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Analysis of error in mathematical modeling problems: An exploratory study of middle school students

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Abstract: This study analyzes students' errors in solving mathematical modeling problems based on their mathematical ability levels through a quantitative, descriptive, and exploratory approach. It involves 72 eighth-grade students at a private school, SMP St. Benediktus. The instruments used are the Mathematical Competence Test (MCT) and the Mathematical Modeling Test (MMT). Both instruments were validated by three associate professors and one mathematics teacher, with validity confirmed by V Aiken's coefficient of 0.83, exceeding the threshold of 0.4. Students completed the MCT and MMT on separate days. Based on the results, students were classified as high (20), medium (19), and low ability (33). MMT responses were analyzed using Newman Error Analysis and the six modeling processes from the Blum and Leiß framework. The results show that 67 students made errors across various stages, mainly in validating (47.56%) and understanding (31.59%), simplifying (37.84%), and mathematizing (39.58%). High-ability students often made errors in interpreting (18%) and validating (25%) processes, medium-ability students in working mathematically (25%), and low-ability students in understanding (38.75%). These results suggest that error types are closely related to students' mathematical abilities. Further research should focus on aligning instruction with student abilities, supporting adaptive learning, and exploring targeted interventions to address specific errors in the modeling process.
Keywords: *Error analysis, Mathematical modeling ability, Modeling process.*

1. Introduction

Mathematical modeling plays a vital role in developing students' competence to solve real-world problem in mathematics education. With the rapid advancement of technology and science, modeling is increasingly recognized as a key competence for the future, not only fostering mathematical literacy but also enhancing society's ability to adapt to shifting conditions [1]. As such modeling serves a critical bridge between real-life scenarios and abstract mathematical representations, providing students with the opportunity to apply mathematical tools to problem encountered in daily life, community settings, and professional contexts [2].

In instructional practice, mathematical modeling supports the development of abstract thinking through contextual and applicable approaches [3]. This multifaceted process includes identifying the real-world problem, selecting relevant variables and parameters, mathematizing situations, and validating the resulting models [4]. However, each of these stages presents potential cognitive demands, especially as students must not only master mathematical concepts but also transfer them across representations and contextual boundaries [5, 6].

Students' ability to carry out the modeling process is influenced by their level of mathematical competence, which determines how effectively they can navigate each stage from understanding the

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problem to validating the solution [7, 8]. Prior studies have shown that modeling tasks often require a high degree of metacognition and situational understanding [9] and students commonly experience or reading comprehension skills [10, 11]. Building on this foundation, the present study aims to analyze the types and tendencies of student errors across each stage of modeling cycle, while also investigating how these errors vary by students' mathematical ability levels. Understanding these patterns is essential for designing instructional support that targets cognitive barriers at each stage of the modeling process.

2. Literature Review

2.1. Mathematical Modeling

Models in a problem are created after the problem is studied to represent the problem. Mathematical models are built through adjustment, determination and mathematization of the real situation of a problem [4]. In modeling, it is necessary to be precise in choosing things that are set aside and things that need to be included in the mathematical model. The important components of mathematics are mathematical modeling and its applications that can encourage students' competence in solving real problems in mathematics education [11, 12]. This activity requires not only mastery of mathematical concepts and procedures, but also skills in critical thinking, choosing appropriate representations, and evaluating solutions reflectively [13, 14].

Mathematical modeling is defined as the process of translating real-world problems into mathematical terms and developing appropriate mathematical strategies to solve the problem [5, 15]. As an essential component of mathematics education, modeling allows students to apply their mathematical knowledge to realistic and complex contexts, whether from daily life, social issues, or the workplace [2, 16].

This process demands not only conceptual and procedural knowledge, but also metacognitive and contextual awareness, especially when transitioning between real contexts and mathematical abstraction [6, 17]. Study has highlighted that each stage in modeling process presents unique cognitive challenges, which can result in a variety of student errors depending on their level of mathematical competence [7, 8]. Unlike traditional problem solving, modeling requires students to navigate a cycle of steps involving understanding the situation, simplifying the problem, mathematizing, working mathematically, interpreting results, and validating the solution, the ability to mathematize real situations, in particular, is noted as one of the most demanding and error-prone stages [14]. Therefore, understanding the type and frequency errors across stages and among students of differing ability levels is critical for designing effective interventions and instructional scaffolds.

2.2. Modelling Competence and Modeling Cycle

Modeling ability includes aspects of mathematical knowledge and skills, as well as the willingness to carry out the modeling process appropriately and goal-oriented and the willingness to apply it [18]. This process also requires the integration of a number of competencies such as reading the context of the problem, developing a solution strategy, building a mathematical model, and interpreting and validating the results [15]. The phases of the mathematical modeling cycle process are understanding the real-world situation; simplifying/idealizing the real-world situation to obtain a model of the real world; mathematizing the real-world model, which is designing a plan to solve the problem by translating the real-world model into a mathematical model; applying mathematical routines and processes; interpreting the mathematical solution by verifying that the problem corresponds to reality; validating the results of the previous stage by checking the adequacy of the results and if necessary repeating certain stages or even the entire modeling process; and presenting the final results of the modeling cycle [19].

The model proposed by Blum and Leiß [14] offers a structured representation of modeling process commonly referred to as the modeling cycle which begin with contextual understanding and culminates in validating mathematical results. This framework provides a lens through which student responses can be categorized and analyzed, especially when identifying where errors or misconceptions occur. The descriptive model of a modeling process, as seen in Figure 1, can be used as a basis for characterizing students' processes in modelling.

