinking ability of 10th grade students at the Vocational High School Center of Excellence in solving controversial problems from the perspective of their computational thinking skills. The research method used is qualitative research with a descriptive approach. The findings of this research are as follows: (1) The mathematical critical thinking ability of students with high computational thinking skills in solving controversial problems falls into the high category, fulfilling three indicators of critical thinking, namely interpretation, analysis, and evaluation; (2) The mathematical critical thinking ability of students with moderate computational thinking skills in solving controversial problems falls into the moderate category, fulfilling two indicators of critical thinking, namely interpretation and evaluation; (3) The mathematical critical thinking ability of students with low computational thinking skills in solving controversial problems falls into the low category, as they fail to meet the interpretation indicator, thus other indicators remain unfulfilled. It can be concluded that there are differences in mathematical critical thinking ability among students with low, moderate, and high computational thinking skills.

Keywords: *Mathematical Critical Thinking Ability, Controversial Problems, Computational Thinking Skills, Vocational High School Center of Excellence.*

INTRODUCTION

The rapid development of technology in the era of Society 5.0 has influenced all aspects of life, including education (Muller et al., 2015). (Rahman et al., 2017) explains that in this era of Society 5.0, the teacher-centered learning model is no longer relevant. To face the Society 5.0 era, the development of 21st-century skills is needed, such as problem-solving skills (Karim et al., 2020). One of the thinking abilities that can support the development of problem-solving competence is critical thinking (Kurjum et al., 2020).

Critical thinking ability is part of the higher-order thinking skills (HOTS) required to make purposeful, reflective, and impartial judgments about whether to trust or predict practical problems in the future (Chusni & Minan, 2022). Critical thinking involves cognitive processes such as systematically and specifically analyzing problems, carefully identifying problem differences, identifying and processing known information to design problem-solving strategies (Azizah et al., 2018). Similarly, in line with the explanation, Glazer (Prihartini et al., 2016) states that mathematical critical thinking involves a combination of abilities and dispositions with basic understanding, mathematical thinking skills, and cognitive steps used to reflectively generalize, provide evidence, and address mathematical problems.

Critical thinking is not limited to the specific field of study pursued by students but can also be applied to other areas effectively for personal development (Marzuki et al., 2017). (Zetriuslita et al., 2016) stated that mathematical critical thinking ability can be measured using three indicators, namely:

The ability to recognize and determine a concept.

The ability to gather data and complete relevant information.

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The ability to evaluate a sequence of logical events (algorithm).

The analysis results by (Novita et al., 2022) at SMK Texmaco Karawang show that the indicator of identifying in critical thinking ability is still categorized as low with a percentage of 39.69%, the indicator of connecting is categorized as low with a percentage of 36.18%, the indicator of analyzing is categorized as moderate with a percentage of 46.05%, the indicator of problem-solving is categorized as moderate with a percentage of 44.08%, and the indicator of evaluating is also categorized as moderate with a percentage of 54.28%. The results of this research indicate that the critical thinking ability of students, especially SMK students, still needs to be improved.

One solution to develop students' mathematical critical thinking ability is by teaching controversial mathematical problems. According to (Sholihah et al., 2020), controversial mathematical problems refer to an issue in the domain of mathematics that tends to generate debates due to differing arguments. When students are given controversial problems during learning activities, cognitive conflicts and conflicting outcomes are often encountered (Lee et al., 2020). It is through the emergence of cognitive conflicts that critical thinking skills and interpersonal communication abilities of students are fostered, enabling them to draw appropriate conclusions (Alfiandra et al., 2018). Referring to the stages of solving controversial problems, which require structured, conceptual, and strategic thinking and problem-solving approaches, computational thinking skills can be an appropriate problem-solving skill to employ (Yadav et al., 2017).

Computational thinking is the process of breaking down complex problems into simpler ones, as described by (Rosyadi et al., 2021). In terms of the indicators of decomposition, pattern recognition, abstraction, and algorithmic thinking, computational thinking skills can be classified into three categories: high, moderate, and low computational thinking skills(Jamalludin et al., 2022). Training in computational thinking during mathematics learning activities in the classroom is beneficial for students as they transition into the professional world (Rijke et al., 2018). Therefore, the application of computational thinking skills should be promoted in mathematics learning activities in the classroom to help prepare students for their future careers, especially for students at the Vocational High School Center of Excellence who are expected to have high-quality performance in their respective fields of expertise (Baking et al., 2023).

