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High school students' modeling abilities in arithmetic sequences using body weight contexts

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Abstract

Background: Mathematical modeling is an important skill in mathematics education, helping students use math to solve real-world problems. Teaching and assessing this skill can be challenging, especially when students need to apply algebraic concepts in their models.
Aim: This study aims to assess the ability of high school students to model mathematical problems related to weight changes using arithmetic sequences. The focus is on how well students can understand the problem, identify relevant mathematical concepts, apply these concepts, and explain their results.
Method: The study involved 28 high school students who were given two open-ended modeling tasks. A qualitative descriptive approach was used to analyze how students performed in four key stages of mathematical modeling: understanding the problem, identifying mathematical concepts, applying mathematical procedures, and explaining the results.
Results: The results showed that 79% of the students reached the minimum proficiency level in mathematical modeling. Students performed very well in understanding the problem (94.05%) and identifying relevant mathematical concepts (90.48%), but had more difficulty in applying these concepts, especially in algebraic calculations (71.43%). This suggests that more attention is needed in teaching algebra within modeling tasks.
Conclusion: The study highlights the benefits of using real-world contexts to improve students' mathematical modeling skills. However, it also points out the need to strengthen students' understanding of algebra to help them apply mathematical concepts more effectively. Integrating more mathematical modeling into the curriculum could better prepare students to solve complex real-world problems.

INTRODUCTION

Mathematics education is recognized as a fundamental part of preparing young people to face global challenges. In today’s complex world, math skills are not just about solving numerical problems but also about understanding and applying mathematical concepts in various real-life situations (Kösece & Doğanay, 2023; Nurhanurawati et al., 2022). This ability, often called mathematical literacy, is increasingly important as it involves using math in relevant contexts, whether in daily life, work, or society. Mathematical literacy is a key measure in international assessments like PISA (Programme for

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International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study), which aim to evaluate how well students can apply their math knowledge to solve real-world problems (Mullis et al., 2020; OECD., 2019).

Moreover, results from PISA and TIMSS have shown a strong link between mathematical literacy and overall academic success (OECD, 2019). Mathematical literacy not only reflects a student's understanding of math concepts but also their ability to think critically, analyze information, and make decisions based on data. In this context, mathematical modeling plays an essential role by allowing students to connect theoretical knowledge with practical applications (Dede et al., 2020; Mestrinho & Cavadas, 2018; Pugacheva et al., 2020). Modeling gives students the opportunity to see how math can be used to understand, analyze, and solve real-world problems, thus making math learning more relevant and engaging.

Despite the recognized importance of mathematical modeling in improving mathematical literacy, its application in classrooms remains limited. One of the main challenges teachers face in teaching mathematical modeling is a lack of adequate training. Many teachers do not have enough experience integrating mathematical modeling into their curriculum, making it difficult to use this approach in everyday teaching (Arseven, 2015; Asempapa & Sturgill, 2019; Jung et al., 2019). This issue is not just due to a lack of professional development but also because of insufficient resources to support modeling instruction in schools. As a result, many teachers hesitate to use mathematical modeling in their lessons, even though they understand the significant benefits it can offer (Gunderson et al., 2012).

In addition to limited training, the lack of time and the pressure of a packed curriculum also hinder the use of mathematical modeling in classrooms (Peng, 2022). Teachers often have to focus on material that will be tested in standardized exams, leaving little room for activities that involve modeling. Yet, mathematical modeling has great potential to help students develop critical and creative thinking skills, as well as to deepen their understanding of math concepts (Jung et al., 2019). Therefore, it's important for educational institutions and policymakers to provide greater support to teachers through training, resources, and curriculum flexibility so that mathematical modeling can be more effectively integrated into teaching.

Arithmetic sequences, as a basic topic in the math curriculum, have strong potential for use in mathematical modeling. An arithmetic sequence is a series of numbers with a constant difference between each pair of consecutive terms, and this concept often appears in various real-world situations. For example, financial planning, population growth, and even weight changes can be modeled using arithmetic sequences (Kişi, 2022; Loenneker et al., 2021). By using these contexts in teaching, teachers can help students understand how the math concepts they learn in class can be applied in real life. This not only makes learning more relevant for students but also increases their motivation to study math because they can see the practical benefits of what they are learning.

