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UNDERSTANDING COMMON ERRORS IN LINEAR EQUATIONS SYSTEMS AMONG EIGHT GRADE STUDENTS

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ABSTRACT

This research employs a qualitative descriptive method. The average student score in the first semester final summative assessments indicates that the minimal completion criteria have been met; however, a review of the list of incorrect responses shows that many of the errors are related to two-variable linear equation systems. Additionally, it is common for students to struggle with converting a mathematical model from the problem. The purpose of this study is to describe the errors made by students in solving problems related to two-variable linear systems and to analyze the factors contributing to these errors. We used data analysis of student responses in this study because it allows us to observe the students' thought processes and ensures the accuracy of the information. According to the study's findings, students' errors in answering the questions stemmed from their inability to grasp relevant concepts. One possible solution is for students who struggle with conceptual understanding to focus more on mastering the material, practice answering questions frequently to become accustomed to various question types, and ultimately enhance their comprehension of mathematical concepts.

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INTRODUCTION

One method to enhance human potential and quality is through education. Efforts to improve the nation's quality through education are essential, as the quality of education significantly influences the learning process (Wijaya et al., 2018). In addition to fostering intelligence, quality learning can also be practical and valuable in everyday life. Our daily challenges include handling and identifying factual information, performing calculations, processing numbers, and understanding social numerical computations. All of these issues can be addressed with the help of the arithmetic lessons we receive in school (Winata & Friantini, 2020).

Mathematics can be viewed from two different perspectives: mathematics as an object and mathematics as an ability. Mathematics as an object focuses on abstract concepts that cannot be seen directly, such as facts, concepts, operations, and mathematical principles. These mathematical objects are derived from human experiences processed through deductive reasoning, allowing mathematical concepts to be easily understood and manipulated by others using a mathematical language that has global significance (Izniati & Miatun, 2022). Mathematics as a skill involves the ability to think logically and deductively. It is not only about understanding mathematical concepts but also about relating those concepts to real-life situations and solving problems using logic. Mathematics as a skill is applied in various aspects of daily life, such as calculating, measuring, and problem-solving, demonstrating that mathematics is not only theoretical but also practical (Maryam & Rosyidi, 2016; Syafri, 2017), Thus, mathematics as an object consists of abstract concepts developed through deductive reasoning, while mathematics as an ability refers to the capacity to think logically and deductively, which is applied in various aspects of life. The ability to understand concepts is crucial for development; in learning, understanding can be taught by teachers or expressed in one's own words (Husna, 2014).

Learning mathematics focuses primarily on developing conceptual understanding. Students must have a solid grasp of mathematical principles in order to interpret previously learned material and solve problems (Febriyanto et al., 2018). In studying mathematics, students must master several concepts. A person's ability to classify something as an example or a non-example defines a concept (Fajar et al., 2018).

The ability to understand concepts is a skill closely related to translating a problem into

a global and functional mathematical form (Lestari & Yudhanegara, 2018). To understand a subject, students need to develop mathematical skills that are highly useful for solving problems. In line with this research, it is stated that the correct understanding of concepts, theorems, rules, and mathematical formulas can be achieved if students are able to focus on the teaching materials being studied and taught by the teacher (Putri, 2012). One of these abilities is the ability to understand concepts (Suraji et al., 2018).

According to the NCTM, there are several standards for the learning process: (1) the ability to understand concepts, (2) problem-solving, (3) mathematical communication, (4) mathematical reasoning and proof, and (5) mathematical connections and representation. Based on this, students are required to have the ability to understand concepts in order to comprehend and solve problems (NCTM, 2000).

The ability to understand mathematical concepts includes seven indicators: (1) restating a concept, (2) classifying objects according to certain properties, (3) providing examples and non-examples of concepts, (4) presenting concepts in various forms of mathematical representation, (5) developing necessary or sufficient conditions for a concept, (6) using, utilizing, and selecting specific procedures or operations, and (7) applying concepts or problem-solving algorithms (Eka Zuliana, 2017). The indicators that the researcher will choose are as follows: (1) restating a concept; (2) presenting a concept in the form of a mathematical representation; (3) using, utilizing, and selecting specific procedures or operations; and (4) applying algorithmic concepts in problem-solving. These choices are based on the descriptions of various opinions regarding indicators of mathematical concept understanding ability.

