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MATHEMATICAL MODELING SKILLS IN PLANE GEOMETRY

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ABSTRACT

This study aims to analyze the process and responses of junior high school students to mathematical modeling in the context of plane figures, as well as to identify relevant solutions to improve these skills. This is particularly important to examine because, without a proper grasp of modeling, students tend to get stuck merely memorizing procedures without being able to translate real-world problems into mathematical language that leads to solutions. Modeling ability itself is a crucial competency that enables students to solve complex problems through simpler notational and symbolic representations. However, field observations indicate that students’ ability to solve geometric word problems remains weak due to difficulties in understanding problem contexts, performing mathematization, and a lack of understanding of formula procedures. Through a qualitative approach using tests and interviews with three eighth-grade students in Ciwidey, it was found that the first subject (S1) had moderate ability with challenges in the accuracy of illustrations and the interpretation of real-world solutions, while the second (S2) and third (S3) subjects were in the low category because they failed to understand the essence of the problem and were unable to solve the problems correctly. This research provides attention for teachers and researchers in developing students' mathematical modeling abilities, where in general students still experience difficulties in interpreting real-world problems into mathematical models.

Penelitian ini bertujuan untuk menganalisis proses dan respons siswa SMP terhadap pemodelan matematika pada materi bangun datar, serta mengidentifikasi solusi relevan untuk meningkatkan kemampuan tersebut. Hal ini menjadi sangat penting untuk dikaji mengingat tanpa penguasaan pemodelan yang tepat, siswa cenderung hanya terjebak pada hafalan prosedur tanpa mampu mentransformasikan persoalan dunia nyata ke dalam bahasa matematika yang solutif. Kemampuan pemodelan sendiri merupakan kompetensi krusial yang memungkinkan siswa memecahkan masalah kompleks melalui representasi notasi dan simbol yang lebih sederhana. Namun, fakta di lapangan menunjukkan bahwa kemampuan siswa dalam menyelesaikan soal cerita geometri masih cenderung lemah akibat kesulitan dalam memahami konteks masalah, melakukan matematisasi, hingga ketidakpahaman pada prosedur rumus. Melalui pendekatan kualitatif dengan teknik tes dan wawancara terhadap tiga siswa kelas VIII di Ciwidey, ditemukan bahwa subjek pertama (S1) memiliki kemampuan kategori sedang dengan kendala pada akurasi ilustrasi dan interpretasi solusi nyata, sedangkan subjek kedua (S2) dan ketiga (S3) berada pada kategori rendah karena gagal memahami esensi masalah serta tidak mampu menyelesaikan soal dengan benar. Penelitian ini memberikan perhatian bagi guru dan peneliti dalam mengembangkan kemampuan pemodelan matematis siswa, dimana secara umum siswa masih mengalami kesulitan dalam menginterpretasikan masalah dunia nyata kedalam model matematika.

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INTRODUCTION

Mathematics is a branch of science that plays a fundamental role in underpinning scientific concepts; furthermore, mathematics also plays a vital role in human life. Mathematics is inseparable from daily life because it serves as a tool to simplify human life (Rachma et al., 2020). Mathematics is an important subject that plays a role in education and the development of science and technology (Nisa & Dahlan, 2025). Therefore, mathematics instruction must be structured in such a way that the learning process runs smoothly. One of the objectives of mathematics instruction is to help students improve their ability to think systematically and to assist them in understanding mathematical concepts.

In the context of learning, mathematics plays a crucial role in solving real-world problems. Real-world problems can be presented in narrative form, often referred to as word problems. In solving word problems, students are required to understand the problem, integrate the problem, plan a solution, and solve it. In solving problems, students must be able to understand the problem presented, construct a mathematical model, and identify the relationship between the problem and their ability to apply formulas and perform accurate calculations, according to Rahmi (Pandiangan & Zulkarnaen, 2021). However, various studies indicate that students' ability to solve word problems remains relatively low. Among the reasons cited are: students' limited understanding of the problems presented in word problems; students' difficulty in translating word problems into mathematical models; and students' lack of understanding of the procedures for determining the formulas used to solve the problems presented (Pandiangan & Zulkarnaen, 2021). This situation indicates a weakness in students' mathematical modeling skills. This aligns with the view of Manar et al. (2025), who state that students struggle to solve word problems involving multiplication and division operations.

