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Theme:

**"Fostering Mathematical Thinking for Sustainable Development Goal:  
Empowering Minds, Transforming Futures"**

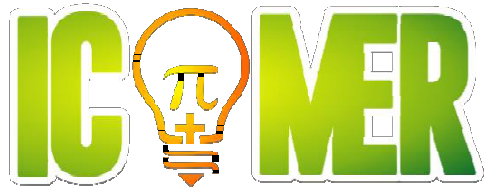
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# Proceedings Book

## International Conference on Mathematics and Learning Research (ICOMER)

Fostering Mathematical Thinking for Sustainable Development  
Goals: Empowering Minds, Transforming Futures

**Editors:**

Mohamad Waluyo, Naufal Ishartono

Surakarta, November 11<sup>st</sup> 2024

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**Proceedings Book of**  
**International Conference on Mathematics and Learning Research (ICOMER) 2024**  
*“Fostering Mathematical Thinking for Sustainable Development Goals: Empowering Minds,  
Transforming Futures”*

Surakarta, November 11<sup>st</sup> 2024

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# PREFACE

Assalamu'alaikum Warahmatullahi Wabarakatuh

Alhamdulillah, we give thanks to Allah SWT for His grace, blessings, and guidance, enabling us to successfully organize the 2024 International Conference on Mathematics and Learning Research (ICOMER), hosted by the Mathematics Education Department of Universitas Muhammadiyah Surakarta, Indonesia.

The theme for this year is "**Fostering Mathematical Thinking for Sustainable Development Goals: Empowering Minds, Transforming Futures.**" The conference aims to provide a dynamic platform for researchers, educators, and practitioners in the field of mathematics and mathematics education to exchange ideas, share their latest research, and explore innovative approaches to teaching and learning. Through this theme, we emphasize the vital role of mathematical thinking in addressing global issues and contributing to the Sustainable Development Goals (SDGs), aligning our efforts with the global vision for a sustainable and equitable future.

The ICOMER 2024 proceedings include a diverse range of papers presented at the conference, showcasing theoretical studies, empirical research, and practical applications in mathematics education. The collection reflects our commitment to enhancing mathematical literacy, problem-solving skills, and critical thinking to better equip learners for the challenges of the 21st century.

While we strive to ensure the quality of these proceedings, we recognize that there may still be areas for improvement. We warmly invite feedback, suggestions, and constructive criticism to help us enhance our future publications.

We hope this compilation serves as a valuable resource for readers, especially those committed to advancing the fields of mathematics and education. May it inspire further research, collaboration, and innovation, ultimately contributing to the transformative power of education.

Wassalamu'alaikum Warahmatullahi Wabarakatuh.

Chairman  
Rini Setyaningsih, M.Pd.

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# Analysis of the Use Intelligent Guess and Test Strategy in Solving Realistic HOTS Problems for Junior High School Students

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**Abstract.** There are various strategies for solving realistic HOTS-type problems, one of which is the intelligent guess and test strategy. However, students have not yet fully understood the use of this strategy. Therefore, this study aims to analyze the use of the intelligent guess and test strategy in solving realistic HOTS-type problems. This research employs a qualitative approach with a case study type. The study was conducted at SMP Widiatmika in Badung Regency, Bali Province, involving 27 eighth-grade students. Data collection techniques included tests and documentation. Data analysis employed qualitative content analysis, thematic coding, constant comparative analysis, and narrative analysis. The results of this study indicate that 96.3% of students chose to solve problems using an arithmetic approach, while 3.7% used an algebraic approach. The study also revealed that students faced difficulties in solving realistic HOTS-type problems, particularly in understanding the problems and determining the methods to use. Furthermore, the study identified three patterns in the use of the intelligent guess and test strategy: incomplete, complete but indirect, and complete and direct. The incomplete pattern occurs when students determine a formula without a strong basis to arrive at the final answer to a problem. The second pattern, complete but indirect, begins after the student understands the problem and makes the most reasonable guess, followed by testing. The student then analyzes the test results and makes the next guess based on the initial guess. This process is carried out cyclically until the student finds the most accurate guess. The third pattern, complete and direct, occurs when the student makes a direct guess because they fully understand the problem and have considered various aspects of the issue. The student tests the first guess and obtains the expected result.

**Keywords:** Intelligent Guess and Test Strategy, Problem Solving, Realistic HOTS Problems, Arithmetic, Algebra

## INTRODUCTION

Mathematical problem-solving ability is a fundamental skill that is crucial for students' cognitive and academic development. According to the National Council of Teachers of Mathematics (NCTM, 2000), problem-solving is not only a goal of mathematics education but also a primary means of gaining a deep understanding of mathematical concepts. Schoenfeld (2016) emphasized that this skill helps students develop logical, critical, and creative thinking, which can be applied in various real-life contexts. Polya (1957), in his famous work, outlined that the process of mathematical problem-solving involves a series of systematic steps that assist students in organizing their thoughts and developing effective strategies. Furthermore, a study conducted by Căprioară (2015) revealed that students proficient in mathematical problem-solving tend to perform better academically overall and are better prepared to face future challenges. Additionally, research by Tambychik and Meerah (2010) found that mathematical problem-solving ability positively correlates with increased self-confidence and learning motivation among students. Finally, as noted by English and Gainsburg (2016), mathematical problem-solving skills also prepare students to participate effectively in a society that increasingly relies on technology and quantitative reasoning.

Although mathematical problem-solving skills have been recognized as a crucial component of mathematics education (NCTM, 2000), many teachers still do not focus their instruction on problem-solving tasks. Schoenfeld (2014) observed that the pressure to complete the curriculum within a limited time often drives teachers to emphasize procedures and formulas rather than problem-solving. A study conducted by Mayer and Wittrock (2006) revealed that many teachers lack confidence in teaching problem-solving strategies due to inadequate training. Furthermore, Schoen and Pritchett (1998) found that standardized tests that focus more on procedural skills tend to lead teachers to "teach to the test" rather than develop students' problem-solving abilities. Tambychik and Meerah (2010) also noted that many teachers experience difficulties in designing and evaluating effective problem-solving tasks. As a result, despite the widespread recognition of its importance, the implementation of problem-solving-focused teaching still faces various challenges in the field.

In the world of mathematics education, there are various types of problem-solving tasks that can be used to develop students' thinking skills. Polya (1957) classified mathematical problems into two main types: problems to find and problems to prove. Meanwhile, Yee (2002) identified five types of mathematical problems: routine problems, process problems, puzzle problems, application problems, and situation problems. Among these various types, realistic problem-solving tasks of the HOTS (Higher Order Thinking Skills) type are becoming increasingly important in the context of modern education. According to Wijaya et al. (2014), realistic problem-solving tasks involve meaningful real-world contexts for students, while the HOTS components, as explained by Brookhart (2010), include the abilities of analysis, evaluation, and creation based on the revised Bloom's taxonomy. Furthermore, a study conducted by Jäder et al. (2020) showed that realistic problem-solving tasks of the HOTS type not only enhance students' mathematical abilities but also develop critical and creative thinking skills essential for facing the challenges of the 21st century. Therefore, as argued by English and Gainsburg (2016), it is important for educators to incorporate more realistic HOTS problem-solving tasks in mathematics instruction to prepare students for the complexities of the real world.

Recent research on the use of the "Intelligent Guessing and Testing" strategy in mathematical problem-solving has yielded valuable new insights. A study conducted by Özcan et al. (2017) revealed that students who were explicitly taught this strategy showed significant improvement in their non-routine problem-solving abilities. Similarly, Rott (2020) found that the use of intelligent guessing and testing often emerged as a key strategy in the problem-solving processes of gifted students. In the context of educational technology, Li et al. (2018) developed an intelligent tutoring system that supports and analyzes the use of intelligent guessing strategies, demonstrating its potential in adaptive learning. Czocher's (2017) research explored how engineering students use this strategy in mathematical modeling, emphasizing its importance in the STEM context. Furthermore, a longitudinal study by Stylianides and Stylianides (2014) showed that students' ability to use intelligent guessing and testing develops over time and contributes to a deeper conceptual understanding. In an international context, Kaur et al. (2019) compared the use of this strategy across different countries, revealing cultural variations in its application. Finally, a meta-analysis conducted by Scherer and Beckmann (2014) confirmed the effectiveness of the intelligent guessing and testing strategy in enhancing overall mathematical problem-solving performance.

Although the Intelligent Guess and Test strategy has been extensively researched in the context of mathematical problem-solving, there are significant research gaps regarding its use in solving HOTS (Higher Order Thinking Skills) realistic problems at the junior high school level. Özcan et al. (2017) investigated the use of problem-solving strategies with 6th-grade students, but their focus was not on HOTS realistic problems. Meanwhile, Rott (2020) explored problem-solving strategies with gifted students but did not specifically examine the Intelligent Guess and Test strategy in the context of HOTS realistic problems. Stylianides and Stylianides (2014) did research on the development of students' problem-solving abilities, but it did not focus on junior high school level or HOTS realistic problems. Furthermore, although Kaur et al. (2019) compared the use of problem-solving strategies across different countries, they did not specifically analyze the use of the Intelligent Guess and Test strategy in the context of HOTS realistic problems at the junior high school level. Additionally, there is no comprehensive research analyzing how junior high school students use the Intelligent Guess and Test strategy to solve HOTS realistic problems and the factors influencing its effectiveness. This gap highlights the need for more in-depth research on how junior high school students apply the Intelligent Guess and Test strategy in the context of HOTS realistic problems and its implications for developing their higher-order thinking skills.

## METHOD

This type of research uses a qualitative case study approach. Creswell and Poth (2018) state that qualitative approaches are well-suited for exploring and understanding phenomena in depth, especially when researchers seek a holistic understanding of students' problem-solving strategy categorization. Case studies, as described by Yin (2018), allow researchers to investigate contemporary phenomena (the use of the Intelligent Guess and Test

strategy) in real-life contexts (solving HOTS realistic problems), particularly when the boundary between the phenomenon and the context is not clear. In this case, the focus is on how junior high school students solve HOTS realistic mathematical problems using the Intelligent Guess and Test strategy. This study is conducted at SMP Widiatmika in Badung Regency, Bali, involving 27 8th-grade students who have already studied arithmetic and algebra.

The research instruments consist of two HOTS (Higher Order Thinking Skills) realistic test questions. The two questions are:

1. Modern Furniture Store sells sofas, loveseats, and chairs that are made from identical parts (of the same size) as shown in the image below. There is only one pair of armrests on each piece of furniture, and all armrests have the same width. The width of the sofa is 220 cm and the width of the loveseat is 160 cm. What is the width of the chair?



2. *Level Twenty One* is one of the malls located in the center of Denpasar and is frequently visited by the public, especially young people, one of whom is Stefan. Stefan, who aspires to work in the Department of Transportation, enjoys observing parking lots by counting the total number of vehicles present. That morning, Stefan recorded 30 vehicles consisting of cars and motorcycles. The total number of wheels of the vehicles in the parking lot was 84. How many cars and motorcycles were there?

Data Collection Techniques are Problem-Solving Test: Design and administer a specific test consisting of HOTS (Higher Order Thinking Skills) realistic problems that allow the use of the Intelligent Guess and Test strategy. This test can be used to measure students' ability to apply the strategy in various contexts. Document Analysis: Collect and analyze students' written work, including worksheets, notes, and test answers involving HOTS realistic problems. This can provide insights into how students apply the Intelligent Guess and Test strategy in written form.

Data Analysis Techniques are Qualitative Content Analysis: This involves careful and systematic reading of students' written documents. The researcher identifies patterns and categories related to the use of the Intelligent Guess and Test strategy. As described by Krippendorff (2018), this analysis allows the researcher to uncover hidden meanings and the context of the strategy's use. Thematic Coding: Miles et al. (2014) suggest using thematic coding to organize and categorize data. The researcher can develop codes related to various aspects of the use of the Intelligent Guess and Test strategy, such as IC (Incomplete), CID (Complete Indirect), and CD (Complete Direct). Constant Comparative Analysis: This technique, derived from Grounded Theory (Corbin & Strauss, 2014), involves continuously comparing new data with previously collected and analyzed data. In this case, the researcher develops and refines analytical categories iteratively, providing a deeper understanding of how students use the Intelligent Guess and Test strategy in various contexts. Narrative Analysis: This technique, as described by Riessman (2008), can be used to analyze students' stories and explanations about their experiences using the Intelligent Guess and Test strategy. Narrative analysis can reveal how students understand and interpret the use of this strategy in their problem-solving contexts.

Below is the categorization of the use of the Intelligent Guess and Test strategy by junior high school students when solving HOTS (Higher Order Thinking Skills) realistic problems:

**TABLE 1.** Categorization of the use of the Intelligent Guess and Test strategy

Intelligent Guess and Test category	Code	Description
Incomplete	IC	Students choose guesses using formulas without a basis and do not test the results of these guesses
Complete Indirect	CID	Students make an initial guess and test it, then revise the guess to obtain the best correct answer
Complete Direct	CD	Students make an accurate guess directly and test that guess

## RESULTS AND DISCUSSION

Out of the 27 students tested, 26 used an arithmetic approach through the "intelligent" guess and test strategy to solve HOTS realistic problems, while only 1 student used an algebraic approach. This finding indicates a tendency for students to prefer the arithmetic approach using the "intelligent" guess and test strategy over the algebraic approach using equations. Several factors influence this preference. According to Drijvers et al. (2019), many students face difficulties in transitioning from arithmetic to algebra, especially in modeling problem situations into algebraic equations. As a result, they tend to choose a more familiar and concrete approach. Walkington et al. (2019) found that students often feel more confident with numerical strategies like intelligent guess and test because these strategies allow them to start with specific values and adjust iteratively. Research by Napaphun (2017) revealed that students using the intelligent guessing strategy showed higher levels of engagement and motivation in problem-solving, possibly due to the exploratory and hands-on nature of this approach. Furthermore, Khoshaim and Nwabueze (2022) observed that students who lack confidence in formal algebra manipulation often choose the trial-and-improvement method as a more accessible alternative. Ojose (2020) argued that the preference for arithmetic approaches might stem from students' prior experiences and curricula that emphasize numerical computation before formal algebra introduction. Finally, Hitt et al. (2017) highlighted that the ability to switch between arithmetic and algebraic representations is an important skill that develops gradually, suggesting that an initial preference for arithmetic methods might be a natural stage in the development of students' mathematical understanding.

From the 27 students, 13 students (48.15%) answered question 1 correctly, and 7 students (25.93%) answered question 2 correctly. The students who answered correctly were then analyzed based on the Intelligent Guess and Test strategy they used. For question 1, the distribution was as follows: 9 students (69.23%) were categorized as IC (Incomplete), 3 students (23.08%) were categorized as CID (Complete Indirect), and 1 student (7.69%) was categorized as CD (Complete Direct). For question 2, the distribution was: 3 students (42.86%) were categorized as CID and 4 students (57.14%) were categorized as CD. These findings indicate that students did not fully understand the problems and faced difficulties in analyzing HOTS realistic problems. Several factors contribute to this issue. According to Wijaya et al. (2014), students often struggle to transfer their mathematical knowledge to real-world situations, primarily due to a lack of contextual understanding. Apino and Retnawati (2017) identified that many students have difficulty identifying relevant information in complex problems, which is a key skill in HOTS. Research by Jäder et al. (2020) revealed that students often stick to routine procedures and struggle to switch to higher-order thinking required for non-standard problems. Furthermore, Gurat (2018) found that many students lack metacognitive skills, which are essential for monitoring and evaluating their own understanding when facing complex problems. Saleh et al. (2018) highlighted that a lack of experience with contextual problems in everyday learning contributes to students' difficulties in analyzing realistic problems. Finally, Yuberti et al. (2019) argued that mathematical anxiety and lack of confidence often hinder students' ability to engage effectively with HOTS problems, causing them to avoid the in-depth analysis required. These factors collectively explain why many students face challenges in understanding and analyzing HOTS realistic problems.

Based on these results, the next step is to describe the patterns of students solving problems using the Intelligent Guess and Test strategy for each category. Specifically, Subject 1 represents a student categorized as IC for question 1, Subject 2 represents a student categorized as CID for question 1, and Subject 3 represents a student categorized as CD for question 1. Furthermore, Subject 4 represents a student categorized as CID for question 2, and Subject 5 represents a student categorized as CD for question 2. The following is a description of the five subjects when using the Intelligent Guess and Test strategy to solve HOTS realistic problems.

*Description of Subject 1 (S1)*

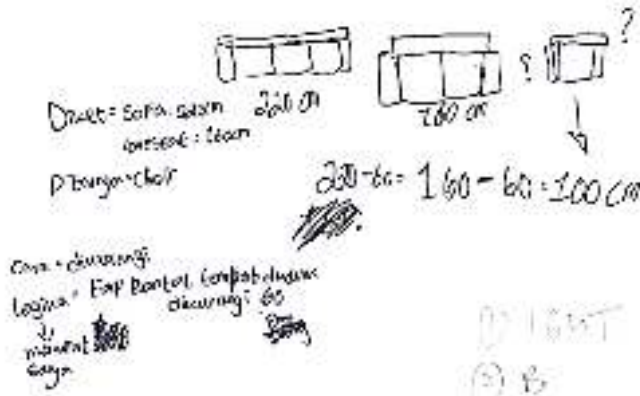


FIGURE 1. S1's answer when solving question 1

Subject 1 (S1) began by writing down the known information and the question from the problem, then creating an illustration in the form of a diagram. This indicates that S1 understood the problem at hand. Next, S1 chose a strategy by “subtracting, each cushion reduced by 60.” S1 implemented this as a formula: 220 minus 60 results in 160, then 160 minus 60 results in 100 cm. S1's answer is correct but incomplete, as there was no testing of the initial guess and final result obtained. In this case, S1 made a guess but did not test that guess. Additionally, the logic used for the initial guess was based on the assumption that 60 cm refers only to the cushion width excluding the armrests.

Description of Subject 2 (S2)

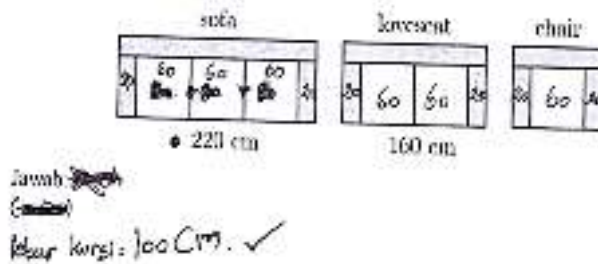


FIGURE 2. S2's answer when solving question 1

Subject 2 (S2) initially guessed that the width of each cushion for the sofa was 80 cm, then tested this guess and found that the total exceeded 220 cm. S2 then revised the guess to 60 cm per cushion and 20 cm per armrest, and upon summing these, the result was 220 cm. This was then applied to the loveseat, resulting in the correct measurement of 160 cm. S2 then applied the same approach to the chair and obtained 100 cm. In this case, S2 used their intelligence in making guesses (not just random guessing). S2 made an initial guess and revised it after testing the initial guess. The second guess also demonstrated intelligence, where the guess of 80 cm was adjusted to 60 cm. The second guess was smaller than the first because the analysis showed that a guess of 80 cm resulted in 240 cm. Therefore, the next guess needed to be smaller to get a total less than 220 cm. This indicates that the Intelligent Guess and Test strategy was used comprehensively.

Description of Subject

Translate:

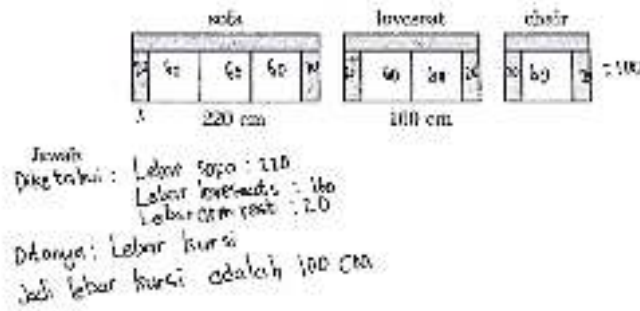
Given: Sofa = 220 cm  
 Loveseat = 160 cm  
 Asked: Chair

$$220 - 60 = 160 - 60 = 100 \text{ cm}$$

Method: Subtraction  
 Logic: Each cushion is reduced by 60 (in my opinion)

Translate

Answer:  
 Width of the chair = 100 cm



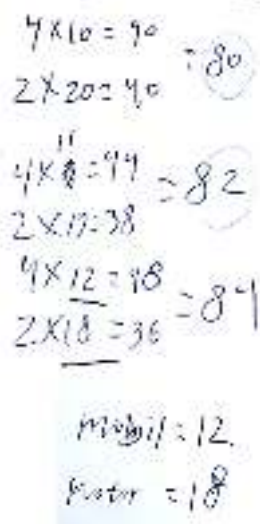
Translate

Given: Width of the sofa = 220 cm  
 Width of the loveseat = 160 cm  
 Width of the armrest = 20 cm  
 Asked: Width of the chair?  
 So, the width of the chair is 100 cm.

FIGURE 3. S3's answer when solving question 1

Subject 3 (S3) initially identified the known values: width of the sofa as 220 cm, width of the loveseat as 160 cm, and provided additional information by guessing the width of the armrest as 20 cm. S3 then determined what was being asked, which was the width of the chair, and concluded that the width of the chair was 100 cm. The final result of 100 cm was obtained from the testing conducted (as shown in the image), starting with tests for the sofa width of 20, 60, 60, 60, and 20. Then the loveseat width was tested as 20, 60, 60, and 20. Finally, the chair was tested with 20, 60, and 20, resulting in 100 cm. In this case, S3 made guesses and tested them directly. The intelligence demonstrated by S3 was in determining the armrest width as 20 cm.

Description of Subject 4



Translate

Answer  
 $4 \times 10 = 40$   
 $2 \times 20 = 40$   
 = 80  
 $4 \times 11 = 44$   
 $2 \times 19 = 38$   
 = 82  
 $4 \times 12 = 48$   
 $2 \times 18 = 36$   
 = 84  
 Car = 12  
 Motor = 18

FIGURE 4. S4's answer when solving question 2

Subject 4 (S4) began by understanding the problem that there were 30 vehicles consisting of cars and motorcycles, with their individual quantities unknown. Additionally, it was understood that the total number of wheels was 84. This understanding was reflected in the consistent pattern of guesses made. S4 started with an initial guess of 10 cars and 20 motorcycles. Upon adding these, the total number of wheels was found to be 80. S4 then revised the guess to 11 cars and 19 motorcycles, resulting in 82 wheels. Next, S4 tried 12 cars and 18 motorcycles, which yielded a total of 84 wheels, matching the given condition. S4 concluded that the number of cars was 12 and the number of motorcycles was 18. In this case, S4 used the Intelligent Guess and Test strategy comprehensively, starting with understanding the problem, determining the strategy, and implementing it step-by-step by making initial guesses, testing them, analyzing results to refine the guesses, and eventually finding the correct final answer.

Description of Subject 5

Jawab: 30 Kendaraan dan 84 buah  
(Mobil dan motor) (jumlah roda)

$$\text{Jawab} = 4 \times 12 = 48$$

$$30 - 12 = 18$$

$$2 \times 18 = 36$$

$$\begin{array}{r} 48 \\ 36 \\ \hline 84 \end{array} \quad \begin{array}{l} \text{Jadi ada: } 12 \text{ mobil} = 48 \text{ Roda} \\ \text{dan ada: } 18 \text{ motor} = 36 \text{ Roda} \end{array} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} = 84 \text{ Roda } \checkmark$$

Translate

Answer: 30 vehicles (cars and motorcycles) and 84 wheels

Calculation:

4 wheels per car  $\times$  12 cars = 48 wheels

30 vehicles – 12 cars = 18 motorcycles

2 wheels per motorcycle  $\times$  18 motorcycles = 36 wheels

48 wheels + 36 wheels = 84 wheels

So, there are 12 cars (48 wheels) and 18 motorcycles (36 wheels), totaling 84 wheels.

FIGURE 5. S5's answer when solving question 2

Subject 5 (S5) began by identifying the given information: 30 vehicles consisting of cars and motorcycles, and 84 wheels in total. S5 then made an initial guess of 12 cars and 18 motorcycles. This guess was tested by calculating: 4 wheels  $\times$  12 cars = 48 wheels and 2 wheels  $\times$  18 motorcycles = 36 wheels. Upon testing, the total was found to be 48 + 36 = 84 wheels, which matched the problem statement. In this case, S5 made a direct guess and tested it accordingly. The intelligence demonstrated was in determining the number of cars as 12 and aligning this with the information provided in the problem.

Patterns of using the "Intelligent Guess and Test" strategy in solving realistic HOTS problems have been the focus of recent research. The results of this study reveal three patterns of using the "Intelligent Guess and Test" strategy: incomplete, complete indirect, and complete direct.