Vocational High School Center of Excellence is a program initiated by the Ministry of Education, Culture, Research, and Technology, which focuses on the development of the quality and performance of vocational high school graduates through partnerships and alignment with the world of work (Joo, 2018). According to (Fahmayani, 2021), the Vocational High School Center of Excellence is part of the Merdeka Belajar program, which aims to improve the quality of human resources by bringing educational activities closer to the world of work. The Vocational High School Center of Excellence program serves as a collaborative space between the Ministry of Education, Culture, Research, and Technology and local governments, with the aim of enhancing the quality and relevance of vocational high schools to meet the demands of the business and industry sector (Kisno et al., 2022). (Pudyastuti et al., 2022) state that the existence of the Vocational High School Center of Excellence is intended to produce graduates who are ready to enter the workforce or become entrepreneurs through comprehensive and in-depth vocational education. (Shen et al., 2023) The objective of this research is to describe the mathematical critical thinking ability of Grade X students at the Vocational High School Center of Excellence in solving controversial problems from the perspective of students' computational thinking skills.

METHOD

This The type of research applied in this study is descriptive with a qualitative approach. Qualitative descriptive research is a research method that aims to explain and provide an overview of a phenomenon, whether it is a natural phenomenon or a human-engineered outcome, by considering the characteristics, qualities, and relationships among the observed activities (Sukmadinata, in Utami et al., 2021).

The subjects of this study are Grade X students at the Vocational High School Center of Excellence in the province of Bali, specifically focusing on schools with an automotive engineering vocational field. This selection is based on the dominance of mathematics as a subject in the automotive engineering vocational field. In this study, all Grade X Automotive Engineering students at SMKN Bali Mandara, Grade X TM 2 students at SMKN

3 Singaraja, and Grade X TKR 2 students at SMK PGRI 2 Badung, with a total of 71 students, were involved in completing the computational thinking skills test. Out of the total of 71 students, they will be categorized into three levels of computational thinking skills: high, moderate, and low computational thinking skills.

The data collection techniques used in this research are written tests and interviews. The test implementation will be divided into two parts: a computational thinking skills test with adapted questions from the "Bebras Australia Computational Thinking Challenge" book from 2018 to 2022, which consists of several Bebras problems from various countries that have been validated and reliable, and a mathematical critical thinking ability test with controversial problem-based essay questions that have been validated by experts. Additionally, semi-structured interviews were conducted. According to Esteberg in (Sugiyono, 2014), a semi-structured interview is a process of asking structured questions with the aim of deepening problem-solving, where the researched subjects are asked for their opinions and ideas without limitations.

The research instrument used to assess computational thinking skills is adapted from the problems in the Bebras Challenges and modified to fit the context of mathematics for vocational high school students, especially those specializing in the field of automotive science. The computational thinking skills test instrument can be seen in Figure 1.

Figure 1. Computational Thinking Skills Test Instrument

After conducting the test on students' computational thinking skills, the students are then classified into three categories: students with high, moderate, and low computational thinking skills. The criteria for categorizing computational thinking skills used in this study refer to (Subibjo et al., 2019) and can be seen in Table 1.

Table 1. Scale of Criteria for Categorizing Students' Mathematical Critical Thinking Ability.

Category	Interval
High	$x > M + 1SD$
Moderate	$M - 1SD < x < M + 1SD$
Low	$x < M - 1SD$

Based on the categorization, one student will be purposively selected from each category to be given a test on mathematical critical thinking ability using controversial problems. The instrument used to assess mathematical critical thinking ability in this research can be seen in Figure 2.

Masalah Kontroversial Implisit:

1. Sederhanakanlah bentuk aljabar berikut:

$$\frac{a^2 - ab}{a^2 - b^2}$$

Dari bentuk tersebut, disajikan penyelesaian sebagai berikut:

$$\frac{a^2 - ab}{a^2 - b^2} = \frac{a(a - b)}{(a + b)(a - b)} = \frac{a}{a + b}$$

Pertanyaan:

a. Menurut anda, apakah jawaban yang disajikan tersebut masuk akal? Bisakah $(a - b)$ dibagi dengan $(a - b)$? Bagaimana jika $a = b$? Berikan alasannya!

b. Apa yang dapat anda simpulkan dari penyelesaian permasalahan tersebut?

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1. Simplify the following algebraic forms:

$$\frac{a^2 - ab}{a^2 - b^2}$$

From the algebraic form, the problem solving is presented as follows:

$$\frac{a^2 - ab}{a^2 - b^2} = \frac{a(a - b)}{(a + b)(a - b)} = \frac{a}{a + b}$$

Question:

a. According to your opinion, does the solution presented make sense? Can $(a - b)$ devided by $(a - b)$? What if the condition is $a = b$? Give your reasons!