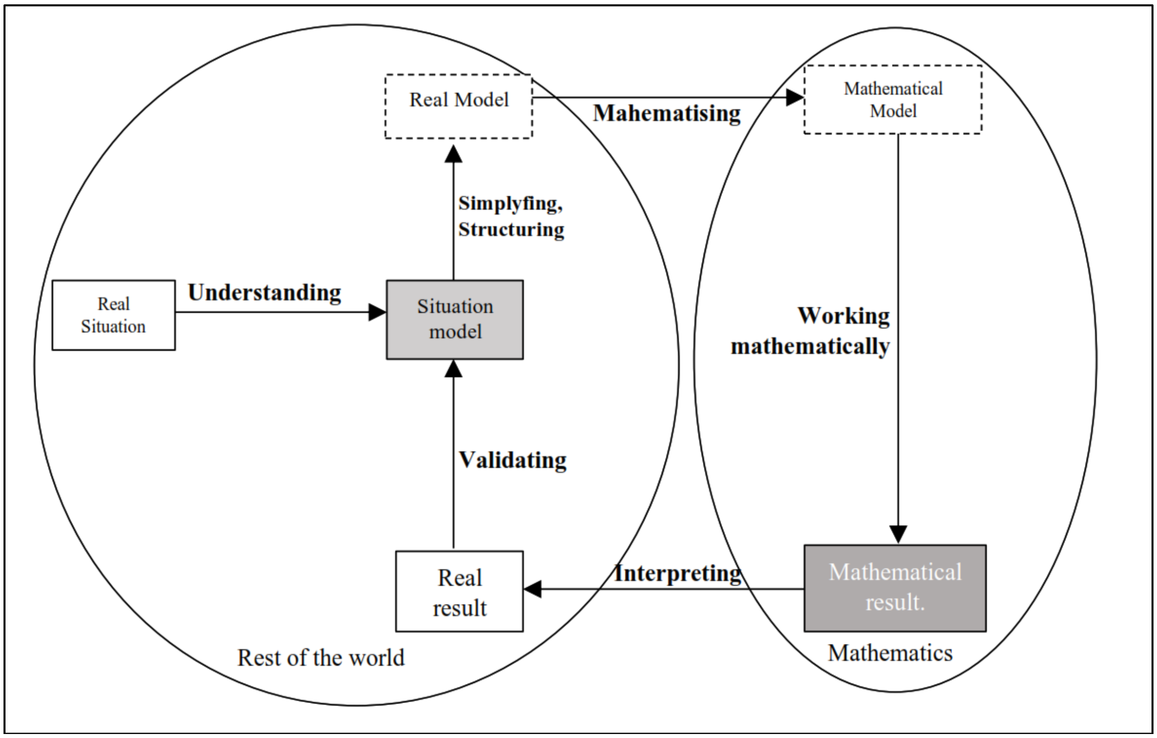


Figure 1.
Modeling cycle followed Blum & Leiß

The modeling process begins with the real situation. By simplifying, structuring, and idealizing this problem, a real model can be identified. The mathematizing of the real model leads to a mathematical model. Additionally, mathematical solutions can be found by working mathematically. This solution has to be interpreted first and then validated. If the solution or the chosen process does not prove to be appropriate to reality, particular steps or maybe even the entire modeling process needs to be worked through again.

2.3. Newman Error Analysis (NEA) and its Relevance to Modeling

To further diagnose students' error, this study also incorporates NEA as a complementary tool. NEA categorizes five key types of student errors including reading, comprehension, transformation, process skills, and encoding when solving mathematical world problems [20]. Previous studies have found strong parallels between Newman's framework and the stages of the modeling cycle Wijaya, et al. [21] making it valuable method to map observed errors during the modeling process.

The integration of NEA with the modeling cycle enables a nuanced analysis of students' errors, especially when combined with data such as written responses and interviews. Table 1 illustrates how each error category aligns with specific stages in modeling process, providing a clear structure for evaluating student performance and identifying common patterns of errors [21].

Table 1.
Newman's error categories and modeling process following Blum and Leiß.

Newman's error categories	Modeling process	Description
Comprehension: errors in understanding the meaning of the problem.	Understanding problems by establishing situational models.	▪ Errors were made by students who could not understand the test. ▪ A student misunderstood a keyword, which was usually a mathematical term.
	Establishing real models by simplifying situational models.	▪ Errors in making assumptions about the problem and simplifying the situation. ▪ Errors in recognizing the quantities that affect the situation. ▪ Errors in naming and identifying key variables.
Transformation: errors in transforming a word problem into an appropriate mathematical problem.	Constructing a mathematical model by mathematizing real model.	Errors in creating a mathematical model.
Process skill: errors in performing mathematical procedures.	Working mathematically to get mathematical solutions.	Errors in applying mathematical knowledge to solve problems, such as calculation errors.
Encoding: errors in representing the mathematical solution into an acceptable written form.	Interpreting mathematical solutions in relation to the original problem situations.	Errors in connecting the results of calculations carried out with the context of the problem.
	Validating the interpreted mathematical solution by checking if it is appropriate and reasonable for its purpose.	▪ Errors in critically examining and reflecting on the found solution. ▪ Errors in evaluating some parts of the model or in repeating the modeling process.

