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Case Study of Students' Errors in Mathematical Modeling: Analysis Based on Solution Plan Stages in Context-Based Problems

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Abstract: This study aims to analyze students' errors in solving context-based systems of two-variable linear equations (STLVE) based on the stages of the mathematical modeling solution process. This study employed a qualitative approach with a descriptive case study design. The research subjects consisted of 28 ninth-grade students from one class at a junior high school in Denpasar, Indonesia, from which eight students were selected as interview participants. The primary data consisted of students' answer sheets from the first summative assessment on the systems of two-variable linear equations topic, as well as interview data obtained from students and mathematics teachers. Data were analyzed qualitatively through the stages of data condensation, data display, and conclusion drawing. Students' errors were classified and interpreted based on the four stages of the mathematical modeling solution process. The results showed that students' errors in solving context-based systems of two-variable linear equation problems occurred at all stages of the solution process, with the highest frequency of errors appearing in the advanced stages of mathematical modeling. These errors were influenced by several factors, including limited understanding of contextual information, insufficient practice, weak mastery of solution methods, the tendency to solve problems hastily without verification, and difficulties in relating calculation results back to the given context. The findings indicate that the mathematical modeling solution process can serve as a systematic framework for identifying and understanding students' errors comprehensively, as well as providing a foundation for developing more meaningful and targeted mathematics learning strategies.

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Introduction

The eight mathematics practice standards developed by the Council of Chief State School Officers (Walle et al., 2012) place mathematical modeling as one of the most important skills for students to have (Nugraha et al., 2023). Modeling is very important for students because it is present in various aspects of daily life (Blum & Ferri, 2009). Through modeling, a complex real-life situation is simplified into a more structured and measurable form.

This importance is also legally integrated into Indonesia's recent curriculum framework, which mandates mathematical representation and modeling as core process elements. Under this policy, representation is explicitly defined as the process of creating and using symbols, tables, diagrams, or other forms to communicate mathematical ideas. The emphasis on representation indicates that mathematical modeling cannot be separated from students' ability to represent real-life situations in mathematical form. In other words,

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representation is part of the modeling steps, namely when students convert contextual information into symbols, equations, or models that can be analyzed mathematically.

Modeling is the process of selecting and using appropriate mathematics and statistics to analyze empirical situations, understand them more deeply, and improve the quality of decision-making (CCSSO, 2010). Modeling in mathematics learning is a process that aims to help students understand and explore problems arising from real-life situations through the use of mathematical representations such as diagrams, tables, and functions (Tong et al., 2019). In line with this, mathematical modeling is defined as a systematic process that involves representing real-world situations in mathematical form. This process aims to understand problems, analyze relationships between variables, and produce solutions or predictions for the phenomena being studied (Bliss & Libertini, 2019; CCSSO, 2010; Greefrath & Vorhölter, 2016; Maaß, 2006, 2010; Niss, 2003; Niss et al., 2007; Niss & Højgaard, 2011; Nugraha et al., 2023; Santos et al., 2015; Tong et al., 2019).

Despite the urgency of mathematical modeling, the reality in the field shows that this skill remains a major challenge for students. Various national and international studies consistently indicate that students often have difficulty applying mathematical concepts to solve non-routine problems. For example, the results of the Programme for International Student Assessment (PISA), an evaluation program organized by the Organization for Economic Co-operation and Development (OECD). Based on the 2022 PISA results, Indonesia scored 366 in mathematics, which is far below the average of OECD member countries, which is 472 points (OECD, 2023).

This score is a decline from PISA 2018, where in 2018 Indonesia scored 371 in mathematics. Referring to the 2022 PISA results, only 18% of Indonesian students were able to achieve level 2 proficiency in mathematics. Almost no students in Indonesia excel in mathematics. According to the OECD, students in Indonesia are not yet able to model complex situations mathematically, nor are they able to select, compare, and evaluate appropriate problem-solving strategies to overcome them (they have not reached level 5 or 6 in the PISA mathematics test). This data clearly shows that there is still a significant gap between expectations and reality regarding the mathematical modeling abilities of students in Indonesia.