1. The incomplete pattern begins with students determining a formula without a strong basis and then providing an answer without testing whether the answer is correct. This is supported by Yeo (2017), who identifies the pattern of using "Intelligent Guess and Test" as a bridge between intuitive and formal understanding, where students use intelligent guesses to explore problems before developing more rigorous solutions.
2. The complete indirect pattern starts with students understanding the problem and making the most reasonable guess, then testing this guess. They analyze the results of the test and make subsequent guesses based on the initial guess. This process is cyclical until they find the most accurate guess. Loc and Uyen (2014) observe that in the context of realistic problems, students often use their situational knowledge to make reasonable initial guesses, which they then refine through iteration. Meanwhile, Gurat (2018) finds that students frequently use this strategy in a cyclic pattern, where they make a guess, test it, reflect on the results, and then make a better guess. Research by Betlich et al. (2015) reveals a pattern where students use "Intelligent Guess and Test" as an initial strategy to understand the structure of the problem before transitioning to a more formal approach.
3. The complete direct pattern involves students making a direct guess because they understand the problem well and have considered various aspects of the issue. Students test the initial guess and achieve the expected result. Metacognitive skills and extensive experience in solving similar problems are key factors for this third pattern. This is reinforced by Rott (2020), who identifies three main steps in using the "Intelligent Guess and Test" strategy: (1) initial guess based on intuition, followed by systematic adjustment; (2) use of domain knowledge to make more informed guesses; and (3) combining guesses with other problem-solving strategies.

## CONCLUSION

The tendency of students to solve problems using an arithmetic approach rather than algebra is evident. This is shown by 96.3% of students choosing to solve problems using an arithmetic approach. This preference is due to students' difficulties in converting realistic HOTS problems into algebraic equations. Additionally, the arithmetic approach is more practical compared to algebra, which requires strong, formal systematic knowledge. The research also indicates that students face challenges in solving realistic HOTS problems, particularly in understanding the problem and determining the approach to use. This is reflected in the fact that out of 27 students, 13 (48.15%) answered question 1 correctly and 7 (25.93%) answered question 2 correctly.

The results of this study reveal three patterns of using the intelligent guess and test strategy: incomplete, complete indirect, and complete direct. The incomplete pattern begins with students determining a formula without a strong basis for arriving at the final answer. The second pattern is complete indirect, where after

understanding the problem, students make the most reasonable guess and then test it. They analyze the results of the test and make subsequent guesses based on the initial guess. This process is cyclic until they find the most accurate guess. The third pattern is complete direct, where students start with a direct guess because they understand the problem well and have considered various aspects of the issue. The students test their initial guess and achieve a result that meets their expectations.

For future research, it is hoped that there will be development of HOTS learning modules focused on realistic HOTS-type exercises. Additionally, there should be a student-centered approach based on problem-solving and realistic mathematics education. The incomplete intelligent guess and test strategy pattern indicates that students need guidance in organizing more systematic problem-solving steps. Teachers can provide step-by-step guidance and emphasize the importance of logical justification in each stage of problem-solving. Students using the complete indirect pattern require more practice in identifying initial assumptions and testing solutions effectively. Exercises with progressively increasing difficulty can help students strengthen their strategies to achieve more efficient problem-solving. Students already using the complete direct pattern can serve as examples or models in learning. Involving them in class discussions to share problem-solving strategies can inspire other students to be more meticulous and critical in analyzing problems.

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### REFERENCES

1. National Council of Teachers of Mathematics (NCTM). (2000). Principles and standards for school mathematics. Reston, VA: NCTM.
2. Schoenfeld, A. H. (2016). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics (Reprint). *Journal of Education*, 196(2), 1-38.
3. Polya, G. (1957). How to solve it: A new aspect of mathematical method. Princeton University Press.
4. Căprioară, D. (2015). Problem solving - purpose and means of learning mathematics in school. *Procedia - Social and Behavioral Sciences*, 191, 1859-1864.
5. Tambychik, T., & Meerah, T. S. M. (2010). Students' difficulties in mathematics problem-solving: What do they say? *Procedia - Social and Behavioral Sciences*, 8, 142-151.
6. English, L. D., & Gainsburg, J. (2016). Problem solving in a 21st-century mathematics curriculum. In L. D. English & D. Kirshner (Eds.), *Handbook of international research in mathematics education* (3rd ed., pp. 313-335). Routledge.
7. Schoenfeld, A. H. (2014). *Mathematical problem solving*. Elsevier.
8. Mayer, R. E., & Wittrock, M. C. (2006). Problem solving. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 287-303). Lawrence Erlbaum Associates.
9. Schoen, H. L., & Pritchett, J. (1998). Students' perceptions and attitudes in a standards-based high school mathematics curriculum. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.
10. Yee, F. P. (2002). Using short open-ended mathematics questions to promote thinking and understanding. In *Proceedings of the 4th International Conference on The Humanistic Renaissance in Mathematics Education* (pp. 135-140).
11. Wijaya, A., van den Heuvel-Panhuizen, M., & Doorman, M. (2015). Opportunity-to-learn context-based tasks provided by mathematics textbooks. *Educational Studies in Mathematics*, 89(1), 41-65.
12. Brookhart, S. M. (2010). How to assess higher-order thinking skills in your classroom. ASCD.
13. Jäder, J., Lithner, J., & Sidenvall, J. (2020). Mathematical problem solving in textbooks from twelve countries. *International Journal of Mathematical Education in Science and Technology*, 51(7), 1120-1136.
14. Özcan, Z. Ç., İmamoğlu, Y., & Bayraklı, V. K. (2017). Analysis of sixth grade students' think-aloud processes while solving a non-routine mathematical problem. *Educational Sciences: Theory & Practice*, 17(1), 129-144.
15. Rott, B. (2020). Problem solving in mathematics education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 686-693). Springer.
16. Li, H., Gobert, J., & Dickler, R. (2018). Intelligent tutoring system for scientific inquiry skills. In R. Nkambou, R. Azevedo, & J. Vassileva (Eds.), *Intelligent Tutoring Systems* (pp. 354-360). Springer.

17. Czocher, J. A. (2017). How can emphasizing mathematical modeling principles benefit students in a traditionally taught differential equations course? *The Journal of Mathematical Behavior*, 45, 78-94.
18. Stylianides, A. J., & Stylianides, G. J. (2014). Impacting positively on students' mathematical problem solving beliefs: An instructional intervention of short duration. *The Journal of Mathematical Behavior*, 33, 8-29.
19. Kaur, B., Toh, T. L., Lee, N. H., Leong, Y. H., Cheng, L. P., Ng, K. E. D., ... & Safii, L. (2019). Twelve questions on mathematics teaching. In T. L. Toh, B. Kaur, & E. G. Tay (Eds.), *Mathematics Education in Singapore* (pp. 35-64). Springer.
20. Creswell, J.W. and Poth, C.N. (2018) *Qualitative Inquiry and Research Design Choosing among Five Approaches*. 4th Edition, SAGE Publications, Inc., Thousand Oaks.
21. Yin, R. K. (2018). *Case Study Research and Applications: Designs and Methods*.
22. Scherer, R., & Beckmann, J. F. (2014). The acquisition of problem solving competence: Evidence from 41 countries that math and science education matters. *Large-scale Assessments in Education*, 2(1), 1-22.
23. Krippendorff, K. (2018). *Content analysis: An introduction to its methodology* (4th ed.). Sage Publications.
24. Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Sage Publications.
25. Corbin, J., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (4th ed.). Sage Publications.
26. Riessman, C. K. (2008). *Narrative methods for the human sciences*. Sage Publications.
27. Drijvers, P., Kodde-Buitenhuis, H., & Doorman, M. (2019). Assessing mathematical thinking as part of curriculum reform in the Netherlands. *Educational Studies in Mathematics*, 102(3), 435-456.
28. Walkington, C., Clinton, V., & Shivraj, P. (2018). How readability factors are differentially associated with performance for students of different backgrounds when solving mathematics word problems. *American Educational Research Journal*, 55(2), 362-414.
29. Napaphun, V. (2017). Development of analytical thinking skills among Thai university students. *Turkish Online Journal of Educational Technology*, 2017(Special Issue for INTE 2017), 862-869.
30. Khoshaim, H. B., & Nwabueze, K. K. (2022). Exploring the algebraic thinking of first-year university students. *International Electronic Journal of Mathematics Education*, 17(2), em0679.
31. Ojose, B. (2020). Applying Piaget's theory of cognitive development to mathematics instruction. *The Mathematics Educator*, 28(1), 96-129.
32. Hitt, F., Saboya, M., & Zavala, C. C. (2017). Rupture or continuity: The arithmetic-algebraic thinking as an alternative in a modelling process in a paper and pencil and technology environment. *Educational Studies in Mathematics*, 94(1), 97-116.
33. Wijaya, A., van den Heuvel-Panhuizen, M., Doorman, M., & Robitzsch, A. (2014). Difficulties in solving context-based PISA mathematics tasks: An analysis of students' errors. *The Mathematics Enthusiast*, 11(3), 555-584.
34. Apino, E., & Retnawati, H. (2017). Developing instructional design to improve mathematical higher order thinking skills of students. *Journal of Physics: Conference Series*, 812(1), 012100.
35. Jäder, J., Sidenvall, J., & Sumpter, L. (2017). Students' mathematical reasoning and beliefs in non-routine task solving. *International Journal of Science and Mathematics Education*, 15(4), 759-776.
36. Gurat, M. G. (2018). Mathematical problem-solving strategies among student teachers. *Journal on Efficiency and Responsibility in Education and Science*, 11(3), 53-64.
37. Saleh, M., Prahmana, R. C. I., Isa, M., & Murni (2018). Improving the reasoning ability of elementary school student through the Indonesian Realistic Mathematics Education. *Journal on Mathematics Education*, 9(1), 41-54.
38. Yuberti, Y., Latifah, S., Anugrah, A., Saregar, A., Misbah, M., & Jermsittiparsert, K. (2019). Approaching problem-solving skills of momentum and impulse phenomena using context and problem-based learning. *European Journal of Educational Research*, 8(4), 1217-1227.
39. Yeo, J. B. W. (2017). Development of a framework to characterise the openness of mathematical tasks. *International Journal of Science and Mathematics Education*, 15(1), 175-191.
40. Loc, N. P., & Uyen, B. P. (2014). Using analogy in teaching mathematics: An investigation of mathematics education students in school of education - Can Tho University. *International Journal of Education and Research*, 2(7), 91-98.
41. Gurat, M. G. (2018). Mathematical problem-solving strategies among student teachers. *Journal on Efficiency and Responsibility in Education and Science*, 11(3), 53-64.

42. Beitlich, J. T., Obersteiner, A., & Reiss, K. (2015). How do secondary school students make use of different representation formats in heuristic worked examples? An analysis of eye movements. In K. Beswick, T. Muir, & J. Wells (Eds.), *Proceedings of the 39th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 97-104). PME.

# Praxeological Analysis of the Mathematics Textbook on the Topic of Translation

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**Abstract.** This study analyzes the sequence of tasks in the Mathematics textbook to identify learning obstacles associated with the concept of translation, with a specific focus on the definition of translation. This analysis employs the theory of praxeology, a key concept in the Anthropological Theory of Didactics (ATD). The findings highlight three potential didactical obstacles and one potential epistemological obstacle within the task sequence. Therefore, these findings should be considered by teachers to anticipate and minimize potential obstacles in teaching the concept of translation.

## INTRODUCTION

Transformation geometry has been introduced to Indonesian students beginning in the 9th grade, as per the 2018 revision of the 2013 curriculum. Previously, it was taught at a higher grade level. Similarly, in the latest curriculum, the Merdeka Curriculum, transformation geometry continues to be taught to 9th-grade students. The learning outcomes are categorized under Phase D (grades VII-IX), where students are expected to perform single transformations (reflection, translation, rotation, and dilation) in the Cartesian coordinate plane and apply these concepts to solve problems. This is in line with [1] standards, which state that students in grades 9-12 should be able to understand and represent translations, reflections, rotations, and dilations of objects in the plane using sketches, coordinates, vectors, function notation, and matrices, and should also be capable of utilizing various representations to understand the effects of simple transformations and their compositions.

In understanding the natural world and their surroundings, a student requires the concept of transformation geometry [2], which can aid in the development of their visual and reasoning skills [3]. Aksoy & Bayazit mention that learning the concept of transformation geometry can support students in performing analysis and synthesis, problem-solving, spatial thinking, as cited in [2], and also in conducting mathematical proofs [4]. Therefore, according to NCTM, transformation geometry is a crucial subject because mastering and subsequently applying transformation geometry enables a student to deeply explore mathematical situations.

The importance of transformation geometry, as previously mentioned and outlined in the curriculum, has not yet aligned with the ideal situation in which students should possess a correct understanding of this material. Data indicates that students still face numerous difficulties and make various errors [5]. Secondary school students continue to struggle with identifying transformations even after they have developed operational understanding, largely because most of them have not yet developed a conceptual understanding [6].

Other findings also reveal various difficulties and errors. For example, [7] found that junior high school (SMP) students have not yet mastered the use of formulas and struggle with accurate calculations in transformation topics. [8] discovered a gap between students' understanding of the concept of an image and the formal definition of transformation, where students tend to define transformation merely as a change. This understanding is inconsistent with the formal mathematical definition of transformation as a bijective mapping. The root cause of this issue is that students are introduced to the concept of transformation geometry through examples of physical changes, such as moving a table, the rotation of a propeller, or enlarging a photo, rather than through a formal definition of the transformation concept.

Furthermore, various errors and difficulties have been identified in each type of transformation geometry. [2] found that while students understand translation as a shift in position, they simultaneously struggle to determine the direction and final position of the translation. Students also face difficulties in identifying the equation of the axis of symmetry for the reflected image and in determining the angle of rotation. Similarly, [7] discovered in

their research that students experience difficulties when asked to determine the translation formula given the initial and image points, identify the image of a point under reflection over the  $x$ -axis,  $y$ -axis, or the origin  $(0,0)$ , and determine the image of a point after a  $90^\circ$  counterclockwise rotation. It was also found that the concept of rotation is not only challenging for junior high school students but also for university students.

[9] revealed that students in university often experience conceptual errors in understanding the concepts of transformation geometry. [10] similarly found that difficulties frequently arise in placing points according to definitions and in determining the image of points after transformation. Additionally, [11] identified that they struggle to prove a mapping as a transformation, including difficulties in interpreting the definition of a mapping, determining the domain and range of a mapping, and identifying contradictions in proving a mapping as an injective function. These challenges are largely attributed to students' inability to apply the fundamental concepts of geometry necessary for transformation geometry.

The difficulties and errors identified in previous studies indicate that learning obstacle have occurred in transformation geometry, particularly among junior high school students. Given these persistent difficulties, it is crucial to explore potential learning obstacles that may be inherent in the instructional design, particularly within the sequence of tasks provided in the textbook. [12] categorizes these learning obstacles into three types: ontogenic obstacles, didactical obstacles, and epistemological obstacles. When viewed from these three types of learning obstacles, several findings emerge. For instance, an ontogenic obstacle is evident where students have not yet mastered the prerequisite material required to study transformation geometry, Karso as cited in [13]. A didactical obstacle is observed when students prefer to rely on procedural knowledge rather than developing a conceptual understanding, struggle to identify related contextual problems, and are less capable of explaining the characteristics of translation, reflection, rotation, and dilation. As for epistemological obstacles, they manifest in the students' inability to apply previously learned concepts to the problems they are currently facing [13]. Additionally, [8] found in their research on didactical obstacles that the sequence of the available materials is not structurally aligned.

Referring to the findings mentioned earlier, there is a possibility that other learning obstacles have not yet been identified. Therefore, further investigation is needed to explore potential learning obstacles in transformation geometry using different theories than those previously employed by researchers. One source of learning obstacles may arise from the sequence of tasks given to students during instruction. Consequently, it is essential to analyze the sequence of tasks in the transformation geometry materials provided to students to determine whether these tasks allow students to construct new knowledge or not. If it is confirmed that learning obstacles originate from the task sequence, then the tasks in the textbooks can be revised, or teachers can prepare anticipatory measures. This study will analyze the sequence of tasks in textbooks used by students to identify potential learning obstacles. The focus will be on one aspect of transformation geometry, namely translation, particularly the definition of translation. This analysis will utilize the Praxeology theory, which is a key concept in the Anthropological Theory of Didactics (ATD), as demonstrated by [14].

## METHOD

This study employs a qualitative research method, utilizing the theory of praxeology, which is a central concept in the Anthropological Theory of Didactics (ATD) [15]. ATD emphasizes the observation of human mathematical activities through the epistemological model of mathematical knowledge itself. This theory posits that knowledge should not only be viewed as objects such as concepts, ideas, or theorems but also in terms of the processes of production, use, and dissemination. Additionally, it can be used to identify students' learning obstacles. The theory then proposes modeling knowledge in terms of praxeology.

Praxeology consists of two components: Praxis (know-how), which refers to human activities, and Logos (know-why), which refers to human thought and reasoning. Each component plays a distinct role within praxeology. Praxis includes the type of task ( $T$ ), which refers to the problems or situations presented as tasks to be solved, and the technique ( $\tau$ ), which is the method used to solve the given problem or task. Logos, on the other hand, comprises technology ( $\theta$ ), which is the rationale or justification for selecting the technique used, and theory ( $\Theta$ ), which is employed to explain and justify the technology ( $\theta$ ).

In this study, the students' mathematics textbooks are the documents being analyzed, with a focus on understanding the definition of translation. The textbooks analyzed include both a student book and a teacher's guide published by the Indonesian Ministry of Education and Culture.

## RESULT AND DISCUSSION

A praxeological analysis was conducted on the textbooks published by the Indonesian Ministry of Education and Culture. These are the latest editions used by 11th-grade students in schools that have implemented the

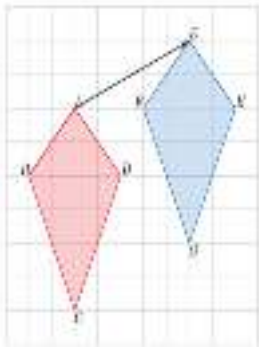
Merdeka Curriculum. Transformation geometry is covered in Chapter 3, which includes topics such as translation, reflection, rotation, congruence, and dilation. This study focuses on the topic of translation, particularly on the sequence of tasks designed to explain the definition of translation.

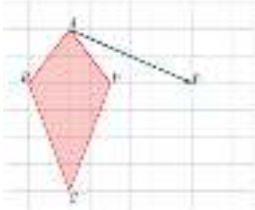
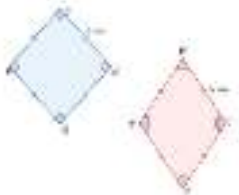
The introduction to translation begins by asking students to observe the movement of objects around them. Following this, the observation is specifically directed toward the movement of a bench, which is mentioned in the textbook as an example of translation. Therefore, in this initial introduction, students are provided with a conceptual understanding of what translation is, though without a straightforward definition.

After providing a general overview of translation, the next sequence of activities involves exploratory tasks. According to the teacher's guide, the learning objective is to explain the concept of translation. The sequence of tasks in this activity will be analyzed using praxeology.

Based on the praxeological analysis, the sequence of tasks in this exploratory activity is analyzed according to the type of task (T), which refers to the problems or situations presented as the tasks to be solved, and the technique ( $\tau$ ), which is the method used to solve the given problem or task. Following this, the technology ( $\theta$ ) is the rationale or justification for the selection of the technique used, and the theory ( $\Theta$ ) is employed to explain the technology ( $\theta$ ). The following table represents the type of task (T) aimed at explaining the definition of translation. This sequence of tasks is arranged in order from T1 to T7.

TABLE 1. Praxeological Analysis

Type of task (T)	Technique ( $\tau$ )	Technology ( $\theta$ )	Theory ( $\Theta$ )
<p><b>T1 :</b> Copy the kite ABCD onto a piece of paper and then cut it out. Place the cut-out on top of the kite ABCD. Next, slide the kite cut-out along the directed line segment <math>\overrightarrow{AE}</math></p>	<ul style="list-style-type: none"> <li>Trace the kite ABCD.</li> <li>Cut out the traced kite ABCD.</li> <li>Place the cut-out (traced ABCD) on top of the kite ABCD.</li> <li>Slide the cut-out kite ABCD along the directed of line AE.</li> </ul>	Translation is the displacement of an object in space while preserving its shape and size, according to a specified distance and direction	In geometry, translation involves changing the position of an object without altering its shape or size, referencing fundamental concepts in geometry.
			
<p><b>T2:</b> Is there any part of the kite EFGH that is not covered by the cut-out kite ABCD?</p>	Examine and compare the red traced triangle and the blue triangle through in-depth visual analysis.	Analysis of form and size equivalence through in-depth visual observation.	The concept of equality and congruence in geometry, which states that two objects with the same shape and size will coincide perfectly when properly positioned.
<p><b>T3:</b> Beside <math>\overrightarrow{AE}</math>, draw the directed line segment that represents the shift of the cut-out kite ABCD to the kite EFGH</p>	Shifting the tracing of triangle ABCD along line AE to identify other directed lines from B to F, D to H, and C to G.	Applying the principle of translation to determine the direction of each point according to the translation vector.	The theory of translation or vectors in geometry, which enables the identification of the direction of an object's movement.

Type of task (T)	Technique ( $\tau$ )	Technology ( $\theta$ )	Theory ( $\Theta$ )
<b>T4:</b> What is the relationship between side AB of the kite ABCD and side EF of the kite EFGH? How about the other sides?	Using visual observation to verify that side AB is parallel to EF, AD is parallel to EF, BC is parallel to FG, and CD is parallel to GH.	The principle of parallelism in geometry, which demonstrates that sides that are parallel before translation will remain parallel after translation.	The theory of parallelism in geometry, which asserts that translation does not alter the orientation or parallelism of a figure's sides.
<b>T5:</b> What are the shape and size of kites ABCD and EFGH?	Using visualization to ensure that both kites have the same shape and size.	The concept of congruence in geometry, which states that two figures with the same shape and size can completely overlap after transformations such as translation.	The principle of congruence in geometry, which refers to the similarity in shape and size between two geometric figures after transformation.
<b>T6:</b> Draw the kite PQRS, with its translation represented by $\overline{AP}$	<ul style="list-style-type: none"> <li>- Tracing the kite PQRS</li> <li>- Shifting the tracing of PQRS along line segment AP</li> <li>- Drawing the new kite according to the specified direction.</li> </ul>	Applying the principle of translation to move the object in the direction of $\overline{AP}$	
			
<b>Figure 2. Task 6</b>			
<b>T7:</b> Given two shapes as shown in following figure. Is the shape TUVW the result of a translation of the shape PQRS? Explain	Using visual analysis and comparison to identify differences in size and shape between the planar figures TUVW and PQRS..	The principle in geometry that states translation preserves the shape and size of an object.	The theory of congruence in geometry, which explains that two translated figures will remain congruent if they have the same size and shape.
			
<b>Figure 3. Task 7</b>			

Subsequently, the sequence of tasks in Table 1 will be discussed, along with the suspected learning obstacles identified. Learning obstacles consist of three types: 1) Ontogenic obstacles, which are learning obstacle based on developmental readiness; 2) Didactical obstacles, which are learning obstacle caused by the incorrect selection of teaching materials and the disorganized sequence of topics; and 3) Epistemological obstacles, which are learning obstacle arising from students' limitations in understanding and applying the mathematical concepts themselves. These obstacles need to be addressed because, fundamentally, mathematical concepts are interconnected. This interconnectedness implies that the understanding of one concept will impact the understanding of related concepts (12).

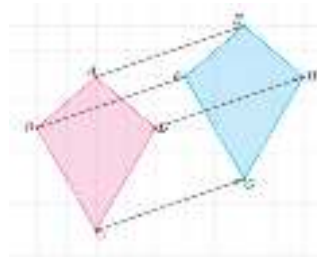
The sequence of tasks (T) for understanding the definition of translation begins with T1, which involves a physical activity using tools such as scissors and graph paper provided by the teacher. Students are then instructed

to trace the kite ABCD, cut out the tracing, place the cut-out on top of the kite ABCD, and slide the kite cut-out along  $\overline{AE}$ , as shown in Figure 1 in Table 1.

The objective of T1 is for students to discover that triangle EFGH is the result of the translation of triangle ABCD. However, in the task, both triangles ABCD and EFGH are already provided. This condition might lead to the misconception that an object and its translation already exist from the start, whereas what students should be doing is finding the result of the translation of triangle ABCD or the image of triangle ABCD. This indicates a skipped step that students should have completed before encountering the shape of triangle EFGH. This situation can be categorized as a potential didactical obstacle

Additionally, in Figure 1, there is a description stating the translation of kite A to B. This description is unclear, as A and B are points, while the text refers to the translation of kite A to B. This is likely a typographical error. Although this can be categorized as a technical error in the instructional materials, it can have significant consequences on the students' ability to acquire accurate knowledge. This can also be categorized as a potential didactical obstacle present in the textbook used.