3. Methodology

This study employs a quantitative descriptive and exploratory approach to examine errors in the mathematical modeling process and explore their relationship with students' mathematical ability levels. This study involves 72 eighth-grade students at a Private School namely SMP St. Benediktus, two classes VIII^{A} (24 girls and 13 boys) and VIII^{B} (20 girls and 15 boys) are randomly chosen form three classes.

This study utilized two instruments are Math competence Test (MCT), comprising 5 essay questions covering topics such as numbers, comparison, arithmetic, and geometry; and Mathematical Modeling Test (MMT), which included 4 essay questions on social arithmetic, numbers, and geometry. Instrument validation was conducted by three associate professors and one mathematics teacher with a master's degree, using a 4-point Likert scale, with an Aiken index threshold of $V \geq 0.4$. The validity value exceeded 0.83, indicating strong content validity.

Data collection occurred over two separate days, where students completed the MCT and MMT within 90-minute sessions, under direct observation by researchers. Students' mathematical ability levels were categorized as high ability $(\text{skor} \geq 80)$, medium ability $(65 \leq \text{skor} < 80)$, and low ability $(\text{skor} < 65)$ based on results MCT. Based on MMT responses students were scored as 1 (correct) and 0 (incorrect), and errors analyzing using the NEA framework integrated with six modelling processes as defined by Blum and Leiß and explore analyzing based on mathematical ability levels.

4. Results

The result of the analysis was conducted on the Mathematical Competency Test (MCT) and Mathematical Modeling Test (MMT) scores is as follows:

Table 2.
Score MCT and MMT.

Statistical Results	MCT	MMT
N	72	72
Mean	61.77	66
Std. Deviation	19.40	19.68
Highest student score	100	100
Lowest student score	60	30
High level ($\text{Score} \geq 80$)	20	22
Medium level ($65 \leq \text{Score} < 80$)	19	15
Low level ($\text{Score} < 65$)	33	35

Based on Table 2, these statistics provide insights into the overall performance distribution and variability among students in both assessments. The MMT mean score (66.60) is slightly higher than the MCT mean score (61.77), indicating differences in students' competencies across the two domains. The fairly high variation in scores (as indicated by the standard deviation) suggests a significant difference in frequency or types of errors between more proficient students and those who tend to make more errors. More than 50% of students are in the medium and low mathematical modeling ability level, this indicates that many students make errors in solving mathematical modeling problems.

The analysis of students' responses reveals that 67 students made errors in the mathematical modeling process, while 5 students managed to complete the entire mathematical modeling process, see Table 3.

Table 3.
Frequencies students made errors in modelling process.

Items	Understanding	Simplifying	Mathematizing	Working within mathematics	Interpreting	Validating
1	14	22	24	25	25	25
2	28	33	34	38	40	40
3	19	20	21	24	24	27
4	30	34	35	39	42	45

Based on Table 3, There is an increasing trend of errors from item 1 to item 4 at all stages. This shows that the more complex the problem given, the more likely students are to make errors in all aspects of the modeling process. The highest errors are consistently found at the validating (the highest at item 4 = 45 errors) and interpreting (item 4 = 42 errors) process. This reflects students are not yet accustomed to reflecting or re-checking their modeling results against the context of the problem. Although still significant, the understanding process shows a lower frequency of errors relative to other. This shows that understanding the initial context of the problem is easier for most students to achieve than the mathematization and evaluation processes of the model. The mathematization process (changing real problems into mathematical representations) and working within mathematics (solving models) also show a high frequency of errors, indicating that students face not only conceptual but also procedural challenges in solving mathematical problems.

These results indicate that students' mathematical modeling abilities are multilevel and interrelated. Students who do not understand the problem well will have errors in simplifying, modeling, solving, and interpreting and validating solutions. Therefore, learning needs to focus more attention on the stages of interpretation and validation, develop students' reflective and critical thinking skills, and increase problem-solving exercises that require more than just procedural skills.
The percentages of errors in each mathematical modeling process are illustrated in Figure 2.

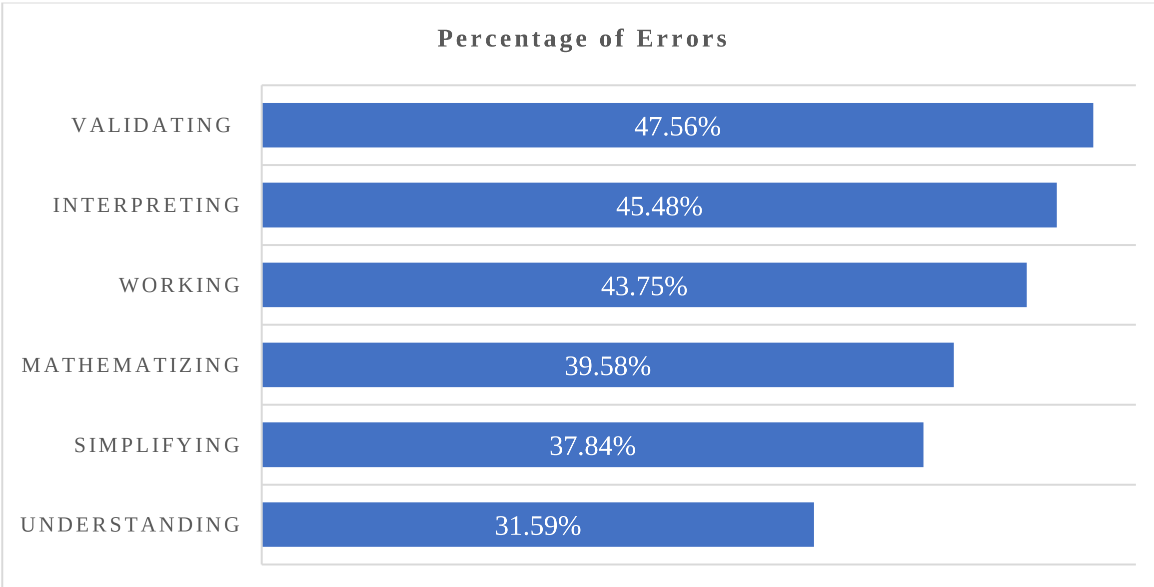


Figure 2.
Percentage of errors in the modeling process.

