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EXPLORING MATHEMATICAL MODELING ABILITIES IN SOLVING WORD PROBLEMS

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Abstract

Students' mathematical problem solving ability in solving word problems still faces various challenges, especially in terms of transforming contextual problems into appropriate mathematical models. Many students have difficulty in identifying variables, compiling equations, and validating the solutions obtained, resulting in low success rates in solving complex mathematical problems. Therefore, it is necessary to conduct an in-depth analysis of students' problem solving abilities to identify the specific obstacles they face and the strategies that can be developed to overcome them. This study aims to analyze students' problem solving abilities through mathematical modeling strategies in solving word problems. A qualitative approach with a phenomenological design is used to explore students' thinking processes in depth. The subjects of the study were 31 ninth grade students of SMP Negeri 4 Klaten who were selected by purposive sampling based on variations in academic ability. Data collection was carried out through observation, written tests, and in-depth interviews, then analyzed inductively. The results showed that students who answered correctly were able to understand the context of the problem, compile mathematical models appropriately, complete calculations and interpret the results systematically, especially on questions with low to medium difficulty levels. Conversely, students who answered incorrectly had difficulty in transforming the problem into mathematical form and evaluating the final results, especially on complex questions. The conclusion of this study is that the mathematical modeling strategy is effective in improving problem solving skills, but further emphasis is needed on the transformation and reflection stages to optimize students' understanding and validation of solutions.

Keywords: Mathematical concepts; mathematical modeling; problem solving; word problems

Abstrak

Kemampuan pemecahan masalah matematika siswa dalam menyelesaikan soal cerita masih menghadapi berbagai tantangan, terutama dalam hal mentransformasi kontekstual ke dalam bentuk model matematika yang tepat. Banyak siswa mengalami kesulitan dalam mengidentifikasi variabel, menyusun persamaan, dan memvalidasi solusi yang diperoleh, sehingga berdampak pada rendahnya tingkat keberhasilan dalam menyelesaikan masalah matematika yang kompleks. Oleh karena itu, perlu dilakukan analisis mendalam terhadap kemampuan pemecahan masalah siswa untuk mengidentifikasi hambatan-hambatan spesifik yang mereka hadapi serta strategi yang dapat dikembangkan untuk mengatasinya. Penelitian ini bertujuan untuk menganalisis kemampuan pemecahan masalah siswa melalui strategi pemodelan matematika dalam menyelesaikan soal cerita. Pendekatan kualitatif dengan desain fenomenologi digunakan untuk menggali proses berpikir siswa secara mendalam. Subjek penelitian adalah 31 siswa kelas IX SMP Negeri 4 Klaten yang dipilih secara purposive berdasarkan variasi kemampuan akademik. Pengumpulan data dilakukan melalui observasi, tes tertulis, dan wawancara mendalam kemudian dianalisis secara induktif. Hasil penelitian menunjukkan bahwa siswa yang menjawab benar mampu memahami konteks masalah, menyusun model matematika secara tepat, menyelesaikan perhitungan dan menginterpretasikan hasil dengan sistematis, khususnya pada soal dengan tingkat kesulitan rendah hingga sedang. Sebaliknya, siswa yang menjawab salah mengalami kesulitan dalam mentransformasikan masalah ke bentuk matematis dan mengevaluasi hasil akhir, terutama pada soal yang kompleks. Kesimpulan penelitian ini adalah strategi pemodelan matematika efektif dalam meningkatkan kemampuan pemecahan masalah, namun diperlukan penekanan lebih lanjut pada tahap transformasi dan refleksi guna mengoptimalkan pemahaman dan validasi solusi siswa.

Kata kunci: *Konsep matematika; pemecahan masalah; pemodelan matematika; soal cerita*

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INTRODUCTION

Mathematics learning in the modern era requires students not only to master computational concepts but also to develop higher order thinking skills (HOTS) to solve complex real world problems. Problem solving ability serves as the foundation for mathematical modeling, since students must first analyze and interpret problems before they can translate them into appropriate mathematical representations. Mathematical modeling has emerged as a strategic approach that enables students to connect abstract mathematical concepts with practical applications through a systematic process encompassing problem identification, mathematization, and solution validation Çibukçiu (2025). Panhuizen (2020) emphasizes that mathematical modeling must be done systematically, where students not only apply mathematical concepts but also understand their meaningful connection to the real world.

The reviewed studies demonstrate that mathematical modeling is not only an instructional approach but also a means to cultivate higher-order thinking skills (HOTS) such as logical, critical, and creative thinking. This is highly relevant to the present study, which seeks to analyze students' problem solving abilities through mathematical modeling strategies. The findings of Alpaslan & Yalvac (2023) and Verschaffel et al. (2020) align with the research focus, highlighting that problem-based and modeling-oriented learning fosters deeper reasoning skills and strengthens students' capacity to tackle complex problems.

At the same time, the challenges identified by Jankvist and Niss (2020) underscore the necessity of investigating students' difficulties in dealing with non-routine or unstructured problems. This resonates with the current study's emphasis on understanding where students struggle in transforming contextual problems into mathematical models. Additionally, the issues raised by Cevikbas et al. (2023) and Santos-Trigo (2024) concerning technological competencies reveal another layer of complexity in modern mathematical learning, which is significant in today's digital era.

Therefore, this research is positioned within an important discourse: while mathematical modeling holds great promise for developing problem solving skills and preparing students to face real-world challenges, it also demands careful attention to the barriers students encounter, both in cognitive and technological aspects.