In learning mathematics, many students still struggle to understand the problems presented in mathematical questions (Andayani & Lathifah, 2019). Students face difficulties in understanding problems in questions that require them to investigate (analyze), make considerations (evaluate), and create solutions. One of the topics to be studied is the Two-Variable Linear Equation System (TVLES). In the summative results of the first semester of the 2023/2024 academic year, it is evident that students' abilities in solving two-variable linear systems are still low.

Table 1. Results of the Final Summative Assessment for the First Semester on the Material of Two-Variable Linear Equation Systems

Number of students (32 Students)	Average student grades	Question number 11 to 20 (includes material)
Grade 8	77,67	12, 13, 15, 17,18,19

The table above indicates that the class has an average score; however, an analysis of the material on the system of linear equations with two variables reveals several incorrect question numbers. Questions 12 and 15 are presented in the form of contextual stories, while question 13 is displayed as a graph. Questions 17, 18, and 19 are also contextual questions that are interrelated; if the mathematical model is incorrect, then all three questions will also be incorrect, and vice versa.

Students often make mistakes in contextual questions related to the system of linear equations due to several factors, including misunderstandings about the questions. This includes students' inability to translate contextual problems into mathematical models. These errors can occur either in the results or during the process of solving the questions, including calculations (e.g., lack of accuracy in performing calculations, errors in calculating, and frequent mistakes in multiplication, division, addition, and subtraction).

Errors in solving problems related to the system of linear equations cannot be separated from previous material that has not been well mastered, such as algebraic operations. The results of Putri, Zulkardi and Riskanita's (2022) study indicated that there are still many difficulties for students to perform arithmetic operations on algebra forms. Additionally, the TVLES material was identified as difficult by Capate and Lapinid (2015) in their Mathematics Assessment Test for grade VIII students in the Philippines, revealing that the percentage of completion scores in graphical, algebraic, and problem-solving contexts related to SPL was still below 50%.

The results of the math teacher interviews indicate that students who took the first semester final summative exam met the minimum completion requirements with an average score. However, a review of the list of incorrect answers reveals that many of the errors are related to the content of the two-variable linear equation system. Furthermore, the instructor noted that students frequently struggle to convert a problem into a mathematical model.

Based on the preceding description, the researcher examined student errors in solving problems related to the two-variable linear system content with respect to conceptual

understanding. This study aims to characterize student errors in solving linear systems with two variables and to investigate the contributing causes behind these errors.

METHOD

The type of research used in this study is a qualitative descriptive method. The study was conducted at Junior High School Al Kautsar in Bandar Lampung. Data collection techniques included tests and interviews. The test used was a descriptive assessment focused on the material of the two-variable linear equation system. The technique used to select research subjects was simple random sampling. The subjects in the study consisted of 32 eighth-grade students. Tests serve as a means to assess a student's ability (Arifin, 2011). To measure conceptual understanding in this study, a research instrument in the form of a descriptive test with four questions is required. The test questions have been adjusted based on indicators of students' abilities to understand mathematical concepts. The stages of the test administration include presenting students with the descriptive questions, analyzing their answers, and determining the percentage of students who have understood the concepts based on the indicators to be measured, as well as identifying factors that affect conceptual understanding. Students were also asked about the challenges they faced during unstructured interviews.

Students' abilities to restate concepts, classify objects according to specific qualities, provide examples and non-examples of concepts, present concepts in various forms of mathematical representation, develop necessary or sufficient conditions for a concept, use and select specific procedures or operations, and apply concepts or problem-solving algorithms are all indicators of their understanding of mathematical concepts (Zuliana, 2017).

Table 2. Indicator of Conceptual Understanding

No	Indicator	Error indicator
1	Restate a concept	Students are unable to restate the concept of the material on the system of linear equations in two variables
2	Presenting concepts in the form of mathematical representation	Students cannot represent problems using mathematical models.
3	Using, utilizing, and selecting certain procedures or operations	Students are unable to determine the appropriate procedure or method for solving the problem.
4	Applying algorithmic concepts in problem solving	Students cannot apply concepts effectively in problem-solving.