Figure 2. Mathematical Critical Thinking Test Instrument

In qualitative research, ensuring data validity is crucial. In this study, data validity was examined using the triangulation technique. Triangulation is a data collection technique that combines different methods to obtain data from the same source (Sugiyono, 2014). The collected data from the test on students' mathematical critical thinking ability and the interview data were checked by the researcher. Subsequently, a comparison was made between the two sets of data. If both sets of data show a similar tendency, then the obtained data can be considered valid.

The data from the critical thinking ability test range from 0 to 4. Before analyzing the data, it was first described according to the indicators of mathematical critical thinking by Facione (2015), which include: (1) interpretation,

(2) analysis, (3) evaluation, and (4) inference. The scoring rules for assessing students' critical thinking ability according to Karim & Normaya (2015) are represented in Table 2.

Table 2. Scale of Criteria for Categorizing Students' Mathematical Critical Thinking Ability

Critical Thinking Indicators	Indicator Descriptions	Score
Interpretation	Students are able to write the known information and the information requested from the problem accurately and completely.	4
	Students are able to write the known information and the information requested from the problem accurately but not completely.	3
	Students are able to write only the known information accurately or only the requested information accurately.	2
	Students write the known information and the requested information inaccurately.	1
	Students are unable to write the known and requested information.	0
Analysis	Students are able to analyze the mathematical model presented in the problem accurately, according to the relevant material, and provide correct and complete explanations.	4
	Students are able to analyze the mathematical model presented in the problem accurately, according to the relevant material, but there are errors in their explanations.	3
	Students are able to analyze the mathematical model presented in the problem accurately, according to the relevant material, without providing explanations.	2
	Students are able to analyze the mathematical model presented in the problem, but it is not accurate according to the relevant material.	1
	Students are unable to analyze the mathematical model presented in the problem according to the relevant material.	0
Evaluation	Students are able to evaluate problem solutions with accurate and complete calculations or explanations.	4
	Students are able to evaluate problem solutions completely but make errors in calculations or explanations.	3
	Students are able to evaluate problem solutions, but the evaluation is incomplete or they use an inappropriate strategy that is still complete.	2
	Students evaluate problem solutions with an inappropriate and incomplete strategy.	1
	Students are unable to evaluate problem solutions.	0
Inference	Students are able to draw conclusions accurately, in accordance with the context of the problem, and complete.	4
	Students are able to draw conclusions accurately, in accordance with the context, but it is not complete.	3
	Students draw conclusions that are not accurate, even though they are adjusted to the context of the problem.	2
	Students draw conclusions that are not accurate and do not match the context of the problem.	1
	Students do not draw conclusions.	0

The described data is then categorized into three categories: high, moderate, and low. The categorization criteria used refer to the categories by Sudijono(2013), as presented in Table 3.

Table 3. Scale of Criteria for Categorizing Students' Mathematical Critical Thinking Ability

Category	Interval
High	$x > 10{,}67$
Moderate	$5{,}33 < x < 10{,}67$
Low	$x < 5{,}33$

The data from the critical thinking ability test range from 0 to 4. Before analyzing the data, it was first described according to the indicators of mathematical critical thinking by Facione(2011), which include: (1) interpretation, (2) analysis, (3) evaluation, and (4) inference. The described data is then categorized into three categories: high, moderate, and low. After the researcher categorized the sudents based on their critical thinking skills, then data reduction was carried out until the data was celar so that three student answers were obtained which would later be further examined through interviews. The result of the interviews and answers from the selected students will be presented descriptively.

RESULT

From the results of the computational thinking skills test, one student was selected from each level of computational thinking. Subject S1 in this study is a student with high computational thinking skills, subject S2 is a student with moderate computational thinking skills, and subject S3 is a student with low computational

thinking skills. The mathematical critical thinking ability of students in solving controversial problems will now be described based on their respective levels of computational thinking skills.

Mathematical Critical Thinking Ability of Students in Solving Implicit Controversial Problems from the Perspective of Computational Thinking Skills

Mathematical Critical Thinking Ability of Students with High Computational Thinking Skills in Solving Implicit Controversial Problems

Given an algebraic problem in the form of $\frac{a^2-ab}{a^2-b^2}$, and the question is whether the answer to the problem is reasonable or not. Also, whether $(a - b)$ in the numerator can be divided by $(a - b)$ in the denominator after simplification if $a = b$?