This condition is reinforced by findings from research on a more limited scale. Syam (2019) conducted an analysis of junior high school students' mathematical modeling competencies in one city in Indonesia. The results of the analysis showed that in high and medium strata schools, only 25.81% and 15.96% of students reached the highest level, which is the level where students are able to validate the mathematical solutions they have obtained (Syam, 2019). In line with these findings, other studies also show that students' ability to create mathematical models is still largely in the low category (Khusna & Ulfah, 2021).

Referring to the modeling cycle or stages (Bliss & Libertini, 2019; Blum & Leiß, 2005; CCSSO, 2010; Greefrath, 2011; Maaß, 2006), mathematical modeling is not an easy thing for students to do (Nuryadi & Hartono, 2020). As shown in Figure 1, the modeling cycle according to Blum and Leiß (2005) appears to be very complex.

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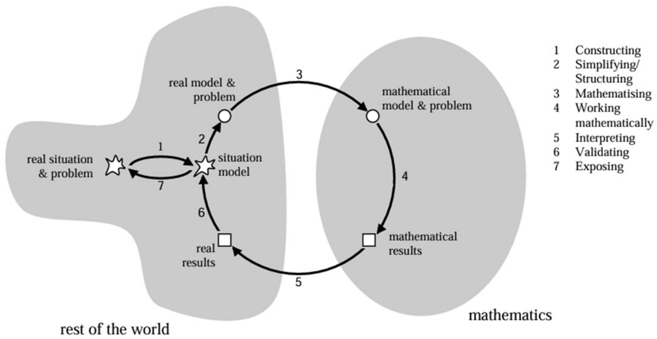

Figure 1. The modeling cycle according to Blum and Leiß (2005)

This shows that in conducting mathematical modeling, familiarization is necessary and requires support from teachers. One form of support that is sufficient and can be used in mathematical modeling is the solution plan (Blum & Ferri, 2009; Blum & Leiß, 2007; Schukajlow et al., 2015). This solution plan is designed to reduce the complexity of representation and help students understand the modeling steps (Schukajlow et al., 2015). The four steps in the solution plan are shown in Table 1 below.

Table 1. Solution Plan

Solution Plan	Description
Understanding Task	• Read the text carefully • Visualize the situation clearly • Making a sketch
Searching Mathematics	• Finding the necessary data and making assumptions if necessary • Searching mathematical relationships (for example through equations or geometric formulas)
Using Mathematics	• Solving equations, changing formulas, drawing graphs • Using other procedures if unsuccessful
Explaining Result	• Generalizing results appropriately • Connecting results to problems and double-checking • Writing down the final answer

The relationship between the modeling cycle according to Blum and Leiß (2005) and the solution plan is as follows: (1) steps 2 and 3 in the modeling cycle become one unit in the *searching mathematics* level of the solution plan; and (2) steps 5, 6, and 7 in the modeling cycle become one unit in the *explaining results* level of the solution plan (Nugraheni et al., 2018). Through the solution plan stages, students are expected to be able to easily perform mathematical modeling and overcome common difficulties (Nuryadi & Hartono, 2020; Sakinah et al., 2020).

One relevant material to review through the modeling perspective is the Two-Variable Linear Equation System. This topic is often associated with everyday problems, and thus has the potential to be used as a context for assessing students' mathematical modeling abilities. However, various studies show that students still often make mistakes when modeling and solving Two-Variable Linear Equation System problems (Johari & Shahrill, 2020; Pulungan & Suhendra, 2019). Although a number of studies have examined errors in constructing mathematical models (Amni & Kartini, 2021; Masfiyah & Shodikin, 2021; Permata et al., 2025; Pranitasari & Ratu, 2020; Setiyawati et al., 2022), they predominantly focus on general procedural mistakes, leaving a critical gap in mapping how these errors occur systematically across distinct cognitive phases. Currently, there is no study that systematically maps student

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errors at each specific stage of the mathematical modeling *solution plan*. This study addresses this gap by comprehensively analyzing students' errors through the specific lens of the four solution plan stages within context-based problems. This analysis not only provides a structured framework for diagnosing contextual problem-solving difficulties, but also reveals the precise stages in the *solution plan* that are most prone to errors in the students' mathematical modeling process.