From the diagram in Figure 2, validating (47.56%) showed the highest error rate. This indicates that many students have errors in checking their solutions against the context of the problem. Validating requires a deep understanding of the relationship between mathematical results and real situations, which is often overlooked. Interpreting (45.48%) also showed high errors. This reflects the challenge in presenting calculation results with contextual meaning. Students may not be able to solve the model, but fail to interpret the results meaningfully. Working mathematically (43.75%) refers to the process of mathematical manipulation. Errors at this stage can come from incorrect algebraic procedures, calculation errors, or inappropriate application formulations.

Mathematizing (39.58%) shows that students still have errors in converting real-world situations into mathematical representations. This can be caused by misconceptions or lack of experience in building models. Simplifying (37.84%) indicates that the process of harmonizing information from context to a form that can be modeled is also a challenge. Students may be unable to identify important information and distinguish it from irrelevant information. Understanding (31.59%) has the lowest percentage of errors, but is still significant. This shows that although most students can understand the context of the problem, there are still some who have errors in understanding the initial information as a whole.

Based on the distribution of error percentages, it can be seen that students experience increasing errors along with the complexity of the mathematical modeling process. The lowest errors occurred at the understanding process (31.59%), indicating that most students were able to understand the problem situation initially. However, as the process progressed, errors increased gradually, reflecting conceptual and procedural difficulties. The final process such as interpreting (45.48%) and validating (47.56%) had the highest error rates, indicating students' weak ability to connect mathematical results with real-world contexts and to verify the solutions obtained. This indicates that critical reflection on results and contextual understanding are still major challenges in the modeling process.

The results analysis errors in the mathematical modeling process made by students in the high, medium, and low mathematical ability levels are presented.

Table 4.
Student errors based on the level of mathematical ability.

Groups	Understanding	Simplifying	Mathematizing	Working mathematically	Interpreting	Validating
High	0%	0%	0%	2.08%	18%	25%
Medium	5%	12.5%	15%	25%	35%	37.5%
Low	38.75%	48.75%	52.5%	58.75%	62.5%	66.25%

Based on Table 4, show the lowest error in the understanding process indicates that students are generally able to understand the initial context. Errors in the validating process are consistent with the highest number of errors, indicating weak student metacognition in evaluating model suitability.

In understanding and simplifying process, there were no errors (0%) made by high level students indicating are able to understanding of the problem context and simplification of information. The emergence of initial errors (5% and 12.5%) in medium level students indicates that some students are still not consistently able to understand the problem completely. The substantial proportion of errors (38.75% and 48.75%) in low level students indicates that errors have arisen since the initial interpretation stage of the question.

In mathematizing and working mathematically process, high level ability students still showed good performance, with very low errors (0% and 2.08%). There was an increase in moderate errors (15% and 25%) indicating challenges in transforming real-world situations into formal representations. Errors continued to increase (52.5% and 58.75%) in low level ability students, indicating weaknesses in abstraction and mathematization process.

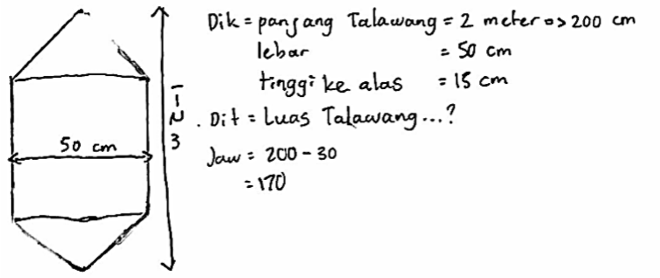
In interpreting-validating process, errors began to dominate (18% and 25%) in high level students, indicating that even high ability students still need guidance to improve the accuracy of interpretation and model evaluation. The highest errors (35% − 66.25%) in medium and low-level students, indicating weak reflective and metacognitive skills in interpreting results and assessing model accuracy.

The pattern of errors is progressive according to the level of student ability, where students with lower abilities tend to make errors at the initial stage, such as understanding the context of the problem (understanding) and the relationship of information (simplifying). This indicates limitations in interpreting important elements of the real-world situation that are the opening for the subsequent modeling process.

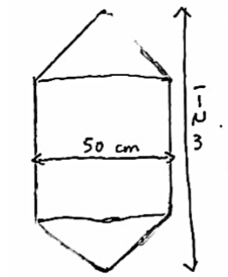
In contrast, students with higher abilities tend to pass the initial stage well, but still make errors at the advanced stages such as mathematization, solving the model (working mathematically), interpretation, and validation. This shows that even though they have better initial understanding capacity, difficulties still arise when they have to transform the context into a mathematical model and ensure that the resulting solution is contextually relevant and accurate.