In particular, Kharisudin and Cahyati (2020) found that students' mathematical self concept plays a significant role in influencing the effectiveness of modeling strategies within problem solving activities, especially during model eliciting tasks. Consistent with this, research by Nurochmah and Kharisudin (2023) also revealed that the use of means ends analysis combined with blended learning can help uncover the cognitive paths students follow throughout modeling processes, including when translating contextual problems into mathematical forms.

An analysis of previous studies reveals a substantial research gap. While various studies have examined the general effectiveness of mathematical modeling and the challenges of its implementation, there is a lack of in depth exploration of students' step by step modeling processes in solving word problems. Prior research has tended to focus more

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on learning outcomes rather than analyzing the detailed processes students go through during each modeling phase, even though understanding these processes is essential to identify difficulties and to develop appropriate instructional strategies Krawitz et al. (2022).

Field observations indicate that students' abilities in solving word problems remain low, particularly in the mathematization and interpretation phases. Students often struggle to translate the problem context into mathematical models and to reinterpret mathematical solutions within real life contexts. This condition is exacerbated by the limited understanding teachers have regarding appropriate scaffolding strategies to support each stage of the modeling process, resulting in instruction that emphasizes calculation procedures over a systematic modeling process.

This study proposes an in depth exploration of students' mathematical modeling processes in solving word problems, employing qualitative analysis of each modeling phase based on Blum's framework, which includes structural inference, mathematization, solving, interpretation, and validation. The research aims to identify students' difficulty patterns at each stage and to analyze the factors that influence the success of the modeling process.

The objective of this study is to develop a comprehensive understanding of students' mathematical modeling abilities in solving word problems, to identify specific obstacles in each phase of the modeling process, and to formulate recommendations for instructional strategies that can effectively enhance students' modeling skills. The findings are expected to contribute theoretically to the development of model based mathematics instruction and practically as a guideline for more effective teaching implementation.

METHODS

This study adopts a qualitative approach with a phenomenological design to explore students' experiences in mathematical modeling when solving word problems. The operational stages of the research include: (1) a preparation phase consisting of instrument development and validation, (2) an implementation phase involving test administration, observation, and interviews, and (3) a data analysis and conclusion drawing phase. The study was conducted over one month during the second semester of the 2024/2025 academic year.

The research site was SMP Negeri 4 Klaten, selected based on the relevance of the grade IX mathematics curriculum, which covers arithmetic sequences and their applications in everyday life. The research subjects were 31 ninth grade students had basic mathematical knowledge but still had difficulty in mathematical modeling. Hartmann et al. (2021) selected through purposive sampling based on the following criteria: (1) having studied the topic of arithmetic sequences, (2) possessing adequate basic mathematical skills, and (3) still experiencing difficulties in mathematical modeling as indicated by pre-test results. Students' academic ability diversity was a key consideration, consisting of 10 high achieving, 15 average, and 5 low achieving students based on their previous semester report grades. The study focused on students' mathematical modeling skills in solving word problems related to two variable linear equations within real life

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contexts, including basic economic problems, practical geometry problems, and basic optimization problems that align with the cognitive levels of junior high school students.

The research instruments consisted of: (1) an essay test on mathematical modeling comprising five word problems with graduated levels of difficulty, (2) a structured observation sheet to monitor students' modeling processes, and (3) a semi structured interview guide designed to explore students' strategies and challenges. Instrument validity was ensured through expert judgment involving two university mathematics lecturers and an experienced mathematics teacher, as well as a limited trial with ten students outside the research sample.

Data collection was carried out using methodological triangulation, which included: (1) administering the essay test to assess students' mathematical modeling abilities, (2) direct observation during the problem solving process to monitor the stages of modeling undertaken by students, and (3) in depth interviews with 12 selected students (four from each ability category), using the stimulated recall technique based on their written work to explore their thought processes and encountered difficulties.

The essay test data were analyzed using an assessment rubric for mathematical modeling competencies based on Blum's five stage framework: structural inference, mathematization, solving, interpretation, and validation. Each stage was scored on a scale of 0 to 4 according to predefined criteria. Observation data were analyzed descriptively to identify patterns in student behavior at each stage of the modeling process. Interview data were analyzed using thematic analysis with an inductive approach, following the steps of coding, categorization, and theme identification (Braun & Clarke, 2022). Data triangulation was conducted by integrating the findings from all three instruments to obtain a comprehensive understanding of students' mathematical modeling abilities.

Data trustworthiness was ensured through: (1) methodological triangulation by employing three different data collection techniques, (2) member checking by confirming the interpretation results with the participants, (3) peer debriefing involving collaborators to minimize researcher bias, and (4) an audit trail documenting the entire research process systematically (Creswell & Creswell, 2018).

The mathematical modeling process in this study followed the stages of: (1) identifying all quantities involved in the real world problem, (2) symbolizing the identified quantities by determining appropriate units and assigning variables and constants, (3) establishing mathematical laws governing the relationships among the variables, (4) determining the solution to the constructed model, and (5) interpreting the model's solution as the answer to the actual problem (Kharisudin et al., 2024). These stages are illustrated in Figure 1, which provides a visual representation of the mathematical modeling cycle applied in this study.