Research Method

This study uses a qualitative approach with a descriptive case study type. This approach was chosen to conduct an in-depth investigation of a specific phenomenon, namely students' mathematical modeling errors. The subjects of this study were 28 ninth-grade students from one class at a junior high school in Denpasar, from which 8 students were selected as informants for interviews. These informants were selected based on the diversity and uniqueness of the error patterns identified in their written responses, rather than their overall academic performance. Specifically, the selected informants represented students who exhibited distinct errors at each of the four mathematical modeling *solution plan* stages, allowing for a richer and more comprehensive exploration of the cognitive obstacles and underlying causes behind these mistakes. The subjects were determined using purposive sampling. The main data in this study were the students' answer sheets in the first summative assessment in the Two-Variable Linear Equation System material that had been carried out previously, as well as the results of interviews with students and mathematics teachers. The test questions focused on context-based problems and became the main instrument of this study. The instrument consisted of two contextual essay problems developed directly by the school's mathematics teacher specifically for this summative assessment. To ensure content validity, the problems were designed based on the school's curriculum indicators for the Two-Variable Linear Equation System material and were reviewed by senior mathematics teachers at the school to evaluate clarity, language appropriateness, and alignment with the mathematical modeling stages.

Data were analyzed qualitatively using the interactive model by Miles, Huberman, and Saldaña (2014), which consists of data condensation, data display, and conclusion drawing. In this study, the analysis focused on classifying students' mathematical modeling errors into the four solution plan stages, understanding the task, searching mathematics, using mathematics, and explaining results, to identify their patterns and causes. Furthermore, data validity was ensured through methodological triangulation, where the written test results were cross-referenced and validated against the data from student interviews and the mathematics teacher's insights.

Results and Discussion

This research was conducted in the odd semester of the 2025/2026 academic year. Error data was taken from the students' answers in summative assessment 1 in the Two Variable Linear Equation System material with 2 context-based questions. The results obtained were then analyzed in more detail based on the *solution plan* stages, then presented as percentages based on the errors in each stage. The summary of student errors at each stage of the solution plan is presented in Table 2.

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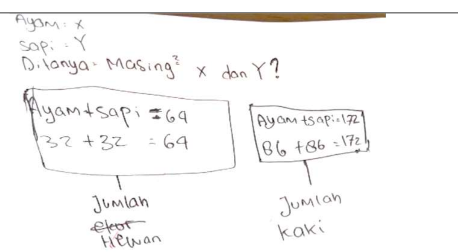
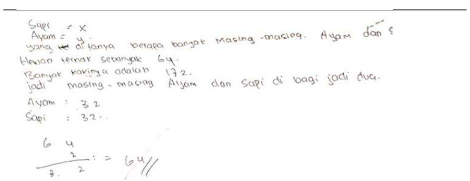
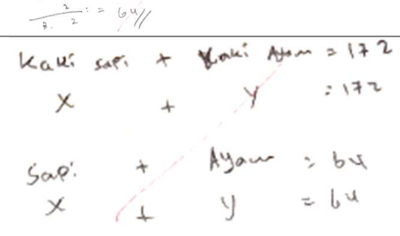
Table 2. Recapitulation of student errors at each stage of the solution plan

Question	Stage	Number of Students Making Errors	Percentage
1	Understanding Task	11	39,29%
	Searching Mathematics	18	64,29%
	Using Mathematics	25	89,29%
	Explaining Result	28	100,00%
2	Understanding Task	2	7,14%
	Searching Mathematics	7	25,00%
	Using Mathematics	23	82,14%
	Explaining Result	26	92,86%

Based on Table 2, it can be seen that the percentage of errors increases at each stage of the solution plan. However, a striking contrast appears when comparing the initial stage between both items. The drastic decrease in Understanding Task errors from Question 1 (39.29%) to Question 2 (7.14%) occurs due to information explicitness. Question 1 requires implicit knowledge which is not stated in the text, confusing some students. Meanwhile, Question 2 explicitly provides all numbers, making it much easier for students to identify the data. Furthermore, the context in Question 2 is more standard and familiar in school exercises compared to the context in Question 1.

Analysis of students' answers to question number 1 can be seen in Table 3. Question number 1 is: "Mr. Andi is a successful chicken and cow farmer. He has 64 livestock. If the legs of these livestock are added together, the total number of legs is 172. The number of chickens and cows owned by Mr. Andi is ...".