The results show that the mathematical modeling process requires not only procedural competence, but also deep reflective and contextual abilities. Therefore, an adaptive pedagogical approach-one that focuses not only on technical skills, but also on strengthening conceptual understanding and higher-order thinking skills is needed to support students at all ability levels.

In this section, an example of errors made by students in the mathematical modeling process.
Example error made by student with low level mathematical abilities in process understanding and simplifying, see Figure 3.



Translate authors:



Given: Length Talawang
= 2meter = 200 cm
Width = 50 cm
Height = 15 cm
Wanted = area of Talawang
Answer = 200 − 300
= 170

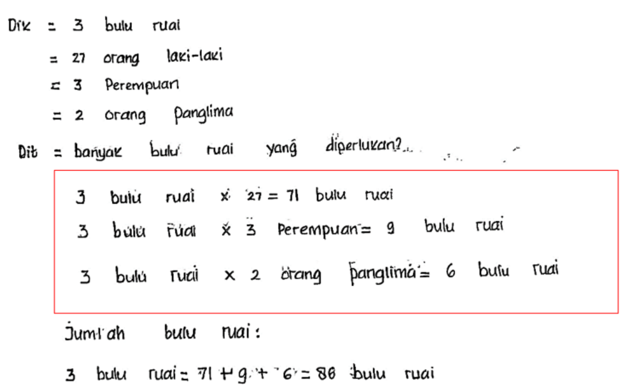
Figure 3.
Examples errors in the understanding and simplifying process.

The interview was conducted based on students' answers to identify assumptions and errors. Below is an excerpt.

R:	Actually, the area of a shape is found by multiplying its length by its width, not by subtracting. Have you ever used the area formula before?
S:	Hmm… I know there is an area formula, but I have trouble remembering it
R:	The area of Talawang is calculated by multiplying its length by its width. If the length is 200 cm and the width is 50 cm, how do you think the calculation should be done?
S:	So, I should multiply 200 × 50?

The student's confusion arises not from misinterpretation of the problem context, but from gaps in recalling basic mathematical knowledge, specifically the formula for area. Although the student eventually arrived at the correct operation with guidance, the initial inclination to subtract suggests a misapplication of prior knowledge. The dialogue also highlights a passive engagement with mathematical rules the student indicates awareness of the formula's existence but lacks confidence and fluency in applying it. This points to challenges in simplifying the situation into a solvable mathematical structure, where foundational misunderstandings create barriers before any formal modeling takes place. This case emphasizes that errors in early modeling stages often stem from low confidence in fundamental skills. Before advancing into more complex phases, first reinforce basic conceptual fluency to ensure that simplification is grounded in correct mathematical reasoning.

Example error made by student with medium level mathematical abilities in process mathematizing, see Figure 4.



Translate authors:
Given= 3 Ruai feathers
= 27 Men
=3 Women
= 2 Commanders
Wanted= how much nedded Ruai feathers?
3 Ruai feathers × 27 = 71 Ruai feathers
3 Ruai feathers × 3 women = 9 Ruai feathers
3 Ruai feathers × 2 comanders
= 6 Ruai feathers
Number of Ruai feathers:
3 Ruai feathers = 71 + 9 + 6
= 86 Ruai feathers

Figure 4.
Example of errors in the mathematizing process.
The interview was conducted based on students' answers to identify assumptions and errors. Below is an excerpt.

R:	Are you assumed each group required a proportional number of feathers, but did the problem state this explicitly?
S:	I assumed that the same factor should apply to men, women, and commanders.
R:	That's a common error. In your final step, you wrote 3 Ruai feathers = 71 + 9 + 6 = 86 Ruai feathers. What does the left-hand side of the equation represent?
S:	I was trying to show the total number of feathers.
R:	The way it is written, 3 Ruai feathers = 86 Ruai feathers, suggests that 3 feathers are equal to 86, which is incorrect.

The student demonstrates a misunderstanding of representational equivalence. By writing 3 Ruai feathers = 86 Ruai feathers, they not only misrepresented a relationship but also introduced an illogical equation suggesting direct equality between unequal quantities. This indicates a failure to distinguish between symbolic representation and real-world meaning, a key element in mathematical modeling literacy. Further, the assumption that a uniform proportion could be applied to all groups (men, women, commanders) without justification from the problem context reflects a premature generalization. This example highlights that error during the mathematizing process often stem from inappropriate assumptions and misuse of mathematical language or symbols. The misrepresentation of relationships and failure to verify the logic behind model construction underscore the need for instruction that emphasizes critical thinking, contextual sensitivity, and representational accuracy in modeling activities.

Example error made by student with medium level mathematical abilities in process working mathematically, see Figure 5.