Based on the given information in the problem, in my opinion, the answer to the problem is reasonable as long as a is not equal to b. For example, if we take $a = 1$ and $b = 2$, the expression can be simplified and the answer would be reasonable. However, if we substitute $a = b$ into the expression, then:

$$\frac{b^2 - b.b}{b^2 - b^2} = \frac{b^2 - b^2}{b^2 - b^2} = \frac{0}{0}$$

The conclusion is that the expression cannot be simplified as indicated in the problem, as a can potentially be equal to b.
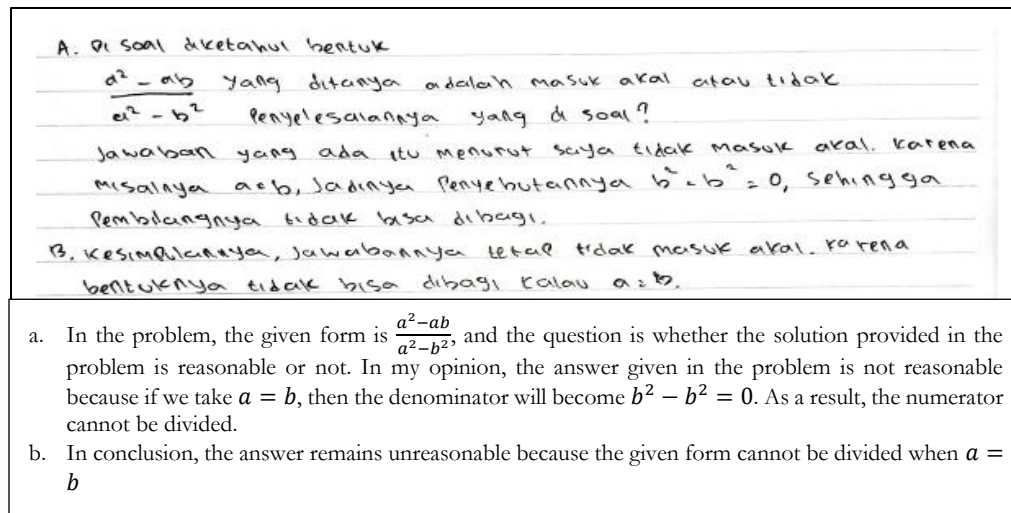
Figure 3. Written Test Results of Subject S1 in Solving Implicit Controversial Problems

Considering the interpretation indicator, Subject S1 has successfully identified the known information and the information being asked accurately and completely. In their answer, Subject S1 states that the known information is the algebraic form $\frac{a^2-ab}{a^2-b^2}$ dan and the question is whether the given solution is reasonable or not if $a = b$. Additionally, Subject S1 has also been able to analyze the inappropriateness of the problem solution, noting that the provided solution will be reasonable if $a \neq b$. However, the supporting explanation for this analysis is not entirely accurate as Subject S1 provides a condition that leads to a contradiction by assuming that $a = 1$ and $b = 2$.

Regarding the evaluation indicator, Subject S1 has performed an evaluation process to recheck the problem solution based on the given condition in the problem. Subject S1 states that if $a = b$ is substituted, then $\frac{a^2-ab}{a^2-b^2}$ will be the same as $\frac{b^2-b^2}{b^2-b^2}$ resulting in a final result of $\frac{0}{0}$. The evaluation process conducted is actually correct; however, Subject S1 does not explain what will happen if the final result obtained is $\frac{0}{0}$. At the end of the problem solution, Subject S1 provides a conclusion that the algebraic form presented cannot be simplified using the given solution method because $a = b$ might be possible. This conclusion is still somewhat inaccurate, although it has been adjusted to the context of the problem.

Based on the description of Subject S1's solution to the implicit controversial problem, it can be concluded that Subject S1 has fulfilled the three indicators of mathematical critical thinking, namely interpretation, analysis, and evaluation. Guided by the validated scoring rubric, Subject S1 obtained a score of 12, indicating that Subject S1 belongs to the group of students with a high level of mathematical critical thinking ability in solving implicit controversial problems.