Among these real-world contexts, body weight serves as a particularly relatable and practical example for exploring arithmetic sequences in mathematical modeling.

Weight changes, whether influenced by dietary habits, exercise, or natural growth, often follow predictable patterns that can be effectively modeled using arithmetic sequences (Helland & Nordbotten, 2021; Pistelli et al., 2021). When students apply mathematical concepts to the context of body weight, they gain a clearer understanding of how these sequences function in real life. This contextual learning not only bridges the gap between abstract mathematical theory and practical application but also deepens students' engagement by connecting the material to something personally meaningful (Zhang et al., 2017). Moreover, incorporating body weight as a context allows for the exploration of health-related topics, adding an interdisciplinary dimension to mathematics education. Such an approach encourages students to perceive mathematics not merely as an academic subject, but as a valuable tool for analyzing and making informed decisions about real-world phenomena.

Furthermore, the application of mathematical modeling in the context of arithmetic sequences strengthens students' understanding of fundamental math concepts. By modeling real-world situations, students learn to connect abstract ideas, such as arithmetic sequences, with practical applications, thereby deepening their comprehension. For instance, when tasked with modeling weight changes using arithmetic sequences, students not only identify numerical patterns but also explore how these patterns can be used to predict outcomes or understand specific phenomena (Jannah et al., 2023). This integration of theory and practice makes math learning more meaningful and equips students with skills that will prove useful throughout their lives.

Mathematical modeling not only helps students deeply understand math concepts but also teaches them how to think analytically and creatively when facing real-world problems. In the context of math education, mathematical modeling acts as a bridge between theory and practice, allowing students to apply the math concepts they learn to real-life situations (Liu & Yang, 2023). For example, by involving students in modeling tasks that use relevant contexts like weight changes in arithmetic sequences, they can learn to make predictions, analyze data, and develop solutions based on mathematical principles (Liu & Yang, 2023). This not only enriches their learning experience but also enhances critical thinking skills and problem-solving abilities, which are crucial in everyday life. Furthermore, using mathematical modeling, students can learn to see math as a useful tool in their lives, not just an academic subject. This approach can help change students' perceptions of math, from something abstract and difficult to something relevant and meaningful. In the long run, this can increase students' interest and motivation in studying math, as well as prepare them to face future challenges. Therefore, mathematical modeling should become an integral part of the math curriculum in schools, with adequate support from teachers, educational institutions, and policymakers.

To effectively integrate mathematical modeling into the curriculum, it is crucial to understand how students develop and apply these skills in various contexts. Numerous studies have explored mathematical modeling from different angles, providing valuable insights into its impact on students' learning. For instance, research on the analysis of mathematical modeling abilities has been conducted in various contexts and from different perspectives. Khusna & Ulfah (2021) studied how students solve contextual problems, while Pratikno (2019) focused on mathematical abilities. Rosmawati (2020) examined modeling based on learning styles, and Hauda et al. (2023) explored it in the context of linear programming related to Palembang Lamonde. Maulani et al. (2022) linked modeling abilities with Gregorc thinking styles, Sabatini (2018) analyzed it in relation to academic achievement, and Kurniati (2017) looked at gender differences. However, there has been no specific study that investigates students' mathematical modeling abilities using body weight as a context within arithmetic sequences. This study aims to fill that gap by exploring how high school students model mathematical situations related to body weight changes in the context of arithmetic sequences, thereby providing new insights into mathematics education.

METHODS

Design:

This study is a descriptive qualitative research aimed at describing and analyzing high school students' mathematical modeling abilities in the context of arithmetic sequences using real-life situations, specifically body weight changes. Qualitative research is a multi-method approach that focuses on interpretation and a natural approach to the research subjects. This means that the study is conducted in the natural setting where the subjects are, with the goal of understanding and interpreting phenomena based on the meanings within the community (Dr. Muhammad Hasan, et al., 2022).. This approach allows the researcher to gain a deep understanding of how students develop and apply their mathematical modeling skills in contexts that are relevant to everyday life.