There are metrics that demonstrate the extent to which students possess a high level of mathematical concept understanding ability (Agustini & Pujiastuti, 2020).

Table 3. Criteria for Interpreting Scores of Mathematical Concept Understanding Ability

No	Percentage	Level of understanding
1	0% - 20%	Very Low
2	21% - 40%	Low
3	41% - 60%	Enough
4	61% - 80%	Good
5	81% - 100%	Very good

There is a percentage formula for the ability to understand mathematical concepts as follows: *score of correct answers ÷ maximum total score* x *100%*.

RESULT AND DISCUSSION

The purpose of this study is to assess students' comprehension of mathematical concepts by evaluating their ability to accurately solve problems related to the content of two-variable linear equation systems. This study examines the depth of students' understanding of mathematical concepts. To measure these skills, researchers developed a set of descriptive questions ranging in difficulty from easy to challenging. These questions are derived from the Final Semester Summative exam and have been approved by teachers. The four questions presented to the students include various indicators of their grasp of mathematical concepts. The table below provides an overview of the percentage of students proficient in understanding mathematical concepts.

Table 4. Interpretation of Students' Ability to Understand Mathematical Concepts

No	Indicator	Mastering Indicators		
		Number of students	Percentage	Category
1	Restate a Concept	11	73,33%	Good
2	Presenting Concepts in the Form of Mathematical Representation	10	53,33%	Enough
3	Using, Utilizing, and Selecting Certain Procedures or Operations	6	40%	Low
4	Applying Algorithmic Concepts in Problem Solving	5	33,33%	Low
	Average		49,91%	Enough

If we examine each question using the indicators from Table 4, we find that only a small percentage of students have fully grasped the content. The ability to restate a concept is the most understood indicator of conceptual understanding, with 73.33% of students meeting this requirement, equivalent to 11 students. The second most mastered indicator is presenting concepts through mathematical representation, with 53.33% of students—10 students—meeting this criterion. For the third indicator, which involves selecting and employing specific methods or operations, six students (40%) have demonstrated mastery. The least mastered indicator is applying algorithmic concepts in problem solving, with only 33.33% (5 students)

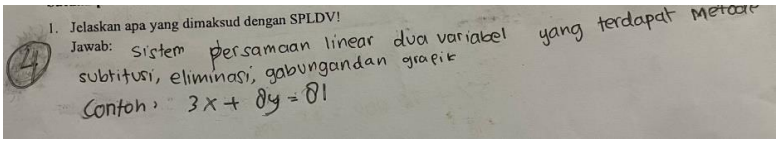
demonstrating proficiency. This indicator falls under the HOTs (Higher-Order Thinking Skills) category as it involves applying concepts to solve problems. Overall, with an average score of 49.91%, the class's conceptual understanding of solving two-variable linear equation systems is moderate. However, the area that requires the most improvement is the application of algorithmic concepts in problem solving.

The questions given to students are adjusted based on their indicators of mathematical concept understanding abilities and are derived from the final summative questions of the first semester. Additionally, the researcher analyzed the responses that students provided after completing the assigned questions. The following four questions pertain to the content of the two-variable linear system:

Indicator: Restate a Concept

Question *1*: "What is meant by a linear system of two variables?"

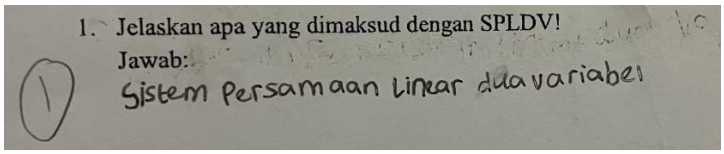
In question 1, students are expected to be able to restate a concept. Figure 1 shows one of the student answers that meets these indicators. In this response, the student restates the concept correctly; although the answer is not entirely accurate, it meets the scoring criteria for understanding mathematical concepts well, including solving techniques and examples. Additionally, the student is able to explain the concept using their own understanding and language.