Mathematical Critical Thinking Ability of Students with Moderate Computational Thinking Skills in Solving Implicit Controversial Problems

A. Di soal diketahui bentuk
$\frac{a^2 - ab}{a^2 - b^2}$ yang ditanya adalah masuk akal atau tidak penyelesaiannya yang di soal?
Jawaban yang ada itu menurut saya tidak masuk akal. Karena misalnya a=b, Jadinya penyebutannya $b^2 - b^2 = 0$, sehingga pembilangnya tidak bisa dibagi.
B. Kesimpulannya, jawabannya tetap tidak masuk akal. Karena bentuknya tidak bisa dibagi kalau a=b.

a. In the problem, the given form is $\frac{a^2-ab}{a^2-b^2}$, and the question is whether the solution provided in the problem is reasonable or not. In my opinion, the answer given in the problem is not reasonable because if we take $a = b$, then the denominator will become $b^2 - b^2 = 0$. As a result, the numerator cannot be divided.

b. In conclusion, the answer remains unreasonable because the given form cannot be divided when $a = b$

Figure 4. Written Test Results of Subject S2 in Solving Implicit Controversial Problems

If we consider the interpretation indicator, Subject S2 has successfully identified the known information and the information being asked accurately and completely. In their answer, Subject S2 writes the known information as the form $\frac{a^2-ab}{a^2-b^2}$ and the information being asked is whether the given solution is reasonable or not. Although it is accurate, the known information can be further supplemented with the conditions given in the problem. Additionally, Subject S2 has also analyzed the inappropriateness of the problem solution, noting that the provided solution in the given problem will be reasonable if $a \neq b$. However, the supporting

explanation for this analysis is still somewhat inaccurate as Subject S2 presents a condition that leads to a contradiction by using the example $a = 1$ and $b = 2$.

When considering the evaluation indicator, Subject S2 has performed the evaluation process and provided an explanation that if $a = b$ is substituted, the denominator will become $b^2 - b^2 = 0$ and the division process cannot be carried out. This evaluation process is nearly accurate as Subject S2 has shown that when $a = b$, he division process cannot be performed because the denominator becomes 0. However, the explanation provided in the evaluation process is still incomplete as Subject S2 only substitutes $a = b$ in the denominator. In the conclusion of their solution, Subject S2 states that the presented problem solution remains unreasonable because the division process in the simplification cannot occur when $a = b$. Although the inference indicator has appeared, the final conclusion drawn by Subject S2 is still not accurate as they only focus on the condition when $a = b$ which can make the presented solution appear unreasonable without considering that the solution can be reasonable if $a \neq b$.

Based on the description of the controversial problem-solving by Subject S2, it can be concluded that Subject S2 has fulfilled two indicators of mathematical critical thinking, namely interpretation and evaluation. Based on the validated scoring rubric, Subject S2 obtained a score of 10, indicating that they have a moderate level of mathematical critical thinking ability in solving implicit controversial problems.

Mathematical Critical Thinking Ability of Students in Solving Explicit Controversial Problems from the Perspective of Computational Thinking Skills

Mathematical Critical Thinking Ability of Students with High Computational Thinking Skills in Solving Explicit Controversial Problems
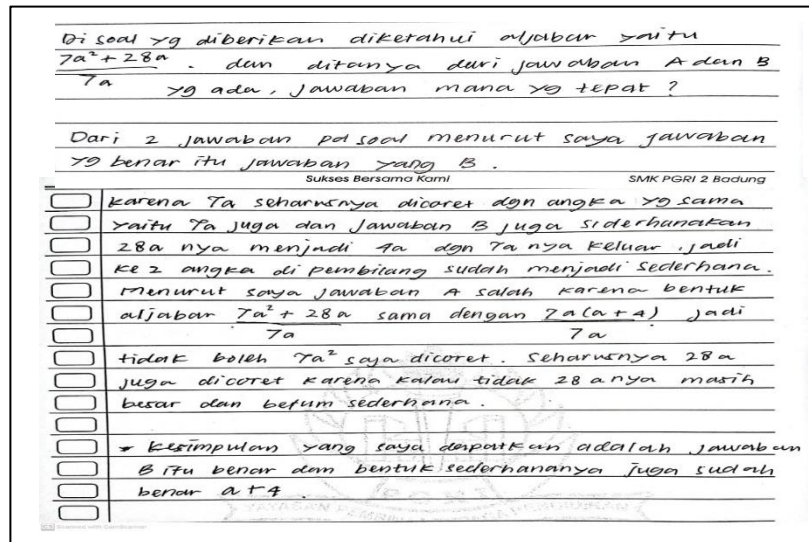
In the given problem, the algebraic expression $\frac{7a^2+28a}{7a}$ is known, and it is asked to determine which of the given answers, A or B, is correct. In my opinion, answer B is the correct one.
This is because the term $7a$ should be canceled out with the same term, which is $7a$ and answer B has already simplified $28a$ to $4a$ by removing $7a$ d from the expression. Thus, both terms in the numerator have been simplified. According to me, answer A is incorrect because the algebraic expression $\frac{7a^2+28a}{7a}$ is equivalent to $\frac{7a(a+4)}{7a}$
Therefore, it is not correct to cancel out only the $7a$ term.
Consequently, it can be concluded that answer B is correct, and the simplest form of the expression is $a + 4$