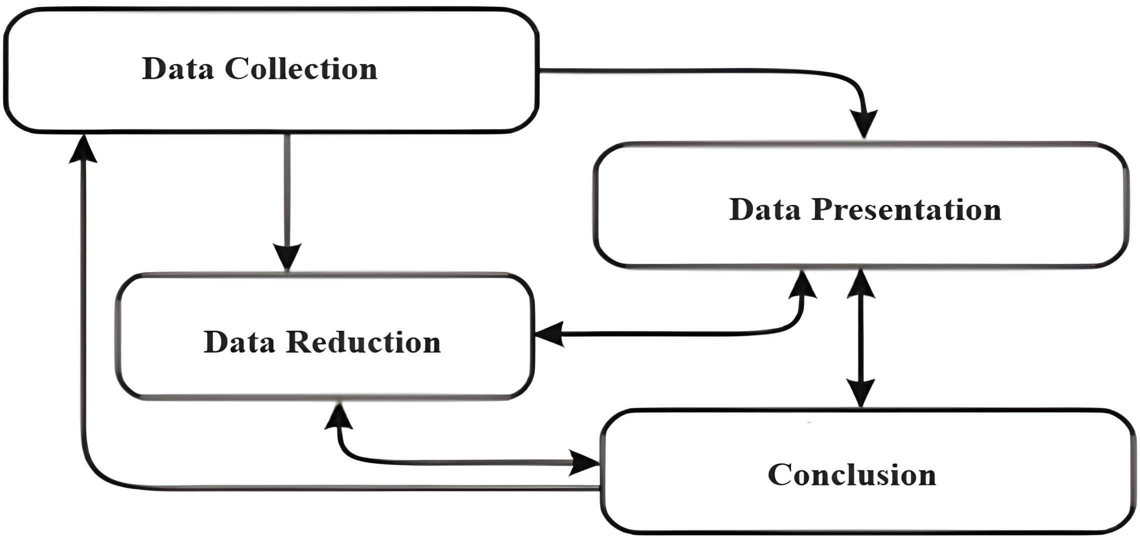


Figure 1. Flowchart of qualitative research

Figure 1 below shows the flowchart of the qualitative research conducted. This flowchart outlines the steps taken in the research process, from selecting subjects, collecting data, to analyzing the data. Each step in this flowchart is designed to ensure that the data collected provides an accurate and in-depth picture of the students' mathematical modeling abilities.

Participants:

The participants in this study are 28 eleventh-grade students from SMA Negeri 1 Lembak. The participants were selected using a purposive sampling method, based on specific criteria relevant to the research objectives. The selected students are expected to have varying levels of mathematical ability, so the results can reflect the different levels of mathematical modeling skills among the students. This sample allows the researcher to analyze how mathematical modeling skills develop in different contexts and what factors influence these skills.

Instruments:

Data collection in this study was carried out using several methods: tests, observations, and interviews. Tests were used to measure how well students could understand and apply mathematical concepts in modeling contexts. Observations were conducted to directly observe the thought processes and steps students took while working on modeling tasks. Meanwhile, interviews were conducted to gain deeper insights into the students' understanding of the modeling tasks and the reasons behind their decisions and actions. The combination of these three techniques is expected to provide a comprehensive picture of the students' mathematical modeling abilities.

***Data Analysis*:**

The data obtained from tests, observations, and interviews were analyzed descriptively to describe the stages of mathematical modeling performed by the students. These stages include: 1) Understanding the task, which refers to the students' ability to understand the given problem and identify the key information needed to solve it; 2) Searching for mathematics, which involves the students' ability to identify the relevant mathematical concepts or procedures for the problem at hand; 3) Using mathematics, which refers to the students' ability to apply mathematical concepts or procedures to solve the problem; and 4) Explaining the results, which is the students' ability to interpret the results obtained and communicate them clearly. This analysis was conducted by comparing the results from the three data collection techniques to gain a deep and holistic understanding of the students' mathematical modeling abilities.

