Numeracy
Volume 12, Number 2, 2025 pp. 149-162
P-ISSN: 2355-0074 E-ISSN: 2502-6887
Open Access: https://ejournal.bbg.ac.id/numeracy

STUDENTS' ERRORS IN SOLVING PISA QUESTIONS ON *SPACE AND SHAPE* CONTENT

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ARTICLE INFO

Article history:
Received : Aug 30, 2025
Revised : Sep 21, 2025
Accepted : Oct 24, 2025
Available online : Oct 31, 2025

Keywords:
Error Analysis, Mathematical Reasoning, Newman's Theory, Secondary Education, PISA

ABSTRACT

The main objective of this study is to identify and explain students' errors in solving PISA questions on Space and Shape content using Newman's Error Analysis. The errors analyzed include five categories: reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors. This study employs a descriptive qualitative approach with data collected through tests and interviews. The research subjects are ninth-grade students at SMP Negeri 7 Muaro Jambi. The results show that students frequently made errors in the stages of understanding the questions, modelling the questions into mathematical forms, and process skills. These errors were by weaknesses in processing information, limited mathematical skills in real-life contexts, and a lack of experience in practicing PISA questions. These findings highlight the importance of familiarizing students with contextual problems as an effort to minimize errors in solving PISA questions.

INTRODUCTION

The Programme for International Student Assessment (PISA) is an international assessment program that evaluates the skills and knowledge of 15-year-old students in reading, mathematics, and science (OECD, 2023). Essentially, PISA focuses on literacy and reasoning, emphasizing the application of concepts to real-life contexts (OECD, 2023; Ridzkiyah & Effendi, 2021). In addition, Pereira et al. (2022) state that students are required to demonstrate the ability to read, comprehend, construct arguments, and apply mathematical concepts, procedures, and facts to solve problems in accordance with the PISA framework.

In its assessments, PISA divides content into four domains, one of which is Space and Shape (OECD, 2023). According to Asdarina & Ridha (2020), Space and shape is among the most challenging PISA content areas for students to understand. This difficulty arises because Space and Shape task demand a strong grasp of spatial visualization, measurement, and algebraic understanding (OECD, 2017, 2019, 2023). Furthermore, students often struggle to comprehend problems contexts because they are not accustomed to practicing PISA-type mathematics questions (Amalia & Malasari, 2024).

These difficulties lead to various types of errors made by students when solving PISA questions. Pereira et al. (2022) report that students frequently make mistakes in interpreting the problems, resulting in solutions that do not align with the required mathematical models. Similarly, Khusnah et al. (2023) found that many students make errors in process skills, often due to carelessness in identifying and processing information, which leads to incorrect solutions. This indicates that many students continue to make errors when solving problems, especially PISA questions on Space and Shape domain.

When solving PISA questions, especially those in Space and Shape domain, which are considered complex, students are required to demonstrate a high level of problem solving ability, one of which is mathematical reasoning ability (Asdarina & Ridha, 2020). Sholihah & Listanti (2022) explain that students can be considered to possess mathematical reasoning skills if they are able to present mathematical statements, make conjectures, perform mathematical manipulations, gather evidence and provide justification for their solutions, as well as draw conclusions and verify their validity. The most common errors made by students when solving PISA questions are related to understanding and transforming the questions into mathematical forms (Nusantara et al., 2024; Pereira et al., 2022). These transformation errors are caused by students' carelessness in interpreting the meaning of the questions (Nusantara et al., 2021). Meanwhile, Mathaba et al. (2024) state that the most frequent errors involve conceptual understanding and problem solving processes. This indicates the students' errors, particularly at the stages of comprehension and transformation, reflect their weak mathematical reasoning skills.

Several studies have examined students' errors in solving PISA problems in the Space and Shape domain (Pereira et al., 2022), the Quantity domain (Pitri et al., 2025), and Change and Relationship domain (Pranitasari & Ratu, 2020). However, only a limited number of studies have explored the relationship between students' reasoning abilities and their errors in solving PISA problems, particularly in the Space and Shape domain. The purpose of this study is to describe the types of students' errors based on Newman's theory in solving PISA questions on the Space and Shape content.