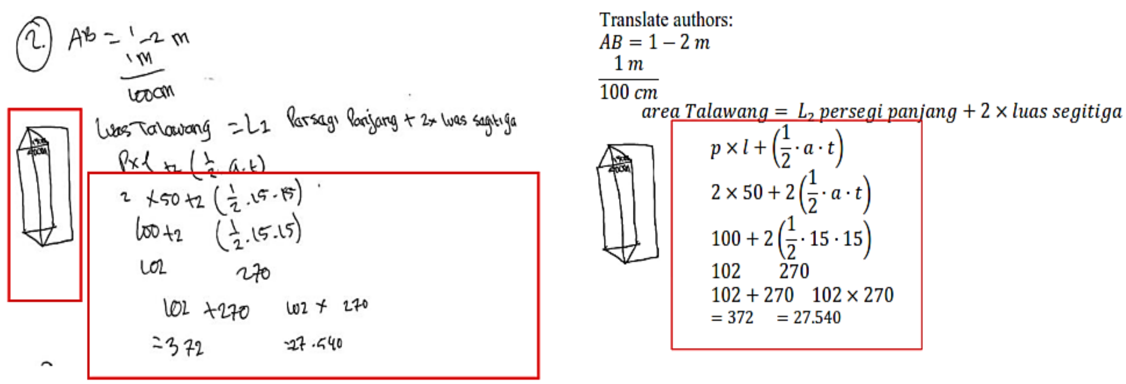


Figure 5.
Example of errors in the working mathematically process.

The interview was conducted based on students' answers to identify assumptions and errors. Below is an excerpt.

R	: That is the correct approach. However, let's review your calculations. In one of your steps, you wrote "102 × 270 = 27.540." Do you think this result makes sense?
S	: Hmm… It should be correct because I added the areas and multiplied them.
R	: Actually, there is an error in the mathematical operation at this stage. The total area should be calculated by addition, not multiplication.
S	: Oh, I see! I should have just added the values instead of multiplying them.

The student's error lies not in the approach, but in executing the correct mathematical operation. While they understood that area values needed to be combined, they mistakenly applied multiplication instead of addition demonstrating a misalignment between procedural execution and conceptual understanding. This suggests that while the student may possess surface-level familiarity with problem requirements, their decision-making during the calculation phase is mechanical rather than reflective.

The fact that the student misunderstood the purpose of multiplication versus addition in context also highlights weaknesses in interpreting quantitative relationships between mathematical entities. This example illustrates that errors during the working mathematically phases are not always due to conceptual misunderstanding, but may stem from flawed operational decisions. Instructional emphasis should therefore include not only the mastery of concepts and procedures, but also guided reflection on the logic behind chosen operations.

Example error made by student with high level mathematical abilities in process interpreting and validating, see Figure 6.

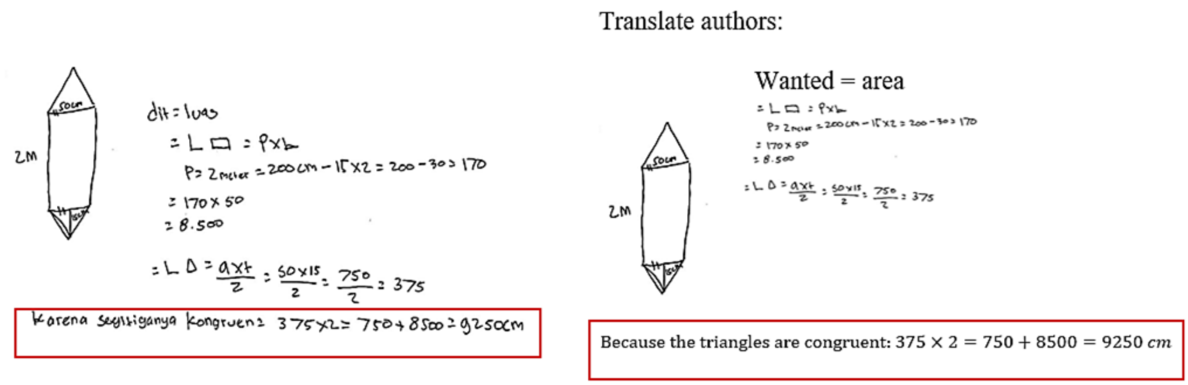


Figure 6.
Example of errors in the interpreting and validating process.

The interview was conducted based on students' answers to identify assumptions and errors. Below is an excerpt.

R:	Alright, based on what you wrote, do you think your answer is correct?
S:	Hmm… It should be correct because I multiplied the length and width.
R:	Actually, there is an error in the unit notation. When calculating area, the unit should not be cm, but cm^2, because area represents two dimensions, not one dimension like length or width.
S:	I wrote **cm** without realizing that it should have been cm^2**.**

This interview illustrates a subtle yet impactful error that reflects a student's incomplete understanding of mathematical conventions specifically unit usage when interpreting and validating a solution. The student correctly performed the procedure (multiplying length by width), but failed to recognize the dimensional implications of their result, indicating that procedural fluency is not always accompanied by conceptual awareness. This aligns with prior results suggesting that the validation process poses significant cognitive demands, particularly in transitioning from computation to interpretation.

This instance reinforces the errors in the interpreting and validating phases are not merely technical, but point to deeper issues in students' conceptual understanding and metacognitive monitoring. It highlights the importance of fostering reflective thinking and dimensional reasoning in mathematical modeling instruction.

5. Discussion

The results reveal the students exhibit significant and varied errors across all stages of mathematical modeling processes. These errors are closely tied to their mathematical proficiency, with low and medium ability students experiencing errors from the earliest phases such as understanding and simplifying, while even high ability students demonstrate challenges at more advanced stages like interpreting and validating.

Errors often occurred simultaneously or in succession, reflecting not only conceptual misunderstanding but also lapses in procedural fluency and metacognitive oversight. In the initial understanding phase, many students particularly those with lower ability struggles to grasp the context or intent of the task. This aligns with prior research suggesting that students often attempt to solve problems without thoroughly reading or understanding the context [10, 11]. One contributing factor may be the unfamiliar structure of modeling problem compared to conventional classroom exercises.