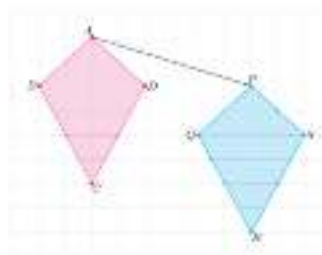
Furthermore, in T3, students are asked to draw another directed line segment, with the answer provided in the teacher's guide as shown in the following image.



**Figure 4.** Answer for T3

The answer provided in the teacher's guide, if considered the only correct answer, could lead to potential misunderstandings among students, as directed line segments can only be constructed between corresponding vertices of the shape before and after translation. This could result in incomplete knowledge, leading students to believe that every point on the object is shifted using a directed line segment. Therefore, it is important to allow students the freedom to create directed line segments from any point on the kite ABCD. This situation could cause students to encounter epistemological obstacles, as they may struggle to fully understand and apply this concept.

Subsequently, in T6, students are asked to draw a kite PQRS, with its translation represented by a directed line segment. In this task, students will apply their prior knowledge of translation and directed line segments between corresponding vertices, as demonstrated in T1 and T3. The answer to this task, according to the teacher's guide, is as follows.



**Figure 5.** Answer for T6

From this answer, it appears that students are expected to immediately draw the triangle PQRS with the assistance of a single line segment  $\overline{AP}$ . This expectation leads to two likely possibilities: 1) students might continue to use the method from T1, tracing and then shifting according to the direction of  $\overline{AP}$ , and 2) students might draw additional line segments from the vertices that are parallel to  $\overline{AP}$ . However, if students opt for the second method, they may overlook and not yet understand a critical aspect, which is the size or length of the directed line segment.

This incomplete understanding may lead to difficulties for students in determining whether the length of the known line segment and the segment they are trying to find are the same. Even if students grasp that the lengths must be equal, how they derive the length of the directed line segment  $\overline{AP}$  and then match it with the segment they are attempting to find is not facilitated in the previous sequence of tasks. This aligns with the findings of [2], who observed that while students can understand translation as a shift in position, they simultaneously struggle to

determine the direction and final position of the shift. If this suspected learning obstacle occurs, it would fall under the category of didactical obstacles, as there is knowledge that was not provided in the sequence of tasks in the student's textbook.

## CONCLUSION

Based on the results and discussion, it was found that the sequence of tasks provided to students to understand the definition of translation revealed three suspected didactical obstacles and one potential epistemological obstacle, particularly in T1, T6, and T3. These findings suggest that teachers should consider revising the sequence of tasks or supplementing them with additional activities that reinforce conceptual understanding. For instance, providing opportunities for students to derive the length of translation vectors through hands-on measurement or visualization exercises could address the gaps identified in T6. This approach could help to anticipate and minimize potential learning obstacles in teaching the concept of translation, thereby improving student outcomes. This study is limited to a praxeological analysis of the tasks aimed at understanding the definition of translation, suggesting that future research could extend the analysis to other task sequences within the topic of translation.

## REFERENCES

- [1] NCTM, *Principles and standards for school mathematics*. 2000.
- [2] G. S. Aktaş and M. Ünlü, "Understanding of Eight Grade Students about Transformation Geometry: Perspectives on Students' Mistakes," *J. Educ. Train. Stud.*, vol. 5, no. 5, p. 103, Apr. 2017, doi: 10.11114/jets.v5i5.2254.
- [3] E. K. A. Gianto, H. L. Mampouw, and D. Setyadi, "The Development of MOSIRI (Geometry Transformation Module) for High School Students," *Al-Jabar J. Pendidik. Mat.*, vol. 9, no. 2, pp. 121–134, 2018, doi: 10.24042/ajpm.v9i2.3402.
- [4] E. E. Kribbs and B. A. Rogowsky, "International Journal of Research in Education and Science (IJRES) A Review of the Effects of Visual-Spatial Representations and Heuristics on Word Problem Solving in Middle School Mathematics A review of the effects of visual-spatial representations and ," *Int. J. Res. Educ. Sci.*, vol. 2, no. 1, pp. 65–74, 2016, [Online]. Available: www.ijres.net
- [5] N. P. Mbusi and K. Luneta, "Mapping pre-service teachers' faulty reasoning in geometric translations to the design of Van Hiele phase-based instruction," *South African J. Child. Educ.*, vol. 11, no. 1, pp. 1–11, 2021, doi: 10.4102/sajce.v11i1.871.
- [6] B. Guven, "Using dynamic geometry software to improve eight grade students' understanding of transformation geometry," *Australas. J. Educ. Technol.*, vol. 28, no. 2, pp. 364–382, 2012, doi: 10.14742/ajet.878.
- [7] T. Trisna, M. Ikshan, and E. Elizar "Abilities and Difficulties of Ninth-Grade Students in Solving Geometry Transformation Problems," *J. Pendidik. MIPA*, vol. 12, no. September, pp. 682–689, 2022.
- [8] I. Nurhikmayati, M. G. Jatisunda, and N. Ratnawulan, "The Practice of Reflection Based on Didactical Design Research: An Analysis of the Geometry Transformation Material," *JTAM (Jurnal Teor. dan Apl. Mat.*, vol. 6, no. 3, p. 565, Jul. 2022, doi: 10.31764/jtam.v6i3.8441.
- [9] S. Napfiah and Y. Sulistyorini, "Errors Analysis in Understanding Transformation Geometry Through Concept Mapping," *Int. J. Res. Educ.*, vol. 1, no. 1, pp. 6–15, 2020, doi: 10.26877/ijre.v1i1.5863.
- [10] I. R. Aulia E, D. Azizah, and D. Hoiriyah, "Analysis of Student Difficulty in Solving Geometry Transformation Problems at UIN Syekh Ali Hasan Ahmad Addary Padangsidempuan," *Logaritma J. Ilmu-ilmu Pendidik. dan Sains*, vol. 11, no. 02, pp. 271–278, 2023, doi: 10.24952/logaritma.v11i02.10292.
- [11] T. S. Maifa, "Analisis Kesalahan Mahasiswa dalam Pembuktian Transformasi Geometri," *J. Ris. Pendidik. dan Inov. Pembelajaran Mat.*, vol. 3, no. 1, p. 8, 2019, doi: 10.26740/jrpiipm.v3n1.p8-14.
- [12] G. Brousseau, "Epistemological Obstacles, Problems, and Didactical Engineering," *Epistemol. Obs. Probl. Didact. Eng. Theory Didact. Situations Math.*, pp. 1970–1990, 79-117., 2002, doi: 10.1007/0-306-47211-2\_6.
- [13] L. Sunariah and E. Mulyana, "The didactical and epistemological obstacles on the topic of geometry transformation," *J. Phys. Conf. Ser.*, vol. 1521, no. 3, 2020, doi: 10.1088/1742-6596/1521/3/032089.
- [14] T. N. HastiYunianta, D. Suryadi, D. Dasari, and T. Herman, "Textbook praxeological-didactical analysis: Lessons learned from the Indonesian mathematics textbook," *J. Math. Educ.*, vol. 14, no. 3, pp. 503–524, 2023, doi: 10.22342/jme.v14i3.pp503-524.
- [15] Y. Chevallard, "Introducing the Anthropological Theory of the Didactic: an Attempt At a Principled Approach," *Hiroshima J. Math. Educ.*, vol. 12, pp. 71–114, 2019.

# Systematic Literature Review: Students' Self-Regulated Learning at Different Levels of Education in Indonesia

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**Abstract.** Self-regulated learning (SRL) is an important skill for students. Students who have SRL can regulate and control themselves in the learning process, especially when dealing with school assignments. The purpose of this study was to review the literature on students' SRL at different levels of education in Indonesia. This study is qualitative and uses the systematic literature review method. The data collection technique used in this study was a literature study and documentation sourced from articles using the keywords "self-regulated learning", "mathematics", and "students". Articles were screened using Publish or Perish software with Google Scholar, Crossref, and Semantic Scholar databases. A total of 2993 works of literature were screened and analyzed using Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) so that 9 articles were obtained representing each level of education. The study results showed differences in students' SRL levels at each level of education. Elementary school students have relatively low SRL. High school students have SRL levels varying between moderate and low.

**Keywords:** educational level, self-regulated learning, students.

## INTRODUCTION

Technological advances pose a major challenge for everyone, including school students, to face and adapt. Teachers play an important role in preparing students to be adaptive and able to face technological growth. Educators in the 21<sup>st</sup> century are not only teachers but also creators of democratic learning conditions and provide integrated challenges in learning current technological developments [1]. In this 21<sup>st</sup> century, qualified human resources are needed to help students develop their potential.

Mathematics is a fundamental discipline that plays a crucial role in advancing science and technology. It is taught to all students, from elementary school through high school and into college [2]. Mathematics learning plays an important role in preparing individuals in society to anticipate changes in circumstances in everyday life. One important thing to develop in students is the ability to manage themselves, especially in the learning process. Self-regulation in the learning process is related to students' ability to solve problems through deep thinking, making decisions, taking initiative in addressing challenges, having responsibility for their tasks, and being accountable for their actions.

One of the several aspects that influence the cognitive process in learning is the individual's condition, which includes aspects such as interests, talents, motivation, enthusiasm, and learning styles, as well as learning independence, or what is known as self-regulated learning (SRL) [3]. SRL is a process where someone takes the initiative to learn, either independently or with assistance, by assessing their learning needs, setting learning goals, identifying available learning, selecting and applying learning strategies, and evaluating their own progress [4]. For students, SRL represents the ability to manage their learning process, particularly when completing school assignments. Students with good SRL can effectively manage their learning experiences in various ways, leading to optimal outcomes.

The ability to regulate oneself in learning mathematics plays a role in improving the quality and quantity of one's learning [5]. In learning activities, SRL needs to be possessed by students to mobilize their potential to learn

learning objects without any pressure or foreign influences outside themselves [6]. Students with high SRL tend to learn better, as they are capable of effectively monitoring, evaluating, and organizing their learning, so they can save time in completing their tasks, and managing both their learning and time efficiently [7]. Students with good SRL will organize themselves in learning, help them manage the material they are studying, apply plans, and find solutions to solving mathematical problems [8]. Thus, SRL will have a significant influence on students' academic achievement. Based on the description above, it is necessary to trace the research results showing students' SRL at various levels of education and its impact on students' academic achievement.

## RESEARCH METHOD

The type of research used in this study is qualitative research with the Systematic Literature Review method. Systematic Literature Review refers to a research methodology carried out to collect and evaluate research related to a particular topic to produce conclusions and recommendations related to the problem being studied [9]. The data analysis technique in this study uses meta-synthesis, which integrates data to obtain new theories or concepts or a deeper and more comprehensive level of understanding [10]. The subject of the study is an article about self-regulated learning (SRL) among students at various levels of education in Indonesia. The research procedure includes several steps, namely identifying research questions, developing research protocols, determining the location of the search area results database, determining selection criteria, selecting relevant research results, data extraction, coding, and presenting results. The identification of research questions is made based on the needs of the selected topic. In this study, identification used the questions "Does the article discuss SRL in mathematics learning in Indonesia?" (RQ1) and "Are there other factors associated with SRL in mathematics learning in Indonesia?" (RQ2). Research protocol development using the keywords "self-regulated learning", "mathematics", and "students". The location of the research database was selected using the Publish or Perish software, with the databases used being Google Scholar, Crossref, and Semantic Scholar. The articles that were collected were selected using inclusion and exclusion selection criteria. The inclusion criteria were publication years 2019-2023, and the research subjects were students at elementary school/equivalent, junior high school/equivalent, or high school/equivalent. The exclusion criteria were articles that used the literature review research method and used college students as research subjects. Furthermore, the data was analyzed using the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) [11]. The results of PRISMA are shown in Figure 1.

Based on the search results using Publish or Perish 8 software with the specified keywords, 2993 kinds of literature were found, consisting of 993 from Google Scholar, 1000 from Crossref, and 1000 from Semantic Scholar. After screening using inclusion and exclusion criteria, 9 articles remained which were then coded and studied intensively.

## FINDINGS AND DISCUSSION

The findings from the articles examined in this study suggest that students' self-regulated learning (SRL) is impacted by various factors, such as the learning strategies or models and the instructional media employed by teachers in the classroom. Students' SRL has different influences on the process and results of students' mathematics learning at each level of education. The following describes the influence of SRL on mathematics learning at different levels of education.

### a. SRL of Elementary School Students

At the elementary school level, SRL has not received enough attention. The study results show that elementary school students' SRL remains relatively low. Elementary school students are still unable to control themselves, including learning. Students cannot independently find, recognize, and formulate questions. In addition to self-factors, the environment influences elementary school students' SRL abilities. They have not been given enough freedom to regulate themselves to learn. The process of self-management is still shaped by the supervision and control of teachers and parents who monitor students' learning development.

Pransisca and Gazali's [12] research on elementary school students' problem-solving and SRL abilities shows that learning strategies that integrate knowledge, skills, and creative thinking are needed and emphasize students' experiences and active involvement in solving mathematical problems. Pransisca and Gazali's [12] found that parenting learning strategies can improve elementary school students' abilities in independent learning and managing their learning process effectively.

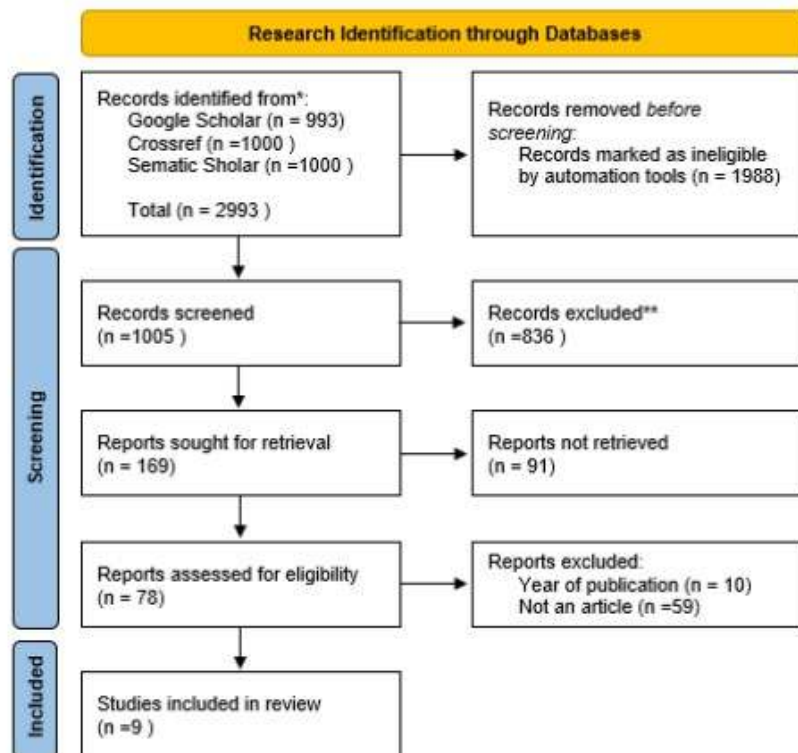


FIGURE 1. PRISMA 2020 Flowchart

#### b. SRL of Junior High School Students

Unlike elementary school students, junior high school students have begun to be able to regulate themselves so that they can develop SRL. Students begin to enter puberty and learn new things that can affect their development process, including in lessons. SRL is the ability of students to organize, manage, and control their own learning process, including understanding problems, planning solution strategies, implementing the plan, and evaluating the results. SRL plays an important role in mathematics learning. Students with high SRL tend to learn better, monitor, evaluate, and organize their learning carefully, save time completing assignments, and manage time in learning [13]. SRL is related to learning independence. Learning independence affects students' problem-solving abilities [14].

SRL is influenced not only by internal factors within students but also by external factors such as learning strategies, models, or media that offer a more independent and personalized learning experience. Kamelia and Pujiastuti [6] stated that mathematics learning needs to be supported by appropriate methods and strategies according to students' intellectual development. Learning strategies or models that can influence the SRL of junior high school students include metacognitive-scaffolding learning strategies [6], the 7E Learning Cycle Model [5], the Inside Outside Circle (IOC) learning model with the Metaphorical Thinking Approach [15], the Missouri Mathematics Project (MMP) learning model [16], the Problem-Based Learning model [17].

Musliha and Revita [17] found differences in the ability to solve mathematical problems among students with different SRL levels. Students with high SRL levels tend to have better abilities in learning mathematics because they are able to manage their thoughts, behaviors, and emotions more effectively to direct or control their learning experiences. Students with moderate and low SRL levels can understand problems, develop solution plans, and implement plans, but have not yet reached the ability to direct and control their learning experiences. SRL makes students more independent in the learning process and able to overcome obstacles that may arise when solving mathematical problems. Students tend to have high learning initiatives and the ability to solve complex problems. Thus, educators are expected to continue to work with parents to develop students' SRL and get them used to solving problems based on problem-solving [18].

#### c. SRL of Senior High School Students

Senior high school students have entered adolescence. At that age, normal students have a mature mindset and self-regulation skills that can affect their learning success. Azizah et al. [19] found a significant impact of SRL on the mathematics learning abilities of students at Islamic senior high schools. In addition to the maturity factor of senior high school students, the use of learning models also affects students' SRL. One of the learning models

that can improve students' SRL is the 7E Learning Cycle Model [20]. Applying the 7E Learning Cycle Model can foster meaningful student learning independence related to their SRL.

The use of learning media also plays a role in students' SRL. Learning media assistance can provide students with an independent and more personal learning experience. Narawidia et al. [21] found that applying the multimedia-assisted SRL learning model significantly affected senior high school students' learning motivation and mathematical problem-solving abilities. Yusuf et al. [22] developed learning media using an articulated storyline to help train senior high school students' mathematical problem-solving and SRL abilities.

The literature review revealed variations in students' SRL abilities across different education levels. This SRL was also found to be closely related to students' mathematical problem-solving abilities. Therefore, SRL needs to be practiced and made a habit. Teachers can use learning models or learning media that encourage students' learning independence so that they have SRL.

## CONCLUSION

Students' self-regulated learning (SRL) varies at each level of education. Students' SRL at elementary school is still relatively low, because teachers and parents still influence their self-management process. Junior high school students' SRL varies at high and moderate, and some are still low. This difference has an impact on their problem-solving ability. Senior high school students, having reached a level of maturity, possess self-regulation skills that enhance their SRL performance. The application of certain learning models and media can provide students with independent and more personal learning experiences, so that they can improve their SRL. Thus, teachers play an important role in choosing learning models and media.

## REFERENCES

36. F. N. Rohmah and I. Bukhori, "Pengembangan Media Pembelajaran Interaktif Mata Pelajaran Korespondensi Berbasis Android Menggunakan Articulate Storyline 3," *Economic & Education Journal*, 2(2), 169-182 (2020).
37. E. R. Harahap and E. Surya, "Kemampuan Pemecahan Masalah Matematis Siswa Kelas VII dalam Menyelesaikan Persamaan Linear Satu Variabel," *Edumatica: Jurnal Pendidikan Matematika*, 7(1), 44-54 (2017).
38. H. Hendriana and G. Kadarisma, "Self-Efficacy dan Kemampuan Komunikasi Matematis Siswa SMP," *Jurnal Nasional Pendidikan Matematika*, 3(1), 153-164 (2019).
39. H. Hendriana, E. E. Rohaeti, and U. Sumarmo, *Hard Skills dan Soft Skills Matematik Siswa* (Refika Aditama, Bandung, 2017).
40. N. P. Utami, R. Eliza, and S. Warahma, "Kemampuan Pemecahan Masalah Matematis dan Self-Regulated Learning dengan Model Pembelajaran Learning Cycle 7E," *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 6(1), 1025-1038 (2022).
41. S. Kamelia and H. Pujiastuti, "Penerapan Strategi Pembelajaran Metakognitif-Scaffolding untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis dan Self-Regulated Learning Siswa," *Journal for Research in Mathematics Learning*, 3(4), 385-392 (2020).
42. L. N. Zamnah, "Hubungan antara Self-Regulated Learning dengan Kemampuan Pemecahan Masalah Matematis pada Mata Pelajaran Matematika Kelas VIII SMP Negeri 3 Cipaku Tahun Pelajaran 2011/2012," *Teorema: Teori dan Riset Matematika*, 1(2), 31-38 (2017).
43. I. Marchis, "How Mathematics Teachers Develop Their Pupils' Self-Regulated Learning Skills," *Acta Didactica Napocensia*, 4, 9-14 (2011).
44. R. Handican and R. G. Gunawan, "Systematic Literature Review: Analisis Kemampuan Representasi Matematis Siswa Terhadap Gaya Belajar," *Griya Journal of Mathematics Education and Application*, 2(3), 577-588 (2022).
45. Siswanto, "Systematic Review sebagai Metode Penelitian untuk Mensintesis Hasil-Hasil Penelitian: Sebuah Pengantar," *Buletin Penelitian Sistem Kesehatan*, 13(4), 326-333 (2010).
46. N. R. Haddaway, M. J. Page, C. C. Pritchard, and L. A. McGuinness, "PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis Campbell Systematic Reviews," 18, e1230, (2022).
47. M. A. Pransisca and M. Gazali, "Analisis Kemampuan Pemecahan Masalah dan Self-Regulatif Siswa SD dalam Pembelajaran Matematika Parenting," *Jurnal Ilmiah Global Education*, 3(1), 10-16 (2022).
48. E. C. Cheng, "The Role of Self-regulated Learning in Enhancing Learning Performance," *International Journal of Research and Review*, 6(1), (2011).
49. D. Sulistiyani, R. Yenita, and Maimunah, "Hubungan Kemandirian Belajar dengan Kemampuan Pemecahan Masalah Matematis," *Jurnal Pendidikan Matematika*, 11(1), 1-12 (2020).

50. M. Riyana, F. Farida, and N. R. Dewi, "Analisis Kemampuan Pemecahan Masalah: Dampak Pembelajaran Inside Outside Circle (IOC) dengan Pendekatan Metaphorical Thinking dan Self Regulated Learning," *Maju*, 8(1), (2021).
51. A. Karim, A. Aziz, and L. Ambarwati, "Eksplorasi Kemampuan Pemecahan Masalah Siswa Ditinjau dari Self-Regulated Learning pada Topik Sistem Persamaan Linear Dua Variabel," *Jurnal Pendidikan Matematika Indonesia*, 8(1), 35-43 (2023).
52. M. Musliha and R. Revita, "Pengaruh Model Pembelajaran Problem Based Learning terhadap Kemampuan Pemecahan Masalah Matematis Ditinjau dari Self Regulated Learning Siswa," *Jurnal Review Pembelajaran Matematika*, 6(1), 68-82 (2021).
53. S. A. Rodliyah, Z. Abidin, and S. Syaifuddin, "Analisis Kemampuan Pemecahan Masalah Berdasarkan Kemandirian Belajar (Self-Regulated Learning) pada Materi Aritmatika Sosial Peserta Didik Kelas VII SMPN 5 Karangploso," *Jurnal Penelitian, Pendidikan, dan Pembelajaran*, 16(12), (2018).
54. A. Azizah, M. Maimunah, and Y. Roza, "Kemampuan Pemecahan Masalah Matematis Siswa pada Materi Peluang Berdasarkan Self-Regulated Learning (S-RL)," *Jurnal Review Pembelajaran Matematika*, 4(1), 23-31 (2019).
55. L. Maulani, "Analisis Learning Cycle 7E untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis dan Self Regulated Learning Ditinjau Berdasarkan AQ," *Jurnal Axioma: Jurnal Matematika dan Pembelajaran*, 6(2), 146-161 (2021).
56. I. N. Narawidia, I. N. Parwati, and I. M. Tegeh, "Pengaruh Model Self-Regulated Learning Terhadap Kemampuan Pemecahan Masalah dan Motivasi Belajar Siswa pada Mata Pelajaran Matematika di SMA," *Jurnal Teknologi Pembelajaran Indonesia*, 12(2), 116-130 (2022).
57. R. M. M. Yusuf, Supratman, and P. Lestari, "Pengembangan Media Pembelajaran Articulate Storyline untuk Mengeksplor Kemampuan Pemecahan Masalah Matematis dan Self Regulated Learning Siswa Pesantren," *Pedagogy*, 8(1), 137-149 (2023).

# STEAM-H to Support Agribusiness Students' Work Skill

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**Abstract.** The study focuses on the importance of work skills for students at Agribusiness Vocational High Schools in meeting the demands of 21st-century competencies. It explores how the STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, Health) approach can assist in developing these work skills. The research aims to assess students' grasp of the STEAM-H concept and to identify the work skills they acquire through learning that incorporates the STEAM-H approach. This investigation adopts a case study design involving 16 eleventh-grade students from the Agribusiness Vocational High School for Agricultural Product Processing in Ciamis Regency. Data was gathered through initial and final tests to gauge the students' understanding of STEAM-H, as well as through observations and interviews conducted while the students were engaged in a project on chicken wonton processing to evaluate their work skills. The results indicated a significant improvement in students' comprehension of the STEAM-H concept after participating in the learning process. This increased understanding corresponded with the students' work skills, as evidenced by their successful completion of the chicken wonton processing project. The study concludes that the STEAM-H approach holds substantial potential for enhancing students' understanding of mathematics, food security, science, health, and technology concepts relevant to the agribusiness sector while also fostering the development of essential work skills required in the workplace. Wonton production requires a strong interdisciplinary approach. Mathematics, especially computational thinking skills, are crucial in designing an efficient and effective production process. The implication of this study underscores the importance of integrating the STEAM-H approach into the curriculum of Agribusiness Vocational High Schools, thereby preparing students to become competent graduates equipped to confront challenges in the era of Industry 4.0.