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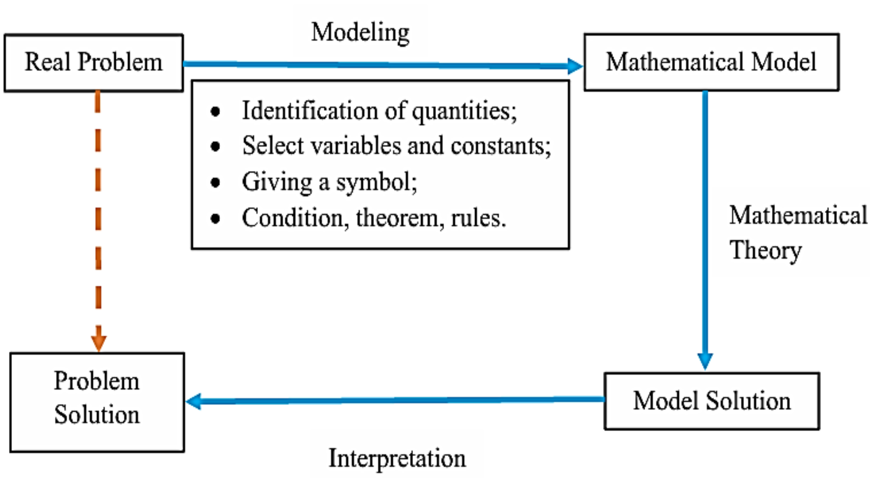

Figure 1. Mathematical Modeling

RESULTS AND DISCUSSION

This study involved 31 students who worked on 5 mathematical word problems to measure problem solving skills with mathematical modeling strategies. Based on the test results, it was found that the students' success rate varied in each problem, with the tendency of difficulty increasing from problem number 1 to problem number 5. Of the 31 students, 9 students were selected for in depth interviews to explore the thought process and modeling strategies they used in solving these problems. The detailed distribution of students' performance on each problem is presented in Table 1.

Table 1. Frequency Distribution of Student Responses

Descriptive Statistics	Score
Number of Students	31
Mean	82,10
Median	85,0
Mode	90,0
Standard Deviation	10,65
Minimum Score	60,0
Maximum Score	95,0

Table 1 presents an overview of students' mathematical problem solving abilities through mathematical modeling strategies. The data show that, overall, students' abilities fall into the good category, with an average score of 82.10. The median score of 85.0 indicates that half of the students demonstrated fairly good modeling abilities, while the mode of 90.0 reflects a tendency toward optimal achievement among the majority of students.

However, the standard deviation of 10.65 reveals significant heterogeneity in students' mastery of mathematical modeling strategies. The score range of 60.0 to 95.0, with a gap of 35 points, reinforces the indication that there is a disparity in problem solving abilities which warrants special attention in instructional design. This variation suggests that, although students generally performed well, differentiated instructional approaches are still needed to accommodate varying levels of modeling skills among students. The distribution of students' answers to each question number can be seen in Table 2.

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Table 2. Frequency Distribution of Student Responses

Number	**Correct Answer**	**Wrong Answer**	**Percentage (%)**
1	30	1	96,77
2	26	5	83,87
3	24	7	77,42
4	24	7	77,42
5	23	8	74,19

Table 2 shows that students' ability to solve word problems using mathematical modeling strategies decreases as the complexity of the problem increases. Problem number 1 with the lowest difficulty level had a success percentage of 96.77%, indicating that most students were able to identify variables and convert the problem into a simple mathematical model. Meanwhile, the more complex problems number 2 and 3 had a success rate of 83.87% and 77.42% because they required deeper analysis. In these two problems, some students began to have difficulty interpreting the problem and choosing the appropriate modeling strategy.

Interestingly, problem number 4, which is structurally an easy problem, was only successfully solved by 77.42% of students. Although similar to problem number 1 in terms of complexity, the interview results showed that the unfamiliar context of the problem caused students to have difficulty understanding and modeling the problem. This shows that the level of difficulty is not always directly proportional to the success of problem solving. Understanding the context also plays an important role in successful mathematical modeling.

Problem number 5 showed the highest level of difficulty with the lowest success rate of 74.19%. This problem requires a high level of reasoning and the ability to integrate several mathematical concepts in one model. Students who failed were generally unable to identify all relevant variables. In addition, they also had difficulty making logical connections between variables in the form of appropriate mathematical models.

Problem number 1 tested students' ability to model contextual problems related to the price of goods with an arithmetic sequence pattern. In this analysis, there are three students' work that will be discussed, namely student A with correct work, and students B and C with incorrect work (Figure 2).

In analyzing students' mathematical problem solving strategies based on the given word problems, the author refers to three indicators of problem solving ability, namely understanding the problem, organizing and problem solving strategies, and confirming the process and answers. Each indicator is described in sub indicators that are adjusted to the use of mathematical modeling strategies.

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Figure 2. Answer Number 1

In problem number 1 student A showed good ability in all problem solving indicators. In the first indicator, student A was able to identify quantities and units correctly by writing down the information that there were 4 items with the lowest price of Rp50.000 and 4 items with the highest price of Rp86.000. The question regarding the amount of change was also recorded correctly. In the second indicator, student A set the variables correctly, using the notation a for the initial price and b for the difference between prices.

Student A also managed to develop a logical mathematical model by compiling a system of equations from a combination of goods prices using the arithmetic pattern $a + kb$. The elimination process was done correctly and the solution of the model was obtained by finding the values of $a = 8000$ and $b = 3000$. Furthermore, student A was able to arrange the five prices of the goods purchased, add them

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up, and subtract from the total money of Rp100.000 correctly, thus obtaining a change of Rp0. In the third indicator, student A also managed to confirm that the whole process and results were following the context of the problem.

During the interview, student A said: "*I looked for a pattern first from the prices of the goods, then I made two equations so that I could find the initial and different values. After that, I filled it in again to find the total price of the five items.*" The answer shows that student A understood the concept of modeling and was able to relate the model to a concrete solution.