In the simplifying and mathematizing process, errors arose when students failed to filter essential information or made incorrect assumptions, often applying proportional reasoning without contextual justification. This consistent with results who noted that simplification is particularly difficult when student lack real-world experience related to the problem situation [8, 22]. The transition from real-world context to a mathematical model proved especially challenging for students with weaker conceptual foundations [9, 23]. The working mathematically process presented frequent errors, especially among students with medium mathematical ability. Common errors included incorrect operations such as unjustified multiplication or flawed addition, suggesting a lack of procedural fluency and number sense. In the interpreting and validating process, even high-ability students made notable errors. While they were often successful in producing a correct mathematical solution, they rarely questioned or verified the relevance of their answer within the context of the problem [11]. This highlights a weakness in metacognitive reflection and a tendency to treat validation as a superficial check rather than critical evaluation step [24, 25].

These results multifaceted nature of mathematical modeling competence, involves a constellation of interrelated sub-competencies that must be developed holistically throughout the modeling process [26]. The persistence of errors across all stages particularly in simplifying, mathematizing, and validating suggests that students may lack not only procedural fluency but also the broader competencies necessary to navigate real-world contexts mathematically. Moreover, the affective and metacognitive dimensions of modeling appear to play a critical role in shaping students' engagement and perseverance [27]. Their study emphasizes that learners' beliefs and dispositions significantly influence how they approach and sustain modeling test. These challenges further resonate that modeling tasks present a dual challenge: grappling with mathematical demands while simultaneously navigating the purpose and intent of the activity [28]. This tension may contribute to persistent errors, particularly when students interpret modeling solely as application rather than exploration. Modeling not just as the application of existing knowledge, but as a generative process through which mathematical ideas are actively constructed and refined [29].

6. Conclusion

The study shows that errors in mathematical modeling arise across multiple stages: understanding, simplifying, working mathematically, interpreting, and validating: due to difficulties in conceptual comprehension, procedural fluency, and translating real-world problems into mathematical forms. Misinterpretations, incorrect assumptions, computational errors, and gaps in logical reasoning further contribute to these errors. Deficiencies in validation indicate a lack of reflection and critical evaluation, impacting the accuracy of students' models.

The study confirms that errors in students' mathematical modeling processes occur at multiple stages, with distinct patterns based on mathematical ability levels. Moreover, the analysis results obtained 67 students who made errors. 67 students made errors, including 39 boys and 28 girls. Errors in understanding (31.59%), simplifying (37.84%), mathematizing (39.58%), with the most common errors were in working mathematically (43.75%), interpreting (45.48%), and validating (47.56%). Errors in understanding were most frequent among low-ability students, suggesting difficulties in grasping problem contexts. Medium-ability students struggled most in working mathematically, indicating challenges in applying formulas and performing calculations. High-ability students showed more errors in interpreting and validating, revealing errors in critically evaluating solutions.

Further research can be developing learning approaches or interventions that are tailored to the level of student ability. Low-ability students need support in understanding the context of the problem, for example through the use of scaffolding, visualization, and simple language. Medium-ability students need to be strengthened in aspects of procedural skills, such as practicing concept mastery and applying formulas. High-ability students should be facilitated with reflective, evaluative, and open activities towards multiple representations to deepen their understanding of the model contextually. There needs to be scaffolding action at the interpreting and validating process because they are the highest errors made by students at these two final stages, it is important to include activities such as group discussions, self-assessment, and peer review to foster students' critical thinking and self-reflection skills.

Institutional Review Board Statement:

This study was reviewed and approved by the Institutional Review Board of Universitas Negeri Surabaya, Indonesia, under protocol number (letter number: B/23583/UN38.3/LT.02.02/2023). All procedures followed the ethical standards of the institution. Informed consent was obtained from all participants prior to data collection.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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References

[1] G. Kaiser, "Modelling and modelling competencies in school. In C. Haines, P. Galbraith, W. Blum, & S. Khan (Eds.), Mathematical Modelling (ICTMA 12): Education, Engineering and Economics," in *Proceedings from the twelfth International Conference on the Teaching of Mathematical Modelling and Applications, 110–119.*, 2007.

[2] J. M. Suh and P. Seshaiyer, *Modeling mathematical ideas, developing strategic competence in elementary and middle school*. Lanham, MD: Rowman & Littlefield, 2017.

[3] D. Milinković and M. Ćurčić, "Mathematical modeling of natural and social context at preschool level of education [Matematičko modeliranje prirodnog i društvenog konteksta u predškolsko doba]," *Croatian Journal of Education*, vol. 20, pp. 157-174, 2018. https://doi.org/10.15516/cje.v20i0.3036

[4] G. A. Stillman, "Applications and modelling research in secondary classrooms: What have we learnt?," in *Selected regular lectures from the 12th International Congress on Mathematical Education*, 2015: Springer, pp. 791-805.

[5] W. Blum and D. Leiss, "How do students and teachers deal with modelling problems? In C. Haines, P. Galbraith, W. Blum, & S. Khan (Eds.), Mathematical modelling (ICTMA 12): Education, engineering and economics," in *Proceedings from the Twelfth International Conference on the Teaching of Mathematical Modelling and Applications*, 222–231, 2007.

[6] G. Greefrath and K. Vorhölter, *Teaching and learning mathematical modelling: Approaches and developments from German speaking countries*. Cham, Switzerland: Springer, 2016.