Mathematical modeling is the process of representing a real-world problem using mathematical language to make it simpler and easier to solve. In solving real-world problems, it is essential to be able to identify what is known and what is being asked, create a mathematical model, and perform calculations. Mathematical modeling plays a crucial role because it enables students to translate real-world problems into mathematical form using notation and symbols. Through mathematical modeling, students will learn to use various mathematical representations and apply appropriate mathematical methods and procedures to solve real-world problems, Zulkarnaen (2020). In line with the views of Riduan et al. (2024) states that mathematical modeling is very important for students because it allows them to solve real-world problems through mathematical concepts, such as social arithmetic concepts in mathematical modeling.
The application of mathematical modeling in mathematics education can help students gain a deep understanding of concepts, improve their ability to think systematically and solve problems, enhance their grasp of mathematical concepts, develop higher-order thinking skills, foster mathematical communication and collaboration, and promote contextual mathematics that supports literacy and competency. The impact of mathematical modeling in classroom learning includes problem-solving skills, critical thinking skills, questioning skills, reasoning skills, metacognitive skills, algorithmic thinking skills, digital skills, mathematical representation skills, geometry skills, reading skills, mathematical concepts, creativity, communication and collaboration, self-efficacy, simulation or experimentation, engagement or motivation, and social awareness, (Tasarib et al., 2025).

Several previous studies have examined students' mathematical modeling skills in solving contextual problems. A study by Fadhlurrahman & Adirakasawi (2023) showed that students' mathematical modeling skills remain low, particularly during the mathematization and interpretation stages, as students are not yet able to identify key elements in word problems. Additionally, Wulandari et al. (2025) also found that students struggle at the interpretation and validation stages, particularly in connecting mathematical results to real-world contexts. Other studies have focused more on efforts to improve mathematical modeling skills through specific learning approaches, such as Realistic Mathematics Education (RME), which has proven effective in enhancing students' mathematical modeling skills compared to conventional instruction (Rahmad & Wijaya, 2020). Meanwhile, Ridha (2025) highlights students' difficulties in constructing mathematical models for the topic of Systems of Linear Equations with Two Variables (SPLDV), which are caused by low mathematization skills and a lack of understanding of the problem context.

However, most of these studies focus on specific topics such as SPLDV or PISA-based contexts, and place greater emphasis on the impact of instructional models on mathematical modeling skills. These studies also tend to analyze mathematical modeling skills in general without specifically examining specific foundational topics in mathematics education. One topic closely related to mathematical modeling is plane figures. When studying plane figures, students still struggle to translate real-world problems into mathematical terms. The difficulties students face in solving contextual problems involving plane figures include trouble creating mathematical models of the presented problems and difficulty in determining the appropriate formulas and procedures. These difficulties are caused by a low level of understanding of the problem context, poor literacy skills, a lack of understanding of the problem's meaning, and difficulties in solving problems and limitations in mastering arithmetic operations.

Based on the above discussion, it can be concluded that mathematical modelling ability is a key variable indluencing student's ability to solve contextual problems, particulary in the area of plane figures. However, research specifically examining mathematical modelling ability in the context of plane figures remains limited. Therefore, this study aims to analyze student's mathematical modelling ability in solving contextual problems involving plane figures. This study is expected to contribute to the development of mathematics education, particularly in designing learning strategies capable of enhancing mathematical modeling skills, and to serve as a reference for future research.

METHOD

The research method used was qualitative research, which involves data collection techniques based on test results and interviews with the aim of measuring students' mathematical modeling abilities in solving contextual problems. According to Pradini et al. (2018), qualitative research is a method that focuses on description or explores understanding to provide a deeper insight into that understanding. This aligns with Imanina (2020) view, who states that qualitative research is a method that describes understanding to facilitate a deeper grasp of it. Another opinion from Setiawan et al. (2024) is that qualitative research is descriptive and analytical in nature. Descriptive in qualitative research means describing and elaborating on the events, phenomena, and social situations being studied.

This study was conducted with eighth-grade students at a junior high school located in Ciwidey Subdistrict, Bandung Regency. Three students were selected as research subjects through purposive sampling to represent the high, medium, and low ability categories. These three subjects were subsequently coded as Student 1 (S1), Student 2 (S2), and Student 3 (S3) to maintain the confidentiality of their identities and to facilitate the data analysis process. The instruments used in this study consisted of two story problems designed to measure mathematical modeling skills in plane geometry, as well as unstructured interviews aimed at exploring the students' thought processes in problem-solving in greater depth. The problems were structured based on the stages of mathematical modeling, including understanding the problem, constructing a mathematical model, performing calculations, and interpreting the results.