Table 3. Analysis of students' answers to question number 1

Stages of the Solution Plan	Student Answers	Error Analysis
Understanding Task	 	In this answer, the student did not carefully grasp the important information in the question. The student also did not imagine the actual situation, so they did not construct a correct representation of the problem and simply divided the numbers evenly without considering the meaning of each piece of information in the question.
Searching Mathematics		In this answer, the student did not establish a mathematical relationship that corresponded to the meaning of the information in the question. The student treated the number of animals and the number of legs with the same equation.

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	) Ayam = x Sapi = y Ayam + Sapi = 64 ekor $\cancel{x+y=64}$ Jumlah Seluruh kaki = 172 -) Ayam kaki 4 8 $x+y=64\ (\times 4)$ $4x+2y=172\ (\times 4)$	In this answer, the student did not succeed in mathematical establishing relationship a that corresponded to the information about the number of legs, resulting in an incorrect equation. The student wrote the equation for the number of legs backwards.
Using Mathematics	jawab : $x+y=64$ $2x+4y=172$ $2x+4y(64-x)=172$ $2x+16x=172$ $-x=15-16$ $+x=+1$ $x=1$ $y : x=1$ $y=64-x$ $y=64-(1)$ $y=g-1$ $y=8$ $x=1$ $y=8$	In this answer, the student did not apply the substitution method procedure correctly. The student also did not follow the basic rules of algebraic operations.
Explaining Result	) Sapi + Ayam=64 kaki sapi + kaki ayam = 172 x = sapi , y = ayam jawab : $x+y=64\ (\times 4)$ $4x+2y=172\ (\times 1)$ $4x+4y=256$ $4x+2y=172$ $\cancel{4x-4x}+4y-2y=256-172$ $\frac{2y}{2}=\frac{84}{2}$ $y=42$ $4x+2y=172$ $4x+2(42)=172$ $4x+84=172$ $4x=172-84$ $\frac{4}{4}=\frac{88}{4}$ $x=22$	In this answer, the student did not interpret the calculation results in the context of the problem, so the solution that did not obtained connected to the story of the question.

Furthermore, the analysis of the students' answers to question number 2 can be seen in Table 4. Question number 2 is: “Andika and Candra are shopping at the market. Andika buys 5 small oranges and 6 apples, while Candra buys 10 small oranges and 3 apples. The total cost of Andika and Candra's purchases is Rp40,000 and Rp35,000, respectively. If Boni comes to the same market and buys 2 small oranges and 2 apples, Boni must pay Rp...”.

Table 4. Analysis of students' answers to question number 2

Steps of the Solution Plan	Student Answers	Error Analysis
Understanding Task	44rp//	In this answer, the student did not identify the necessary information and immediately gave an answer without processing the context of the problem.
Searching Mathematics	$5x+6y=\cancel{40000}$ 35.000 $10x+3y=40000$	In this answer, the student did not correctly establish the mathematical relationship between the number of items and the total price, resulting in an equation that was reversed.
	$5x+6y=40.000\ (2)$ $10x+2y=35.000\ (1)$	In this answer, the student did not write the equation correctly based on the context information. The student incorrectly placed the coefficient on the variable y.

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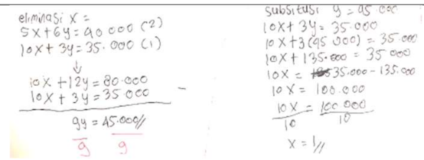
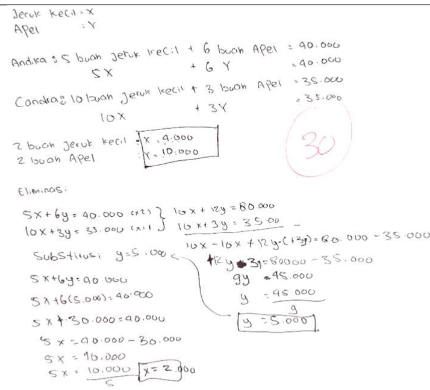
Using Mathematics		In this answer, the student did not complete the elimination procedure to find the value of the variable y, before substituting it into the equation to find the value of the variable x. The student also did not continue the procedure to answer the question.
Explaining Result		In this answer, the student did not write the final result. The student also did not connect back result with the context of the question.