## INTRODUCTION

The inclusion of STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health) in agribusiness education is increasingly important for addressing complex real-world problems (1). Research has shown that project-based learning integrated with STEM is effective in enhancing students' entrepreneurial skills in vocational schools (2) and also improves students' engineering skills in crop agribusiness courses (3). To promote entrepreneurship among agribusiness students, educational institutions should prioritize creating experiences through industry partnerships, applied courses, and internships (4). It is noted that students inclined towards entrepreneurship are often male, risk-takers, and have parents involved in production agriculture (4). Agriculture serves as a conceptual and contextual integrator for STEAM-H learning in crop agribusiness schools (1). This initiative aligns with the demands of 21st-century education, which emphasizes science and technology literacy among students (3) and focuses on developing work skills for vocational high school students.

Work skills are important for students of SMK Agribisnis in agricultural product processing. Teamwork activities through work-based learning make a significant contribution to the development of vocational high school students' work skills (5). The curriculum of Agricultural Vocational High Schools is aligned with industry needs, with a focus on competencies required for level two certification in the Indonesian National Qualification Framework (6). In addition, green skills are increasingly important in the labor market, with Agricultural Vocational High Schools students showing fairly good overall green skills but needing improvement in waste

management, communication, and innovation to meet employer demands (7). These studies highlight the importance of industry-aligned practical skills and the need for innovative teaching methods to prepare students for the evolving labor market in agricultural product processing.

The understanding of STEAM-H and work skills when students process chicken wontons are the focus of this study. Chicken wontons are animal products where students of vocational high schools majoring in agricultural processing agribusiness class XI must achieve learning, namely carrying out animal processing production. Through the activity of processing chicken wontons, students are required to understand science, technology, engineering, mathematics, and health. Students will be aware of chicken processing methods that will have an impact on nutritional composition, digestibility, and safety. Steamed chicken showed higher digestibility of essential amino acids compared to other processing methods, with actual digestibility exceeding 90% for most amino acids (8). The superheated steam treatment of chicken thighs and breasts, combined with marination and hot smoking, resulted in high overall acceptance scores and good nutritional composition (9). The processing of these products involves a lot of discipline within the scope of STEAM-H to support work skills.

Research on 21st-century workforce competencies has identified several key skills that are essential for success. Analysis of the O\*NET database revealed five key competencies: problem-solving, fluid intelligence, teamwork, achievement/innovation, and communication skills (10). Other opinions, about the supporting competency categories are analytical skills, interpersonal skills, ability to execute, information processing, and capacity to change and learn (11). In addition, there are other opinions about work skill indicators, namely sense-making, social intelligence, novel and adaptive thinking, cross-cultural competency, computational thinking, new-media literacy, transdisciplinarity, design mindset, cognitive load management, and virtual collaboration (11,12). The last indicator offered will be explored in this study. Thus, the main objective of this study is to determine the description of STEAM-H understanding and work skills of students in chicken wonton production.

## METODE

This study used a case study method (14). This study was conducted at SMK Agribisnis Pengolahan Hasil Pertanian. A public school in the city of Ciamis, West Java, Indonesia. Participants in this study were 16 eleventh-grade students. Participants were divided into four groups. The flow of this study is illustrated in Figure 1 below.

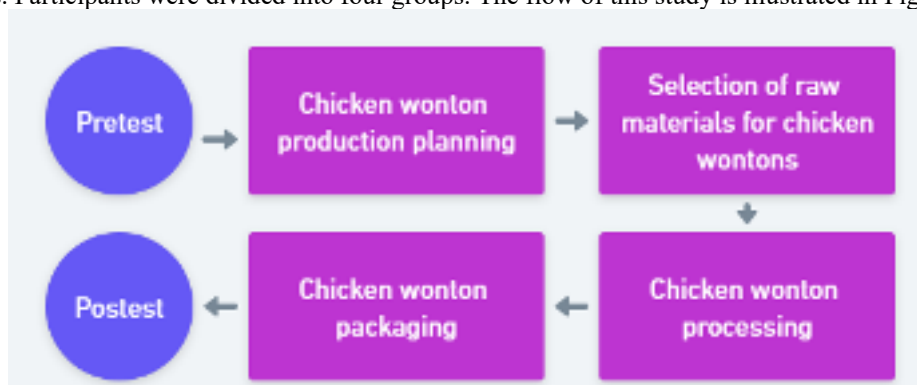


FIGURE 1. Research Flow

During the pretest and posttest, students were given 20 questions covering the subjects of science, technology, engineering, agriculture, mathematics, and health. The agriculture section focused on understanding food security, while mathematics and food security had five questions each. This emphasis on mathematics and agribusiness was due to them being the main subjects, as natural science subjects are not part of the grade eleven curriculum in vocational high schools. Natural and social science subjects are only studied in grade ten. Science and health had three questions each, while technology and engineering had two questions each. The N-Gain formula was used to analyze the results and determine the increase in students' understanding of STEAM-H.

During the chicken wonton production process, students are provided with worksheets. At the planning stage, all students focus on working on worksheets to find information related to the nutrition contained in chicken wontons and their health benefits, engineering carried out on the chicken wonton recipe above, planning the chicken wonton processing flow and the technology used, calculating the estimated cost of wonton ingredients, predicting results and selling prices. At the raw material selection stage, students also measure/weigh. During the processing process, students cut, boil, and do other activities until chicken wontons are ready to be packaged. Observations and interviews were carried out from planning to packaging to determine students' work skills based on ten indicators from. The results of observations and interviews were analyzed to determine the characteristics of students' work skills possessed by students.

## RESULTS AND DISCUSSION

The results of this study consist of two major parts, namely STEAM-H understanding and work skills based on the chicken wonton production process. Based on the results of the pretest and posttest, the average understanding of STEAM-H was obtained in the high category. Figure 2 below illustrates the percentage of students' N-Gain categories.

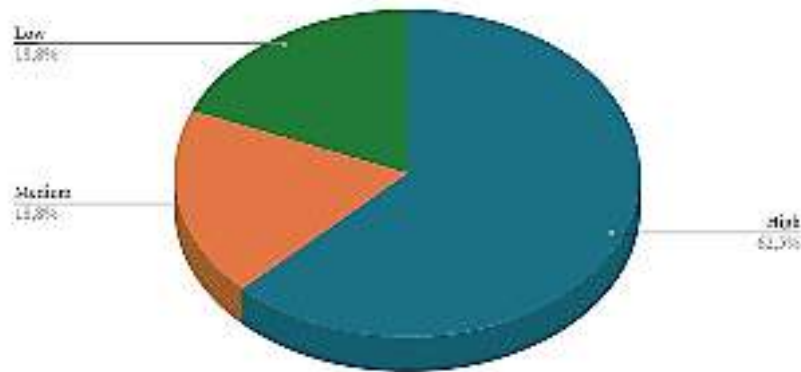


FIGURE 2. Percentage of N-Gain of Students' STEAM-H Understanding

The significant number of students who achieved a high level of understanding in STEAM-H cannot be overlooked, and their success is closely related to their experience in making chicken wontons. Research on STEAM-H in the field of education is still not very common. When we consider integrated learning such as STEM, we find numerous benefits for students engaging in specific projects. Studies indicate that STEM-based projects enhance students' grasp of scientific concepts, improve their problem-solving skills, and boost their motivation (13,14). It has also been observed that STEM-PjBL helps to develop students' scientific process skills, such as questioning, observing, formulating hypotheses, and communicating (15).

STEAM-H understanding can also be identified through observation and interviews related to students' work skills both explicitly and implicitly. The description of work skills consists of nine indicators, where virtual collaboration is not part of the work skills carried out in this project, all of which are carried out by students together in real-time in the same place. Therefore, the results presented only consist of sense-making, social intelligence, novel and adaptive thinking, cross-cultural competency, computational thinking, new-media literacy, transdisciplinarity, design mindset, and cognitive load management.



FIGURE 3. Chicken Wonton Production Process (a) Planning (b) Selection of Raw Materials (c) Material Refining (d) Boiling (e) Seasoning Making (f) Packaging

In this context, sense-making refers to students' ability to connect information, analyze it, and make relevant decisions for the chicken wonton processing project. This skill can be observed when students search for information and develop recipes. For instance, students search for information about the nutritional content of chicken wontons, particularly the protein from chicken meat and its health benefits, such as muscle growth and tissue repair. Specifically, groups 2 and 4 demonstrate sense-making by adjusting the recipe based on their experience. They choose not to use dried cayenne pepper due to familiarity with taste considerations. In contrast, groups 1 and 3 also display sense-making by adding dried cayenne pepper to create a different, spicier taste. This indicates their understanding of the impact of variation in cooking on taste. In process and technology planning, students are able to create a logical and efficient processing flow by considering the sequence of steps, time required for each stage, and the necessary equipment. Students also identify the technology that might be used, such as a blender for grinding meat or a digital scale for accurate ingredient measurement. Moreover, students' understanding of the protein denaturation process demonstrates their ability to relate scientific concepts to cooking practices. They understand that adding ice cubes when grinding meat can help maintain the meat's chewy texture.

The incident, in which groups 1, 2, 3, and 4 proposed alternatives for making wontons, such as creating various wonton shapes and using molds, demonstrates the presence of innovative and forward-thinking among students. The proposal to create various wonton shapes other than the traditional shape shows creativity and a willingness to think outside the box. Students are not only focused on a single shape but are willing to experiment with different designs to produce more interesting products. The suggestion by groups 2 and 4 to use wonton molds reflects forward-thinking in terms of time and efficiency. They recognize that by using tools such as molds, the wonton-making process can be accelerated without compromising on quality.

Sense-making is a critical process in learning, involving students actively connecting, analyzing, and making decisions based on information (16,17). It encompasses gap facing, defining, bridging, and resolution (16). In academic contexts, sense-making differs from everyday experiences and is discipline-specific, requiring teachers to employ various practices to position students as active sense-makers (18). Interactive learning environments, both technology-enhanced and collaborative, play a significant role in facilitating effective sense-making (16,19). Understanding collaborative sense-making processes in discovery-based learning environments can further enhance educational practices (19).

Social intelligence is a person's ability to interact, understand, and build good relationships with others. This ability is very important in various aspects of life, including working together in groups. Social intelligence is the ability to interact, understand, and build relationships with others effectively (20). When students divide tasks into groups, they demonstrate the ability to understand the role of each member and work together to achieve common goals. This shows an awareness of the strengths and weaknesses of individuals in the group. The interactions that occur during the wonton-making process, such as giving and receiving input, demonstrate the student's ability to communicate effectively. They are able to listen to others' opinions, provide constructive feedback, and work together to find the best solution.

Transdisciplinarity is the ability to connect and integrate concepts from various disciplines to solve problems or create new knowledge. Transdisciplinarity is an approach that integrates cross-disciplinary knowledge to solve complex problems and create new insights (21). In the wonton-making activity, students not only use cooking skills but also acquire knowledge from various other disciplines, especially mathematics. Students use mathematics to measure the amount of ingredients needed. They use units of measurement such as grams, milliliters, and tablespoons. Students do simple calculations such as addition to determine the total amount of ingredients needed. Students adjust the amount of ingredients using the concept of proportion. The cooking process involves chemical changes, such as protein denaturation when meat is ground and heated. Students also consider the nutritional value of the ingredients used, such as protein and vitamin content, and pay attention to aspects of food hygiene and sanitation to prevent contamination by microorganisms.

New media literacy refers to a person's ability to search for, evaluate, create, and communicate information using digital technology. This form of literacy includes the ability to access, analyze, evaluate, and create digital content in different contexts (22). Students make use of various digital platforms such as social media, particularly Google, and also rely on information from teachers. This demonstrates their ability to access information from diverse sources. In addition to searching for information, students also evaluate it by comparing information obtained from various sources with their existing knowledge or previous experience in making wontons. This ability to assess the credibility of information is a crucial aspect of new media literacy. Students also create promotional content in the form of templates containing information about their products (wontons), showcasing their ability to produce engaging and informative digital content.

A design mindset is a way of thinking that prioritizes the user in the design process. It involves understanding user needs, pinpointing issues, and creating innovative solutions. The design mindset is a crucial element in innovation and design practice, as it influences behavior and performance (23). Students realized that the most crucial part of the wonton is the filling, demonstrating their understanding of consumer preferences for taste and ingredient quality. The suggestions from groups 2 and 4 to add salt or powdered broth to the filling dough reflect their effort to enhance the taste and quality of the product, showing that students are aware and always seeking

ways to improve their products. Furthermore, students adhere to the planning of the wonton-making process, indicating their understanding of the importance of a clear work plan before production begins.

Cognitive load management refers to a person's ability to organize and manage the information entering their brain in order to focus on the task at hand. Cognitive Load Theory provides a framework for understanding and optimizing mental processing in working memory (24). During the task of making wontons, students were able to focus on the task at hand and were not distracted by irrelevant things. The use of timers and notes helped students manage their time and remember the steps that needed to be taken. These aids reduced the students' cognitive load, allowing them to focus more on the task at hand. Specifically, groups 2 and 4 identified the problem they faced, which was that the dumpling skin was too thin and easily torn. This shows their ability to filter information relevant to the task at hand. Identifying the problem with the dumpling skin shows that students are trying to understand why the problem occurs and find a solution. This is an example of an effort to maximize cognitive function.

Cross-cultural competence is the ability to interact and work with people from different cultural backgrounds. This ability includes understanding different values, customs, and perspectives. Students know that wontons originate from Chinese culture. This demonstrates a basic understanding of the origins of the food and the cultural context in which it originated. Students' knowledge of the health benefits of natural ingredients demonstrates an appreciation for local wisdom and traditional knowledge from different cultures. Many cultures have extensive knowledge of medicinal plants and healthy foods.

Computational thinking is the ability to think logically, systematically, and analytically, and to solve problems using computational concepts. Computational thinking is a cognitive process that involves solving problems using computational concepts (25). It includes skills such as systematic problem-solving, data analysis, algorithmic thinking, abstraction, and recognition. A wonton recipe is a simple algorithm that contains the steps and ingredients needed. Students translate this recipe into concrete actions. Calculating the amount of ingredients needed based on the desired number of servings is a simple example of data-based reasoning. Students perform calculations to ensure that all ingredients are available in sufficient quantities. Measuring ingredients such as flour, water, and meat, and then converting them to smaller units of measurement (e.g., grams or tablespoons) is the process of translating quantitative data into physical actions. Determining the selling price of a product (wontons) involves calculating production costs (raw materials, labor) and determining profit margins. This is another example of data-based reasoning.

The role of mathematics in this chicken wonton-making project turned out to be very crucial and involved various aspects. Computational and interdisciplinary thinking skills are key to solving the challenges that arise. Starting from the raw material preparation stage, the production process, to the final cost calculation, students are invited to apply mathematical concepts directly. For example, in designing a budget, each group must make careful calculations to determine the amount of raw materials needed and the cost of purchasing them. The results are also varied, as seen in Figure 1, where each group has a different cost estimate. This shows that mathematics is not just numbers, but also an effective tool for solving real problems in everyday life.

All descriptions of students' work skills led to the success of the four groups in producing chicken wontons, which is part of the learning outcomes of agricultural processing. STEAM-H knowledge support makes students think creatively, actively, and critically. Learning with the STEAM-H approach is quite promising to be implemented in other learning outcomes such as the production of processed vegetables and spices.

## CONCLUSION

This study successfully showed a significant increase in students' understanding of the STEAM-H concept after carrying out the chicken wonton production activity. Through this activity, students not only gain knowledge about science, technology, engineering, and mathematics but also develop various work skills that are relevant to the 21st century. The results of this study also show that the chicken wonton production activity can be an effective medium for developing various student work skills. Students have sense-making abilities, namely being able to connect the information obtained, analyze it, and make relevant decisions. Students have novel and adaptive thinking abilities by demonstrating creativity and the ability to think outside the box in designing products. Students have social intelligence abilities: which are characterized by being able to collaborate well in groups and communicate effectively. Students have transdisciplinarity abilities, namely being able to integrate concepts from various disciplines in solving problems. Students have design mindset abilities by demonstrating the ability to understand user needs and create innovative solutions. Students demonstrate computational thinking abilities by being able to translate data into abstract concepts and perform the necessary calculations. Students have new media literacy abilities by being able to search for, evaluate, and create digital content. The chicken wonton production activity also helps students develop cross-cultural competence through an understanding of the origins of food and the values contained therein.

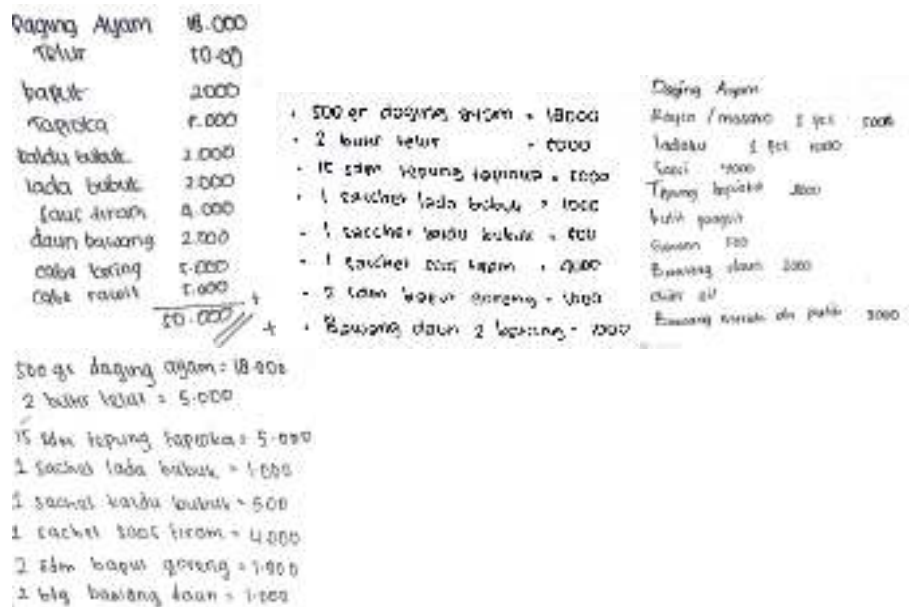


FIGURE 1. Student Response Examples

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## REFERENCES

1. Fatimah AT, Isyanto AY, Toto. Science, technology, engineering, agriculture, mathematics, and health in agribusiness curriculum. *International Journal of Evaluation and Research in Education (IJERE)*. 2023;12(4):2316–26.
2. Supiase M, Riswandi R, Sunyono S. Desain Project Based Learning Terintegrasi Stemm Untuk Meningkatkan Kemampuan Berwirausaha Siswa. *Akademika*. 2023;12(01).
3. Siti Nuryani H. Pembelajaran Berbasis Stem (Science Engineering Mathematics And Science) Untuk Meningkatkan Kemampuan Teknik Siswa. *Pendas : Jurnal Ilmiah Pendidikan Dasar*. 2022;6(2).
4. Higgins LM, Schroeter C, Wright C. Lighting the flame of entrepreneurship among agribusiness students. *International Food and Agribusiness Management Review*. 2018;21(1).
5. Subekti S. The Implementation of Work-Based Learning for the Development of Employability Skills of Vocational Secondary School Students Through Teamwork Activity. *Innovation of Vocational Technology Education*. 2019;15(1).
6. Subijanto, Sumantri D, Murdiyningrum AIDMY, Soroeida T. Kesesuaian Kurikulum SMK Dengan Kompetensi Yang Dibutuhkan Dunia Kerja: Kompetensi Keahlian Agribisnis Pengolahan Hasil Pertanian. *Kementerian Pendidikan dan Kebudayaan*. 2019.
7. Handayani MN, Ali M, Wahyudin D, Mukhidin M. Student's green skills in agricultural vocational school. In: *IOP Conference Series: Materials Science and Engineering*. 2020.
8. Cho WH, Choi JS. Sensory quality evaluation of superheated steam-treated chicken leg and breast meats with a combination of marination and hot smoking. *Foods*. 2021;10(8).
9. Oba PM, Utterback PL, Parsons CM, De Godoy MRC, Swanson KS. Chemical composition, true nutrient digestibility, and true metabolizable energy of chicken-based ingredients differing by processing method using the precision-fed cecectomized rooster assay. *J Anim Sci*. 2019;97(3).
10. Burrus J, Jackson T, Xi N, Steinberg J. Identifying The Most Important 21st Century Workforce Competencies: An Analysis Of The Occupational Information Network (O\*NET). *ETS Research Report Series*. 2013;2013(2).
11. Hawkins JN, Neubauer DE. Twenty-First Century Work Skills and Competencies. In: *International and Development Education*. 2015. p. 9–23.

12. Davies A, Devin F, Marina G. Future Work Skills 2020. Vol. 540, Institute for the Future for University of Phoenix Research Institute. 2011.
13. McGrath B, Sayres J, Lowes, S. &, Lin P. Underwater LEGO robotics as the vehicle to engage students in STEM: The BUILD IT project's first year of classroom implementation. International Conference of Engineering Education. 2008;
14. Saputra B, Sujarwanta A. Transformasi Pembelajaran Berbasis Proyek Science, Technology, Engineering And Mathematics Di Masa Pandemi Covid-19. *BIOLOVA*. 2021;2(1).
15. Bhakti YB, Astuti IAD, Okyranida IY, Asih DAS, Marhento G, Leonard L, et al. Integrated STEM Project Based Learning Implementation to Improve Student Science Process Skills. In: *Journal of Physics: Conference Series*. 2020.
16. Guo L, Jafri M, Williams PJ, Wang C. Students' sense-making in technology-enhanced interactive environments. *EMI Educ Media Int*. 2022;59(4).
17. Hardman J, Ovando CJ, Collier VP. Bilingual and ESL Classrooms: Teaching in Multicultural Contexts. *TESOL Quarterly*. 2000;34(1).
18. Fitzgerald MS, Palincsar AS. Teaching Practices That Support Student Sensemaking Across Grades and Disciplines: A Conceptual Review. *Review of Research in Education*. 2019;43(1).
19. Li X, Reynolds RB. An exploratory study of middle school students' sensemaking in a collaborative game design educational project. In: *Proceedings of the ASIST Annual Meeting*. 2013.
20. Sadiku MNO, Alam S, Musa SM. Social Intelligence: A Primer. *International Journal of Research - GRANTHAALAYAH*. 2019;7(9).
21. Appel J, Kim-Appel D. Towards A Transdisciplinary View: Innovations In Higher Education. In 2018.
22. Livingstone S. Media literacy and the challenge of new information and communication technologies. *Communication Review*. 2004;7(1).
23. Lavrsen JC, Daalhuizen J, Carbon CC. The Design Mindset Inventory (D-Mindset0): A Preliminary Instrument For Measuring Design Mindset. In: *Proceedings of the Design Society*. 2023.
24. Paas F, van Merriënboer JJG. Cognitive-Load Theory: Methods to Manage Working Memory Load in the Learning of Complex Tasks. *Curr Dir Psychol Sci*. 2020;29(4).
25. Rodríguez del Rey YA, Cawanga Cambinda IN, Deco C, Bender C, Avello-Martínez R, Villalba-Condori KO. Developing computational thinking with a module of solved problems. *Computer Applications in Engineering Education*. 2021;29(3).

# Forecasting Import-Export Volume and Value Using Support Vector Machines and Random Forests

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**Abstract.** National trade plays a crucial role in a country's economy by meeting the demand for goods and services. Imports and exports are vital components that significantly influence economic growth. This study aims to forecast and analyse the volume and value of imports and exports in the coming years, thereby helping the country to prepare for and enhance its competitiveness on the international stage. To achieve this, the study employs Support Vector Machine (SVM) and Random Forest methods, which have gained popularity for their high efficiency in handling classification and regression problems. These methods are particularly effective in producing accurate forecasts, especially when dealing with seasonal variations in data. The research also explores the potential of combining these methods for even more robust predictions. Additionally, the study considers external factors, such as global market trends and policy changes, which can influence trade dynamics. The findings of this research demonstrate the ability to predict future import and export volumes and values accurately. By comparing the error values in the form of Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE) from the model, it is proven that the SVM model is highly effective for export-import forecasting. Lower error values indicate higher prediction accuracy, highlighting the model's reliability in capturing complex trade dynamics. The insights from this study can be instrumental for policymakers and businesses in strategising for future trade activities, allowing them to make informed decisions that align with anticipated market shifts.