After the test results and interview data were collected, the researchers conducted a qualitative analysis through the stages of data reduction, data presentation, and drawing conclusions. The analysis was conducted by examining each student's responses based on indicators of mathematical modeling ability, thereby providing a comprehensive picture of the differences in students' abilities across each category.

1. The length of a rectangle is 6 cm longer than its width. Given that the perimeter of the rectangle is 80 cm, draw a diagram of the problem and calculate the area of the rectangle!
2. Dina wants to create a garden in her backyard. She plans to install a fence around the garden. However, Dina only has 50 meters of fencing. She is considering the following two garden shapes:
   - **Garden A**: An isosceles triangle with a base length of 12 meters and the lengths of the other two sides each being 10 meters. The fence will be installed along all sides of the garden.
   - **Garden B**: A parallelogram with a base length of 10 meters, a height of 6 meters, and a sloping side (not parallel to the base) of 8 meters. A fence will also be installed around the garden.

   Create an illustration of the problem above in the form of a calculation of the perimeter of each park, then determine which park shape Dina can build based on the amount of fencing available.

Figure 1. Mathematical Modeling Ability Questions

The data collection methods in this study were carried out in several stages, namely: (1) administering story problems directly to students to measure their mathematical modeling skills regarding plane figures; (2) observing students' answer sheets to identify their problem-solving processes and the errors that arose; (3) conducting unstructured interviews with students to explore in greater depth their thought processes, the strategies used, and the reasoning behind each step of the solution; and (4) identifying the challenges students faced during the problem-solving process, whether related to conceptual understanding, procedures, or problem interpretation.Subsequently, data analysis was conducted qualitatively by referring to the stages of mathematical modeling. These stages include: (1) understanding the problem context and identifying relevant variables; (2) constructing a mathematical model appropriate to the given situation; (3) manipulating the model through computational processes or mathematical procedures; and (4) interpreting the results obtained and drawing conclusions consistent with the problem context.

The analysis was conducted by examining each student's answer based on these four stages, thereby identifying the profile of students' mathematical modeling abilities within each ability category. Consequently, the analysis results not only illustrate the students' success in obtaining answers but also provide a deeper understanding of the thinking processes and difficulties students encountered at each stage of mathematical modeling.

RESULTS AND DISCUSSION

Result

The results of the study indicate that students with high ability levels (ST) demonstrate relatively strong mathematical modeling skills in solving contextual problems involving plane figures. This is evidenced by the students' ability to understand real-world situations and identify key variables in the problems, such as the length, width, and perimeter of a rectangle, as shown below:

Figure 2. Answers from high-ability students

Based on the results of the responses, students with high ability levels (ST) have a strong understanding of real-world situations. In addition, these students also demonstrate a good initial understanding of problem situations. This is evident from their ability to identify important variables in geometry problems, namely the length, width, and perimeter of a rectangle. The influence of student ability levels, namely high, medium, and low, on the ability to solve contextual problems using mathematical modeling shows a significant difference, as concluded in the study (La Arua & Samron, 2022). This is consistent with research Suryani et al., (2023) and Nurhayati (2024) what distinguishes students' metacognitive levels is that high-ability students are classified at the "strategic use" level of metacognition, which explains that students demonstrate strong conceptual understanding and planning in problem solving. This is evidenced by their ability to clearly identify and describe problems. However, even high-ability students are not immune to mistakes. There is an error in terminology because the student wrote “square” when the flat shape referred to was a “rectangle.” Furthermore, the student made a visual representation error by writing the perimeter of the rectangle in the illustration of the long side, which indicates a conceptual misrepresentation. Errors in writing the type of flat shape and placing the perimeter are in line with the research Anugrah & Pujiastuti, (2020) which highlights common mistakes made by students in solving perimeter and area problems, often caused by confusion between basic geometric and procedural concepts. In addition, students are also less thorough in their final formulation because they write down two area conclusions. Although the students' answers are correct, deficiencies at this stage of presentation identify that, even though the students are classified as ST, the modeling process they carry out is not yet complete and perfect. This is a finding that should be highlighted, because high-ability (ST) students have a complete process when using mathematical modeling to solve situational problems, with correct answers and final results (Pandiangan & Zulkarnaen, 2021).