Based on Figure 2, Student B demonstrated a reasonably systematic attempt at mathematical modeling during the initial stages of problem solving. The student successfully identified key information from the problem and formulated two linear equations $4a + 6b = 50.000$ and $4a + 18b = 86.000$, representing the total prices of the four cheapest and four most expensive items, respectively. The elimination strategy was applied correctly by subtracting the two equations to eliminate variable a, resulting in the value $b = 3.000$. However, although the elimination procedure was conceptually accurate, several technical errors occurred during the calculations, indicated by inconsistent repetitions in the substitution steps.

After obtaining the value of b, the student proceeded with the substitution step to find a, arriving at $a = 8.000$. Up to this point, the student's work was still acceptable. However, inaccuracies emerged in the following steps. The student attempted to calculate the price of nine different items using the formula $O_1 = a$, which is conceptually correct. Nevertheless, the substitution process was incorrect, indicating inconsistencies in calculation and a lack of understanding in verifying the final solution.

Additionally, the student appeared to try several numbers without clarifying their connection to the original mathematical model. This aligns with the student's statement during the interview: "*I tried inserting numbers that seemed to fit*", suggesting that the student's understanding of the model's function as a problem solving tool had not yet fully developed. In other words, although the student was able to construct mathematical models and apply elimination and substitution techniques, they were not yet able to connect the results to the problem context thoroughly. Thus, the solution remained incomplete and lacked full logical coherence.

Based on Student C's response, they were able to construct both equations correctly from the information provided in the problem. The first equation was written as $50.000 = 4a + 6b$, and the second as $86.000 = 4a + 18b$. Both models align with the context of the problem, indicating a sound understanding of the initial step in mathematical modeling. The student also performed elimination correctly, subtracting the two equations to derive $32.000 = 12b$, and concluded that $b = 3.000$. Subsequently, they substituted this value into the first equation to obtain $a = 8.000$, which was also done correctly.

However, after obtaining the values of a and b, the student immediately wrote $S = 0$ and concluded that no change would be received, without demonstrating how this remainder was calculated. This step is essential as part of the verification process for the computed results. There

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was no explanation or calculation showing that the total price of four items was indeed Rp50.000 and the total price of the other four items was Rp86.000 using the derived values of a and b. Thus, despite arriving at the correct final answer, the student omitted the model verification stage, which should have explained how the value of the remaining balance was obtained. This suggests that the student has not yet fully implemented the problem solving steps in a complete and systematic manner.

When interviewed, student C explained: "*I thought the important thing is that the sum of the five items fits the money, so I just tried to add up the prices.*" This shows a trial and error approach without an understanding of mathematical modeling as a tool in developing a logical and systematic solution.

Thus, it can be concluded that only student A meets all indicators of problem solving ability with mathematical modeling strategies. Meanwhile, student B and student C still have difficulties at the stage of compiling the model and confirming the solution, which indicates the need to strengthen the concept of mathematical modeling in learning.

In analyzing students' mathematical problem solving based on problem number 2 related to two way arithmetic sequence, three indicators of problem solving ability were used, namely understanding the problem, organizing and problem solving strategies, and confirming the process and answers. These three indicators were analyzed based on the mathematical modeling strategy (Figure 3).

Student D was able to solve this problem correctly and fulfill all problem solving indicators. On the indicator of understanding the problem, student D successfully identified that the pattern from the left forms an arithmetic sequence of 2, 5, 8, ... with a difference of 3, and the pattern from the right forms a sequence of 1, 5, 9, ... with a difference of 4. He also wrote the known information correctly, namely Budi's position from the left and right, as well as the question addressed regarding the total number of children. On the indicator of organizing and problem solving strategies, student D arranged the two arithmetic lines completely, and determined Budi's position as the 14th term from the left and 11th from the right. He then deduced the number of children by using the mathematical model $14 + 11 - 1$, because one child is counted twice from two sides. The final result obtained was 24 children, which was the correct answer and in following the context of the problem.

In the last indicator, student D was able to confirm that the results were consistent and in accordance with the logic of the two way view. During the interview, student D explained: "*At the first I find out what order Budi is in from two sides, then because one child is counted twice, so I subtract one from that number.*" This statement shows a complete understanding of the modeling strategy and its application in the requested context.

In contrast, student E experienced errors in the indicators of organizing and problem solving strategies. This student understood that the problem was related to two number patterns from two different directions, and was able to determine that from the left, Budi was in the 14th position. However, when determining the position from the right direction, student E miscalculated the

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location of number 41 in the row pattern with a difference of 4, thus obtaining an incorrect order. This error had an impact on the final calculation model, which added up the two incorrect positions and produced an incorrect number of children.

In the indicator of understanding the problem, student E was able to recognize quantities and units, but was unable to form an accurate mathematical model. In the third indicator, he did not check or verify his answer. In the interview, student E said: "*I already know the position from the left, but from the right I guess I just guessed.*" This indicates that although the student understood the context of the problem, he was not able to model the two way situation correctly.