Based on the analysis of both questions, a consistent pattern of errors was observed. In the understanding task stage, most students made mistakes in identifying and understanding important information in the questions. In the searching mathematics stage, students made mistakes in constructing equations that matched the questions. In the using mathematics stage, students made mistakes in applying the elimination and substitution procedures. Meanwhile, in the explaining result stage, most students did not relate the results back to the context of the questions. This study supports the results of previous studies conducted by several researchers (Amni & Kartini, 2021; Masfiyah & Shodikin, 2021; Permata et al., 2025; Pranitasari & Ratu, 2020; Setiyawati et al., 2022).

Subsequently, interviews were conducted with 8 students who were the subjects of the study to obtain more in-depth information regarding the difficulties experienced by students in working on the questions and the causes of errors in working on these questions, with 2 students for each stage. Interviews were also conducted with 1 mathematics teacher to reinforce these findings.

Causes of Errors in the Understanding Task Stage

At the understanding task stage, the interviews showed that students' errors were caused by their inability to understand important information in the questions. The first student revealed that he was absent when the material was explained, so he did not know the steps to solve the questions. The student also expressed confusion in understanding the context of the question, for example, in a question about the number of animal legs, even though he had read the question repeatedly. Then, the second student gave a similar response. The student revealed that she did not prepare thoroughly before taking the test and forgot the steps to solve the problem. In addition, the student also experienced confusion when reading the information in the question even though she had tried to understand the information in the question many times.

Based on the results of interviews with the two students, it was shown that the main cause of errors at this stage was a lack of understanding of the context and information in the questions. This finding was reinforced by the results of interviews with mathematics teachers who stated that, although students were able to read the questions, they often had difficulty

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understanding the content, especially in questions with long sentences and rich information. The teacher's statement is consistent with the students' admission that they were confused in understanding the context of the question even though they had read it repeatedly. This finding is in line with Masfiyah & Shodikin (2021), who stated that the cause of errors at this stage was that students did not understand the components of the problem or the information in the question. This finding confirms that reading comprehension and literal translation of text act as primary barriers in the initial phase of mathematical modeling. The students' inability to grasp the core information under a high cognitive load aligns with Newman's error analysis theory, which posits that comprehension errors often stem from a lack of semantic knowledge in word problems. Furthermore, it supports the arguments of Wijaya et al. (2014),who found that Indonesian students frequently struggle to identify mathematically relevant structures within contextual narratives, making the initial stage a major bottleneck for subsequent modeling steps.

Causes of Errors in the Searching Mathematics Stage

At the searching mathematics stage, student errors are related to their inability to construct mathematical equations that correspond to the information in the question. The third student stated that he actually understood how to make analogies, but still had difficulty constructing equations because he did not fully understand the information in the question. Doubts about the equations he had constructed also arose during the test, but the student did not double-check them. Similarly, the fourth student also made a similar mistake because she misinterpreted the question, resulting in an incorrect equation. The student revealed that she had tried to recheck his work, but only briefly due to time constraints. In addition, the student also stated that she did not really understand what was being asked in the question. These findings show that the student's mistakes were caused by a lack of understanding of the information and a lack of thoroughness in rechecking the equations that had been constructed.

The findings are supported by interviews with teachers, who confirmed that the main obstacle for students was not their ability to create equations, but rather their difficulty in understanding the information in the questions. This is in line with the research by Dwiguningtyas et al. (2025), which states that the factor causing errors at this stage is the students' lack of precision in understanding the problems. According to teachers, students often misunderstand the meaning of the problem, resulting in the equations they construct being incorrect. This failure in transitioning to mathematical formulation supports the modeling framework of Galbraith & Stillman (2006), which identifies the shift from real-world contexts to mathematical models as highly vulnerable to cognitive blockages. this study highlights that text misinterpretation inevitably leads to flawed mathematization, regardless of students' actual calculation skills.

Causes of Errors in the Using Mathematics Stage

At the using mathematics stage, the interview results revealed that students' errors stemmed from their inability to correctly apply the procedure for solving a system of two variable linear equations. The fifth student explained that she had forgotten the elimination steps and felt uncertain when performing the calculations. The student also had difficulty applying the substitution method and did not have time to double-check the results of her calculations. In addition, the student admitted that she did not fully understand the material during the learning process and did not practice independently enough. Similarly, the sixth student stated that she had almost the same problem, namely not fully understanding the meaning of substitution and the steps for solving a system of two linear variables using either the elimination or substitution method. Although the student had practiced several times

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before the test, she still had difficulties during the test and did not have time to check her answers.