**Keywords:** *Forecasting, Ekspor, Impor, SVM, Random Forest, MAPE, RMSE, MAE.*

## INTRODUCTION

National trade is a crucial pillar in the global economy, enabling countries to meet the demand for goods and services(1). Two critical international trade activities, exports and imports, are fundamental components that indirectly influence economic growth(2). Both are essential, but accurate import-export forecasting plays a critical role in supporting government policymaking, preparing human resources, and establishing benchmarks for enhancing a country's competitiveness on the international stage(3). Therefore, precise forecasting of import-export volumes is of paramount importance. Imports represent an international business activity involving the entry of goods into a country's customs territory, in this case, Indonesia. These activities are undertaken by individuals or companies engaged in export-import transactions while adhering to applicable laws and regulations(4). Importing involves transporting goods and merchandise from one country to another, typically as part of international trade agreements. This process requires customs clearance in exporting and importing countries, ensuring the goods comply with all regulatory requirements. Imports play a vital role in international trade by fulfilling the domestic demand for goods that are either not produced locally or are insufficient to meet the population's needs. Moreover, importing goods in bulk can also be a strategic move for countries to access products at competitive prices, enhance the quality of life, and stimulate economic activity(5). As global supply chains become increasingly interconnected, the importance of efficient import processes and accurate forecasting grows, making it essential for countries to stay ahead in the competitive international market.

Exporting is selling goods and services from one country to another and serving as a primary source of income for many economies(6). By exporting, a country can expand the market for its domestic products, create jobs, and boost national income. Exports also contribute to economic diversification, enabling countries to reduce their reliance on domestic markets and mitigate financial risks(7). In today's globalised world, exporting has become increasingly important due to rising economic integration and strengthening international relationships. The export process involves not only economic factors but also political, social, and cultural considerations. Trade policies, international agreements, and government regulations significantly influence a country's ability to export goods and services. Moreover, shifts in global demand, emerging technologies, and innovations in production also play crucial roles in determining the competitiveness of export products(8). Understanding export potential is, therefore, essential for decision-makers who aim to formulate effective business strategies(9). A comprehensive grasp of the global market landscape allows countries to identify new opportunities, adapt to changes in consumer preferences, and leverage technological advancements(10). By fostering robust export strategies, nations can

enhance their economic resilience, secure a stable income stream, and position themselves favourably in the international market.

Forecasting is both an art and a science involving predicting future events based on historical data and mathematical models(11). It encompasses using scientific methods—rooted in technology and mathematics—to project future trends(12). However, forecasting is not exclusively based on scientific or structured procedures; it can also involve intuition and informal group discussions. The concept of Support Vector Machines (SVM) was introduced by Vapnik et al. in 1996(13). SVM is a versatile algorithm widely used for both classification and regression tasks. For regression, SVM operates on principles similar to classification but with some variations. It involves mapping input data into a high-dimensional space using kernel functions, which assist in finding optimal hyperplanes for separating data points(14). Several kernel functions can be employed for forecasting, including polynomial kernels, radial basis functions (RBFs), sigmoid functions, and linear functions. Each kernel function has its advantages depending on the nature of the data and the forecasting objectives(15). SVM is a supervised learning model investigating data to classify samples into distinct categories. Training algorithms for SVM build models that can accurately classify new datasets. SVM excels in linear and nonlinear classification and regression, demonstrating its robustness and adaptability in various machine-learning applications.

On the other hand, Random Forest offers significant advantages, including reduced overfitting and increased accuracy, by aggregating the predictions of multiple decision trees(16). This ensemble learning method handles complex data sets with numerous variables and intricate interactions. Applying machine learning methods, such as Random Forest, in forecasting import and export trends has gained traction among researchers worldwide(17). For example, a study by Zhang et al. (2020) in China demonstrates that the Random Forest model outperforms traditional linear models in predicting import trends. This advantage is particularly evident when dealing with large and complex datasets where simpler models do not easily capture interactions between variables (18). The effectiveness of the Random Forest method is attributed to its ability to average multiple decision trees, thereby reducing the risk of overfitting and enhancing predictive accuracy(19). However, achieving optimal performance with Random Forest requires careful parameter selection. Tuning parameters such as the number of trees, tree depth, and splitting criteria are crucial for maximising the model's accuracy. This research underscores the potential of Random Forest to improve forecasting precision across various contexts and highlights the importance of proper model configuration to leverage its full capabilities.

A technique known as the network search method is instrumental in identifying optimal parameters for models, which is crucial for accurately predicting unlabeled data, such as experimental datasets(20). This method is classified as a comprehensive approach because it first requires defining the type of prediction value being sought. It then evaluates and scores different parameter values to determine the most suitable one(21). The network search method is beneficial when the maximum desired value falls within a specified range defined by each independent variable's upper and lower bounds. For algorithms like Support Vector Machines (SVM) and Random Forest, employing network search techniques is essential for parameter optimisation (22). Network search systematically explores various parameter sets, allowing researchers to identify the combination that delivers the best model performance. This approach enables fine-tuning algorithms to achieve more accurate and reliable forecasting models. The ultimate goal is to enhance the model's predictive capabilities, leading to improved forecasting outcomes.

## RESEARCH METHODS

This study analyses and forecasts the volume and value of imports and exports using relevant historical data. The dataset for this study comprises import and export records from one of Indonesia's ports, spanning the years 2017 to 2021. Key variables considered in the forecasting model include the volume and Free on-board (FOB) value of imports and exports. The research begins with collecting historical data, which will be scrutinised for missing values and normalised for analysis. The cleaned data will then be used to build the forecasting model, while a separate test dataset will be utilised to evaluate the model's performance(23). Forecasting time series data can be approached through various methods. Traditional forecasting techniques often struggle to capture complex patterns in the data(19).

In this study, we employ Support Vector Machines (SVM) and Random Forests, enhanced through Grid Search, to address these challenges(24). Adopting these machine learning methods reflects their growing popularity and efficiency in solving classification and regression problems. This study aims to assess the effectiveness of these advanced seasonal regression methods for time series analysis(25). We strive to develop hybrid models combining SVM and Random Forest to assist the government in making informed decisions that could stimulate economic growth. Once the model is trained, its performance will be evaluated using the test dataset, with evaluation metrics focusing on the Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE) (26).

## RESULTS AND DISCUSSION

### Data Collection

The data presented in Table 1 and Table 2 provide a comprehensive view of import and export activities at one of Indonesia's ports from 2015 to 2021. Table 1 shows the historical figures for import and export volumes and their corresponding free-on-board (FOB) values. The volume data indicates the total quantity of goods handled through the port each year. At the same time, the FOB values represent the monetary worth of these goods at the point of shipment, excluding shipping and insurance costs. This historical data is crucial for identifying trends and patterns in trade activities over the years. For example, the volume of imports fluctuated from approximately 7.5 billion in 2015 to 19.9 billion in 2021, and the FOB values ranged from around 13.8 billion in 2015 to 20 billion in 2021, reflecting variations in trade value.

Table 2 shows the actual or target data for import and export volumes and FOB values. This table provides benchmarks for evaluating the forecasting models. The volume and FOB value figures presented here reflect the targets or observed outcomes that forecasting models aim to achieve. For instance, the volume of imports and exports in 2021 reached 24.7 billion and 12.7 billion, respectively, with FOB values of 24.8 billion and 23.7 billion. Comparing these figures with those in Table 1 allows for a critical assessment of forecasting accuracy. Table 1 is the foundation for developing and training forecasting models by offering historical data. In contrast, Table 2 provides the actual or target values necessary for evaluating the performance of these models. We can refine the models by analysing the differences between forecasted and actual values to enhance their accuracy and reliability in predicting future import and export volumes and values.

**TABLE 1.** Volume and Value of FOB Import and Export in 2015-2021

Tahun	Volume		FOB Value	
	Impor	Ekspor	Impor	Ekspor
2015	7.575.099.724	17.855.508.362	13.834.238.519	12.860.631.493
2016	12.860.631.493	18.745.023.600	13.593.078.453	13.225.617.968
2017	18.113.578.743	8.279.827.963	14.916.241.514	15.623.611.329
2018	16.329.264.807	8.917.386.074	16.229.591.088	14.795.634.023
2019	19.926.618.318	8.867.656.834	15.505.375.823	16.459.279.308
2020	17.598.146.661	9.335.942.648	15.637.718.463	14.292.945.130
2021	18.870.972.615	9.692.156.946	19.003.961.273	18.118.959.324

**TABLE 2.** Actual/Target Volume Data and FOB Value of Import Export

Year	Volume		FOB Value	
	Impose	Export	Impose	Export
2022	19.908.876.109	10.225.225.578	20.049.179.143	19.115.502.087
2023	21.003.864.295	10.787.612.985	21.151.883.996	20.166.854.702
2024	22.159.076.831	11.380.931.699	22.315.237.616	21.276.031.710
2025	23.377.826.057	12.006.882.942	23.542.575.685	22.446.213.454
2026	24.663.606.490	12.667.261.504	24.837.417.347	23.680.755.194

### Forecasting Analysis Using SVM

The last five years of the entire dataset were selected as the validation pool. Given the seasonal component, SVM is automatically run, setting seasonality as  $t=5$  (5-year calculation). The selected forecasting is then compared with the actual validation data. The comparison is shown in the figure.

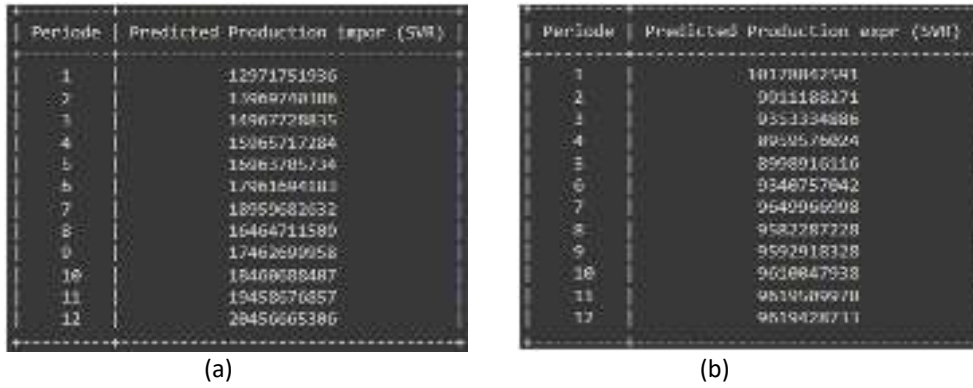


Figure 1. Volume Forecasting Results

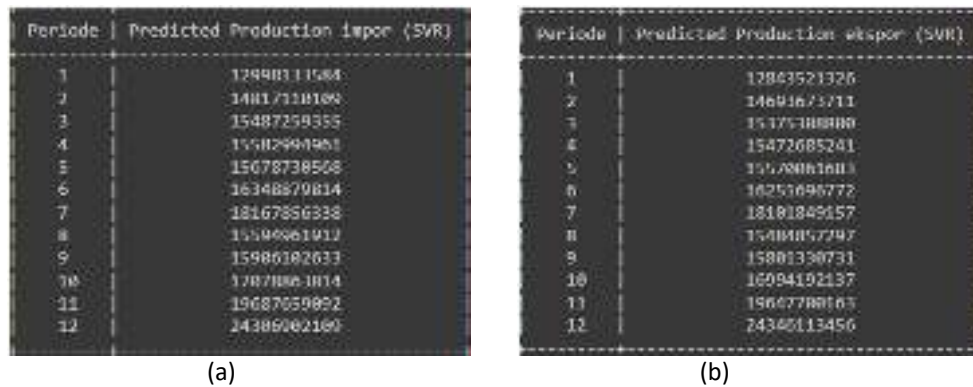


Figure 2. FOB Value Forecasting Results

The figure above presents the forecasting results using the Support Vector Machine (SVM) model for 2015 to 2026, focusing on the forecast for 2022 to 2026. The forecast predicts a continued increase in import volumes, which could signal a rise in domestic demand or changes in trade policies that encourage higher import levels. This upward trend suggests that ports and warehouses may need to adjust their capacities to effectively accommodate the growing import volumes. Conversely, the forecast for export volumes indicates stability with some improvement. This stability suggests consistent performance in the export sector and efficient export processes. This predictability in export volumes benefits ports as it supports more reliable planning and optimisation of export logistics.

The forecasted increase in the FOB value of imports points to rising import costs, which could be attributed to higher international commodity prices, increased import volumes, or elevated tariffs. This trend is crucial for monitoring, as rising import costs can impact the domestic economy. In contrast, the FOB value of exports shows some fluctuations, reflecting the influence of international market prices and varying commodity types. These fluctuations may necessitate adjustments in foreign markets' pricing strategies or product offerings.

Overall, the forecast results reveal a trend of increasing volumes for both imports and exports, with the export sector remaining relatively stable with minor fluctuations in FOB value. This information is vital for strategic planning by ports and logistics providers, allowing them to enhance operational capacity and efficiency in response to these trends. Policymakers can use this forecasting analysis to assess the economic impact of import and export trade changes and make informed decisions to support financial stability and growth.

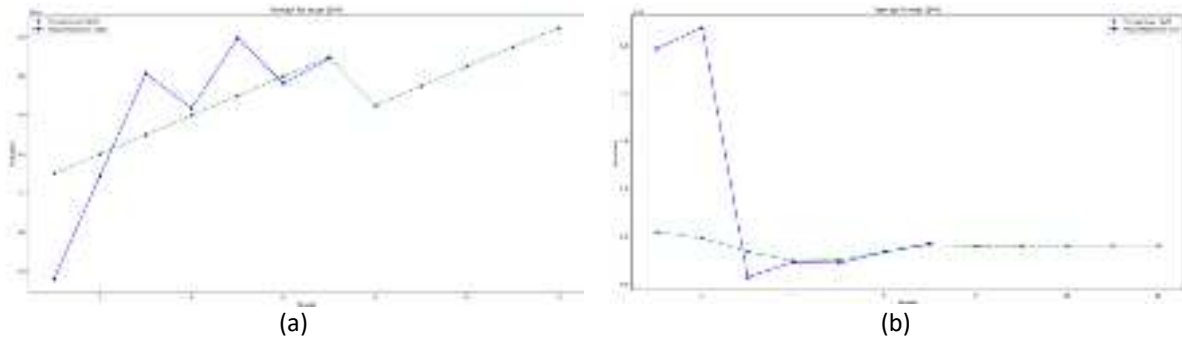


Figure 3. Volume Forecasting Results Chart

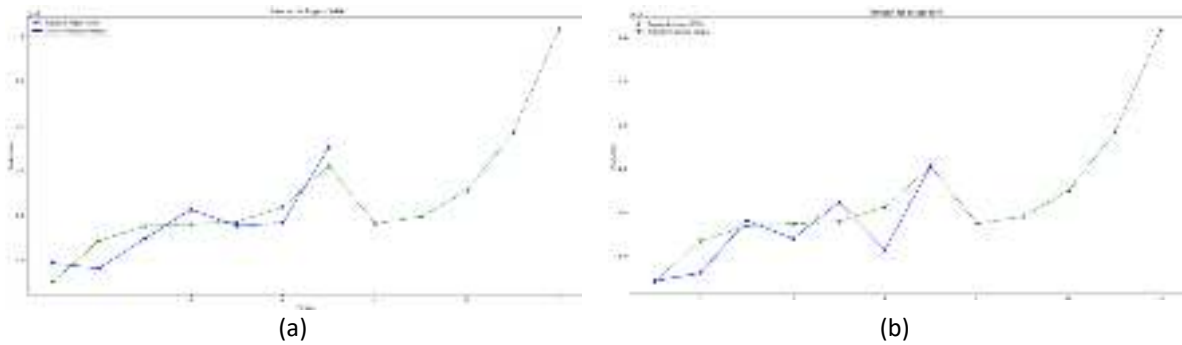


Figure 4. FOB Value Forecasting Results Chart

Based on Figures 3 and 4 display the forecast results for several bound variables. The subplots represent the forecast results for different periods. The subplot shows the general trend of the actual data (blue line) and the predicted data (green line). The comparison between these two lines provides an idea of how well forecasting models can capture historical patterns. Variations in data and predictions make it clear that some subplots show significant value fluctuations, which may reflect external factors affecting import-export activities.

### Forecasting Analysis with Random Forest Regressor

The historical data collection, which includes import and export volume and value, undergoes a preprocessing phase. This phase involves optimising the data using advanced methods to enhance the accuracy of forecasting models. Specifically, the process employs a technique that builds many decision trees, combining their results to improve overall accuracy and reduce observational errors. Grid search techniques are also utilised to find the optimal parameter combinations that yield the best forecasting results.

Periods	Predicted Production Input (RANDOM FOREST)	Periods	Predicted Production Input (RANDOM FOREST)
1	122798597232	1	14001371071
2	12945074219	2	14881370671
3	14531933988	3	12392710022
4	16757008457	4	10333250024
5	17937790494	5	9867587338
6	18139967365	6	7250738957
7	18339007267	7	9232710917
8	15240541768	8	17986480547
9	15240541768	9	12989789547
10	16323215003	10	13210702971
11	17384344700	11	4823887319
12	18131079672	12	745816885

Figure 5. Volume Forecasting Results

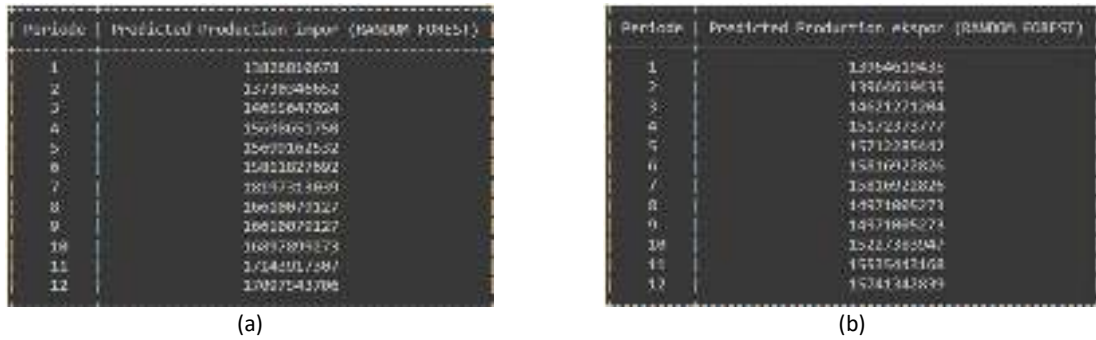


Figure 6. FOB Value Forecasting Results

The forecast of import volumes for the period 1-10 exhibits fluctuations, which may be attributed to seasonal factors. This indicates that the Random Forest model effectively captures variations in historical data, reflecting its robustness in handling temporal changes. In contrast, the export volume predictions for the same period, as generated by the NUGA model, reveal different dynamics. Some periods show significant spikes or drops, suggesting that the NUGA model identifies patterns or anomalies that differ from the historical trends.

Evaluating forecasting models involves comparing their predictions with historical data. If the forecasted values closely align with past trends and demonstrate accuracy in capturing variations, it indicates that the models have been well-optimized. Effective optimisation ensures the models can predict future trends based on historical patterns and current data.

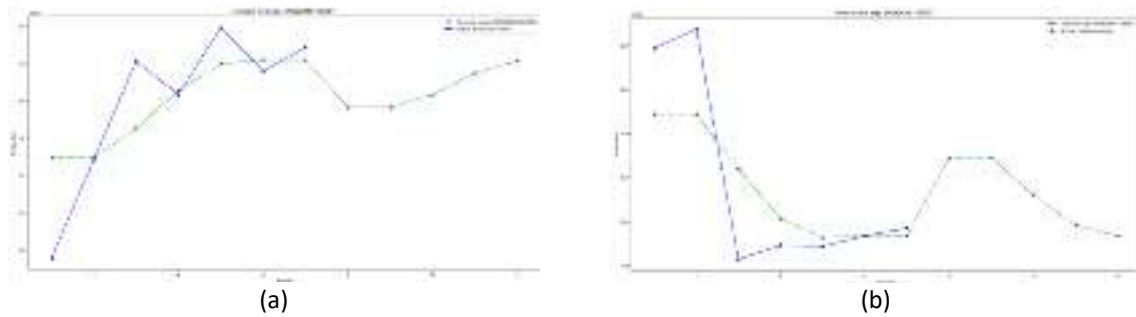


Figure 7. Volume Forecasting Results Chart

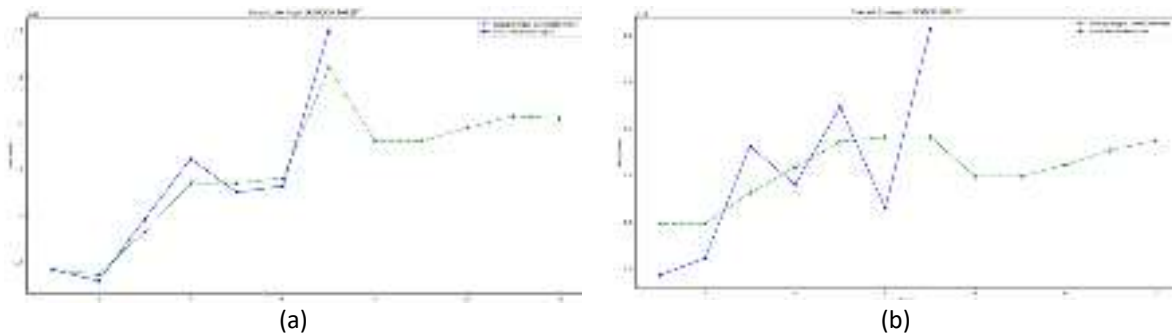


Figure 8. FOB Forecasting Results Chart

The graph reveals notable fluctuations in import volumes. The blue line, representing the actual data, displays sharp variations with distinct peaks and dips. In contrast, the predictions for import volumes show more stability, with the green line—indicating the model’s forecasts—generally aligning with the blue line over most of the period. This demonstrates that while the Random Forest model effectively captures broader trends in import volumes, it may not fully account for all the observed fluctuations.

For the FOB (Free on Board) values, the green line shows a trend closer to the blue line than the import volume predictions. This indicates that the model is more successful in capturing overall trends in FOB data. However,

there are still points where the predicted values deviate from the actual data, suggesting that the model might not fully capture some influencing factors affecting FOB values.

Overall, the graphical results suggest that the Random Forest model provides reasonably good predictions for import volumes and FOB values, but there is room for improvement. The fluctuations in the import volume graph highlight the need to explore additional variables or employ other techniques to enhance prediction accuracy. Similarly, while the FOB chart shows closer alignment between predictions and actual data, the existing deviations point to the complexity of the factors influencing FOB values, necessitating further evaluation and refinement of the model.

### MAPE Calculation on the Support Vector Machine (SVM) Method

Calculating MAPE (Mean Absolute Percentage Error) is crucial for evaluating forecasting accuracy. By determining the smallest MAPE, we can identify the most accurate method for predicting Indonesia's port import and export volumes for 2022-2026. To calculate MAPE, we need the forecasted and actual values from previous data processing. The following table presents the results of the MAPE calculation for the SVM model's import volume forecasts.

In addition to MAPE, two other evaluation metrics commonly used are MAE (Mean Absolute Error) and RMSE (Root Mean Square Error). MAE measures the average absolute difference between the predicted and actual values, providing a clear view of the forecast error magnitude. On the other hand, RMSE gives more weight to more significant errors, as it calculates the square root of the average squared error. By using these three metrics—MAPE, MAE, and RMSE—we can comprehensively assess the performance of the forecasting model and choose the most suitable method for analysing import and export volume data. The table below presents the error calculation results for the import volume forecast using the SVM model.