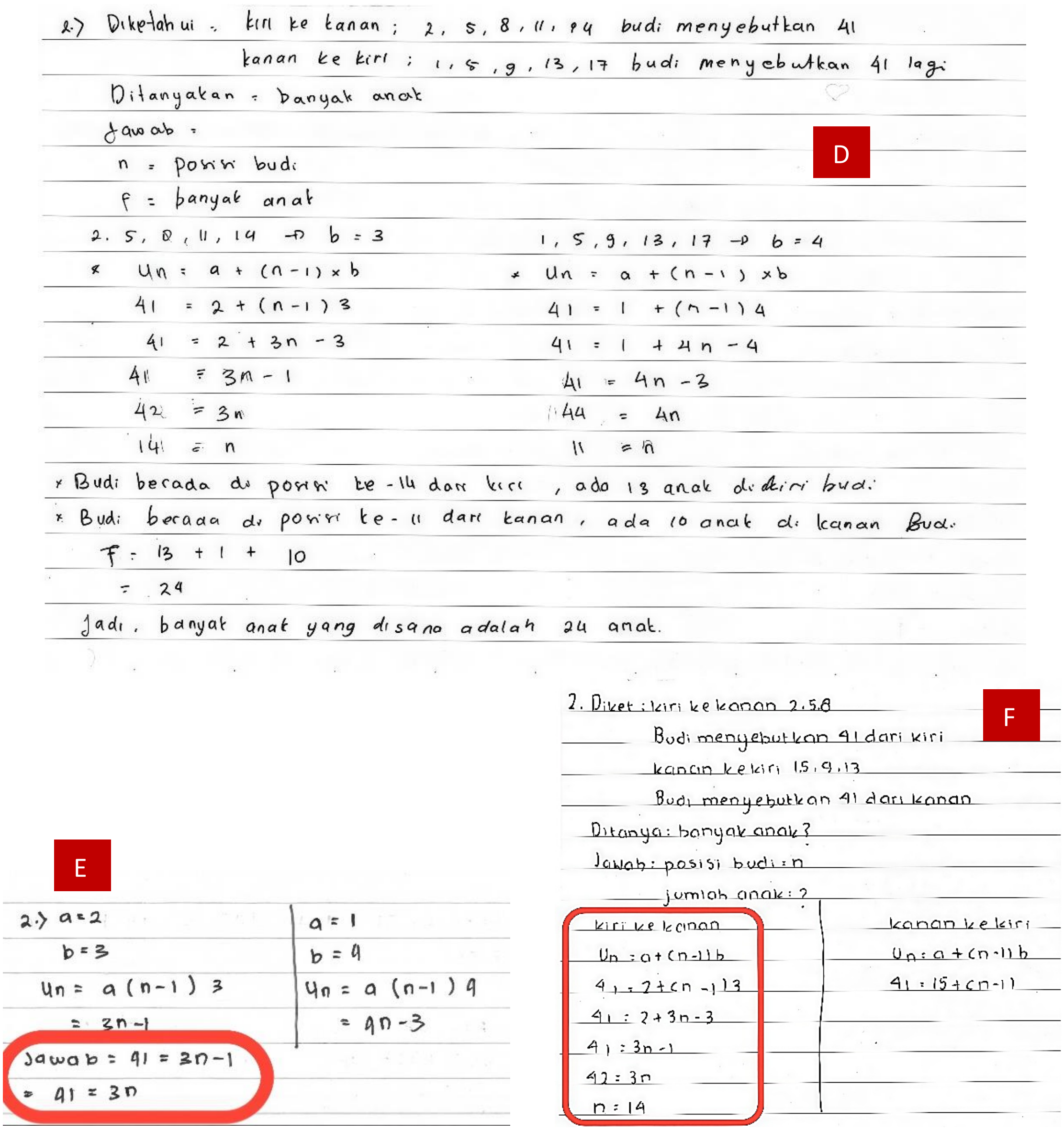

Figure 3. Answer Number.

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Meanwhile, student F showed more problems, especially in the indicators of understanding the problem and organizing strategies. He only arranged the rows from one direction, namely from left to right, and ignored the information in the opposite direction. He immediately concluded that Budi's position from one side was enough to determine the total number of children, without considering that the problem asked for information from two points of view. As a result, he did not develop the correct mathematical model, and his answer was not logical. In the organizing strategy indicator, student F did not give symbols to the variables or compile an appropriate calculation model.

In addition, he also did not confirm or check the final result. During the interview, student F said: "*I thought it was enough from one side, so I didn't think it needed to be calculated from the right.*" This shows that student F has not understood the essence of using two directions in developing mathematical modeling, and still uses a simple approach without thorough logical consideration.

Thus, the correct answer to problem number 2 was only shown by student D, who met all indicators of problem solving ability with mathematical modeling strategies. Meanwhile, student E and student F still had difficulties, especially in modeling and confirming the solution. The indicators that were not met by student E were in the strategy of organizing and confirming the results, while student F did not meet the indicators of understanding the problem or organizing the solution. This shows the need to strengthen understanding of the two way concept in arithmetic sequence and how to model the situation mathematically in learning.

In analyzing students' mathematical problem solving performance on problem number 5, which involves a cake production scenario following an arithmetic sequence, three indicators of problem solving ability are employed: understanding the problem, organizing and selecting appropriate strategies, and verifying the process and final answer.

Based on the three results (Figure 4), student G was the most accurate because they were able to apply the formula systematically. Student H only managed to form the quadratic equation without solving it, while student I used the sum of terms formula incorrectly.

Student G managed to solve the problem correctly and fulfill all problem solving indicators. In the indicator of understanding the problem, student G correctly identified the known information, namely the total cakes of the first 5 days were 75 pieces and the total cakes of the first 9 days were 171 pieces, as well as the question of on what day the total cakes reached 200 pieces. Student G also correctly understood that this problem involved an arithmetic sequence and the sum of its terms.