RESULTS AND DISCUSSION

Result

After the first learning session, the researcher administered a test to the students during the second session. The test consisted of two open-ended questions and was given to 28 students from class XI MIPA 2 at SMA Negeri 1 Lembak. The purpose of the test was to measure the students' ability to model mathematical situations based on the learning they had received. Each student was given 85 minutes to complete the test individually, allowing the researcher to gather valid data on their mathematical modeling skills.

The test questions were designed to evaluate the students' abilities across four key stages of mathematical modeling: 1) Understanding the problem; 2) Identifying relevant mathematical concepts; 3) Applying mathematical concepts to solve the problem; and 4) Explaining the results. Each of these stages aims to assess the students' skills in addressing real-world problems that require a deep understanding of mathematics. The analysis was conducted carefully, comparing each student's results to provide an accurate picture of their abilities.

After the test was completed, the results were categorized into different achievement levels for a more structured assessment. These categories included "Excellent," "Good," "Fair," and "Needs Improvement," each reflecting the students' success in completing the modeling tasks. Table 1 below shows the distribution of student scores across these categories, providing insight into how well the students were able to apply mathematical modeling concepts to the given situations.

Table 1. Categorization of Students' Mathematical Modeling Scores

Score	Category	Frequency	Percentage
88-100	Excellent	7	25%
74-87	Good	15	54%
60-73	Fair	4	14%
< 60	Needs Improvment	2	7%
Total		**28**	**100%**

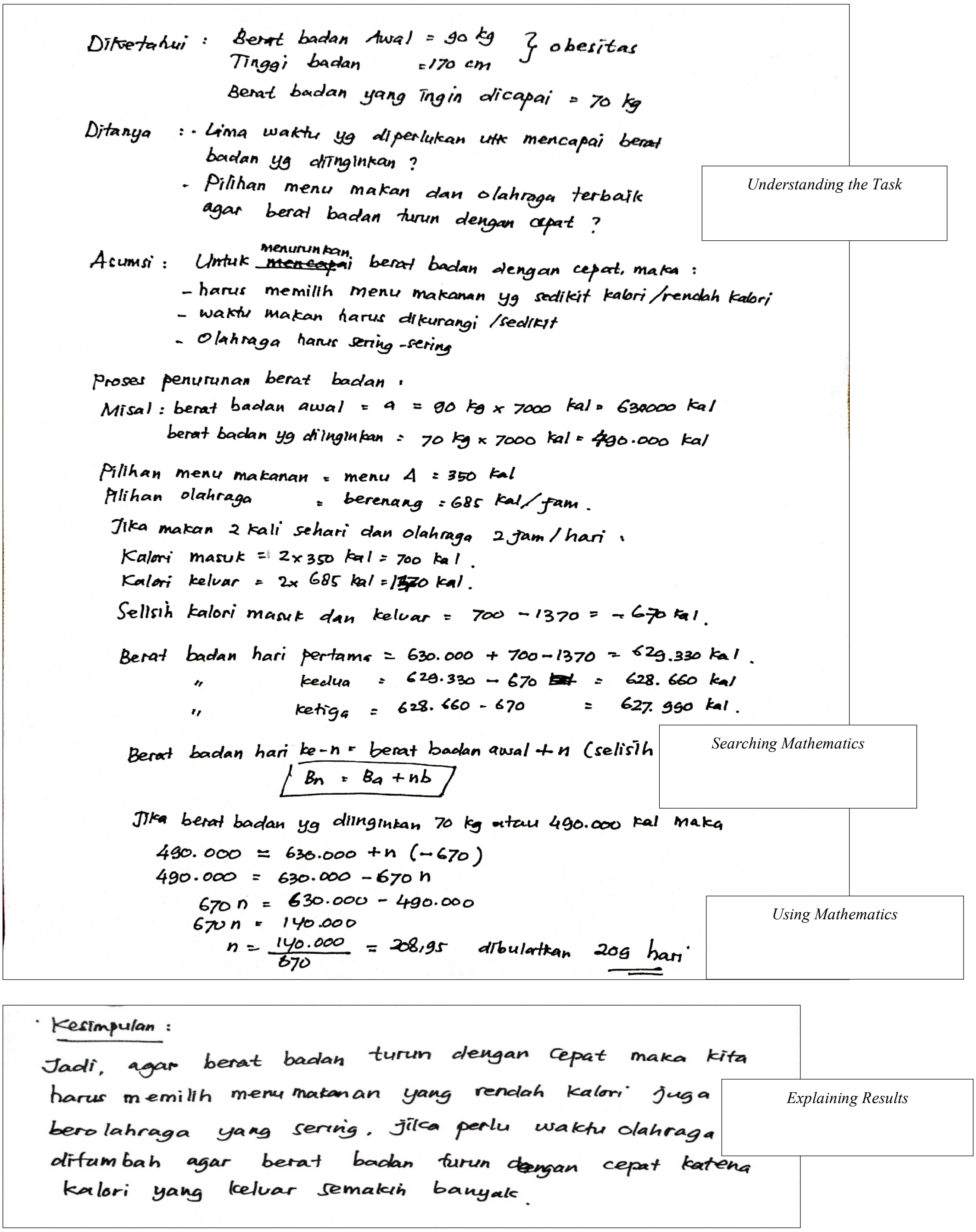
As seen in Table 1, the majority of students, 22 out of 28 (79%), successfully met the minimum proficiency level. This indicates that most students had an adequate ability to model the mathematical situations presented to them. However, six students (21%) did not meet the minimum proficiency level, suggesting that some students may need additional support or different approaches to strengthen their understanding. These results highlight the importance of addressing the variations in students' abilities and adjusting teaching strategies to be more effective.