METHOD

This study employed a qualitative research method with a descriptive approach. Qualitative research is a method that examines natural phenomena or what is often referred to as a natural setting because the research is conducted in real life conditions (Sugiyono, 2021). In this study, the researcher describes and explains students' errors in answering PISA questions based on Newman's Theory. The research instruments consist of tests and interviews. The test employed original PISA essay-type questions, which were analysed, and particularly interesting responses were discussed in this study. Meanwhile, interviews were conducted to gain a deeper understanding of the difficulties students face when solving the problems.

The research subjects consisted of 5 out of 29 ninth-grade students from SMP Negeri 7 Muaro Jambi. The selection of subjects in this study employed a purposive sampling technique, which involves selecting participants based on specific criteria (Sugiyono, 2021). The selection was also made based on recommendations from the mathematics teacher.

Data collection was carried out through test and interviews. The test items were adopted from the 2012 PISA mathematics assessment. Before being used, the test was validated in terms of language by two validators, namely mathematics education lecturers, to ensure that the items were appropriate for administration to students. After the students completed the test, their responses were analysed using Newman's Error Analysis (NEA). Before the analysis, several students representing the Newman's error indicators were selected for in-depth interviews to explore their problem solving processes and the difficulties they encountered while working on the tasks.

Data were analysed descriptively by identifying students' errors in solving PISA questions based on Newman's error indicators. The analysis results were then supported by semi-structured interview data, which provided additional evidence to strengthen the finding of the error analysis. The Newman's Error Analysis indicators used in this study are presented in Table 1.

Table 1 Newman's Error Analysis Indicators

Stages	Error Indicators	Code
Reading	a. Incorrect in writing down the numbers given in the question	NE 1
	b. Incorrectly writing arithmetic operation symbols in the question	
Comprehension	a. Unable to interpret what is known and asked in the question	NE 2
	b. Incorrect interpretation of the information in the question	
	c. Incorrect in selecting/using relevant data from the question	
Transformation	a. Using formulas/calculations that are not relevant to the question	NE 3

Stages	Error Indicators	Code
	b. Lack of knowledge about the formula/calculation to be used c. Unable to create a mathematical model from the problem presented	
Processing Skill	a. Unable to determine the procedures/steps to be used b. Errors in computation c. Unable to continue the solution procedure d. Unable to explain the computational process in the answer sheet	NE 4
Encoding	a. Incorrect calculation in the final answer b. Unable to determine and write down the final answer c. Writing an incorrect answer d. Did not write the appropriate unit e. errors in writing mathematical notation/symbols	NE 5

Source: Safegi et al., (2021) and Noutsara et al., (2021)

Table 1 provides a detailed explanation of Newman's Error Analysis indicators. The first indicator, Reading (NE 1), refers to students' ability to identify information in the problem, and identify information presented in the problem. The second indicator, Comprehension (NE 2), assesses students' understanding of the problem statement, including what is known and what is being asked. The third indicator, Transformation (NE 3), focuses on students' ability to convert information into appropriate mathematical models and to select the correct concept to solve the problem. The fourth indicator, Processing Skill (NE 4), evaluates students' ability to perform the required calculations accurately. The final indicator, Encoding (NE 5), examines students' ability to write the final answer correctly, including both the numerical result and its unit.

RESULT AND DISCUSSION

Result

Students errors in completing PISA questions on Space and Shape based on Newman's Errors can be seen in Table 2.

Table 2. Student Error Data Based on NEA

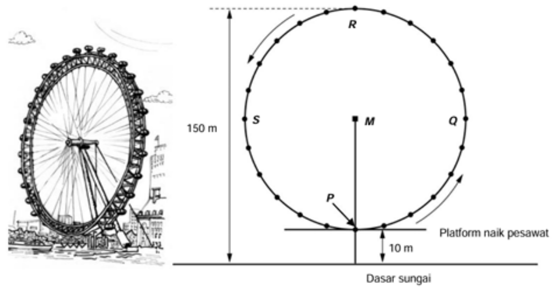
Error Category	AL	RF	DW	AM	TR
Reading	-	-	-	-	✓
Comprehension	-	✓	-	✓	✓
Transformation	-	✓	✓	-	✓
Processing Skill	✓	-	-	-	✓
Encoding	-	✓	-	-	✓

Based on the error data for each subject presented in Table 2, several students made errors categorized under NEA when solving PISA problems. As shown in Table 2, the most common errors made by students were related to comprehension and transformation. There were three students who made comprehension errors, namely RF, AM, and TR. Meanwhile, three students also made transformation errors, specifically RF, DW, and TR. Other types of errors such as reading errors, processing skill errors, and encoding errors were made by only one or two students.