Figure 6. Written Test Results of Subject S1 in Solving Explicit Controversial Problems

In terms of the interpretation indicator, subject S1 has successfully identified the known information and the question accurately and completely. In the answer, subject S1 states that the known information is the algebraic expression $\frac{7a^2+28a}{7a}$ and the question is which option presents the correct solution to the problem. Furthermore, subject S1 has also been able to analyze the reason why the solution in option B is considered correct, which is because by removing $7a$ the original algebraic expression becomes $\frac{7a(a+4)}{7a}$, thus simplifying $28a$ by dividing it by $7a$.

Regarding the evaluation indicator, subject S1 has carried out the evaluation process to review the problem solution based on the given conditions in the problem. Subject S1 states that if they want to simplify the expression $\frac{7a^2+28a}{7a}$, both $7a^2$ and 28 should be divided by $7a$. Conceptually, this evaluation is correct, but the reason provided is not accurate because subject S1 mentions that $28a$ should be divided because if not divided, its value will still be large. From this answer, it is apparent that subject S1 has not been able to connect their reasoning with the appropriate mathematical concept. At the end of the problem solution, subject S1 has drawn a conclusion that the correct option is option B and the simplified form of the algebraic expression is $a + 4$. This conclusion is correct, complete, and in line with the given problem.

Based on the description of subject S1's explicit resolution of a controversial problem, it can be concluded that subject S1 has been able to meet the three indicators of mathematical critical thinking: interpretation, analysis, and evaluation. Following the validated scoring rubric, subject S1 achieved a score of 12, indicating that subject S1 belongs to students with a high level of mathematical critical thinking ability in solving explicit controversial problems.

Mathematical Critical Thinking Ability of Students with Moderate Computational Thinking Skills in Solving Explicit Controversial Problems

a. What is known in the problem is the algebraic expression: $\frac{7a^2+28a}{7a}$

The question in the problem is: Which solution is the most accurate among the given options?

In my opinion, answer B is the most accurate. Answer A is incorrect because if we want to use the cancellation method, it should be done like this:

$$\frac{7a^2 + 28a}{7a} = a + 4$$

Everything should be canceled out or divided because the greatest common divisor (GCD) of 7 and 28 is 28.

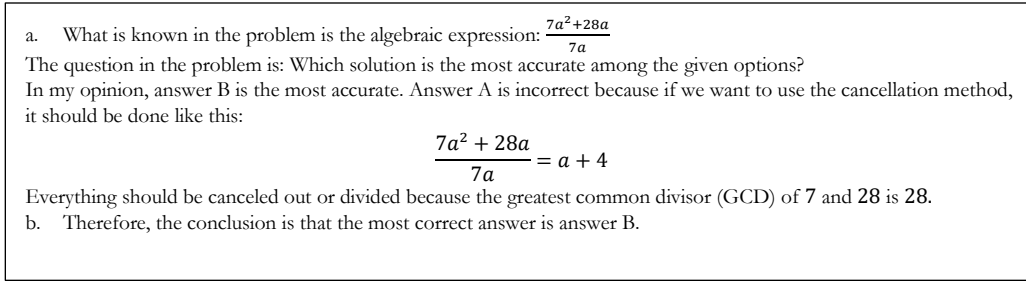b. Therefore, the conclusion is that the most correct answer is answer B.

Figure 7. Written Test Results of Subject S2 in Solving Explicit Controversial Problems

When aligned with the interpretation indicator, subject S2 has successfully identified the asked information accurately. However, they have not been able to identify the known information accurately. In their answer, subject S2 states that the known information is the form $\frac{7a(a+4)}{7a}$ and the asked information is which option presents the most accurate solution to the problem. Based on the given answer, subject S2 made a mistake in identifying the known information, as they mentioned the answer choices listed in the options instead of the known information. Furthermore, subject S2 has analyzed which option provides the correct problem solution. However, in conveying their analysis, subject S2 did not supplement it with the appropriate reasoning when connected to relevant mathematical concepts.