After writing down the variables, students know how to solve problems by writing down the questions in the problems. In the picture of the answers above, it can be seen that students are also able to perform mathematical modeling steps by (1) Creating Mathematical Models. Students are able to apply basic mathematical models. Students can convert questions in problems into mathematical language as written by students on the answer sheet. Where students make assumptions that x is length and y is width. This shows that students are able to build appropriate models to solve problems. (2) Performing calculations, in performing calculations, students first find the width. In the answer, the students have performed the calculation steps correctly. (3) Interpreting the results, students are able to provide conclusions even though there are errors because there are two conclusions. These mathematical modeling steps are in line with those stated by Febriani et al. (2024), which states that mathematical steps are understanding the problem, determining the mathematical model of the real problem, solving the mathematical problem in the mathematical model, and interpreting the mathematical results in real-life situations.

To find out the reasons for the errors in writing representations and types of flat shapes, the researcher interviewed the students.

P : Can you tell me what steps you took when working on this problem?
S : First, I read the question. Then I write down the information I know and what I need to ask.
P : Did you make an analogy or mathematical model from the question?
S : Yes, I made an analogy first, for example, length and width.
P : Why did you choose that mathematical model?
S : Because I think it fits the formula I learned.
P : After making the model, how did you calculate it?
S : I calculated step by step so that I wouldn't make a mistake. After getting the value, I checked the result again, especially the perimeter, to see if it was correct.
P : So you double-checked the calculation?
S : Yes, I recalculated it to make sure the result was correct.
P : Did you find it difficult to do this problem?
S : Actually, it wasn't too difficult, but I forgot to include the height of the parallelogram and mistakenly entered the width as the perimeter, so my initial result was incorrect.
P : In your opinion, what caused the error?
S : I was not careful enough and a bit rushed, so I missed something.

P : Other than that, did you find it difficult to write down the answers or mathematical symbols?
S : Sometimes I get confused about writing the correct notation.

The results of the interview analysis indicate that students possess strong foundational skills in mathematical problem-solving, particularly in understanding problems, formulating assumptions, and constructing accurate mathematical models. Their ability to perform calculations systematically and even verify perimeter results demonstrates a good grasp of procedures. However, there are some weaknesses related to precision and mathematical communication. The main errors that emerged were conceptual errors caused by oversights (regarding the height of a parallelogram) and errors in communication/notation when transforming mathematical results into representations.

Based on the results above, it can be concluded that high-ability students already possess strong skills in constructing mathematical models and applying them effectively to solve contextual problems. However, there were errors in the presentation stage and in the final results, where students wrote two conclusions and made errors in representation.

Next, an analysis of mathematical modeling skills was conducted among students with moderate ability (S2) to identify differences in characteristics compared to high-ability students. The students' work is presented in the following figure:

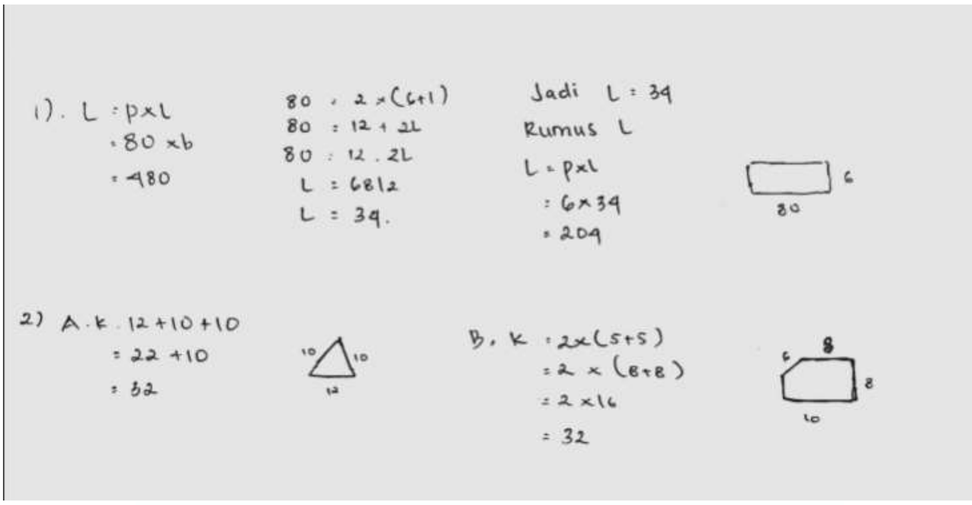

Figure 3. Answers from students with average abilities

The second group of students studied were those with average abilities. Students with average abilities showed significant inconsistency between conceptual potential and procedural implementation accuracy. This can be seen from the number of transformation errors and weaknesses in mathematical communication. Although students have a fairly good basic understanding, as evidenced by their ability to create mathematical models in the second question, they consistently face challenges in the early stages of problem solving. In question number 1, students did not write down the information but solved the problem even though the final answer was not correct. This indicates a barrier that stems from students' inability to conceptualize problems. This is reinforced by transformation errors such as misplacing the perimeter on the long side, placing the base and slant side measurements of the parallelogram in the illustration, which reflects students' inability to translate the information in the question into accurate models and symbols. This is in line with research Sari (2023) which states that transformation errors are often identified as the main obstacle to problem solving. Furthermore, students show a lack of discipline in writing down information about the question and do not include units at the end of their answers. This is confirmed by research Putri (2021) which confirms that students' failure to rewrite known and asked information is a weakness that marks failure in the early stages of understanding. This indicates a lack of metacognitive awareness in students to check the completeness of the steps. The metacognitive level of students with moderate abilities is classified as "Aware Use" metacognition, which explains that students are aware of the thinking process and strategies but need guidance in their application. Students are able to recognize calculations but cannot correct them, and students do not write down conclusions.

To find out the reasons for the errors and mistakes in writing representations, the researcher interviewed the students.

P : Try to explain how you understood the first question before you started working on it.
S : I read the question, then immediately remembered the formulas for the perimeter and area of flat shapes that I had learned.
P : Did you feel that you understood what was known and what was being asked in the question?
S : Actually, I knew the formula, but I was confused about determining the length.
P : Which part confused you?
S : I wasn't sure which length to use, so even though I knew the formula, I didn't know what value to plug in.
P : So, did that difficulty affect your ability to solve the problem?
S : Yes, because I couldn't determine the correct measurement, I couldn't continue the calculation to the end.
P : For the second question, how did you understand the question?
S : I understood the second problem better because the information was clearer, so I tried to calculate it right away.
P : Did you write down the known and unknown information before calculating?
S : No, I answered right away without writing it down.
P : Why didn't you write down the information?
S : Because I'm used to doing it right away without writing down the initial steps.
P : In the question about parallelograms, what did you understand about the properties of this flat shape?
S : I forgot the properties of parallelograms, so I thought it was like a trapezoid.
P : What impact did this mistake have on solving the problem?
S : I misplaced the height and slanted side measurements, so the calculations were incorrect..

The results of the interview analysis indicate that in the first question, students have poor basic mathematical problem-solving skills, particularly in understanding problems involving formulas and the ability to translate problems. The main weakness of students lies in the problem comprehension stage, where even though students know the formulas for perimeter and area, they experience confusion in determining the length from the available information, causing them to fail to solve the problem. In the second question, students showed improvement in understanding the information in the question, but they still did not write down the information in the question because of their habit of answering questions directly. This mistake continued when students solved the question on parallelograms, where students forgot the properties of parallelograms and confused them with trapezoids, causing students to be unable to place the height and slanted sides in the question. Based on the above results, it can be concluded that overall, although students have knowledge of formulas and problem-solving skills, they are hampered by variable analysis and mastery of essential concepts of flat shapes.

Next, an analysis of mathematical modeling skills was conducted among students with low proficiency (S3) to identify differences in characteristics compared to high-ability students. The students' work is presented in the following figure:

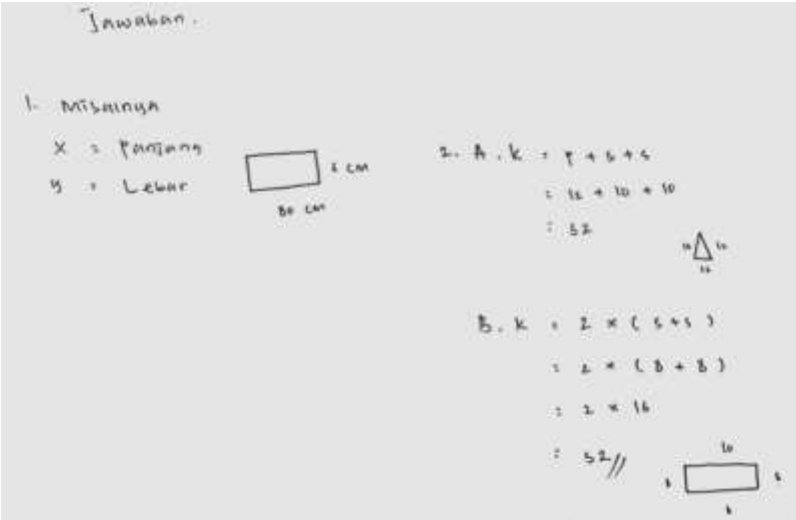

Figure 4. Answers from low-ability students

The third group of students studied were those with low abilities. Students with low abilities showed significant inconsistency between conceptual potential and procedural implementation accuracy. The most fundamental deficiency was that students did not write down the information obtained from the questions in all numbers, which hindered solution finding and verification. In line with the study Putri (2021) which confirms that students' failure to rewrite known and asked information is a weakness that marks failure in the early stages of understanding. In the first question, students failed to solve the problem due to misrepresentation, where students mistakenly placed the circumference measurement as the side length in the illustration. Conversely, in the second question, students demonstrated good procedural strength, being able to create mathematical models and solve them correctly, as well as create correct illustrations. However, there were notation errors where students did not write down the units and were inaccurate in placing the information obtained regarding the size of the base sides. In line with the opinion Ratnamutia & Pujiastuti, (2020) In his research, he states that the types of errors made by students with low abilities are errors in concepts, principles, skills, and facts.

To find out the reasons for the errors and mistakes in writing representations, the researcher interviewed the students:

P : Take a look at question number 1. You wrote down the formulas for circumference and area correctly, but why did you stop there?
S : Yes, sir, I'm confused. I know the formulas, but I don't know how to find the length.
P : What confuses you when you want to determine the value?
S : I don't know where to start when only the circumference is given.
P : Moving on to question number 2. You answered it correctly, but why are the 'Given'

and 'Asked' sections blank?
S : Eh... yes, sir. I actually understand the question, but I thought it wasn't necessary to write it down because the information is already in the question. So I just calculated it quickly.
P : Are you used to calculating like that?
S : Yes, I usually work it out in my scratch paper and then write the answer here.
P : Well, for the parallelogram question, there is something that is not quite right. Can you explain why you put this number on the slanted side as the height?
S : Isn't the height the vertical line on the side, sir?
P : Take a look at the shape of this figure. What shape is it in your opinion?
S : I think it's a trapezoid... eh, or a parallelogram? I often get confused because the shapes are similar, so I used the method I usually use for trapezoids for this parallelogram.
P : So you are confused about which is the height and which is the slanted side when the shape is slanted like this?
S : Yes, I thought the slanted side could also be the height.

Based on the results of the interviews, students were confused about question number 1 in determining the length of a rectangle. Although the students knew the formula for the perimeter and area of a rectangle, they were unable to determine the length, so they could not complete the question. This happened because the students were confused. In the second question, the students understood the question but did not write down the information in the question. This happened because the students were accustomed to not writing down the information in the question since it was already stated in the question and they answered it directly. The students did not fully understand parallelograms, so they did not correctly place the height and slanted sides in the question. This happened because the students confused parallelograms with trapezoids.

CONCLUSION

The results of the study indicate that junior high school students' mathematical modeling skills regarding plane figures are still suboptimal and show significant variation among participants. Of the three students who participated in the study, only one student (S1) fell into the moderate ability category, while the other two students (S2 and S3) fell into the low ability category. These variations were primarily evident in differences in their ability to understand problem contexts, construct mathematical models, perform mathematical manipulations, and interpret solutions in real-world contexts.

The student with moderate ability demonstrated fairly good procedural mastery but still made errors in mathematical communication and representational accuracy. Meanwhile, students with low ability face challenges in the early stages of modeling, ranging from difficulty understanding the problem, inaccuracies in recording information, to errors in representing the properties of two-dimensional shapes. These challenges reinforce previous research findings that weak mathematical literacy and limited conceptual understanding are the primary causes of low mathematical modeling ability.

Based on these findings, this study confirms that improving mathematical modeling skills requires learning interventions that are contextual, systematic, and focused on conceptual understanding. The use of interactive media, the provision of relevant contextual problems, and the implementation of real-world problem-based learning approaches such as Problem-Based

Learning (PBL), Contextual Teaching and Learning (CTL), and Realistic Mathematics Education (RME) can serve as effective instructional alternatives to enhance students' mathematical modeling skills.

Overall, this study implies that mathematical modeling skills are not only related to procedural mastery but also to the ability to understand context, represent information, and reinterpret mathematical solutions. Therefore, teachers need to design instruction that emphasizes the connection between mathematical concepts and real-world situations so that students can develop modeling competencies more comprehensively.

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