Translation: "A system of linear equations in two variables containing the combined elimination, substitution methods, and graphs. Example: 3x+8y=81"

Figure 1. Correct Answer

Figure 2 shows one of the incorrect answers. The student is not yet able to restate the concept, as their response merely rewrites the question without providing a detailed explanation of its meaning. Furthermore, the student cannot restate the concept using their own understanding and language. This error also occurs because the student does not know or understand what the question is asking, leading to an incorrect solution to the problem (Ananda et al., 2018)



Translation: "System of linear equations with two variables"

Figure 2. Incorrect answer

Indicators: Presenting Concepts in the Form of Mathematical Representation

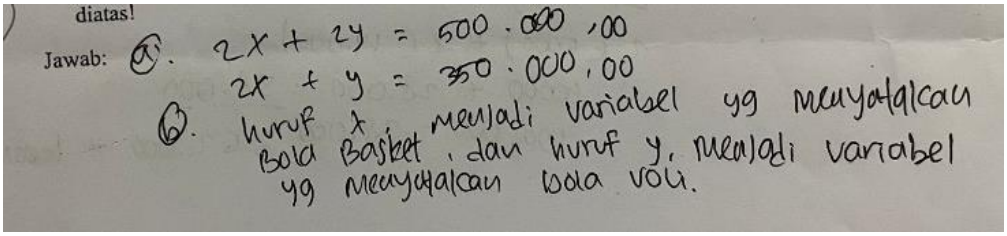
Question Number 2:

"Brother bought four basketballs and two volleyballs for IDR 500,000.00. Adik bought two basketballs and one volleyball for IDR 350,000.00.

a. Write two mathematical equations that express the statement above (use the letters x and y as variables)!

b. Explain what the letters x and y represent in the equations you wrote above!"

In question number 2, students are expected to present concepts in the form of mathematical representations. Figure 3 shows one of the student answers that meets these indicators. In this question, students are given a story problem and are required to represent it as a mathematical model. It can be seen in Figure 3 that the student was able to present their answer correctly and completely according to the instructions provided in the question.



Translation: "b. The letter x represents the variable for basketballs, and the letter y represents the variable for volleyballs."

Figure 3. Correct Answer

In Figure 4, one of the student's answers is incorrect because they are not yet able to represent it in a mathematical model. In question (a), it can be seen that the student cannot represent the mathematical model correctly because variables are not used, so it cannot be considered a linear system of two variables. Since they fundamentally do not understand the concept, while addressing the questions, students misinterpret the problem, resulting in errors in applying the concept (Anwariyah & Nurhanurawati, 2023). This is in line with his research, which indicates that most students still struggle to express what they know by creating mathematical models (Kurniawan et al., 2019)

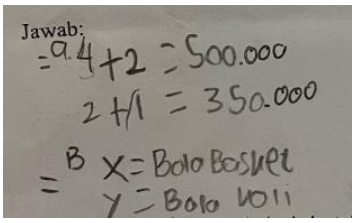


Figure 4. Incorrect Answer

Indicator: Using and Selecting Certain Procedures or Operations

Question number 3: "Andi bought 2 erasers and 3 pencils for IDR 8,500.00, while Didit bought 3 erasers and 2 pencils for IDR 9,000.00. If Anita buys 1 eraser and 1 pencil, how much does she have to pay?"

In question number 3, students are expected to be able to use and select certain procedures or operations. In Figure 5, one of the student answers meets these indicators. Students are presented with a story problem, and they need to solve it correctly using specific procedures or operations.

Figure 5 shows the way students answer the questions using a combined method (elimination and substitution). First, students define two variables for erasers and pencils. Then, they represent the existing problem as a mathematical model and produce two equations. Next, one of the variable values is determined. After that, the student substitutes the value of one variable into one of the existing equations. This indicates that students have a good understanding of the concepts related to this indicator.