Based on the interviews, both students emphasized that weaknesses in the use of solution methods were the main cause of errors at this stage. This finding was reinforced by interviews with teachers, who stated that some students were able to solve two-variable linear equation systems in one meeting, but easily forgot the solution steps in the next meeting. The teacher emphasized that this cycle continues to repeat itself, especially among students who have poor study habits and lack independent practice. This is in line with the students' admission that they forget the elimination steps, have difficulty with substitution, and lack consistent independent practice. These findings are in line with Bahir & Mampouw (2020), who stated that the factor causing errors at this stage is a lack of practice in working on contextual problems independently.

Causes of Errors in the Explaining Result Stage

At the stage of explaining result, interviews showed that students did not reinterpret the context of the question even though they were actually capable of doing so. The seventh student stated that time constraints made her a little panicky, especially after making a mistake in her calculations. The student felt that writing down the interpretation of the results was not very important and chose to save time, even though, according to her admission, she was actually able to relate the results back to the context of the question. Similarly, the eighth student experienced the same thing. The student forgot to write down the interpretation of the results because she felt that time was running out. In the practice questions during the learning process, the student did not have any difficulty interpreting the results. However, in the test, the students skipped the explaining result stage. The interview results indicated that negligence and time management were the main factors for errors in the explaining result stage, not an inability to interpret or explain the results.

In contrast to the students' views, the math teacher explained that most students often failed to reinterpret their calculations because they forgot the meaning of the variables used in the analogy stage. This made it difficult for students to relate their calculations back to the context of the problem. Upon further investigation, the teacher explained that his response was based on his observation of students whose conceptual understanding still needed improvement. Thus, the teacher's explanation shows that, in addition to rushing, there are conceptual obstacles that also affect students' inability to complete the explaining result stage.

Overall, it can be seen that errors occurred in all stages of the solution plan, with students making more errors in the advanced stages of mathematical modeling. In the understanding task, these findings are in line with the research by Sipaami et al. (2025), which states that the reading and understanding stage had the highest percentage of errors. In the searching mathematics stage, this is reinforced by the research by Dwiguningtyas et al. (2025) and Ramadhani & Roesdiana (2023), which confirms that the main error found was in modeling the problem. Furthermore, in the using mathematics stage, the findings in this study are in line with the research by Bahir & Mampouw (2020), which states that one of the students' errors is completing the mathematical model that has been constructed. Finally, in the explaining result stage, this study is also consistent with the research by Sipaami et al. (2025), which emphasizes that the answer writing stage also has the highest percentage of errors.

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Conclusion

This study shows that students' errors in solving two-variable linear equation systems based on context occur in all stages of the solution plan, such as most students making mistakes in identifying and understanding important information in the question; students making mistakes in constructing equations that match the question; students making mistakes in applying the elimination and substitution procedures; and most students not reconnecting the results with the context of the question. Based on all these errors, students made more errors in the advanced stages of mathematical modeling. These errors were influenced by a lack of understanding of the context or information in the question, a lack of continuous practice, weak mastery of the solution method, a habit of working hastily without double-checking, and difficulty in reconnecting the calculation results with the context of the question. The results of this study show that a solution plan can be a systematic framework for comprehensively mapping and understanding student errors, as well as a basis for developing more meaningful learning strategies.

Recommendation

Based on the results of the study, to address the critical error rates in the final modeling stages, teachers should implement targeted instructional interventions focusing on Using Mathematics and Explaining Result. For the Using Mathematics stage, teachers must counter procedural forgetfulness and poor retention by integrating error-analysis exercises and distributed independent practice alongside structured self-checking checklists to reduce calculation slips under test anxiety. For the Explaining Result stage, teachers must bridge the gap between students' poor time management and their conceptual confusion regarding variable meanings by explicitly modeling the de-mathematization phase, which should be reinforced by using classroom assessment rubrics that allocate specific score points for final contextual conclusions rather than just abstract numerical values, thereby forcing students to systematically reconnect calculations back to the real-world problem.

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