TABLE 3. Table of calculation results of Import Volume MAPE SVM Model

IMPOR					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	19.908.876.109	16.464.711.509	0,17	688.832.919,97	1,18623E+19
2023	21.003.864.295	17.462.699.959	0,17	708.232.867,16	1,25398E+19
2024	22.159.076.831	18.460.688.408	0,17	739.677.684,60	1,36781E+19
2025	23.377.826.057	19.458.676.857	0,17	783.829.839,95	1,53597E+19
2026	24.663.606.490	20.456.665.306	0,17	841.388.236,77	1,76984E+19
<b>EROR</b>			16,93%	3.761.961.548,45	3.771.956.419,30

TABLE 4. Table of SVM Model calculation results Export Volume MAPE

EKSPOR					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	10.225.225.578	9.582.287.228,00	0,06	642.938.350,03	4,1337E+17
2023	10.787.612.985	9.592.918.329,00	0,11	1.194.694.655,82	1,4273E+18
2024	11.380.931.699	9.610.047.938,00	0,16	1.770.883.760,99	3,13603E+18
2025	12.006.882.942	9.619.509.978,00	0,20	2.387.372.964,43	5,69955E+18
2026	12.667.261.504	9.619.428.734,00	0,24	3.047.832.770,26	9,28928E+18
<b>EROR</b>			15,37%	1.808.744.500,31	1.998.275.686,90

**TABLE 5.** Table of MAPE calculation results Import FOB Value SVM Model

IMPOR					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	20.049.179.143	15594961912	0,22	4.454.217.231,02	1,98401E+19
2023	21.151.883.996	15906102634	0,25	5.245.781.361,88	2,75182E+19
2024	22.315.237.616	17078863814	0,23	5.236.373.801,65	2,74196E+19
2025	23.542.575.685	19687659093	0,16	3.854.916.591,52	1,48604E+19
2026	24.837.417.347	24306902109	0,02	530.515.238,16	2,81446E+17
<b>EROR</b>			17,80%	3.864.360.844,85	4.240.747.862,67

**TABLE 6.** Table of MAPE calculation results FOB Export Value SVM Model

EKSPOR					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	19.115.502.087	15484857297	0,19	3.630.644.789,82	1,31816E+19
2023	20.166.854.702	15801330731	0,22	4.365.523.970,60	1,90578E+19
2024	21.276.031.710	16994192137	0,20	4.281.839.573,18	1,83342E+19
2025	22.446.213.454	19647700163	0,12	2.798.513.291,24	7,83168E+18
2026	23.680.755.194	24346113457	0,03	665.358.262,77	4,42702E+17
<b>EROR</b>			15,21%	3.148.375.977,52	3.430.682.425,33

Table 3 shows the MAPE, MAE, and RMSE results for forecasting import volumes using the SVM model. The MAPE values for import volumes range from 0.17 in 2022 to 0.17 in 2026, MAE values 688.832.919,97 in 2022 to 841.388.236,77 and RMSE values 1,18623E+19 in 2022 to 1,76984E+19, with an overall MAPE of 16,93%, MAE of 3.761.961.548,77 and RMSE of 3.771.956.419,3. This indicates that the model performs reasonably well but shows increased error in later years. The increase in error percentages over time suggests that while the model captures general trends, its accuracy diminishes as the forecast horizon extends. Thus, while the SVM model is effective for short-term forecasts, its predictive accuracy for more extended periods could be improved. Table 4 presents the MAPE, MAE, and RMSE calculation results for export volumes. The values fluctuate, with a minimum of 0.06 in 2022 and a maximum of 0,24 in 2026 to MAPE values, leading to an overall MAPE of 15.12, a minimum of 642.938.350,03 in 2022 and a maximum of 3.047.832.770,26 in 2026 to MAE values, leading to an overall MAE of 1.808.744.500,31 and a minimum of 1,4273E+18 in 2023 and a maximum of 9,28928E+18 in 2026 to RMSE values, leading to an overall RMSE of 1.998.275.686,90. This variation reflects the model's differing accuracy across years, with significant deviations observed, particularly in the later forecast periods. The model's performance indicates that while it can forecast export volumes with moderate accuracy, there are challenges in maintaining consistent precision significantly further into the forecast period.

Table 5 details the error results for import FOB values. The MAPE, MAE, and RMSE values for FOB forecasts overall were 17,80%, 3.864.360.844, and 4.240.747.862. Table 6 provides the MAPE results for export FOB values. The MAPE, MAE, and RMSE values for FOB forecasts overall were 15,21%, 3.148.375.977, and 3.430.682.425. The significant deviations reflect the complexity and volatility in international markets, which may not be fully captured by the model.

Overall, the consistent results of MAPE, MAE, and RMSE for both volume and FOB values indicate that SVM could be an effective forecasting model for better accuracy. However, these findings highlight the need for further model comparisons or alternative forecasting techniques to achieve better accuracy and reliability in long-term predictions.

## Error Calculation on the Random Forest Method

In forecasting import and export volumes and FOB values, it is crucial to evaluate the accuracy of different models to determine the most reliable method for predicting future trends. This evaluation is typically conducted using the Mean Absolute Percentage Error (MAPE), which measures forecast accuracy by comparing the predicted values with the actual data. The following tables present the MAPE calculation results for the SVM and Random Forest models, focusing on import and export volumes and FOB values from 2022 to 2026. These results offer insights into the performance of each model and highlight areas for potential improvement.

In addition to MAPE, two other evaluation metrics commonly used in forecasting are Mean Absolute Error (MAE) and Root Mean Square Error (RMSE). MAE measures the average absolute difference between the predicted and actual values, providing a simple measure of the prediction error without considering the direction of the error. RMSE, on the other hand, calculates the square root of the average squared error, making it more sensitive to more significant errors or outliers. By combining MAPE, MAE, and RMSE, we can obtain a more comprehensive view of the model's performance and determine which model provides the most accurate predictions for import, export, and FOB value trends.

**TABLE 7.** Table of MAPE calculation results of Import Volume of Random Forest Model

IMPOR					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	19.908.876.109	15.646.441.748	0,21	4.262.434.360,83	1,81683E+19
2023	21.003.864.295	15.646.441.748	0,26	5.357.422.546,81	2,8702E+19
2024	22.159.076.831	16.323.215.008	0,26	5.835.861.823,02	3,40573E+19
2025	23.377.826.057	17.484.344.390	0,25	5.893.481.666,73	3,47331E+19
2026	24.663.606.490	18.126.269.673	0,27	6.537.336.816,85	4,27368E+19
<b>EROR</b>			24,99%	5.577.307.442,85	5.628.454.584,62

**TABLE 8.** Table of MAPE Random Forest Model Export Volume calculation results

EKSPORT					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	10.225.225.578	12906980588	0,26	2.681.755.009,97	7,19181E+18
2023	10.787.612.985	12906980588	0,20	2.119.367.603,18	4,49172E+18
2024	11.380.931.699	11210982992	0,01	169.948.706,99	2,88826E+16
2025	12.006.882.942	9833886339	0,18	2.172.996.603,43	4,72191E+18
2026	12.667.261.504	9358869805	0,26	3.308.391.699,26	1,09455E+19
<b>EROR</b>			18,32%	2.090.491.924,57	2.340.076.127,32

**TABLE 9.** Table of MAPE calculation results Import FOB Value Random Forest Model

IMPORT					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	20.049.179.143	16.610.079.127	0,17	3.439.100.016,02	1,18274E+19
2023	21.151.883.996	16.610.079.127	0,21	4.541.804.868,88	2,0628E+19
2024	22.315.237.616	16.897.899.274	0,24	5.417.338.341,65	2,93476E+19
2025	23.542.575.685	17.143.917.307	0,27	6.398.658.377,52	4,09428E+19
2026	24.837.417.347	17.097.543.707	0,31	7.739.873.640,16	5,99056E+19
<b>EROR</b>			24,25%	5.507.355.048,85	5.703.532.731,44

**TABLE 10.** Table of MAPE calculation results FOB Export Value Random Forest Model

EKSPOR					
TAHUN	TARGET/ACTUAL	FORECAST	MAPE	MAE	RMSE
2022	19.115.502.087	14971005273	0,22	4.144.496.813,82	1,71769E+19
2023	20.166.854.702	14971005273	0,26	5.195.849.428,60	2,69969E+19
2024	21.276.031.710	15227383948	0,28	6.048.647.762,18	3,65861E+19
2025	22.446.213.454	15535443169	0,31	6.910.770.285,24	4,77587E+19
2026	23.680.755.194	15741342840	0,34	7.939.412.354,23	6,30343E+19
<b>EROR</b>			28,04%	6.047.835.328,81	6.189.553.446,59

Table 7 presents the error results for forecasting import volumes using the Random Forest model. The MAPE values range from 0,21 in 2022 to 0,27 in 2026, with an overall MAPE of 24,99%. The MAE values range from 4.262.434.360,83 in 2022 to 6.537.336.816,85 in 2026, with an overall MAE of 5.577.307.442,85. The RMSE values range from 1,81683E+19 in 2022 to 4,27368E+19 in 2026, with an overall RMSE of 5.628.454.584,62. This indicates that the Random Forest model shows a higher average error than the SVM. The increase in error percentages over time suggests that while the model is reasonably good at predicting short-term trends, its performance deteriorates for longer-term forecasts. The fluctuations in error rates highlight the need for additional tuning or incorporating more sophisticated features to improve accuracy. Table 8 shows the Error results for export volume forecasts using the Random Forest model. The MAPE values range from 0,26 in 2022 to 0,26 in 2026, with an overall MAPE of 18,32%. The MAE values range from 2.681.755.009,97 in 2022 to 3.308.391.699,26 in 2026, with an overall MAE of 2.090.491.924,57. The RMSE values range from 7,19181E+18 in 2022 to 1,09455E+19 in 2026, with an overall RMSE of 2.340.076.127,32. The higher error percentages compared to the SVM model suggest that the Random Forest model may not capture export volume trends as effectively, potentially due to its handling of seasonal or other complex factors influencing export volumes.

Table 9 details the error results for import FOB values the Random Forest model predicted. The MAPE values range from 0,17 in 2022 to 0,31 in 2026, with an overall MAPE of 24,25%. The MAE values range from 3.439.100.016,02 in 2022 to 7.739.873.640,16 in 2026, with an overall MAE of 5.507.355.048,85. The RMSE values range from 1,18274E+19 in 2022 to 5,99056E+19 in 2026, with an overall RMSE of 5.703.532.731,44. This higher error indicates that forecasting FOB values using the Random Forest model is more challenging, with considerable errors observed throughout the forecast period. Table 10 provides the Error results for export FOB values using the Random Forest model. The MAPE values range from 0,22 in 2022 to 0,34 in 2026, with an overall MAPE of 28,04%. The MAE values range from 4.144.496.813,82 in 2022 to .939.412.354,23 in 2026, with an overall MAE of 6.047.835.328,81. The RMSE values range from 1,71769E+19 in 2022 to 6,30343E+19 in 2026, with an overall RMSE of 6.189.553.446,59. The higher error rates suggest that the Random Forest model may not be well-suited for capturing the nuances of FOB value fluctuations, possibly due to insufficient handling of market price variability or other external factors.

Overall, the higher error values for ekspor impor forecasts forecasting aspects reveal that while the SVM model is effective to some extent, there are noticeable areas where it falls short compared to the Random Forest model. The higher error values for ekspor impor forecasts indicate a need for further refinement in the model or consideration of alternative forecasting methods to enhance accuracy and reliability in long-term predictions.

### Comparison of MAPE SVM and Random Forest

Error is a critical metric for evaluating the forecasting accuracy of different models. It quantifies prediction error as a percentage of the actual value, with smaller values indicating better accuracy. This comparison highlights the performance of the Support Vector Machine (SVM) and Random Forest models in forecasting import and export volumes and FOB (Free on Board) values.

TABLE 11. Error Volume Impor

Metode Peramalan	MAPE	MAE	RMSE
<b>SVM</b>	16,93%	3.761.961.548,45	3.771.956.419,30
<b>Random Forest</b>	24,99%	5.577.307.442,85	5.628.454.584,62

TABLE 12. Error Volume Ekspor

Metode Peramalan	MAPE	MAE	RMSE
<b>SVM</b>	15,37%	1.808.744.500,31	1.998.275.686,90
<b>Random Forest</b>	18,32%	2.090.491.924,57	2.340.076.127,32

TABLE 13. Error FOB Impor

Metode Peramalan	MAPE	MAE	RMSE
<b>SVM</b>	17,80%	3.864.360.844,85	4.240.747.862,67
<b>Random Forest</b>	24,25%	5.507.355.048,85	5.703.532.731,44

TABLE 14. Error FOB Ekspor

Metode Peramalan	MAPE	MAE	RMSE
<b>SVM</b>	15,21%	3.148.375.977,52	3.430.682.425,33
<b>Random Forest</b>	28,04%	6.047.835.328,81	6.189.553.446,59

Table 11 summarises the error results for the import forecasts. For import volumes, the SVM model achieved a MAPE of 16,93%, MAE of 3.761.961.548,45 and RMSE 1.998.275.686,90, which is lower than the MAPE of 18,32%, MAE of 2.090.491.924,57 and RMSE 2.340.076.127,32 obtained using the Random Forest model. This suggests that the SVM model provides more accurate predictions for import volumes. In the performance analysis, MAPE, MAE, and RMSE values for the Support Vector Machine (SVM) model are lower than those for the Random Forest model. This indicates that the SVM model can make more accurate predictions with minor errors. The reduction in these values reflects the efficiency of the SVM model in handling the given data. Therefore, SVM demonstrates better performance in this context. In conclusion, the SVM model is recommended for applications requiring high accuracy. From the comparison, the SVM model consistently outperforms the Random Forest model in predicting import and export volumes, as evidenced by its lower MAPE values. This suggests the SVM model is generally better at capturing trends and making more accurate volume forecasts. Overall, the choice of model may depend on the specific forecasting requirements and the data characteristics. SVM is superior to Random Forest in situations where non-linear patterns dominate, the dataset is smaller, or there are many relevant features to predict. However, the performance of each model heavily depends on the specific dataset used, so it is always wise to compare their performance using metrics like MAPE, MAE, and RMSE before concluding. Further refinement and exploration of additional features or hybrid approaches could enhance the accuracy of both models.

## CONCLUSION

This study concludes that the SVM (Support Vector Machine) model outperforms the Random Forest model for predicting the volume and value of imports and exports in the coming years. The SVM (Support Vector Machine) model demonstrates superior accuracy, as evidenced by its lower error values in forecasting import and export volumes and FOB values. This finding underscores the effectiveness of SVM in capturing complex patterns in the data compared to random Forest. The application of Param Grid techniques has enhanced our understanding of the influence of input features on model predictions, offering valuable insights

into optimising model performance. By systematically exploring various parameter combinations, the Param Grid method has contributed significantly to improving the accuracy of forecasts, aligning with the growing recognition of the importance of precise model selection for reliable estimates.

Looking ahead, future research could benefit from several avenues of exploration. First, further refinement of the SVM model could be pursued to enhance its predictive capabilities, possibly by incorporating additional features or employing advanced tuning techniques. Second, expanding the analysis to include a broader range of import and export categories may provide a more comprehensive understanding of forecasting dynamics across different sectors. The third addition of variables is intended to compare error results to achieve higher accuracy. Lastly, applying the Param Grid method to other forecasting models could offer comparative insights and validate its effectiveness across diverse contexts. This study provides practical insights for policymakers, government agencies, and customs officials. By leveraging the strengths of the Random Forest model and exploring further refinements and applications, stakeholders can make more informed decisions and develop strategies to optimise trade operations and economic planning.

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### REFERENCE

1. Chalid DA, Cokrodiharjo VR. Peramalan Harga Saham Menggunakan Metode Support Vector Machine (SVM). *Jurnal Pasar Modal dan Bisnis*. 2021 Feb 25;3(1):61–74.
2. Pramana MW, Purnamasari I, Prangga S, Universitas ), Kuaro MJ, Kelua G, et al. Peramalan Data Ekspor Nonmigas Provinsi Kalimantan Timur menggunakan Metode Weighted Fuzzy Time Series Lee [Internet]. Vol. 14. 2021. Available from: [www.unipasby.ac.id](http://www.unipasby.ac.id)
3. Chalid DA, Cokrodiharjo VR. Peramalan Harga Saham Menggunakan Metode Support Vector Machine (SVM). *Jurnal Pasar Modal dan Bisnis*. 2021 Feb 25;3(1):61–74.
4. Ahwan A. Forecasting of Export and Import Value of Industrial in Indonesia based on Monte Carlo Algorithm. Vol. 176, *International Journal of Computer Applications*. 2020.
5. Hauptmann A, Schmerer HJ, Schwanebeck B. Plant-level adjustments to imports and exports at the extensive margin. *China Economic Review*. 2024 Oct 1;87.
6. Dave E, Leonardo A, Jeanice M, Hanafiah N. Forecasting Indonesia Exports using a Hybrid Model ARIMA-LSTM. In: *Procedia Computer Science*. Elsevier B.V.; 2021. p. 480–7.
7. Hauptmann A, Schmerer HJ, Schwanebeck B. Plant-level adjustments to imports and exports at the extensive margin. *China Economic Review*. 2024 Oct 1;87.
8. Purwoko CFF, Sediono S, Saifudin T, Mardianto MFF. Prediksi Harga Ekspor Non Migas di Indonesia Berdasarkan Metode Estimator Deret Fourier dan Support Vector Regression. *Inferensi*. 2023 Mar 29;6(1):45.
9. Yolanda Agatha S, Nurkhamid M, Tipe Madya Pabean Juanda K, Keuangan Negara STAN P, Sektor B V, Selatan T. HIT RATE PEMERIKSAAN BARANG BAWAAN PENUMPANG: PENDEKATAN DATA MINING. *Jurnal Perspektif Bea dan Cukai*. 2022;6(1):2022.
10. Mei J, He D, Harley R, Habetler T, Qu G. A random forest method for real-time price forecasting in New York electricity market. In: *IEEE Power and Energy Society General Meeting*. IEEE Computer Society; 2014.
11. Rum IA, Tukker A, de Koning A, Yusuf AA. Impact assessment of the EU import ban on Indonesian palm oil: Using environmental extended multi-scale MRIO. *Science of the Total Environment*. 2022 Dec 20;853.
12. Petropoulos F, Apiletti D, Assimakopoulos V, Babai MZ, Barrow DK, Ben Taieb S, et al. Forecasting: theory and practice. Vol. 38, *International Journal of Forecasting*. Elsevier B.V.; 2022. p. 705–871.
13. Ameri R, Hsu CC, Band SS, Zamani M, Shu CM, Khorsandroo S. Forecasting PM 2.5 concentration based on integrating of CEEMDAN decomposition method with SVM and LSTM. *Ecotoxicol Environ Saf*. 2023 Nov 1;266.

14. Joachims T. Making large scale SVM learning practical. 1999; Available from: <http://www-ai.informatik.uni-dortmund.de/ls8-reports.html>
15. Sinulingga MA, Asih D, Maruddani I, Hoyyi A, Statistika D, Sains F, et al. VECTOR AUTOREGRESSIVE STABILITY CONDITION CHECK UNTUK PEMODELAN DAN PREDIKSI SUMBER PENERIMAAN PABEAN BELAWAN. JURNAL GAUSSIAN [Internet]. 2020;9(2):193–203. Available from: <https://ejournal3.undip.ac.id/index.php/gaussian/>
16. Gatera A, Kuradusenge M, Bajpai G, Mikeka C, Shrivastava S. Comparison of random forest and support vector machine regression models for forecasting road accidents. *Sci Afr.* 2023 Sep 1;21.
17. Gatera A, Kuradusenge M, Bajpai G, Mikeka C, Shrivastava S. Comparison of random forest and support vector machine regression models for forecasting road accidents. *Sci Afr.* 2023 Sep 1;21.
18. Ren Y, Zhang L, Suganthan PN. Ensemble Classification and Regression-Recent Developments, Applications and Future Directions [Review Article]. Vol. 11, *IEEE Computational Intelligence Magazine*. Institute of Electrical and Electronics Engineers Inc.; 2016. p. 41–53.
19. RAMADHAN MM, SITANGGANG IS, NASUTION FR, GHIFARI A. Parameter Tuning in Random Forest Based on Grid Search Method for Gender Classification Based on Voice Frequency. *DEStech Transactions on Computer Science and Engineering*. 2017 Oct 10;(cece).
20. Semarang. PROCEEDING SEMINAR NASIONAL SCIENCE AND ENGINEERING 2016 “ Quantum Technology for Better Future” Eco-friendly Manufacturing, Design and Construction Methods. 2016.
21. FORECASTING KEBERANGKATAN PENUMPANGDOMESTIKDIBANDARA NGURAH RAI BALI PERIODE 2014 – 2018DENGAN METODE ARIMA.
22. Soewignjo S, Septia Sari NWW, Mediani AP, Kamil MAZ, Amelia D, Chamidah N. CHINESE YUAN EXCHANGE RATE AGAINST THE INDONESIAN RUPIAH PREDICTION USING SUPPORT VECTOR REGRESSION. *BAREKENG: Jurnal Ilmu Matematika dan Terapan* [Internet]. 2024 Aug 2;18(3):1683–94. Available from: <https://ojs3.unpatti.ac.id/index.php/barekeng/article/view/12217>
23. Verleysen Michel. 12th European Symposium on Artificial Neural Networks, ESANN 2004 : Bruges, Belgium, April 28-30, 2004. D-side; 2004. 575 p.
24. Kecman V. Support Vector Machines – An Introduction. In 2005. p. 1–47.
25. Fitri E, Riana D. ANALISA PERBANDINGAN MODEL PREDICTION DALAM PREDIKSI HARGA SAHAM MENGGUNAKAN METODE LINEAR REGRESSION, RANDOM FOREST REGRESSION DAN MULTILAYER PERCEPTRON. *METHOMIKA Jurnal Manajemen Informatika dan Komputerisasi Akuntansi* [Internet]. 2022 Apr 30;6(1):69–78. Available from: <https://ejurnal.methodist.ac.id/index.php/methomika/article/view/926>
26. Rute M, Listrik Heterogen K. Asumsi dan Notasi HEVRP PERNYATAAN MASALAH.

# Didactics Transposition in Mathematics Learning that Facilitates Students' Statistical Literacy

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**Abstract.** Didactic transposition is the process of transferring knowledge from scientific sources to experts, which is then used by teachers in the learning process in educational units. This study aims to describe the use of didactic transposition as a means of student learning and mathematics learning that facilitates students' statistical literacy. This type of research is qualitative research with the summative content analysis method. The data source used comes from literature studies indexed by Scopus, both journals and international conference proceedings. The data analysis technique uses four stages, namely: selecting, comparing, combining, and sorting until relevant meanings are found in knowledge related to didactic transposition and statistical literacy. The results of the study of the literature of relevant Scopus-indexed journals stated that the use of didactic transposition as a means of learning for students that facilitates their statistical literacy can increase enthusiasm in learning mathematics and have an impact on the ease of students understanding what is conveyed by the teacher.

## INTRODUCTION

Learning activities by integrating the approach with the concept of didactic transposition are very important because the systematic process of knowledge transfer [1] can be used to develop and analyze teaching materials [2]. Didactic transposition allows researchers to analyze the teaching materials presented in teaching modules and other learning resources. The analysis will reveal whether the teaching materials taught by teachers in the classroom are oriented to learning objectives or not, whether they are appropriate or not when reviewed from the learning design [3], student conditions, curriculum, and students' mathematical scholarly knowledge [4].

The concept of didactic transposition has the term *noosphere* which can be interpreted as the space of human knowledge. A group of human beings is semantically referred to as society and the composition of the association which together consists of human beings, namely teachers and students. The existence of the society is a forum for developing teaching materials that can facilitate statistical literacy for students through the concept of didactic transposition, namely building bridges on *scholarly knowledge* [5] and *knowledge to be taught* with *taught knowledge* [6]. This can provide space for teachers to develop strategies to overcome the gap, which is further known as *learning obstacles*, so that they can improve the quality of learning.

Through didactic transposition, it is also used to analyze teachers' knowledge of teaching materials based on the principles of scientific knowledge conceptually (Arzarello, et.al., 2004). If the mathematical knowledge possessed by students and teachers is in accordance with scientific knowledge conceptually and the curriculum that is the reference for learning [7], then the teaching and learning process activities between teachers and students can reduce student learning obstacles caused by teaching materials (Jamilah, et.al., 2020).

According to Chevallard, didactic transposition is a process of changing from original knowledge, for example, science at the university level to an easy form to teach for students [8]. This didactic transposition process involves several accompanying processes, such as adaptation, simplification, and reorganization of knowledge from subject matter that has been adapted to the needs and cognitive development of students and learning objectives (Brousseau, 1997; Bergsten et al., 2010). The process of transferring knowledge that is scientific or created by experts to knowledge applied by teachers to the learning process is known as didactic transposition (Brousseau, 1997; Chevallard, 1989). Figure 1 presents the didactic transposition process that occurs for a teacher.

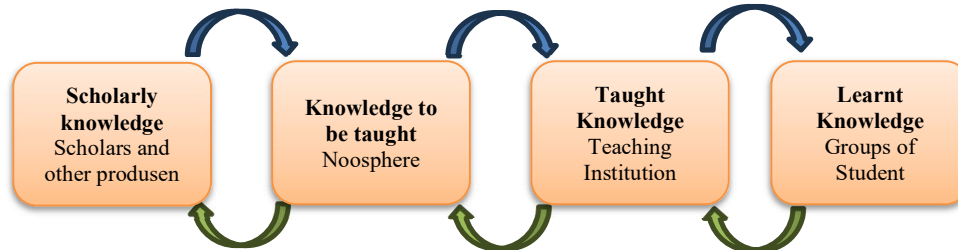


Figure 1. The process of didactic transposition

Figure 1 explains that there are several stages in the didactic transposition process which are described as follows.