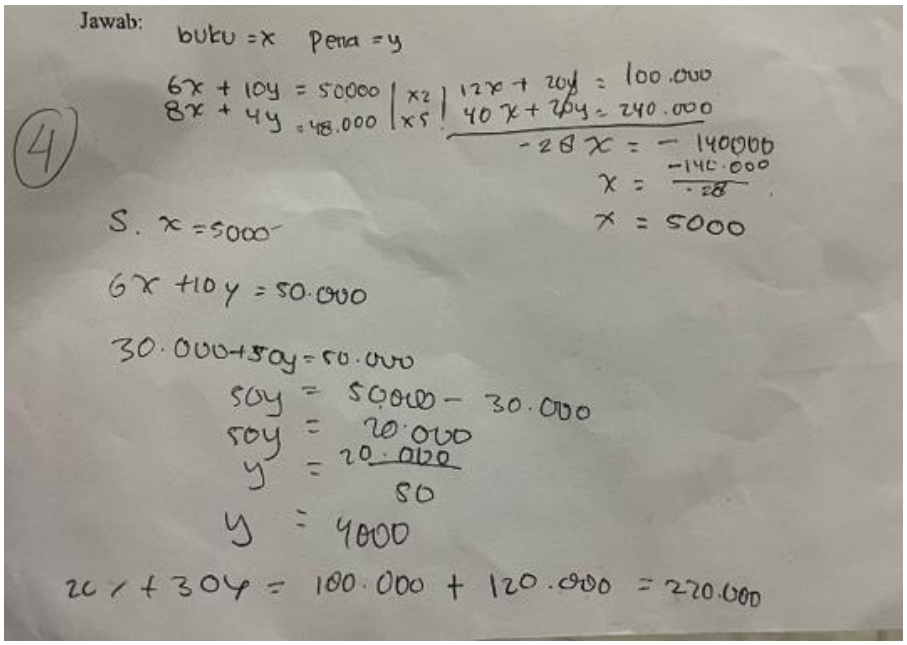


Figure 5. Correct Answer

In Figure 6, one of the student's answers is incorrect because the student is not yet able to use and select certain procedures or operations. It can be seen from the student's response that they have not provided information regarding the variables used, and two equations are formed immediately. The student attempts to use combined methods or procedures (elimination and substitution).

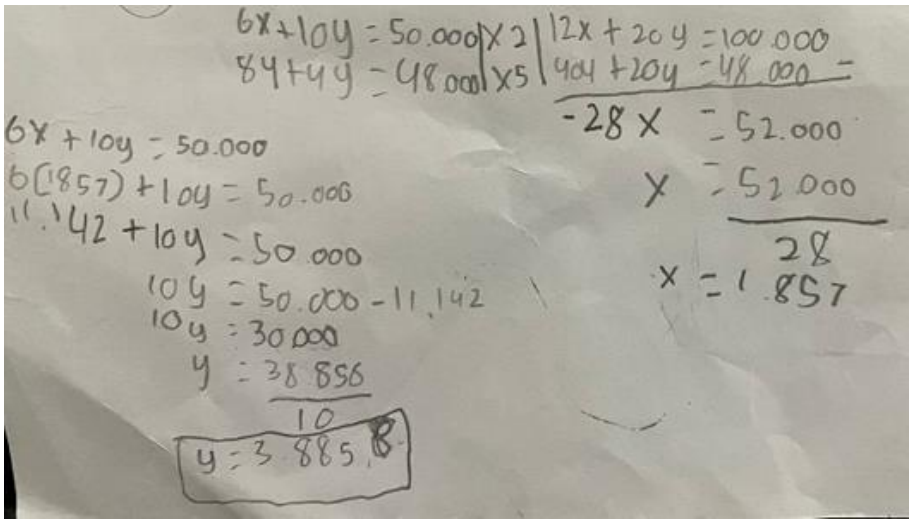


Figure 6. Incorrect Answer

In the process of solving the problem, the student made a mistake in the second equation; they should have written 8x but wrote 8y instead. Additionally, the student did not understand the procedure or operation correctly. They should have multiplied everything in equation 2 by 5, but at the price of 48,000, the student failed to do so, resulting in an incorrect answer because the initial procedure was already flawed. Students with low abilities often experience difficulties in understanding the previous material, which hinders their ability to complete algebraic operations using the elimination method (Hikmah et al., 2019). It can be seen from the answer in Figure 6 that students are not yet able to use and select certain procedures or operations. The research also indicates that students tend to make errors when they do not compile the appropriate formula (Annisa & Kartini, 2021).