[7] H. M. Doerr and L. D. English, "A modeling perspective on students' mathematical reasoning about data," *Journal for Research in Mathematics Education*, vol. 34, no. 2, pp. 110-136, 2003. https://doi.org/10.2307/30034902

[8] K. Maaß, "What are modelling competencies?," *ZDM*, vol. 38, pp. 113-142, 2006.

[9] P. Galbraith and G. Stillman, "A framework for identifying student blockages during transitions in the modelling process," *ZDM*, vol. 38, pp. 143-162, 2006.

[10] J. Plath and D. Leiss, "The impact of linguistic complexity on the solution of mathematical modelling tasks," *Zdm*, vol. 50, pp. 159-171, 2018.

[11] W. Blum, "Quality teaching of mathematical modelling: What do we know, what can we do? In S. J. Cho (Ed.)," in *The Proceedings of the 12th International Congress on Mathematical Education, 73–96*, 2015.

[12] M. Cevikbas, G. Kaiser, and S. Schukajlow, "A systematic literature review of the current discussion on mathematical modelling competencies: State-of-the-art developments in conceptualizing, measuring, and fostering," *Educational Studies in Mathematics*, vol. 109, no. 2, pp. 205-236, 2022. https://doi.org/10.1007/s10649-021-10104-6

[13] J. C. Barbosa, "Mathematical modelling in classroom: A socio-critical and discursive perspective," *Zdm*, vol. 38, pp. 293-301, 2006.

[14] W. Blum and D. Leiß, *Mathematical modelling (ICTMA 12): Education, engineering and economics. How do students and teachers deal with mathematical modelling problems? The example Sugarloaf and the DISUM project*. Amsterdam, The Netherlands: Elsevier, 2007.

[15] G. Kaiser and B. Sriraman, "A global survey of international perspectives on modelling in mathematics education," *Zdm*, vol. 38, pp. 302-310, 2006.

[16] C. Hankeln, C. Adamek, and G. Greefrath, *Assessing sub-competencies of mathematical modelling—development of a new test instrument. In G. Stillman & J. P. Brown (Eds.), Lines of inquiry in mathematical modelling research in education*. Cham: Springer, 2019.

[17] R. Lesh and J. S. Zawojewski, *Problem solving and modeling. In F. K. Lester Jr. (Ed.), Second handbook of research on mathematics teaching and learning*. Charlotte, NC: Information Age Publishing, 2007.

[18] K. Maaß, "Barriers and opportunities for the integration of modelling in mathematics classes: Results of an empirical study," *Teaching Mathematics and Its Applications: International Journal of the IMA*, vol. 24, no. 2-3, pp. 61-74, 2005.

[19] Z. Kohen and D. Orenstein, "Mathematical modeling of tech-related real-world problems for secondary school-level mathematics," *Educational Studies in Mathematics*, vol. 107, no. 1, pp. 71-91, 2021.

[20] M. A. Newman, "An analysis of sixth-grade pupil's error on written mathematical tasks," *Victorian Institute for Educational Research Bulletin*, vol. 39, pp. 31-43, 1977.

[21] A. Wijaya, M. van den Heuvel-Panhuizen, M. Doorman, and A. Robitzsch, "Difficulties in solving context-based PISA mathematics tasks: An analysis of students' errors," *The Mathematics Enthusiast*, vol. 11, no. 3, pp. 555-584, 2014.

[22] W. Blum, *Can modelling be taught and learnt? Some answers from empirical research. In G. Kaiser, W. Blum, R. Borromeo Ferri, & G. Stillman (Eds.), Trends in teaching and learning of mathematical modelling*. Dordrecht: Springer, 2011.

[23] S. Schaap, P. Vos, and M. Goedhart, *Students overcoming blockages while building a mathematical model: Exploring a framework. In G. Kaiser, W. Blum, R. Borromeo Ferri, & G. Stillman (Eds.), Trends in teaching and learning of mathematical modelling*. Dordrecht: Springer, 2011.

[24] R. B. Ferri, "Theoretical and empirical differentiations of phases in the modelling process," *ZDM*, vol. 38, pp. 86-95, 2006.

[25] W. Blum and R. Borromeo Ferri, "Mathematical modelling: Can it be taught and learnt," *Journal of mathematical modelling and application*, vol. 1, no. 1, pp. 45-58, 2009.

[26] M. Blomhøj and T. H. Jensen, "Developing mathematical modelling competence: Conceptual clarification and educational planning," *Teaching Mathematics and its Applications: An International Journal of the IMA*, vol. 22, no. 3, pp. 123-139, 2003. https://doi.org/10.1093/teamat/22.3.123

[27] P. Biccard and D. Wessels, "Development of affective modelling competencies in primary school learners," *Pythagoras*, vol. 32, no. 1, pp. 1-9, 2011. https://doi.org/10.4102/pythagoras.v32i1.20

[28] G. A. Stillman, J. P. Brown, and P. Galbraith, *Challenges in modelling challenges: Intents and purposes. In G. Stillman, G. Kaiser, W. Blum, & J. P. Brown (Eds.), Teaching mathematical modelling: connecting to research and practice*. Dordrecht: Springer Netherlands, 2013.

[29] R. Lesh and B. Caylor, "Introduction to the special issue: Modeling as application versus modeling as a way to create mathematics," *International Journal of Computers for Mathematical Learning*, vol. 12, pp. 173-194, 2007.