n terms of the evaluation indicator, subject S2 has carried out the evaluation process and provided an explanation that if they want to simplify the algebraic expression $\frac{7a^2+28}{7a}$ using cancellation, the process that needs to be done is to cancel both terms in the numerator, which are $7a^2$ and $28a$. Additionally, subject S2 provides information that this process needs to be done because the greatest common divisor (GCD) of 7 and 28 is 28. Although the evaluation regarding the simplification in option A conducted by subject S2 is correct and has connected it to the concept of simplifying the form through the GCD of the given numbers, the accompanying reasoning is still not accurate, as the GCD of 7 and 28 is 7 not 28. In their final resolution, subject S2 states that the correct option is option B. Although there is an inference indicator present, the final conclusion drawn by subject S2 is still incomplete because they only selected the correct option and have not concluded the simplified form of the algebraic expression $\frac{7a^2+28}{7a}$.

Based on the description of subject S2's explicit resolution of a controversial problem, it can be concluded that subject S2 has been able to meet two indicators of mathematical critical thinking: interpretation and evaluation. Following the validated scoring rubric, subject S2 achieved a score of 10, indicating that subject S2 belongs to students with a moderate level of mathematical critical thinking ability.

Mathematical Critical Thinking Ability of Students with Moderate Computational Thinking Skills in Solving Explicit Controversial Problems

a. The correct answer is answer A because the greatest common divisor (GCD) of $7a^2$ and $7a$ is $7a$ so the most accurate answer is A.

b. Therefore, the conclusion is that the most appropriate answer is answer A
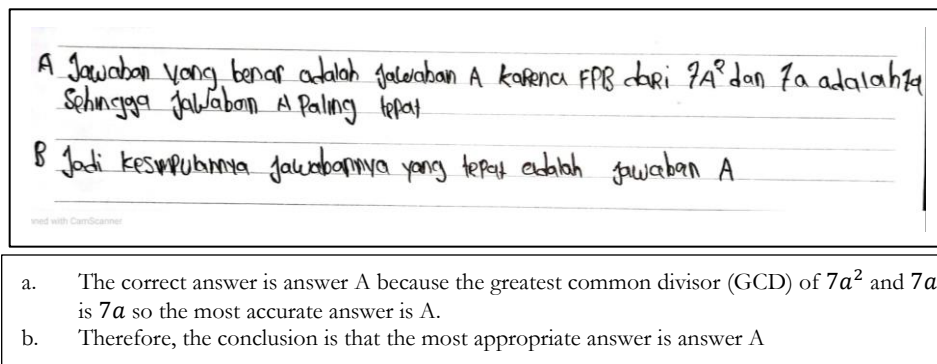
Figure 8. Written Test Results of Subject S3 in Solving Explicit Controversial Problem

Regarding the interpretation indicator, subject S3 did not start the problem-solving process by identifying the known information and the question. Instead, they directly focused on their analysis of the given problem. From the answer in Figure 7, it is apparent that subject S3 immediately wrote down the steps of analysis without utilizing the known information in the problem to support their analysis. When examined from the analysis indicator, subject S3 states that the option that provides the most accurate problem solution is option A. However, this statement lacks the reasoning behind it and fails to explain the process by which the answer in option A can be considered correct when connected to relevant mathematical concepts.

Based on the evaluation indicator, it is evident that subject S3 did not evaluate the other answer options that were deemed incorrect. Therefore, it can be concluded that in the given answer, the evaluation aspect is still missing. From the problem-solving process performed by subject S3, it is inferred that the correct option is option A. However, in writing this conclusion, subject S3 did not provide an explanation as to why option A is considered incorrect and which mathematical concepts could support that conclusion.

Based on the description of subject S3's resolution of a controversial problem, it can be concluded that subject S3 has not been able to interpret the problem effectively, thus the other indicators of mathematical critical thinking have not been met. Following the validated scoring rubric, subject S3 achieved a score of 3, indicating that subject S3 has a low level of mathematical critical thinking ability.

DISCUSSION

Based on the representation of students' critical thinking abilities in solving implicit and explicit controversial problems, several controversial reasoning patterns were identified in Table 4.