Indicators: Applying Algorithmic Concepts in Problem Solving

Question number 4: “Okta bought 3 kg of apples and 5 kg of oranges for IDR 85,000.00. Then his younger brother also bought 5 kg of apples and 7 kg of oranges at the same shop for IDR 123,000. If Okta buys another 2 kg of apples and 2 kg of oranges, how much money does Okta have to pay?”

In question number 4, students are expected to be able to apply algorithm concepts in

problem-solving. In Figure 7, one of the student answers meets these indicators. In this question, students are presented with a story problem and must work through it correctly according to the stages of the material concept, representing it in a mathematical model, and applying appropriate procedures or operations. It can be seen in Figure 7 that students are able to apply algorithm concepts effectively in problem-solving.

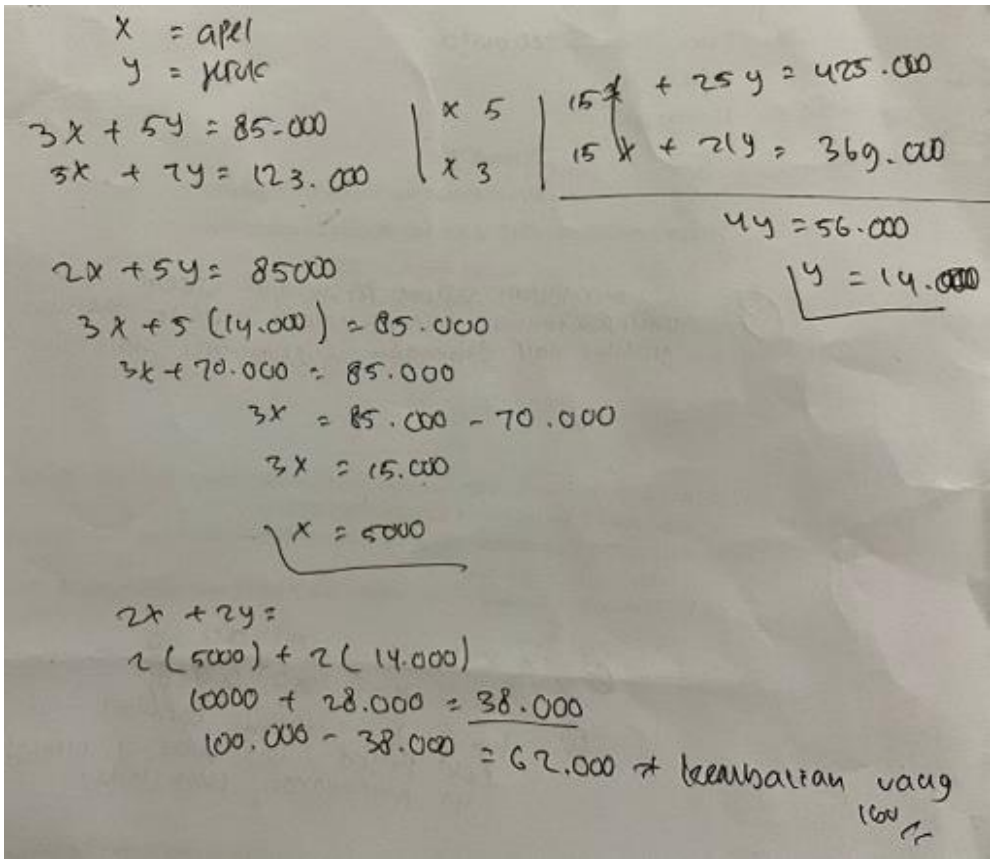


Figure 7. Correct answer

In Figure 8, one of the student's answers is incorrect because the student has not applied the concept of algorithms in problem-solving. It can be seen from the student's response that they provided information regarding the variables used, and two equations were immediately formed. The student attempted to use combined methods or procedures (elimination and substitution). However, in the solution process, the student did not understand the operating procedure; the first equation should have been multiplied by 5 across all terms, not just on the variable *x*. Similarly, in the second equation, the student should have multiplied all terms by 3, not just *x*. Due to these incorrect procedures, the results were also incorrect.