In the indicator of organizing and problem solving strategies, student G gave the right variable symbols, namely using n for the number of days, a for the first term, and b for the difference between terms. He constructed a mathematical model by applying the formula for the sum of the first n terms of an arithmetic sequence, namely $S_5 = \frac{5}{2}(2a + (5-1)b)$ for the first 5 days and $S_9 = \frac{9}{2}(2a + (9-1)b)$ for the first 9 days. Then he systematically developed the equation to find $a = 11$ and $b = 2$, which means the first term is 11 pieces of cake and the daily increase is 2 pieces of cake.

After finding the values of a and b, student G constructed a quadratic equation to find n (the number of days) when the total number of cakes reached 200. He solved the equation $n^2 + 10n - 200 = 0$ with the quadratic formula and found the value of $n = 10$. It is important to note that student G did a back check by

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considering two possible solutions of the quadratic equation and chose $n = 10$ because n must be positive. This shows good logical thinking skills.

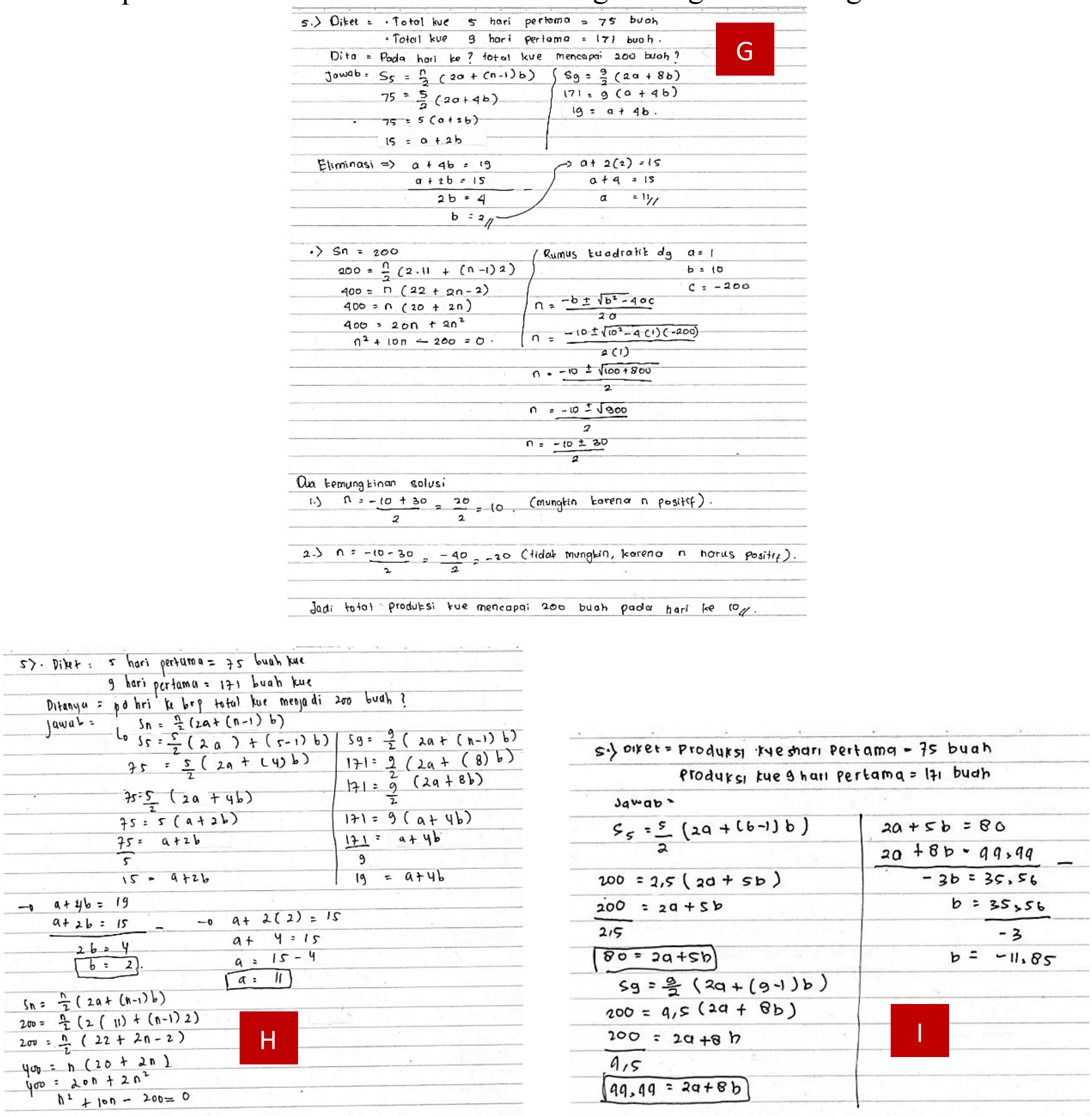

Figure 4. Answer Number 5

On the indicator of confirming the process and answer, student G correctly concluded that the total production of cakes reached 200 pieces on the 10th day. This shows that he understood the context of the problem and was able to interpret the results of his mathematical calculations according to the question asked. In the interview, student G explained: "*I used the concept of arithmetic sequence because the cake production increases by a fixed difference every day. I started by making two equations from the known information to find the values of a and b. After finding that the first day's production was 11 cakes with an increase of 2 cakes per day, I could find on which day the total reached 200 cakes by making a quadratic equation. There are two solutions to the quadratic equation, but since the number of days must be positive, I chose n = 10.*" This explanation shows a deep understanding of the mathematical modeling process and the context of the problem.