Next, the students' mathematical modeling abilities were further analyzed based on their performance across the stages of the modeling cycle. This analysis aimed to evaluate how well students performed each step in the modeling process, which is an important indicator of their deep understanding of mathematics and their ability to apply it in real-world contexts. The results of this analysis are presented in Table 2, providing detailed insights into the students' success at each stage of modeling.

Table 2. Achievement in the Mathematical Modeling Cycle

No	Modelling Stage	Final Scoore	Category
1	Understanding the Problem	94,05	Excellent
2	Identifying Concept	90,48	Excellent
3	Applying Mathematics	71,43	Good
4	Explaining Results	89,29	Excellent
Total		**86,31**	**Excellent**

As shown in Table 2, the highest achievement was in the stage of understanding the problem, with an average score of 94.05%. This indicates that the students were able to identify important information from the problems given and understand the real-world situations they were facing very well. This ability is crucial as it lays the foundation for the subsequent steps in the modeling process. On the other hand, the lowest achievement was in the stage of applying mathematics, with an average score of 71.43%. While still categorized as "Good," some students appeared to struggle with applying the correct mathematical concepts, particularly when dealing with more complex algebraic calculations, such as inverse addition and subtraction or inverse multiplication and division.



Diketahui : Berat badan Awal = 90 kg } obesitas
Tinggi badan = 170 cm
Berat badan yang ingin dicapai = 70 kg

Ditanya : • Lama waktu yg diperlukan utk mencapai berat badan yg diinginkan ?
• Pilihan menu makan dan olahraga terbaik agar berat badan turun dengan cepat ?

Asumsi : Untuk ~~mencapai~~ menurunkan berat badan dengan cepat, maka :
- harus memilih menu makanan yg sedikit kalori / rendah kalori
- waktu makan harus dikurangi / sedikit
- Olahraga harus sering-sering

Proses penurunan berat badan :
Misal : berat badan awal = a = 90 kg × 7000 kal = 630000 kal
berat badan yg diinginkan : 70 kg × 7000 kal = 490.000 kal

Pilihan menu makanan = menu A = 350 kal
Pilihan olahraga = berenang = 685 kal/jam .
Jika makan 2 kali sehari dan olahraga 2 jam / hari ,
Kalori masuk = 2×350 kal = 700 kal .
Kalori keluar = 2× 685 kal = 1370 kal .
Selisih kalori masuk dan keluar = 700 − 1370 = − 670 kal .