Looking back at the problem, the student followed the elimination and substitution method, but failed to address the specific question asked, which was about the amount of

money returned. The student's mistakes lie not only in the process of solving the problem but also in failing to complete it correctly.

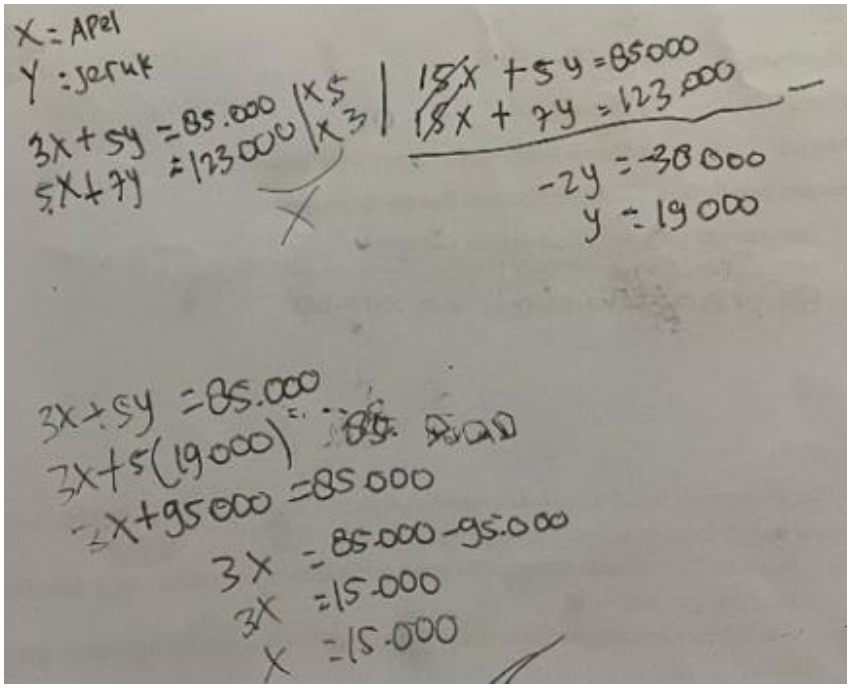


Figure 8. Incorrect answer

In view of the exploration results depicted above, there are still students who do not comprehend concepts well. Understanding concepts is a vital aspect since students can develop their own reasoning and solve problems (Khairunnisa & Aini, 2020). Some students still struggle to represent problems in a mathematical model and have difficulties transforming them because they do not grasp the question, leading to inaccurate answers. While students can outline the steps according to the method, they often make mistakes in calculations or fail to express their reasoning correctly.

The factors causing students' errors in solving story problems include: students being reluctant to write down or identify the problem, errors in the recorded mathematical model that are not checked again, confusion due to a lack of understanding of the material's concepts, mistakes in calculations, and students not being accustomed to writing conclusions (Nurussafa et al., 2016). Among all the factors that can lead to errors while solving problems, the most common is a lack of understanding of the questions given (Zahra, 2019). Factors affecting the low level of students' understanding of mathematical concepts include a lack of concentration while learning, irregular review habits, and less engaging learning methods (Umam & Zulkarnaen, 2022).

CONCLUSION

Based on the results of the research and discussion above, several factors contributing to student errors in solving problems were identified. The first indicator is that students have not been able to restate the concept in their own understanding and language. The second indicator is that students have not been able to present concepts as mathematical representations correctly. The third indicator is that students have not been able to use, utilize, and select certain procedures or operations. The fourth indicator is that students have not applied the concept of algorithms in problem solving.

To address these issues, students who exhibit low conceptual understanding should focus more on grasping the concepts in the material and practice working on two-variable linear equation systems. This practice will help students become more accustomed to tackling various types of questions and improve their ability to understand mathematical concepts effectively. Additionally, adjustments to students' learning styles are needed to facilitate easier comprehension of the material.

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We do like to express my gratitude to the school, especially to the mathematics teachers, who have supported and allowed the research on the analysis of student errors in solving TVLES questions based on students' conceptual understanding. We hope that the findings of this research are useful and contribute positively to the development of education and students' understanding of concepts at school. Thank you for your cooperation and participation.

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