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Student H showed some deficiencies in his problem solving. In the indicator of understanding the problem, student H was able to identify the known and asked information. He also understood that the problem was related to the sum of the arithmetic sequence. In the indicator of organizing and problem solving strategies, student H used the same approach as student G, namely making two equations from the known information. He managed to find the values of $a = 11$ and $b = 2$. However, student H had difficulty when forming a quadratic equation to find the value of n. It can be seen that he noted $n^2 + 10n - 200 = 0$, but did not continue until he got the solution right. In his work, there were many scribbles and unfinished calculations, indicating that he had difficulty in solving quadratic equations.

In the indicator of confirming the process and answer, student H did not show a clear final answer, so it could not be confirmed whether he could interpret the results of his calculations in the context of the problem. From the interview, student H might say: "*I understand how to use the sum formula, but when it comes to finding the value of n in the quadratic equation, I am confused about the next step.*" This shows that student H had difficulty especially at the calculation stage of the quadratic equation.

Student I demonstrated a different approach and exhibited a fundamental error. While the student was able to identify the given information under the indicator of problem understanding, it appeared that he did not fully comprehend the concept of arithmetic sequences as required by the problem. On the indicator of organizing and problem solving strategies, student I used an incorrect formula, namely $S_5 = \frac{5}{2}(2a + (b - 1)b)$ which is an incorrect formula. The correct formula should be $S_5 = \frac{5}{2}(2a + (5 - 1)b)$. This error continued in his work, where he got the equations $2a + 5b = 80$ and $2a + 8b = 44{,}44$.

From this calculation, he produced the value $b = -11{,}8$, which is logically impossible because in the context of the problem, the daily increase in cake production cannot be negative. This shows that student I did not understand the implications of the variable values she found in the context of the problem.

On the indicator of confirming the process and answer, student I did not conclude, and there was no indication that he verified or interpreted the results he obtained. From the interview, student I may have said: "*I tried to use the formula I remembered, but something seems wrong because the result is negative. I'm not sure how to fix it.*" This suggests that student I had difficulty in understanding basic concepts and applying the right formula.

Thus, only student G managed to meet all indicators of problem solving ability with mathematical modeling strategies. Student H had difficulty at the stage of solving the quadratic equation, while student I had fundamental errors in understanding concepts and applying formulas. The indicator most mastered by the three students was understanding the problem, where they were able to identify the known and questionable information. The most difficult indicators were the organization and problem solving strategies, especially in solving the quadratic equation to find the value of n and in applying the correct arithmetic sequence formula.

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The results of the analysis show that most students are able to solve math word problems well on problems with a low level of complexity, which supports the view (Klang et al., 2021) that interaction between students in cooperative learning can encourage better understanding in solving math problems. This finding also reinforces the opinion of Qotrunnada and Prahani (2023), that problem solving ability has a significant contribution to students' cognitive development. In particular, students showed good mastery in understanding the problem and developing a solution plan, as reflected in the indicators of problem solving ability according to NCTM.

Furthermore, the skill of constructing accurate mathematical models in answering problems within the context of arithmetic sequence reflects the stages of problem solving. According to Pólya in Favier (2022), especially in the aspects of planning and implementing solutions, which states that mathematical modeling not only improves mathematical abilities, but also facilitates the development of critical thinking. Students who are able to derive formulas from contextual situations show a level of maturity in organizing information and thinking systematically.

However, there was a decrease in answer accuracy on questions with a high level of complexity, which indicates that there are still challenges in the stage of evaluating the results or validating the solution. This condition is in line with Beckschulte (2020) findings that students often experience difficulties at the interpretation and validation stages because they require high evaluative skills and mastery of the relationship between concepts in real contexts. This indicates the need for more intensive training in process reflection and answer confirmation as part of the third NCTM indicator.

Research by Molina Muñoz et al. (2023) also showed that high interest in mathematics and healthy social relationships can support students in overcoming these barriers and achieving better results in mathematical modeling. Inappropriate teaching methods, for example in online learning, can make it difficult for students to understand mathematical concepts, while strong support from parents and teachers can increase students' positive attitudes and confidence in mathematics (Harun et al., 2021).

Overall, the results of this study support the importance of mathematical modeling strategies as proposed by Govender and Machingura (2023), because these strategies are proven to be able to build students' logical and systematic thinking frameworks in dealing with word problems. When students are able to identify quantities, construct appropriate models, and solve and interpret the results, they not only succeed in academic tasks, but also develop higher order thinking skills that are relevant for dealing with real problems in the future.

CONCLUSION AND SUGGESTION

This study involved 31 students who completed five mathematical word problems of varying difficulty levels. The researchers aimed to analyze students' problem solving abilities through mathematical modeling strategies in word problems. The results showed that although the students' average performance was quite good with a score of 82.10, there was significant variation in their abilities. In addition, the success rate decreased as

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the complexity of the problems increased, from 96.77% on the first problem to 74.19% on the fifth problem. The interview session revealed that students with high test scores consistently mastered the three main indicators, namely understanding the problem, organizing strategies, and validating solutions, while students who were less successful or had low scores tended to have difficulty with the latter two indicators.

In general, understanding problems was the most mastered skill, while organizing strategies and validating solutions remained a challenge. In addition, modeling success was also influenced by the level of relevance of the context to the students' experiences. These findings emphasize the importance of learning that emphasizes the development of problem solving strategies in word problems and the validation of solutions through contextual and systematic mathematical modeling.