These findings are supported by the analysis of the students' worksheets revealed that comprehension errors occurred because students were not thorough when reading the problems. Meanwhile, transformation errors arose due to students' difficulties in translating problem information into appropriate mathematical representations. Each error made by the students was categorized according to NEA and is discussed in more detail below.

The results of the error analysis are based on the questions and students' answers. The following is a PISA question adopted from the 2012 assessment with the code PM934. This is the PISA question on Space and Shape content used in the study.

4. PISA 2012 (Unit PM934 – Ferris Wheel)
A giant Ferris wheel is on the bank of a river. See the picture and diagram below.



The Ferris wheel has an external diameter of 140 metres and its highest point is 150 metres above the bed of the river. It rotates in the direction shown by the arrows. The letter M in the diagram indicates the centre of the wheel. How many matres (m) above the bed of the river is point M?

Figure 1. PISA question on Space and Shape

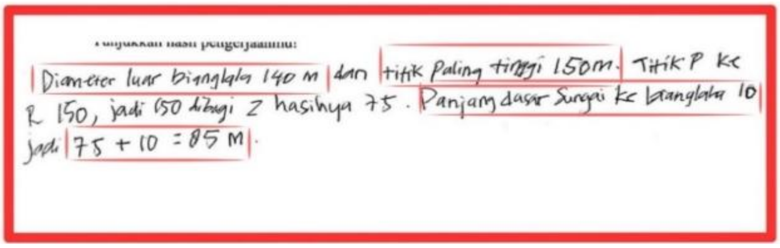
Figure 1 shows a PISA question on Space and Shape with a Ferris wheel context. The question provides an illustration of a Ferris wheel along with a description of the problem regarding the distance between point M and the riverbed. It also includes information on the diameter and the highest point of the Ferris wheel, which can help students calculate the distance between point M and the riverbed.

The indicators observed in this question are as follows: reading is measured by the students' ability to correctly write down the diameter, maximum height, and distance of the Ferris wheel from the riverbed. Comprehension is measured by the students' ability to understand that question focuses on the distance of point M from the riverbed and to recognize that 150 meters represents the maximum height, not the diameter.

Transformation is measured by the students' ability to model information into mathematical form, such as finding the centre height by subtracting the radius from the maximum height. Processing Skill is measured by the students' ability to perform calculations correctly. Encoding is measured by the students' ability to restate the final result and write the units correctly, such as 80 meters.

The following section presents a description of the students' answers and the mistakes they made in solving the PISA Space and Shape question related to the Ferris wheels context.

Reading Errors



ENGLISH VERSION

The outer diameter of the circle is 140 m and the highest point is 150 m. The distance from point P to R is 150 m, so 150 m divided by 2 equals 75 m. The length from the base of the river to the ferris wheel is 10 m. So 75 + 10 = 85 m.

Figure 2. Reading Errors made by student DW

Figure 2 shows that student DW was able to read to question correctly. The student correctly wrote down the numbers based on the information provided in the problem, including 150 meters and 140 meters. The student also correctly performed the calculation, where 75 + 10 = 85.

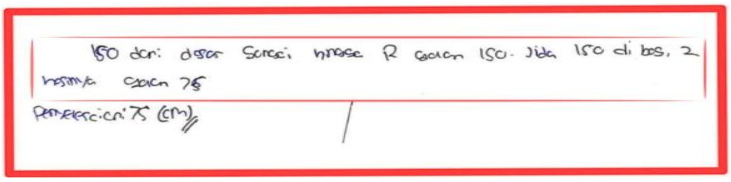
This finding is supported by the results of interviews with students who produced similar responses, as follows:

P :*"What information do you know from the question?"*

DW :*"The question states that the Ferris wheel has a diameter of 140 meters, then the distance from the highest point of the Ferris wheel to the riverbed is 150 meters, and the question is the distance from point M to the riverbed"*

The interview results support the findings in the student worksheets, which help explain the students' mistakes in solving the problem. According to the NEA indicator, DW did not meet the criteria for the NE 1 indicator. This aligns with the NE 1 indicator, which states that students are considered to have mastered this stage if they can identify the information in the question, specifically in writing down the numbers, symbols, and operation signs listed in the question (Noutsara et al., 2021; Safegi et al., 2021).