- Scholarly knowledge* (scientific knowledge) is knowledge that comes from experts and researchers in their fields, for example mathematicians. This scientific knowledge is academic and tends not to be easily understood by students at the school level [11].
- Knowledge to be taught* (knowledge to be taught). In this step, the scientific knowledge that has been selected and determined, then adapted and modified to be suitable for teaching [3]. This process goes through steps of simplification, the use of relevant examples, and the reorganization of the material to make it easy for students to understand.
- Taught knowledge* (knowledge taught). At this stage, the knowledge that has been adapted and modified is then used by teachers to carry out the learning process in certain educational institutions (schools, universities, or others) [3]. The existence of a curriculum that regulates the needs of how the process of teaching knowledge to be taught, the use of teaching methods, and interaction between teachers and students are also some of the factors that affect how the knowledge is received by students.

*Learnt Knowledge* (Knowledge learned). The final stage of the didactic transposition process, students internalize knowledge from what has been taught by the teacher [11]. The knowledge internalized by these students can be in the form of skills, concepts, or values obtained during the learning process.

Based on the important role of didactic transposition, this study describes the process of didactic transposition in mathematics learning for students that facilitates the development of their statistical literacy. In addition, by looking at the learning obstacles experienced by students in learning mathematics caused by teaching materials or inappropriate concept delivery structures, it is necessary to conduct an in-depth study related to the preparation of efficient teaching material systematics so that it can make the design in the learning process more effective. In addition, teachers need to pay attention to *the learning trajectory* process of students so that it can be designed in learning tools in designing learning.

## METHOD

This type of research is qualitative research with the summative content analysis method. Content analysis is used to produce an objective and systematic description of the content contained in the text media. Content analysis is also interpreted as a systematic technique to analyze the meaning of a message and how to express a message. Initially, content analysis developed in the realm of communication and health sciences, but in its development it is now used in various fields of science. The content analysis has objectives including: 1) describing the tendency of the content of communication/messages, 2) tracking the development of knowledge, 3) detecting the existence of propaganda or hidden ideology, 4) identifying the intention and nature of communicators/writers. The essence of a content analysis is to find out the content and intent of a text. Descriptive studies in this case are needed to find out the content, while to find out the meaning of the text is carried out by making inferences and interpretations based on the analytical construct that is built.

The steps used in this content analysis method are presented in the following figure 2.



Figure 2. Stages of content analysis research

1. Identify the research question: develop research questions that are appropriate to the research theme and topic
2. Define the population: at this stage, the researcher looks at the population used so that it can be used to make references to all members.
3. Select the research design: There are several steps taken at this stage, namely: selecting literature with analysis that is appropriate to the research question, creating a coding scheme, developing a coding system.
4. Gather data: Data collection is carried out by selecting, comparing, combining, and sorting information that is appropriate to the research question. Researchers must try
5. avoid personal subjectivity.

Interpreting and reporting: This stage requires checking all the data obtained and combining the appropriate information to answer the research questions. The result of this interpreting stage is a comprehensive report with a focus on understanding didactic transposition and mathematics learning in statistics material and can be a recommendation for further research topics and potential improvements in mathematics teaching that facilitates students' statistical literacy.

## RESULT AND DISCUSSION

### Result

The results of this analysis content research produced an analysis of various 8 studies indexed by Scopus by comparing the research objectives, samples and research designs used in the study, which are presented in the following table 1.

**Table 1.** Comparison of research objectives, samples, and design

Title of Paper	Objective	Sample	Research Design
The faculty development model of the University of MilanBicocca: towards an integration of general and disciplinary didactics [12]	Describe the training structure of the faculty development program at the University of Milan-Bicocca through large classroom teaching workshops	More than 200 professors, data taken since June 2017	Qualitative research, case studies, use participatory evaluation and feedback from participants.
The process of proof in the geometric workspace: Initial training teachers [13]	Learn how beginner teachers relate their knowledge of the process of proofing in geometry between high school and university contexts.	19 teaching practice students and 25 first-year students who failed in the Geometry course.	Qualitative research using interviews, questionnaires, surveys, and document analysis
Initial training in the teaching master: Reflections around the implementation of a didactic proposal for a reading and literary education [14]	Analyze the impact of the master of education program (MAES) on the formation of student teaching practices	One MAES student, a 3rd grade high school student, a tutor and a practice supervisor	Qualitative research, case studies, using questionnaires, field journals, direct observations, and discussions with practice tutors.

Title of Paper	Objective	Sample	Research Design
Evolution of Didacticists' meta-didactical Praxeologies and Documentation Work [15]	Understand the relationship between lecturers' meta-didactic praxeology to design and execute teacher professional development (PD) programs and their documentation work for the program itself	Two lecturers and 17 junior high school mathematics teachers.	Instrumental case studies using data from worksheets, slides, video transcripts, and teacher protocols
Resources and Praxeologies Involved in Teachers' Design of an Interdisciplinary STEAM Activity [16]	Examine the collaborative design of interdisciplinary STEAM activities conducted by junior high school teachers from various disciplines	4 teachers (art, music, technology, and math/science)	Case studies involving semi-structured oral interviews; data analysis using a combination of Documentation on Didactic and Meta-Didactic Transposition
Consistency between the teaching strategies and the curricular beliefs of teachers second cycle from educational activities [17]	Descriptively reveal the coherence/incoherence between didactic strategies and curricular beliefs in senior teachers.	16 Primary School Teachers	Descriptive qualitative research with a hermeneutic approach

In addition, the next stage of research is to analyze the content based on the results and limitations of the research presented in table 2 below. (The order of content analysis has been adjusted to the order in table 1 above)

**Table 2.** Comparison of results and limitations of the study

Result	Limitation
Inter- and transdisciplinary approaches are important for the interlinkage of the three principles of training development design in the faculty. Dialogue between disciplines supports the development of didactic skills. Workshops encourage self-reflection and teaching practice. The program has been expanded [12].	A single case study limits generalizations. It does not discuss the evaluation of the success of the program. Focus on the lecturer's perspective
Students of teaching practice show instability in understanding proof, often switching between paradigms. Visualization affects their reasoning. There is a mismatch between how proof is treated in universities and high schools. Students often rely on pragmatic evidence [13].	Small sample sizes limit generalizations. Focus on geometry, findings may not be transferable to other domains. It does not discuss the practical implications for teacher education program design.
The implementation of didactic units has succeeded in increasing student interest and engagement. Feedback from practice tutors emphasized the importance of early session management, task follow-up, innovative strategies, and diverse assessments. Students enjoy activities, especially those involving group work, creativity, and technology [14].	It is theoretical and does not involve empirical research with teachers or students. It would be beneficial to include concrete examples of how these principles can be implemented in a variety of learning contexts.
The documentation work of lecturers is closely related to their meta-didactic praxeology and reflects the goals of the PD program. Lecturer praxeology and documentation evolve over time, influenced by changes in program objectives. 'Help cards' appear as an important element in task design. This research proposes an interpretive model for lecturers' work [15].	A single case study may have limitations in terms of generalization. The main focus is on the lecturer's perspective. The research does not address in detail how interpretive models can be applied to other contexts or disciplines.

Result	Limitation
<p>The documentation work of each teacher is influenced by their expertise and goals, related to the discipline being taught, and based on a variety of resources with a specific utilization scheme.</p> <p>Teachers develop meta-didactic praxeology together, emphasizing hands-on experience before the formalization of mathematics. Mathematics is recognized as a lens through which to interpret the world [16].</p>	<p>There are difficulties in managing the time to collaborate together in one time and one place.</p>
<p>High level of coherence between didactic strategies and teachers' curricular beliefs. Some inconsistencies were found, mainly due to teachers' beliefs about didactic strategies. Teachers show a diverse understanding of didactic concepts. Various didactic strategies and resources are used.</p> <p>Some teachers point out inconsistencies in distinguishing between strategies and resources [17].</p>	<p>Small sample sizes limit generalizations. Focus on the second cycle of teachers. It does not discuss how teachers' beliefs are formed or how they can be changed.</p>

## Discussion

Based on the research stage that has been carried out, namely, determining research questions that are in accordance with the researcher's research topic, finding the population and sample, as well as the research design, and the results of the research, then, the researcher then looks for a new knowledge (insight) that can be a novelty in the researcher's research theme, namely didactic transposition for mathematics learning that facilitates students' static literacy. The following results of content analysis to find insights are presented in the following table.

### *Article 1*

Didactic transposition begins with the scholarly knowledge stage which provides material sources from experts. The idea of developing didactic transposition research based on the results of the research in this article includes the didactic position at the university level involving the adaptation of teaching content and methodologies [11] to meet the specific needs of students and disciplines. In addition, an interdisciplinary approach can facilitate the development of didactic skills by guiding didactic transposition and educational reconstruction [5].

### *Article 2*

The results of the research and the limitations of the research found in this article provide an overview of how to conduct research related to didactic transposition involving prospective teacher students. In addition, there are several things related to the content of the material that should be used by educators so that it does not become a conceptual error in didactic transposition [10]. Some of the things that were found as insights in the next didactic transposition research are that the didactic position that is not explicit about proof in universities creates difficulties for prospective teachers in bridging the gap between the practice of proof [3] at the university and high school levels.

More so, including explicit training on proofing and didactic transposition in teacher education programs is important to prepare them to teach mathematical concepts effectively [18].

### *Article 3*

The results of the research mentioned show that there is an opportunity in the development of research related to didactic transposition, which he said, is that the didactic position is needed to bridge the gap between the academic knowledge of prospective teachers and the knowledge needed to teach effectively [19]. In addition, the importance of connecting theory with practice through hands-on experience in the classroom during teacher training [20].

### *Article 4*

In this article, the researcher obtained things related to praxeology for lecturers, namely educators at universities so that they are expected to be able to initiate prospective teachers through their lectures. Some of the findings in the development of research ideas on didactic transposition are: 1) the meta-didactic phenology of lecturers and their documentation work develops over time, influenced by the goals of professional development programs and collaboration with teachers and 2) didactic transposition is a dynamic process that involves continuous adaptation of teaching materials and approaches [21].

#### *Article 5*

The researcher found things that support the novelty of the researcher's research related to didactic transposition, namely: 1) the collaborative design of STEAM activities by teachers involves the use of various resources and special utilization schemes; 2) the meta-didactic praxeology together guides the teacher's documentation work and emphasizes hands-on experience before the formalization of mathematics; 3) mathematics serves as a unifying tool in STEAM activities, interpreting real-world phenomena studied in various disciplines [22].

#### *Article 6*

The insights obtained include 1) teachers' beliefs about the curriculum and teaching strategies can affect their practice in the classroom and student learning outcomes; 2) the importance of alignment between teaching strategies and curricular beliefs for effective teaching; 3) the need for further research on how teachers' beliefs are formed and how they can be changed to improve alignment with teaching strategies [23].

Based on the content of the analysis, it can be concluded that there is an important role of teachers who teach and are student-centered, both at the school and university levels. The importance of adapting content and teaching methods that are in accordance with the specific context at the elementary school level to university and cross-cultural education. This is in line with the idea that complex mathematical knowledge needs to be transformed into a form that is more accessible and understood by students ([24];[25]). In the context of statistical literacy, this means presenting statistical concepts in a way that is relevant and meaningful to students [26], relating them to their previous experience and knowledge.

Some articles distinguish between external didactic transposition (the transformation of scientific knowledge into knowledge to be taught) and internal didactic transposition (the transformation of knowledge to be taught into knowledge to be taught in the classroom) (Pound, 2006; Bulut Atalar et al., 2018). These two stages are important in developing students' statistical literacy. External transposition ensures that the math curriculum includes relevant statistical concepts, while internal transposition ensures that those concepts are taught in a way that is appropriate to the student's level of understanding and learning objectives.

In succeeding in the performance of students in mastering statistical literacy, it is inseparable from collaboration between teachers, students and lecturers. This can be done in the form of collaboration and self-reflection by teachers because it is very important for continuous development and improvement in improving the quality of teaching practices and materials presented to students (Pocalana & Robutti, 2023; Aldon et al., 2013). In the context of statistical literacy, reflection and collaboration can help teachers identify student misconceptions, develop innovative teaching strategies, and create a learning environment that supports the development of statistical literacy.

In addition to teachers, lecturers also have an important role in the didactic transposition stage as an introduction to the understanding of scholarly knowledge. Mathematics teachers and lecturers play a central role in bridging the gap between formal mathematical knowledge and student understanding (Montoya Delgadillo, 2014; Aldon et al., 2013). This shows that teachers and lecturers need to have strong didactic knowledge related to mathematical content including statistics so that they can carry out didactic transposition effectively. Mathematics learning carried out with the concept of didactic transposition which is student-centered can indirectly facilitate students' statistical literacy. This provides opportunities for students to take an active role in their learning based on their interests and abilities.

Modern mathematics education, including the teaching of statistics, is increasingly oriented towards a student-centered approach to learning (Mara, 2017). The articles emphasize the importance of empowering students to take an active role in their own learning. Didactic transposition in this context should focus on presenting statistical concepts in a way that is relevant and meaningful to students, encouraging them to explore data, make guesses, and develop their own understanding of statistical concepts.

In addition, it is natural that all students have their own cultural values. Therefore, teachers are expected to be adaptive to cross-cultural issues that need to be considered specifically in order to be effective in the application of the concept of didactic transposition in the learning planning that will be presented.

Based on the content of the analysis above, the use of didactic transposition in mathematics learning that facilitates students' statistical literacy also has challenges and opportunities to be implemented effectively and

efficiently, including: 1) the gap between formal knowledge and student understanding, 2) the role of technology, 3) the importance of context, 4) cross-cultural considerations.

The challenge in bridging the gap between the formal mathematical knowledge that teachers have and the level of student understanding in teaching that facilitates statistical literacy. This means that the mathematics teaching presented by teachers needs to present complex statistical concepts in a way that is appropriate to the cognitive development of students ([Montoya Delgadillo, 2014](#)).

The potential of technology, such as computer algebra systems (CAS) and e-learning platforms, in supporting didactic transposition and improving mathematics learning, including statistical literacy ([Gyöngyösi et al., to appear](#); [Aldon et al., 2013](#)) is a challenge as well as an opportunity in implementing didactic transposition. Technology can provide opportunities for students to visualize data, conduct simulations, and analyze large data sets, thereby improving their understanding of statistical concepts.

More than that, the importance of connecting mathematical concepts, including statistics, with real-world situations and authentic problems ([Pocalana et al., 2024](#)) is also a challenge for teachers to prepare for varied learning. This approach can help students see the relevance and usefulness of statistics in everyday life, thereby increasing their motivation and engagement in learning. In the context of statistical literacy, the understanding and interpretation of data can be influenced by the cultural context. Educators need to be sensitive to these cultural differences and adapt their teaching ([Wang et al., 2023](#)).

## CONCLUSION

The content analysis of the article reveals that didactic transposition is a crucial element in mathematics learning, especially in the context of developing students' statistical literacy. Didactic transposition is not just an adaptation of content, but also the transformation of complex mathematical knowledge into a form that is more accessible and understood by students. This involves adaptation of content and methodologies, the active role of teachers, student-centered learning approaches, collaboration, reflection, and consideration of cultural contexts. The implications of the results of this research are the importance of teacher professional development, responsive curriculum design, technology utilization, as well as collaboration and reflection, mathematics teachers need to continue to improve their didactic knowledge, especially in terms of statistical literacy.

Ongoing professional development programs can help teachers understand statistical concepts in depth, develop effective teaching strategies, and integrate technology in learning. The math curriculum needs to be designed with didactic transposition in mind, ensuring that statistical concepts are presented in a relevant and meaningful way for students. The curriculum also needs to accommodate the diversity of students and cultural contexts. Technology can play an important role in supporting didactic transposition and improving statistical literacy learning. Teachers need to be trained to use technology effectively in math learning. Collaboration between researchers, lecturers, and teachers, as well as self-reflection by teachers, is essential to improve teaching practices and develop effective learning materials in statistical literacy. Research opportunities that can be carried out in the future are related to the evaluation of the effectiveness of didactic transposition, the development of didactic transposition models, the use of technology in didactic transposition, and cross-cultural didactic transposition.

In carrying out this study, the researcher found limitations in the study, namely that some of the studies analyzed had limitations in terms of generalization of findings due to small sample sizes or focus on specific contexts, research focused on the teacher's perspective, while the student's perspective was also important to understand the didactic transposition process comprehensively, the research did not explicitly discuss the practical implications of their findings for curriculum development and teaching practice. Didactic transposition is a complex process and requires further attention and research, especially in the context of developing students' statistical literacy. By overcoming existing research limitations and exploring new research opportunities, it can improve understanding of didactic transposition and contribute to the development of more effective mathematics teaching practices to develop students' statistical literacy.

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## REFERENCES

- [1] T. H. Do and V. T. T. Nguyen, "The structure of didactic transposition capability - analysis of an example of didactic transposition of physical knowledge in the training of pedagogical students," *Vietnam J. Educ.*, vol. 4, no. 1, pp. 44–52, 2020, doi: 10.52296/vje.2020.7.
- [2] B. Pepin, "Connectivity in support of student co-design of innovative mathematics curriculum trajectories," *ZDM - Math. Educ.*, vol. 53, no. 6, pp. 1221–1232, 2021, doi: 10.1007/s11858-021-01297-4.
- [3] F. B. Atalar and M. Ergun, "Evaluation of the knowledge of science teachers with didactic transposition theory," *Univers. J. Educ. Res.*, vol. 6, no. 1, pp. 201–210, 2018, doi: 10.13189/ujer.2018.060130.
- [4] M. Bosch *et al.*, "External Didactic Transposition in Undergraduate Mathematics," 2019.
- [5] V. D. Phuong and N. H. Quan, "The Didactic Transposition Competence of Mathematics Preservice Teachers," *hnu J. Sci.*, vol. 68, no. 3, pp. 151–165, 2023, doi: 10.18173/2354-1075.2023-0071.
- [6] S. Sumirattana, A. Mekanong, and S. Thipkong, "Using realistic mathematics education and the DAPIC problem-solving process to enhance secondary school students' mathematical literacy," *Kasetsart J. Soc. Sci.*, vol. 38, no. 3, pp. 307–315, 2017, doi: 10.1016/j.kjss.2016.06.001.
- [7] B. Schneuwly and H. J. Vollmer, "Bildung and subject didactics: exploring a classical concept for building new insights," *Eur. Educ. Res. J.*, vol. 17, no. 1, pp. 37–50, 2018, doi: 10.1177/1474904117696096.
- [8] Y. Chevallard, "On didactic transposition theory: some introductory notes," *International Symp. Sel. Domains Res. Dev. Math. Educ.*, pp. 1–9, 1989, [Online]. Available: [http://yves.chevallard.free.fr/spip/spip/article.php3?id\\_article=122](http://yves.chevallard.free.fr/spip/spip/article.php3?id_article=122)
- [9] Brosseau, *Theory of Didactical Situations in Mathematics*. 1997.
- [10] C. Bergsten, E. Jablonka, and A. Klisinska, "A Remark on Didactic Transposition Theory," *Math. Math. Educ. Cult. Soc. Dimens. Proc. MADIF 7*, no. 7, pp. 58–68, 2010, [Online]. Available: [https://www.researchgate.net/profile/Eva\\_Jablonka3/publication/259602856\\_A\\_Remark\\_on\\_Didactic\\_Transposition\\_Theory/links/00b4952cdcff0ed3d7000000/A-Remark-on-Didactic-Transposition-Theory.pdf](https://www.researchgate.net/profile/Eva_Jablonka3/publication/259602856_A_Remark_on_Didactic_Transposition_Theory/links/00b4952cdcff0ed3d7000000/A-Remark-on-Didactic-Transposition-Theory.pdf)
- [11] Jamilah, D. Suryadi, and N. Priatna, "Analysis of Didactic Transposition and HLT as a Rationale in Designing Didactic Situation," vol. 513, pp. 567–574, 2021, doi: 10.2991/assehr.k.201230.164.
- [12] F. Passalacqua and E. Nigris, "The faculty development model of the university of milan-bicocca: Towards an integration of general and disciplinary didactics," *Int. Conf. High. Educ. Adv.*, vol. 2020-June, pp. 1235–1243, 2020, doi: 10.4995/HEAD20.2020.11240.
- [13] E. M. Delgadillo, "The process of proof in the geometric work space: Initial training teachers," *Ensen. las Ciencias*, vol. 32, no. 3, pp. 227–247, 2014, doi: 10.5565/rev/ensciencias.1049.
- [14] C. Romero Claudio and R. Jiménez Fernández, "La formación inicial del máster de profesorado: reflexiones en torno a la implementación de una propuesta didáctica para una educación lectoliteraria," *Investig. Sobre Lect.*, no. 12, pp. 1–34, 2019, doi: 10.37132/isl.v0i12.283.
- [15] G. Pocalana and O. Robutti, "Evolution of Didacticists' meta-didactical Praxeologies and Documentation Work," *Int. J. Sci. Math. Educ.*, no. 0123456789, 2023, doi: 10.1007/s10763-023-10367-w.
- [16] G. Pocalana, O. Robutti, and E. Ciartano, "Resources and Praxeologies Involved in Teachers' Design of an Interdisciplinary STEAM Activity," *Educ. Sci.*, vol. 14, no. 3, 2024, doi: 10.3390/educsci14030333.
- [17] P. Kavalari, D. M. Kakana, and V. Christidou, "Consistency between teaching practice and curriculum guidelines in a preschool classroom: A case study," *Int. J. Early Child. Learn.*, vol. 20, no. 4, pp. 1–10, 2014, doi: 10.18848/2327-7939/CGP/v20i04/48425.
- [18] E. L. Mara, "New perspective of learner-centered education in nowadays didactics," *MATEC Web Conf.*, vol. 121, pp. 1–7, 2017, doi: 10.1051/mateconf/201712112013.
- [19] F. Rønning, "Opportunities for language enhancement in a learning environment designed on the basis of the theory of didactical situations," *ZDM - Math. Educ.*, vol. 53, no. 2, pp. 305–316, 2021, doi: 10.1007/s11858-020-01199-x.
- [20] L. Marty, P. Venturini, and J. Almqvist, "Teaching traditions in science education in Switzerland, Sweden and France: A comparative analysis of three curricula," *Eur. Educ. Res. J.*, vol. 17, no. 1, pp. 51–70, 2018, doi: 10.1177/1474904117698710.
- [21] M. Marfuah, D. Suryadi, T. Turmudi, and M. G. Isnawan, "Providing Online Learning Situations for In-Service Mathematics Teachers' External Transposition Knowledge During COVID-19 Pandemic: Case of Indonesia," *Electron. J. e-Learning*, vol. 20, no. 1 Special Issue, pp. 69–84, 2022, doi: 10.34190/ejel.20.1.2388.
- [22] J. Hunter, K. B. Syversen, C. Graves, and A. Bodensteiner, "Balancing Outdoor Learning and Play: Adult

- Perspectives of Teacher Roles and Practice in an Outdoor Classroom,” *Int. J. Early Child. Environ. Educ.*, vol. 7, no. 2, pp. 34–50, 2020.
- [23] C. Winsløw, “Anthropological theory of didactic phenomena : Some examples and principles of its use in the study of mathematics education,” in *annual conference of the Finnish Association for Research in Mathematics and Science Education*, 2015, vol. 10, no. January 2011, pp. 117–138.
- [24] F. Schott and N. M. Seel, “Instructional Design,” *Int. Encycl. Soc. Behav. Sci. Second Ed.*, no. December 2015, pp. 196–200, 2015, doi: 10.1016/B978-0-08-097086-8.92032-4.
- [25] G. Aldon, “The meta-didactical transposition: A model for analysing,” *Proc. 37th Conf. Int. Gr. Psychol. Math. Educ.*, no. 2013, p. 31, 2013, [Online]. Available: [https://www.researchgate.net/publication/280813379\\_THE\\_META-DIDACTICAL\\_TRANSPOSITION\\_A\\_MODEL\\_FOR\\_ANALYSING\\_TEACHERS\\_EDUCATION\\_P  
ROGRAMS](https://www.researchgate.net/publication/280813379_THE_META-DIDACTICAL_TRANSPOSITION_A_MODEL_FOR_ANALYSING_TEACHERS_EDUCATION_PROGRAMS)
- [26] E. N. Risqi and R. Setianingsih, “Statistical Literacy of Secondary School Students in Solving Contextual Problems Taking Into Account the Initial Statistical Ability,” *Pi Math. Educ. J.*, vol. 4, no. 1, pp. 43–54, 2021, doi: 10.21067/pmej.v4i1.5285.

# Misconceptions in Solving Remaining Problems of Dividing Exponential Numbers

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**Abstract.** Preliminary research results show that many students still experience errors in determining the remainder of the distribution of exponential numbers. This error is important for further analysis. Therefore, this study aims to identify student errors in determining the remainder of the division of exponential numbers. This type of research is descriptive qualitative research. The subjects of this study consisted of 4 students from the mathematics education study program. The data collected in this study consisted of the results of the subject's work and transcripts of interviews with the subject. Analysis of the results of the subject's work was carried out descriptively to determine the characteristics of the errors. Analysis of the transcripts of the interview results was carried out by coding the words that indicated the causes of misunderstandings. The results showed that the misunderstanding of the concept in determining the remainder of the division of exponential numbers by integers consisted of errors in changing the exponential form into the sum of exponential numbers, errors in translating exponential numbers, errors using modulo congruence, and errors in dividing the sum of exponential numbers. The factor that causes this misunderstanding in general is a lack of understanding of the basics of operations on exponential numbers and modulo properties.