Berat badan hari pertama = 630.000 + 700 − 1370 = 629.330 kal .
" kedua = 629.330 − 670 = 628.660 kal
" ketiga = 628.660 − 670 = 627.990 kal .

Berat badan hari ke-n = berat badan awal + n (selisih
$\boxed{B_n = B_a + nb}$

Jika berat badan yg diinginkan 70 kg atau 490.000 kal maka
490.000 = 630.000 + n (−670)
490.000 = 630.000 − 670 n
670 n = 630.000 − 490.000
670 n = 140.000
$n = \frac{140.000}{670}$ = 208,95 dibulatkan 209 hari

• Kesimpulan :
Jadi, agar berat badan turun dengan cepat maka kita harus memilih menu makanan yang rendah kalori juga berolahraga yang sering, jika perlu waktu olahraga ditambah agar berat badan turun dengan cepat karena kalori yang keluar semakin banyak.

Figure 2. Students' Mathematical Modeling Test Responses

Based on Figure 2, it can be concluded that after the learning sessions, most students were able to solve the real-world problems presented to them without needing additional guidance. This suggests that the students had effectively internalized the problem-solving process, enabling them to work independently. They demonstrated a strong ability to analyze the problem, which included carefully reading and understanding the problem statement, identifying the key information provided, and discerning which aspects of the problem were critical for developing a solution (understanding the problem). This level of comprehension is crucial, as it forms the foundation for successful problem-solving. Moreover, the students showed proficiency in pinpointing important variables and recognizing unknowns that were essential to solving the problem. For instance, they were able to accurately identify the initial weight and calculate the difference between calories consumed and burned, which are necessary steps in constructing a mathematical model that mirrors the real-world scenario (identifying concepts).

In addition to their analytical skills, the students also exhibited competency in applying the mathematical concepts they had identified. Although some students encountered challenges, particularly with more complex calculations such as those involving algebraic inverses, the majority were able to navigate these difficulties and perform the necessary calculations correctly (applying mathematics). This ability to apply mathematical reasoning to solve real-world problems is a key indicator of their understanding and mastery of the material. Finally, the students were not only able to reach a solution but also to draw meaningful conclusions from their results. They successfully interpreted the outcomes of their calculations and related these results back to the original problem, demonstrating an understanding of how their mathematical solutions applied to the real-world context they were addressing (explaining results). This final step is critical, as it reflects the students' ability to use mathematics as a tool for understanding and solving real-world issues, thereby reinforcing the practical value of their learning.

Discussion

The results of this study show that most students were able to understand and apply mathematical concepts in real-world contexts after the learning sessions. With 79% of students meeting the minimum proficiency level, this study supports previous findings that real-world context-based learning can enhance understanding and mathematical modeling skills. For example, research by Khusna & Ulfah (2021) also found that using contextual problems in learning helps students better grasp mathematical concepts and apply them to real situations. These results highlight the importance of teaching approaches that connect mathematical theory with practical applications.

Although students demonstrated a good understanding of the problem, the stage of applying mathematics showed lower results, with only 71.43% of students successfully applying mathematical concepts. This difficulty is similar to findings by Maulani et al. (2022), who reported that students often struggle with more complex mathematical applications, particularly in algebraic calculations. In Maulani's study, students with certain thinking styles faced greater challenges in effectively manipulating mathematical concepts. This suggests a need for greater focus on strengthening algebraic understanding in teaching so that students can overcome challenges in the application stage of mathematics.

Students' success in the problem-understanding stage, with a score of 94.05%, is crucial in the overall mathematical modeling process. Research by Pratikno (2019) also showed that a strong understanding of the problem is key to mathematical modeling ability, where students who can identify important variables and understand the problem context are more likely to succeed in solving complex mathematical problems. These findings align with this study, where good problem understanding helped students proceed confidently and accurately to the next modeling stages.