Comprehension Errors



ENGLISH VERSION

150 from the riverbed to point R inside the ferris wheel is 150. If 150 m is divided by 2, the result is 75.
Solution: 75 cm

Figure 3(a). Comprehension *E*rror made by student RF

Figure 3(a) shows the student RF misinterpreting the question. The student did not fully understand the problem and mistakenly interpreted 150 meters, which should represent the maximum height of the Ferris wheel from the riverbed, as the diameter of the Ferris wheel. This misunderstanding of the problem's meaning led the student to make errors in determining the appropriate steps to solve the PISA Space and Shape question.

This finding is supported by the results of interviews with students who produced similar responses, as follows:

P : *"Do you think the question was difficult?"*
RF : *"Yes, I don't understand the question"*
P : *"What part didn't you understand?"*
RF :*"I didn't know which formula to use to solve it, and I was quite confused about the purpose of each piece of information"*
P :*"Then, why did you divide 150 meters by 2 in your solution?"*
RF :*"I thought 150 meters was the diameter of the Ferris wheel"*
P :*"But when you solved the problem or before submitting your answer, did you read and check it again?"*
RF :*"No, because I was already quite sure of the answer"*

The interview results support the finding on the student worksheet, which explain the errors made in solving the problems. According to the NEA indicators, the mistakes made by student RF fall under the NE 2 category. This aligns with the NE 2 indicator, which states that students are considered to have mastered tis stage if they can understand the meaning of the question, what is known and what is asked in the question (Noutsara et al., 2021; Safegi et al., 2021).

Additionally, there are other answers that also fall under NE 2 in solving the PISA Space and Shape question, as follows:

Figure 3(b). Comprehension errors made by student TR

Figure 3(b) shows the answer of student TR, who misinterpreted the question. The student did not understand the problem and left the worksheet blank because she did not know where to begin. She was unable to identify what was being asked and what information was given in the question. Consequently, her inability to understand the meaning of the problem prevented her from solving it correctly.

This finding is supported by the results of interviews with students who produced similar responses, as follows:

P : *"Was the question so difficult that you couldn't answer question number 4?"*
TR : *"Yes, I didn't understand the question"*
P : *"Which part didn't you understand?"*
TR : *"I didn't know which formula to use to solve it"*
P : *"But do you understand what the question is asking?"*
TR : *"No, because I rarely practice questions like this"*

The interview results support the findings on the student's worksheet, which explain the students' errors in solving the problems. According to the NEA indicators, the mistakes made by student TR fall under the NE 2 category. This is consistent with the NE 2 indicator, which states that students are considered to have mastered the NE 2 indicator if they can understand the meaning of the question, what is known and shat is asked in the question (Noutsara et al., 2021; Safegi et al., 2021).

Transformation Errors

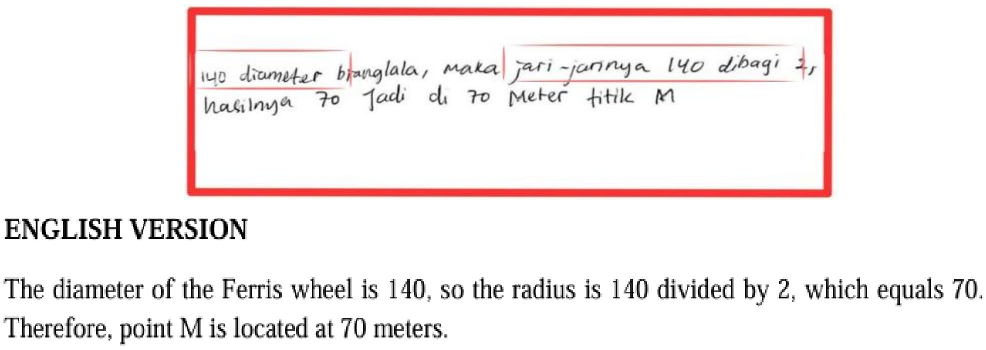


Figure 4. Transformation Errors made by student AM

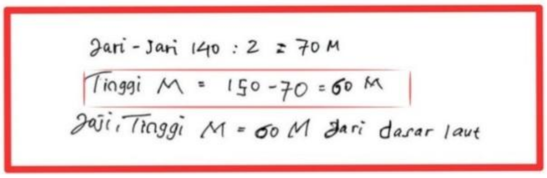
Figure 4 shows that student AM's answer was incorrect in converting information into mathematical form. The student misunderstood the problem, which led to an incorrect formulation of the question. In fact, the mathematical representation in the students' worksheet was not clearly visible, indicating that the student was unable to transform the information into a proper mathematical model.