## INTRODUCTION

Number Theory course is part of mathematics which discusses the properties of natural numbers, one of which focuses on prime numbers [1]. The material in this number theory course is important for students to learn. This is because there are many methods learned in it that can be used to solve problems related to natural numbers or prime numbers.

One of the materials studied in number theory is the division of remainders. The division of remainders is mathematically denoted by  $n = qm + r$  (where  $q$  is the quotient and  $r$  is the remainder after dividing  $n$  by  $m$ ). For example, the number 10 is divided by 3, so the remainder is 1 which can be written in form  $10 = 3(3) + 1$ . One application of this residual division is to determine the remainder of the exponential number when divided by an integer. For example, how much is the remainder of  $3^{100}$  if divided by 4? This problem can be solved by applying residual division. Therefore, as a student, prospective teachers must master the concept of residual division and its application.

However, the results of the preliminary research of 25 students who solved the problem of determining the units of exponential numbers obtained 18 experienced errors and 7 answered correctly. This means that 72% of students experience errors. One way to overcome this problem is to further analyze the errors that appear. This is because these misunderstandings are important to uncover to get an overview of student weaknesses [2] and as valuable lessons to improve student understanding (Setiawan, 2020a, 2020b, 2021d, 2021c). Apart from that, it can also be used by lecturers or teachers to improve learning in class (Setiawan, 2021a) and can also be used to improve teacher or lecturer communication skills in teaching mathematics [8]. Thus it can be seen that the error analysis aims to correct these errors.

The importance of research on error identification has become a concern for several researchers. Research [9] analyzed students' difficulties in solving problems in number theory courses which showed that students still had difficulties understanding and using the concept of congruence and congruence applications. Research [10] that analyzed student errors based on gender showed that male students made more mistakes than female students. Research [11] analyzes the ability to prove which shows that students tend to give up when experiencing difficulties in solving number theory problems. Research (Setiawan et al., 2021) shows that students' ability to recheck answers is still weak. Previous research also shows that students still have problems doing mathematical proofs in number theory courses [13], [14].

However, none of these studies have discussed student errors in solving the problem of the remainder of the distribution of exponential numbers. Therefore, research is still needed to analyze student errors in the remainder of the distribution of exponential numbers. Unlike previous research (Hartati, 2020; Meilanawati & Pujiastuti, 2020; Nurrahmah & Karim, 2018; Setiawan et al., 2021; Sinaga & Siahaan, 2019; Stavrou, 2014), this study aims to identify errors that carried out by students in solving the problem of the remainder of the division of rank numbers along with the factors that cause them.

The theoretical benefit of the results of this study is to develop a theory of misunderstanding in solving mathematical problems in the application of remainder division. While the practical benefits of the results of this study are that they can be used by students or students to correct their misconceptions. The results of this study can also be used by teachers or lecturers in teaching the application of the remainder of division to exponential numbers.

## METHOD

This type of research is qualitative research with a case study approach to 4 students who experience errors in solving the problem of applying the remainder of division to exponential numbers. This research was carried out at a university in Malang City in the 2023 academic year. The procedure for selecting subjects in this study was carried out in 3 stages. The first stage was to ask 25 students to complete UTS questions, one of which was the problem of applying residual division. The second stage is correcting answers based on right and wrong answers. The third step is to classify wrong answers based on the types of errors so that different error characteristics are obtained. From each characteristic one was selected as the subject of this study.

The data collected in this study consisted of work results and interview transcripts. The procedure for collecting work results data is carried out by the procedure for taking subjects. The procedure for collecting interview transcript data was carried out in two stages. The first stage is to conduct interviews with research subjects. Interviews were conducted online and at the time of the interviews were recorded. The results of the interviews were transcribed word for word until data were obtained in the form of interview transcripts.

The research instrument consisted of the problem of applying residual division (see Figure 1) and an interview guide. This research instrument can be solved by applying several concepts, namely: (a) the concept of residual division or the concept of modulo, (b) properties of exponents, and (c) exponential operations. If students get stuck in the concept errors used in completing this instrument, then students experience conceptual errors. Therefore, this research instrument can be used to identify conceptual errors in solving the problem of division with remainders of exponential numbers.

Find:  
 (a) The remainder of  $3^{100}$  when divided by 4.  
 (b) The remainder of  $2^{2.021}$  when divided by 9.

Figure 1. Research Instruments

Analysis of the results of student work was carried out by classifying student errors based on the types of errors that can be seen in Table 1. Meanwhile, the analysis of the transcripts of the interview results was carried out by coding the words that indicated the causes of the errors made by students. Through these two analyses, students' mistakes in solving the problem of residual division can be identified.

Checking the validity or validity of the results of this study was carried out using the member checking technique, in which the researcher asked the subject to check the accuracy of the findings of this study [15]. Subjects in this study stated that the findings in this study were in accordance with what they thought and did.

## RESULTS AND DISCUSSION

The results showed that out of 25 students, 18 students had errors. From the 18 students, a classification of conceptual errors was obtained which can be seen in Table 1.

Table 1 Classification of Concept Errors in Solving Remaining Problems of Dividing Exponential Numbers.

Error type	Description	Characteristics of misconceptions	Many of students
Misconceptions	Misunderstanding of concepts related to	Misunderstanding to change the exponential form to the sum of exponential numbers	11
		Misconception of generalizing remainders of exponential division	3

Error type	Description	Characteristics of misconceptions	Many of students
	remainder division	Misunderstanding of changing the form of a modulo congruence	2
		Misunderstanding divides the sum of exponential numbers	2
<b>Total</b>			<b>18</b>

From Table 1 it can be seen that there are 4 characteristics of conceptual errors in solving the problem of applying the concept of residual division. Furthermore, from each of these characteristics, 1 student was taken as a research subject for further analysis. The results of the analysis of the four subjects are presented below. The first misconception is to change the exponential form to the sum of exponential numbers. Of the 11 students who experienced this error, 1 student was selected as the first subject (S1) whose work results can be seen in Figure 2.

$$\begin{aligned}
 \text{b.) } 2^{2021} &= (2^3)^{673} + 2^2 \\
 &= \frac{(9-1)^{673} + 2^2}{9} \\
 &= \frac{4(9-1)^{673}}{9} \\
 2^{2021} &\text{ dibagi } 9 \text{ sisa } 4
 \end{aligned}$$

Figure 2 Error Converting Exponential Form to Additive Form

From Figure 2 it can be seen that the subject experienced an error in changing the form  $2^{2021}$  to  $(2^3)^{673} + 2^2$ . The correct change is  $2^{2021} = (2^3)^{673} \times 2^2$ . As a result of this error, the subject experienced an error in determining the units of exponential numbers. The causal factors can be identified from the following excerpt of the interview transcript.

P : Jelaskan cara Anda menjawab soal tersebut!

S1 : ... untuk  $2^{2021}$  adalah 2 itu saya pangkatkan 3, terus saya pangkatkan lagi menjadi 673 ditambah  $2^2$  per 9. Sehingga hasilnya 9 - 1. Sembilan itu dari  $2^3$ . Sedangkan 673 itu tetap dari pangkatnya yang pertama tadi plus  $2^2$  dibagi 9, sehingga hasilnya itu 4 dikali 9 dikurangi 1 pangkat 673 per 9. Jadi  $2^{2021}$  dibagi 9 sisanya itu menjadi 4.

From the transcript of the interview results, it can be seen that the subject immediately changed the form  $2^{2021} = (2^3)^{673} + 2^2$ . This means that the factor causing this error is a misunderstanding of the subject who understands that the addition of exponents with the same base is done by adding up the exponents.

The second misconception is the misunderstanding of generalizing the remainder of the division of exponential numbers. Of the 3 students who experienced this error, 1 student was selected as the second subject (S2) of this study. The results of S2's work can be seen in Figure 3.

$$\begin{array}{l} \text{) Sisa } 2^{2021} \text{ dibagi } 9. \\ \text{ex} = 2^{3n} : 9 \end{array}$$

$n=1$	$\Rightarrow 2^{3(1)} : 9 = \text{sisa } 8$
$n=2$	$\Rightarrow 2^{3(2)} : 9 = \text{sisa } 1$
$n=3$	$\Rightarrow 2^{3(3)} : 9 = \text{sisa } 8$
$n=4$	$\Rightarrow 2^{3(4)} : 9 = \text{sisa } 1$
$n=5$	$\Rightarrow 2^{3(5)} : 9 = \text{sisa } 8$

karena  $2021 = 100 \times 20 + 21$  maka  
 hasil  $2^{2021}$  jika dibagi 9  
 sisa  $2^{21}$  maka jika dibagi 9 yaitu 8.

Figure 3 Error generalizing the remainder of the division of exponential numbers

From Figure 3 it can be seen that the subject made the mistake of only focusing on the remainder of  $2^{21}$  which was divided by 9 and left by 8, of form  $2021 = 100 \times 20 + 21$ , without paying attention to the remainder of  $2^{100(20)}$  which was divided by 9. Thus the subject experienced an error in solving the problem. The factors that cause this error can be seen in the following interview transcript excerpts.

- P : Jelaskan cara Anda menjawab soal tersebut!
- S2 : ... untuk  $2^{2021}$  dibagi 9, saya contohkan sebagai  $2^{3n}$  dibagi 9, saya mengambil sampel 1 sampai 5. Sampel pertama yakni  $2^{3(1)}$  dibagi 9 tidak ada sisa. Sampel kedua merupakan  $2^{3(2)}$  dibagi 9 sisa 1. Kemudian yang sampel ketiga  $2^{3(3)}$  dibagi 9 sisa 8, maka itu membentuk pola 1, 8, 1, 8 dan seterusnya. **Karena 2021 itu sama dengan  $100 \times 20 + 21$ , maka hasil dari  $2^{2021}$  dibagi 9 sisanya  $2^{21}$ , maka jika dibagi 9 yaitu 8.**

From the excerpt of the interview transcript, it can be seen that the subject did not pay attention to the unit of  $2^{100(20)}$  if divided by 9, whereas the subject only paid attention to the remainder of  $2^{21}$  divided by 9, namely the remainder of 8. Therefore the factor causing this error was the subject's attention only focusing on the remainder of the division whose pattern has been found, without regard to the remainder of the numbers of other powers.

The third misconception is the misunderstanding of changing modulo congruence. Of the 2 students who experienced this error, 1 student was selected as the third subject (S3) can be seen in Figure 4.

(a) Sisa dari  $3^{100}$  jika dibagi 4  
 $3^2 \equiv 3^2 \pmod{4}$   
 $3^2 \equiv 9 \pmod{4} \quad (4 \cdot 2 + 1) \pmod{4}$   
 $3^2 \equiv 1 \pmod{4}$   
 $3^{50} \equiv 1^{50} \pmod{4}$   
 $3^{100} \equiv 1 \pmod{4} \rightarrow \text{sisanya } 1$

(b) Sisa dari  $2^{2021}$  jika dibagi 9  
 $2^3 \equiv 2^3 \pmod{9}$   
 $2^3 \equiv 8 \pmod{9} \quad (9 \cdot 1 - 1) \pmod{9}$   
 $2^3 \equiv -1 \pmod{9}$   
 $2^{673+2} \equiv -1^{673+2} \pmod{9} \rightarrow \text{sisa } -1$

Figure 4 Error Changing Modulo Congruence Forms

From Figure 4 it can be seen that when solving questions (a) the subject answered correctly. However, the method used in answering question (a) cannot be used to answer question (b).

- P : Jelaskan cara Anda menjawab soal tersebut!
- S3 : Disini saya mengambil 3 pangkat 100 disederhanakan, kemudian diambil pangkat yang paling rendah, yaitu  $3^2$  kongruen dengan  $3^2$  modulo 4. Nah  $3^2$  itu hasilnya 9. 9 modulo 4 itu didapat dari 4 dikali 2 ditambah 1, maka menghasilkan 1 modulo 4, **terus 3 dipangkatkan 2 pangkat 50**

***kongruen dengan 1 dipangkatkan 50 modulo 5, jadi pangkat 50 tidak bisa modulo 4, makanya pakai modulo 5. Jadi hasilnya 3 pangkat 100 modulo 5 dan sisanya 1.***

From the excerpts of the interview transcript, it can be seen that the subject changes modulo congruence only based on counts whose results cannot be determined so that they directly use numbers that are easy to determine the results. This means that the cause of this error is that the subject does not understand modulo congruence and has difficulty determining the results of calculations.

The fourth misconception is the error in dividing exponential numbers by integers. Of the 2 students who experienced this error, 1 student was selected as the fourth subject (S4) can be seen in Figure 5.

$$\begin{aligned}
 3^{100} &= (3^4)^{25} \\
 &= (81)^{25} \\
 &= (80 + 1)^{25} \quad (80 \text{ habis dibagi } 4) \\
 &= (1)^{25} \\
 &= 1
 \end{aligned}$$

Jadi  $3^{100}$  dibagi 5 sisa 1 //

Figure 5 Errors in Dividing Exponential Numbers

From Figure 5 it can be seen that the subject's final answer is correct, namely,  $3^{100}$  divided by 5, the remainder is 1. However, the subject made a conceptual error, namely  $(80 + 1)^{25}$  with 80 divisible by 4, then 1 is written as the remainder. The factors that cause this error can be seen in the following interview transcript excerpts.

- P : *Jelaskan cara Anda menjawab soal tersebut!*  
 S4 : *... untuk  $3^{100}$  saya sederhanakan menjadi  $(3^4)^{25}$ . Lalu  $3^4$  saya kalikan yakni menjadi  $(81)^{25}$ , 81 saya pecah menjadi 80 ditambah 1 pangkat 25. Lalu 80 saya bagi dengan 4, makanya habis dibagi 4. Lalu 1 pangkat 25 hasilnya 1, maka 3 pangkat 100 dibagi 5 hasilnya sisa 1.*

From the excerpts of the interview transcript, it can be seen that the subject changed the exponential form to the correct exponential form. However, after determining the result of exponents, namely  $3^4 = 81$  and 81 cannot be divided by 4, it is split into  $80 + 1$ . This means that the factors that cause this error are when the subject finds the arithmetic operations difficult, the subject immediately looks for easy calculations without analyzing the wrong concepts used.

From the explanation of the results of the study above, the characteristics of student errors in solving the problem of applying the division of remainders to exponential numbers and their causal factors are obtained which can be seen in Table 2.

Table 2 Characteristics of Concept Errors Solving Remaining Problems of Dividing Exponential Numbers and Their Causing Factors

No.	Characteristics of Misconceptions	Causal Factors
1	Misconception to change the exponential form to the sum of exponential numbers	The misunderstanding of adding exponents with the same base is done by adding up the exponents.
2	Misconception of generalizing remainders of exponential division	Attention that is not thorough, that is only focused on the remainder of the distribution whose pattern has been found and does not pay attention to the remainder of the numbers with other powers.
3	Misconception of changing the form of a modulo congruence	Not understanding of modulo congruence and difficulties in determining the results of calculations.
4	Misconception divides the sum of exponential numbers	Difficulties in completing arithmetic operations, so they switch to looking for easy calculations without analyzing that the concepts used are wrong.

The results of this study contribute to developing a theory of misunderstanding of concepts in solving mathematical problems, namely the problem of the remainder of dividing numbers by integers. The results of this study are to the results of previous studies which show that students still experience errors and difficulties in solving problems in number theory courses (Hartati, 2020; Meilanawati & Pujiastuti, 2020; Nurrahmah & Karim, 2018; Setiawan et al., 2021; Sinaga & Siahaan, 2019; Stavrou, 2014). However, the results of this study expand

the results of previous studies by explaining students' misunderstandings in solving the problem of the remainder of the distribution of exponential numbers.

The first misconception is the misunderstanding of adding exponential numbers. The cause of the error that occurs is adding up the powers of the two exponential numbers that are added. Various research results also show that students still experience various calculation errors (Setiawan, 2021c, 2021b, 2021e, 2021d; Setiawan & Surahmat, 2021). The results of this study expand the results of previous studies by showing that calculation errors can also be caused by conceptual errors. Thus it is important to carry out learning that emphasizes the concepts of arithmetic operations.

The second misconception is the error of generalizing the remainder of the division of exponential numbers. The cause of this error is the lack of thorough attention to the problem. Therefore, an important finding in this study is that attention is important in solving exponential number problems. The results of the study also show that attention that is not thorough can cause errors in solving math problems (Setiawan, 2020d, 2020c; Setiawan et al., 2020). Thus it is important to pay close attention to the problem to be solved. Thus generalizing concept errors can be overcome.

The third misconception is the error in changing the modulo congruence form. This shows that writing modulo congruence notation in the form of remainder division is very important to be given to students who are taking number theory courses. Besides that, it is also important to learn about the properties of modulo congruence.

The fourth misconception is the error of dividing the sum of exponential numbers. This is caused by the method being used is too difficult and then moving to an easier method, but the method is wrong. This can also be interpreted that students who are stuck in mistakes solving math problems will look for other ways without analyzing whether the method is right or wrong. Therefore, it is also important in learning to provide various alternative solutions that can be used by students in solving mathematical problems.

The results of this study imply that it can be used as a learning material for the remainder of the distribution of rank numbers. Where 4 ways can be used to overcome students' misunderstanding of concepts in solving the problem of the remainder of the distribution of exponential numbers, namely: (1) recalling the properties of exponential number operations, (2) paying thorough attention to the problem, (3) explaining congruence notation modulo in the form of remainder division, and (4) explaining various alternative solutions in solving the problem of the remainder of the division of exponential numbers.

## CONCLUSION

From the results of the research and discussion, four characteristics of students' conceptual errors were obtained in solving the problem of the remainder of the division of exponential numbers. The first misconception is changing the exponential form into the sum of exponential numbers due to a misunderstanding of the sum of exponential forms. The second misconception is to generalize the remainder of the distribution of exponential numbers due to insufficient attention in solving the problem. The third misconception is changing the form of modulo congruence due to a lack of understanding about modulo congruence. The fourth misconception is the error in dividing the sum of raised numbers due to difficulties in solving problems.

In general, the factors that cause this error are a lack of understanding of the basics of operations on exponential numbers and also a lack of understanding of modulo properties. Thus the suggestion for solving the problem of the remainder of the division of exponential numbers is to put more emphasis on the basics of operating exponential numbers and modulo properties and their applications. This research is only limited to the remainder of the distribution of exponential numbers. Thus further research can analyze errors in the Number Theory material.

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## REFERENCES

- [1] D. Downing, *Dictionary of Mathematics Terms*, Third Edit. New York: Barron's Educational Series, Inc., 2009. doi: 10.2307/3614426.
- [2] H. M. Siregar, "Analisis Kesalahan Siswa dalam Menyelesaikan Soal Tes Kemampuan Berpikir Kreatif Matematis Materi Lingkaran," *Aksioma J. Progr. Stud. Pendidik. Mat.*, vol. 8, no. 3, pp. 497–507, 2019, doi: <https://doi.org/10.24127/ajpm.v8i3.2379>.
- [3] Y. E. Setiawan, "Kesalahan mahasiswa semester pertama dalam menyelesaikan masalah fungsi trigonometri sudut tidak lancip," *AKSIOMA J. Progr. Stud. Pendidik. Mat.*, vol. 10, no. 2, pp. 599–614,

- 2021, doi: <http://dx.doi.org/10.24127/ajpm.v10i2.3458>.
- [4] Y. E. Setiawan, "Identifikasi kesalahan mahasiswa dalam menyelesaikan masalah matematika (Studi kasus masalah segitiga pada mata kuliah trigonometri)," *J. Kependidikan J. Has. Penelit. dan Kaji. Kependidikan di Bid. Pendidikan, Pengajaran dan Pembelajaran*, vol. 7, no. 3, pp. 649–662, 2021, doi: <https://doi.org/10.33394/jk.v7i3.3329>.
- [5] Y. E. Setiawan, "Analisis Kesalahan Siswa dalam Menggeneralisasi Pola Linier," *J. Nas. Pendidik. Mat.*, vol. 4, no. 2, pp. 180–194, 2020, doi: <http://dx.doi.org/10.33603/jnpm.v4i2.3386>.
- [6] Y. E. Setiawan, "Analisis Kesalahan Siswa dalam Menilai Kebenaran Suatu Pernyataan," *J. Didakt. Mat.*, vol. 7, no. 1, p. GHBLOL,aQ, 2020, doi: 10.24815/jdm.v7i1.14495.
- [7] Y. E. Setiawan, "Analisis Kesalahan Mahasiswa Semester Pertama dalam Menentukan Nilai Fungsi Trigonometri Sudut Istimewa," *SJME (Supremum J. Math. Educ.)*, vol. 5, no. 1, pp. 321–334, 2021, doi: 10.35706/sjme.v5i1.4531.
- [8] I. K. Guce, "Mathematical Writing Errors in Expository Writings of College Mathematics Students," *Int. J. Eval. Res. Educ.*, vol. 6, no. 3, p. 233, 2017, doi: 10.11591/ijere.v6i3.8549.
- [9] L. Hartati, "Analisis Kesulitan Mahasiswa Dalam Menyelesaikan Soal," in *Prosiding Seminar Nasional Sains*, 2020, vol. 1, no. 1, pp. 373–381.
- [10] P. Meilanawati and H. Pujiastuti, "Analisis Kesalahan Mahasiswa Mengerjakan Soal Teori Bilangan Menurut Tahap Kastolan Ditinjau dari Gender," *Maju*, vol. 7, no. 2, pp. 182–190, 2020.
- [11] A. Nurrahmah and A. Karim, "Analisis Kemampuan Pembuktian Matematis Pada Matakuliah Teori Bilangan," *J. e-DuMath*, vol. 4, no. 2, p. 21, 2018, doi: 10.26638/je.753.2064.
- [12] E. Setiawan, G. M. Muhammad, and M. Soeleman, "Analisis Kemampuan Pemecahan Masalah Mahasiswa pada Mata Kuliah Teori Bilangan," *Mosharafa J. Pendidik. Mat.*, vol. 10, no. 1, pp. 61–72, 2021.
- [13] S. G. Stavrou, "Common Errors and Misconceptions in Mathematical Proving by Education Undergraduates," *IUMPST J.*, vol. 1, no. 2014, pp. 1–8, 2014.
- [14] R. F. Sinaga and F. B. Siahaan, "Analisis Kemampuan Pembuktian Matematis Mahasiswa dengan Pendekatan Konstruktivisme pada Mata Kuliah Teori Bilangan," *JKIPM (Jurnal Kegur. dan Ilmu Pendidik. Mat.)*, vol. 1, no. 1, pp. 58–63, 2019.
- [15] J. W. Creswell, *Educational Research Planning, Conducting and Evaluating Quantitative and Qualitative Research*, Fourth. Boston: Pearson Education, Inc., 2012.
- [16] Y. E. Setiawan and Surahmat, "Error analysis of prospective mathematics teachers in solving of applying radian measurement problem in trigonometry courses," *Al-Jabar J. Pendidik. Mat.*, vol. 12, no. 2, pp. 343–357, 2021, doi: <https://doi.org/10.24042/ajpm.v12i2.9874>.
- [17] Y. E. Setiawan, "Analisis Kesalahan Mahasiswa Semester Pertama dalam Menentukan Nilai Fungsi Trigonometri Sudut Istimewa," *SJME (Supremum J. Math. Educ.)*, vol. 5, no. 1, pp. 110–121, 2021, doi: 10.35706/sjme.v5i1.4531.
- [18] Y. E. Setiawan, "Kesalahan mahasiswa semester pertama dalam menyelesaikan masalah kecepatan sudut pada mata kuliah trigonometri," *PYTHAGORAS J. Pendidik. Mat.*, vol. 16, no. 1, pp. 19–32, 2021, doi: 10.21831/pg.v16i1.38560.
- [19] Y. E. Setiawan, "The Thinking Process of Students Using Trial and Error Strategies in Generalizing Linear Patterns," *Numer. J. Mat. dan Pendidik. Mat.*, vol. 4, no. 1, pp. 1–12, 2020, doi: <https://doi.org/10.25217/numerical.v4i1.839>.
- [20] Y. E. Setiawan, "Proses Berpikir Siswa dalam Memperbaiki Kesalahan Generalisasi Pola Linier," *Mosharafa J. Pendidik. Mat.*, vol. 9, no. 3, pp. 371–382, 2020, doi: <https://doi.org/10.31980/mosharafa.v9i3.751>.
- [21] Y. E. Setiawan, Purwanto, I. N. Parta, and Sisworo, "Generalization Strategy of Linear Patterns From Field-Dependent Cognitive Style," *J. Math. Educ.*, vol. 11, no. 1, pp. 77–94, 2020, doi: <http://doi.org/10.22342/jme.11.1.9134.77-94>.