While problem understanding is a strong foundation, the results of this study show the need to strengthen the understanding of basic mathematical concepts, particularly in algebraic applications. Research by Rosmawati (2020) emphasizes the importance of more interactive, problem-solving-focused approaches to help students overcome difficulties in applying mathematical concepts. The findings of this study are consistent with this, as some students struggled with algebraic calculations. Therefore, more in-depth teaching and focused practice on algebraic manipulation and the application of concepts in real-world contexts are needed to improve these skills.

When compared with other relevant studies, the results of this research indicate that real-world context-based learning and a focus on mathematical modeling can significantly enhance students' skills in understanding and applying mathematical concepts. However, to maximize its effectiveness, greater emphasis is needed on teaching fundamental mathematical concepts, especially algebra. In addition, educators need to provide more opportunities for students to apply mathematics in various real-world scenarios, as suggested by Sabatini (2018), to strengthen their critical thinking and problem-solving abilities. Further research is also needed to explore more effective teaching methods for overcoming challenges in mathematical application, thereby improving students' performance in all stages of modeling.

Implication

The results of this study have several important implications for teaching mathematics at the high school level. First, the finding that most students were able to understand and apply mathematical concepts in real-world contexts shows that mathematical modeling is a highly effective tool for enhancing students' analytical and problem-solving skills. Therefore, mathematics teachers are encouraged to integrate mathematical modeling more frequently into their daily lessons, as it helps students see the direct relevance of the mathematical concepts they learn to real-life situations. Additionally, the study's results, which indicate difficulties in applying algebraic concepts, highlight the need to strengthen algebra instruction, both through more intensive practice and interactive teaching approaches. By reinforcing students' foundational mathematical understanding, particularly in challenging areas like algebraic calculations, they will be better prepared to tackle complex problems and apply mathematical concepts with greater confidence. These implications also suggest that curriculum development should consider a more systematic integration of mathematical modeling, providing opportunities for students to explore and apply mathematics in various practical and relevant scenarios.

Limitation

Although this study provides valuable insights into students' mathematical modeling abilities, there are several limitations that should be acknowledged. First, the study involved only 28 students from one high school, so the findings may not be generalizable to a broader population. The relatively small sample size and focus on a single location could affect the representativeness of the results. Second, the study used a qualitative descriptive approach, which, while allowing for an in-depth exploration of the phenomenon, does not provide strong statistical analysis to measure causal relationships between variables. Additionally, the evaluation of mathematical modeling abilities was based on only two open-ended questions, which may not cover all aspects of mathematical modeling skills. The variation in the type and number of questions could influence the results obtained. Lastly, the study did not consider external factors such as prior educational background, learning motivation, or family support, which might also play a role in influencing students' mathematical modeling abilities. Given these limitations, further research with a more comprehensive design and larger sample size is needed to strengthen the findings and expand the understanding of teaching mathematical modeling.

CONCLUSIONS

This study shows that most students have an adequate ability in mathematical modeling, especially in understanding problems and identifying relevant mathematical concepts. However, the difficulties faced in applying algebraic concepts highlight the need for stronger algebra instruction. Using real-world contexts in teaching has proven to be effective in enhancing students' mathematical modeling skills. Despite this, further improvements are needed to ensure that students can apply mathematical concepts correctly in various situations. The results also emphasize the importance of systematically integrating mathematical modeling into the curriculum to strengthen students' analytical and problem-solving skills. Greater support in the form of practice and interactive teaching approaches is also needed to address challenges in applying mathematics. Overall, this study provides valuable insights into how to improve mathematics teaching in high schools. The implications of these findings can help in developing more effective and relevant teaching strategies.

AUTHOR CONTRIBUTION STATEMENTS

AR : Took the lead in developing the research idea, designing the study methodology, and providing oversight throughout the entire research process.

NA : Was primarily responsible for data collection, performing statistical analyses, and significantly contributed to drafting the results and discussion sections.

D : Focused on conducting the literature review, creating the theoretical framework, and played a key role in writing the background and conclusion sections.

SL : Led the editing and revision of the manuscript, ensuring clarity and coherence, and managed all communication with the journal and tasks related to the publication process.

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