This finding is supported by the results of interviews with students who produced similar responses, as follows:

P : *"How did you solve the problem?"*
S : *"By simply subtracting, based on my assumptions"*
P : *"Why didn't you clarify the operation symbols?"*
S : *"We didn't really know how to start using the symbols"*
P : *"So you're not sure what this material is related to?"*
S :*"No, but we can estimate what steps need to be taken"*
P : *"Why is it difficult to estimate the steps to solve it?"*
S :*"Because we are not usually given problems like that. They are usually numbers, figures, and simple pictures"*

The interview results support the finding on the student's worksheet, which explain the students' mistakes in solving the problems. According to the NEA indicators, the mistakes made by student AM fall under the NE 3 category. This aligns with the NE 3 indicator, which states that students are considered to have mastered this stage if they can transform information into mathematical models and select the appropriate concepts (Noutsara et al., 2021; Safegi et al., 2021).

Processing Skills



ENGLISH VERSION

radius = 140 : 2 = 70 m
Height M = 150 - 70 = 60 m
Therefore, height M = 60 m from the riverbed

Figure 5. Processing Skill Error made by student AL

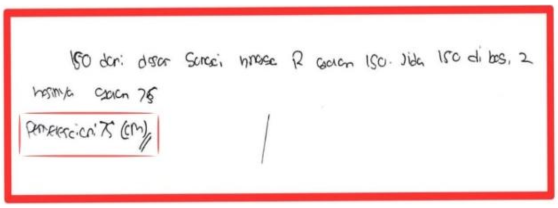
Figure 5 shows that student AL's answer is incorrect. Based on AL's calculation process, the result should have been 150 – 70 = 80. However, AL wrote 60 as the final answer. This indicates an error in the calculation process.

This finding is supported by the results of interviews with students who produced similar responses, as follows:

P : *"How did you solve the problem?"*
AL : *"First, I found the radius, and then I subtracted the radius from 150 to find the distance of point M from the riverbed"*
P :*"After you finished working on it; did you check your work again?"*
AL :*"No, but it seems that I was not careful enough when doing it yesterday"*

The interview results support the findings on the students' worksheet, which explain the students' mistakes in solving the problem. According to the NEA indicators, the mistakes made by student AL fall under the NE 4 category. This aligns with the NE 4 indicator, which states that students are considered to have mastered this stage if they can perform calculations accurately (Noutsara et al., 2021; Safegi et al., 2021).

Encoding Errors



ENGLISH VERSION

150 from the riverbed to point R inside the ferris wheel is 150. If 150 m is divided by 2, the result is 75.
Solution: 75 cm

Figure 6. Encoding Error made by student RF

Figure 6 shows that RF's answer was incorrect, resulting in an inaccurate final answer. Based on RF's calculation, the result obtained was 75 from the division, and the unit used in the question was meters. However, RF wrote centimetres as the unit. This indicates an error in writing the unit at the end of the answer.

This finding is supported by the results of interviews with students who produced similar responses, as follows:

P : *"What information did you get from the question?"*
RF : *"It is stated that the highest point of the Ferris wheel is 150 meters and its outer diameter is 140 meter. Then, it asks for the location of point M from the riverbed"*
P :*"Did you double-check your answer before submitting it?"*
RF :*"No, because I was confident in my answer"*
P : *"So the information provided is in meters. Why did you use cm in your final result?"*
RF :*"Because I was in a hurry yesterday, I made a mistake in writing the unit in the final answer"*

The interview results support the findings on the students' worksheet, which explain the students' mistakes in solving the problem. According to the NEA indicators, the mistakes made by student RF fall under the NE 5 category. This aligns with the NE 5 indicator, which states that students are considered to have mastered this stage if they can correctly write down the final answer, including both the calculated value and the unit (Noutsara et al., 2021; Safegi et al., 2021).