Table 4. Characteristics of Levels of Controversial Mathematical Reasoning

Levels	Mathematical Controversial Reasoning
Initial	Students can recognize the controversy in a problem but may not be able to explore the components causing the contradiction. For example, students are aware that $\frac{0}{0}$ and two different answers in simplifying the same algebraic expression are a contradiction, but they may not be able to identify which component causes the controversy.
Exploration	Students can identify the components causing the controversy but may not be able to provide clarification of the existing controversy. For example, students can determine that in simplifying a fraction (where the numerator involves addition), it is not allowed to divide one of the components by the denominator. However, students may not be able to provide a reason as to why this situation occurs.
Clarification	Students can clarify the problem using various logical reasons that justify their solution. For example, students demonstrate that the simplified form of $\frac{7a^2+28}{7a}$ is $a + 4$. This answer is reinforced by the use of the concept of the greatest common divisor (GCD) in simplifying the algebraic expression, where the GCD of 7 and 28 is 7. Therefore, both the components $7a^2$ and $28a$ in the numerator should be simplified by dividing them by 7a to obtain the simplest form, which is $a + 4$.

In general, students with high and moderate computational thinking skills demonstrate good mastery of the interpretation indicator, as evidenced by their ability to identify the known information and the question. In contrast, students with low computational thinking skills may struggle to mention the information presented in the problem, both the known information and the question. These research findings align with the findings of (Palts et al., 2020), stating that students with low computational thinking skills may not be able to identify the known information and the question accurately, leading to inaccurate problem-solving solutions. Interestingly, these research findings contradict the findings of (Lestari et al., 2020), who suggested that students with low computational thinking skills can accurately state the known information and the question, albeit in a shorter description compared to students with high or moderate thinking skills.

In this study, it was also found that among the three levels of computational thinking skills, only students with high computational thinking skills could meet the analysis indicator effectively. In solving controversial problems, students with high computational thinking skills can explain the errors in the given problem solutions and the conditions that make those solutions incorrect. However, these findings were not observed in written form but rather during in-depth interviews conducted to enhance students' mathematical critical thinking skills. However, the previous findings by (Kamil, 2021) showed different results for the analysis indicator. In their study, it was found that students with sufficient computational thinking skills were able to identify errors in problem-solving and were able to correct those errors.

From the evaluation indicator, it has been found that students with low computational thinking skills are the only ones who cannot perform proper checks on both the problem solutions and the conditions presented in the controversial problem. These research findings confirm the results of the study by (Kamil, 2021), which stated that students with low computational thinking skills have low checking skills, as they do not know how to verify whether a problem-solving process is correct or not.

Another finding obtained from this study is that all students, whether they have high, moderate, or low computational thinking skills, ultimately cannot provide complete and accurate conclusions. This can be seen in the description of research results presented in subsection 4.1, where none of the students obtained full scores in the inference indicator. These research findings align with the results proposed by (Lestari et al., 2023), stating that students with high, moderate, or low computational thinking skills still lack the ability to write conclusive statements at the end of the problem-solving process they present. However, both of these research findings contradict the results of the study by (Labusch et al., 2019), which suggested that only students with low computational thinking skills cannot provide accurate conclusions, while students with high and moderate computational thinking skills can already provide appropriate conclusions that align with relevant concepts.

Not only providing a description of students' mathematical critical thinking abilities in solving controversial problems based on their computational thinking skills, but there are also other findings in this study. From the scores obtained for critical thinking skills, as seen in Appendix 5, it can be noted that 32 students still scored below 8 in computational thinking skills. This indicates that 45% of the 71 students from the Vocational Excellence Center class X involved in this study still have low computational thinking skills. Considering that students from the Vocational Excellence Center are expected to have good problem-solving abilities to succeed in their professional careers, the low level of computational thinking skills among these students needs to be addressed by both the students themselves and the educational institutions within the Vocational Excellence Center environment.

The limitation of this study lies in the problems provided as a test of mathematical critical thinking skills, which were limited to controversial problems with algebraic content. Thus, a comprehensive description of students' mathematical critical thinking abilities when solving controversial problems with other content areas has not been obtained. Furthermore, the selection of subjects is another limitation, as only one class from each Vocational Excellence Center was chosen to take the computational thinking skills test, and only two students were purposively selected as research subjects to be given controversial problems. It would be interesting to explore the overall mathematical thinking abilities of students to obtain more valid research results.

CONCLUSION

Based on the presented research findings and analysis, it can be concluded that: (1) students with high computational thinking skills have high mathematical critical thinking abilities in solving controversial problems, (2) students with moderate computational thinking skills have moderate mathematical critical thinking abilities in solving controversial problems, (3) students with low computational thinking skills have low mathematical critical thinking abilities in solving controversial problems.

From this research, it is evident that there is a significant gap between the mathematical critical thinking abilities of students with high and low computational thinking skills. Therefore, it is recommended that learning activities further develop training in students' critical thinking and mathematical thinking abilities to strengthen their problem-solving skills in the face of the societal era.

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