Future research is recommended to diversify the contexts of mathematical problems beyond arithmetic sequences, integrating broader mathematical domains to enrich students' modeling experiences. In addition, longitudinal studies are needed to monitor the development of modeling competencies over time and to explore how diverse student characteristics influence their performance in mathematical modeling.

REFERENCES

Alpaslan, M. M., & Yalvac, B. (2023). Integrating mathematical modelling into problem based research: An evaporation activity. *Journal of Problem Based Learning in Higher Education*, *11*(3), 61–73. https://doi.org/10.54337/ojs.jpblhe.v11i3.7501

Beckschulte, C. (2020). Mathematical modelling with a solution plan: An intervention study about the development of grade 9 students' modelling competencies. In G. A. Stillman, G. Kaiser, & C. E. Lampen (Eds.). *Springer International Publishing*. https://doi.org/10.1007/978-3-030-37673-4_12

Braun, V., & Clarke, V. (2022). Toward good practice in thematic analysis: Avoiding common problems and be(com)ing a *knowing* researcher. *International Journal of Transgender Health, 24*(1), 1–6. https://doi.org/10.1080/26895269.2022.2129597

Cevikbas, M., Greefrath, G., & Siller, H. S. (2023). Advantages and challenges of using digital technologies in mathematical modelling education – a descriptive systematic literature review. *Frontiers in Education*, *8* https://doi.org/10.3389/feduc.2023.1142556

Çibukçiu, B. (2025). The impact of constructivist methods on students' mathematical problem-solving. *Discover Education*, *4*, 83 (2025). https://doi.org/10.1007/s44217-025-00475-w

Cotrunnada, N. A., & Prahani, B. K. (2023). The effectiveness of using digital books on the problem-solving ability of high school students in physics learning. *SAR Journal – Science and Research*, *6*(2), 83–88. https://doi.org/10.18421/SAR62-04

Cresswell, C., & Speelman, C. P. (2020). Does mathematics training lead to better logical thinking and reasoning? A cross-sectional

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v14i3.12722

assessment from students to professors. *Plos One*, *15*(7). https://doi.org/10.1371/journal.pone.0236153

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). *SAGE Publications*.

Favier, S. (2022). A characterization of the problem-solving processes used by students in classroom: proposition of a descriptive model. *Hiroshima Journal of Mathematics Education*, *15*(1). https://doi.org/10.24529/hjme.1504

Govender, R., & Machingura, D. (2023). Ascertaining grade 10 learners' levels of mathematical modelling competency through solving simultaneous equations word problems. *Pythagoras, 44*(1), a728. https://doi.org/10.4102/pythagoras.v44i1.728

Hartmann, L. M., Krawitz, J., & Schukajlow, S. (2021). Create your own problem! When given descriptions of real-world situations, do students pose and solve modelling problems? *ZDM – Mathematics Education*, *53*(4), 919–935. https://doi.org/10.1007/s11858-021-01224-7

Harun, Kartowagiran, B., & Manaf, A. (2021). Student attitude and mathematics learning success: A meta-analysis. *International Journal of Instruction*, *14*(4), 209–222. https://doi.org/10.29333/iji.2021.14413a

Jankvist, U. T., & Niss, M. (2020). Upper secondary school students' difficulties with mathematical modelling. *International Journal of Mathematical Education in Science and Technology*, *51*(4), 467–496. https://doi.org/10.1080/0020739X.2019.1587530

Kharisudin, I., & Cahyati, N. E. (2020). Problem-solving ability using mathematical modeling strategy on model eliciting activities based on mathematics self-concept. *Journal of Physics: Conference Series*, 1567(3), 032067. https://doi.org/10.1088/1742-6596/1567/3/032067

Kharisudin, I., Radika, W., & Masrukan. (2024). Representation ability in mathematical modeling based on learning independence. *Hipotenusa: Journal of Mathematical Society*, *6*(2), 150–167. https://doi.org/https://doi.org/10.18326/hipotenusa.v6i2.2424

Klang, N., Karlsson, N., Kilborn, W., Eriksson, P., & Karlberg, M. (2021). Mathematical problem-solving through cooperative learning—the importance of peer acceptance and friendships. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.710296

Krawitz, J., Chang, YP., Yang, KL. et al. (2022). The role of reading comprehension in mathematical modelling: improving the construction of a real-world model and interest in Germany and Taiwan. *Educational Studies in Mathematics* *109*, 337–359. https://doi.org/10.1007/s10649-021-10058-9

Molina-Muñoz, D., Contreras-García, J. M., & Molina-Portillo, E. (2023). Does the psychoemotional well-being of Spanish students influence their mathematical literacy? An

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v14i3.12722

evidence from PISA 2018. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1196529

Nurochmah, Y., & Kharisudin, I. (2023). Mathematical modeling problem solving viewed from students' mathematical self-concept on means-ends analysis based on blended learning. *Unnes Journal of Mathematics Education*, *12*(2), 167-176. https://doi.org/10.15294/ujme.v12i2.74003

Panhuizen, M. van den H. (2020). International reflections on the Netherlands didactics of mathematics (1st ed.). *Springer International Publishing*. https://doi.org/10.1007/978-3-030-20223-1

Santos-Trigo, M. (2024). Problem solving in mathematics education: tracing its foundations and current research-practice trends. *ZDM Mathematics Education 56*, 211–222. https://doi.org/10.1007/s11858-024-01578-8

Verschaffel, L., Schukajlow, S., Star, J., & Van Dooren, W. (2020). Word problems in mathematics education: a survey. *ZDM - Mathematics Education*, *52*(1), 1–16. https://doi.org/10.1007/s11858-020-01130-4