Discussion

The results of the study show that the most common mistakes made by students occurred at the comprehension and transformation stages. The finding that students often misinterpreted information in the questions, for example, assuming the maximum height as the diameter, evidences this. Reinforced by the interview results, these mistakes occurred because students were not careful when reading the questions and were reluctant to review their answer. This finding aligns with the opinion of Safegi et al. (2021), who stated that comprehension errors arise due to students' lack of thoroughness in interpreting the meaning of the questions, their weak thinking skills, and their limited experience in practicing PISA-type mathematics problems.

In addition to misunderstandings, many students were also unable to translate the information in the questions into the correct mathematical form, resulting in answers that did not match what was being asked. These errors were due to students' unfamiliarity with PISA question, which left them unsure of which mathematical strategy to use (Noutsara et al., 2021; Pereira et al., 2022; Safegi et al., 2021). The mistakes made by students in this study are consistent with the opinion of Pereira et al. (2022), who emphasized that students' main difficulties in solving PISA problems are interpreting the questions (Comprehension Error) and modelling the information into mathematical form (Transformation Error).

Reading Errors in this study were rare because most students were able to identify or write numbers and symbols correctly. For example, the calculation method 150 ÷ 2, then 140 ÷ 2, and 75 +10. Encoding Errors were also rarely found because most students wrote down the final answer correctly, either in numerical or with the appropriate units. However, a few students still made errors in writing the final answer due to carelessness, such as writing the unit as "cm" instead of "m".

When viewed from the mathematical reasoning indicator, misunderstanding errors indicate students' weakness in presenting mathematical statements and making assumptions. This aligns with the mathematical reasoning indicator, which states that students should be able to present mathematical statements based on their ability to identify and write down information, whether in the form of numbers, text, diagrams, or images, related to the question (Sholihah & Listanti, 2022). Meanwhile, making assumptions can be seen in students' ability to make estimates based on the information presented. Transformation errors are associated with students' weakness in performing mathematical manipulations, consistent with the statement by Sholihah & Listanti (2022), who explain that students are considered capable of performing mathematical manipulations if they can convert the information provided into a mathematical form. Meanwhile, process skill errors indicate students' weakness in providing arguments and justifications. Students are said to be able to provide sound reasoning when they can apply the correct formulas and steps, accompanied by logical explanations supporting their solutions (Sholihah & Listanti, 2022).

These findings support the research results of Safegi et al. (2021) and Pereira et al. (2022), who found that students are still weak and frequently make errors when solving PISA problems based on real-world contexts, particularly in the Space and Shape content, which requires a strong understanding of spatial visualization. Therefore, it is important to familiarize students with PISA-type mathematical problems (Gustiningsi et al., 2023; Nusantara et al., 2020). Integrating real-world contexts into mathematical problems can make learning more meaningful, relevant, and engaging for students (Sartika et al., 2024).

Moreover, the integration of local contexts can capture students' interest and attention while also increasing their familiarity with their environment and culture, thereby contributing to the preservation of local heritage (Gustiningsi et al., 2023; Murtadlo et al., 2023; Putri et al., 2022). Such questions are not only engaging and relevant but can also enhance students' mathematical reasoning skills. Therefore, the development of contextual PISA-type mathematical problems for students, especially those focusing on Space and Shape is essential to support the improvement of students' mathematical reasoning abilities.

CONCLUSION AND RECOMMENDATIONS

This study shows that errors in comprehension, transformation, and processing skills are the most common mistakes made by students at SMP Negeri 7 Muaro Jambi when completing PISA questions on Space and Shape. For example, students misinterpret the information in the questions, leading to comprehension errors, and are unable to connect this information to mathematical forms, resulting in transformation errors. Meanwhile, errors in reading, processing skills, and encoding were less frequent, although some students still made such mistakes. These errors were caused by students' carelessness in reading and solving problems, their limited reasoning skills, and their lack of familiarity with practicing PISA-type mathematical problems, particularly those involving local context. In this study, original PISA questions on Space and Shape were used, so the problems presented were not entirely relevant to the students' context. Therefore, it is necessary to develop PISA-type mathematical problems, especially those involving Space and Shape in real contexts, as practice material for students.

ACKNOWLEDGEMENT

This research was supported by the DIPA of Universitas Jambi 2025, Contract Number: SP DIPA 139-03.2.693426/2025, under the beginner lecturer research. The author would like to express their gratitude to the mathematics teacher and the students of Class IX F at SMP Negeri 7 Muaro Jambi for their valuable contributions and active participation.

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