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ORIGINAL

What Are the Learning Obstacles in Students' Algebraic Thinking During the Introduction of Plane Geometry Material?

¿Cuáles son los obstáculos de aprendizaje en el pensamiento algebraico de los estudiantes durante la introducción del material de geometría plana?

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ABSTRACT

This research addresses the challenges elementary students face in developing algebraic thinking skills, particularly during the introduction of plane geometry topics such as squares and rectangles. Algebraic thinking, essential for identifying patterns, relationships, and generalizations, is often hindered by various learning obstacles. Using a qualitative approach with Didactical Design Research (DDR), data were collected through tests, interviews, and document studies. The research involved 30 second-grade students, with six selected for detailed unstructured interviews to confirm their responses. The findings highlight five major learning obstacles: (1) difficulty understanding word problems, (2) difficulty representing problems mathematically, (3) difficulty in measurement and calculations, (4) challenges in communicating solutions, and (5) inability to generalize solutions. These results emphasize the need for improved didactic designs that address learning obstacles and foster algebraic thinking. The study offers actionable insights for enhancing mathematics education in elementary schools.

Keywords: Learning Obstacles; Algebraic Thinking; Squares and Rectangles.

RESUMEN

Esta investigación aborda los desafíos que enfrentan los estudiantes de primaria al desarrollar habilidades de pensamiento algebraico, especialmente en la introducción de temas de geometría plana como cuadrados y rectángulos. El pensamiento algebraico, crucial para identificar patrones, relaciones y generalizaciones, a menudo se ve obstaculizado por diversas dificultades de aprendizaje. Utilizando un enfoque cualitativo con Investigación de Diseño Didáctico (DDR), se recopilaron datos mediante pruebas, entrevistas y análisis de documentos. Participaron 30 estudiantes de segundo grado, de los cuales seis fueron seleccionados para entrevistas detalladas no estructuradas. Los resultados identificaron cinco obstáculos principales: (1) dificultad para entender problemas enunciados, (2) dificultad para representar problemas matemáticamente, (3) problemas con mediciones y cálculos, (4) desafíos al comunicar soluciones, y (5) incapacidad para generalizar soluciones. Estos hallazgos destacan la necesidad de diseños didácticos mejorados que aborden los obstáculos de aprendizaje y fomenten el pensamiento algebraico, ofreciendo así ideas clave para mejorar la educación matemática en primaria.

Palabras clave: Obstáculos para el Aprendizaje; Pensamiento Algebraico; Cuadrados y Rectángulos.

INTRODUCTION

Algebraic thinking is considered an important skill that needs to be developed early on, especially in arithmetic reasoning in elementary school. According to[1,2], algebraic thinking acts as a bridge between arithmetic and formal algebra.[3] The ability to think algebraically allows students to understand mathematics more deeply and makes it a key element in mathematical thinking.[4] At the primary school level, algebraic thinking includes the introduction of numbers and algebra which helps students recognize patterns, understand variables and functions,[5] as well as develop the thinking skills of abstraction, analysis, and modeling.[6] Therefore, early mastery of these skills eases the transition from arithmetic to formal algebra, helping students develop more complex mathematical thinking abilities.

The problems faced by students in thinking algebraically and understanding the concept of flat shapes, especially squares and rectangles, are still relatively weak.[7,8,9] Observations show that students often experience difficulties when flat shapes are presented in visual variations. Their understanding is limited to standard shapes, so when a square is rotated, they often mistakenly identify it as a rhombus. This suggests that students rely more on visual displays rather than understanding essential geometric properties such as the similarity of side lengths and right angles that remain, even if the position of the shape changes. Other research shows the weakness of elementary school students in algebraic thinking, especially in the introduction of flat building materials such as squares and rectangles. This difficulty can be seen from their limited understanding in identifying geometric properties and representing these shapes mathematically, as well as in connecting basic concepts with problem solving involving these two shapes.[2,10,11,12,13,14] This difficulty reflects students' weak ability to model situations and use appropriate mathematical representations, as found by[15]. In addition,[16] noted that students are often confused when the structure of the problem changes, especially in basic mathematical operations. These learning barriers emphasize the need for teaching that focuses on deep concept understanding, rather than just visual shape recognition, for students to overcome barriers to learning mathematics.

Learning barriers are a common problem that is often faced in learning, especially in mathematics. According to[17], learning barriers are caused by neurological, psychological or other factors that interfere with the process of understanding the material. In the context of mathematics, these barriers are often caused by limited understanding, non-interactive teaching methods, or differences in cognitive development between students.[16,18] Difficulties in mathematics do not only occur at the primary level, but also continue into higher education. This is an important concern because mathematics is a discipline that develops critical, creative, and analytical thinking skills.[19] Therefore, understanding and overcoming learning barriers is essential to ensure that mathematics learning takes place effectively and is able to help students better understand concepts, especially in flat building material which is the foundation for further geometry concepts. This article discusses the learning barriers of students' algebraic thinking in the introduction of square and rectangular shapes. The aim is to identify students' learning barriers in algebraic thinking in the introduction of flat shapes, especially squares and rectangles, at the elementary school level. Knowledge of these learning barriers will be used as a basis for designing didactical designs that can reduce student learning barriers.

Algebraic thinking, a key cognitive skill in mathematics, bridges arithmetic and formal algebra by fostering the ability to generalize patterns, understand variables and functions, and model problems.[3,6,20] Early development of algebraic thinking through patterns, variables, and symbolic relationships helps students solve complex problems.[21,22,23] However, learning obstacles often arise from cognitive challenges or ineffective teaching, impacting students' ability to grasp concepts like squares and rectangles.[17,18,24] Addressing these barriers through interactive strategies ensures better understanding of geometric properties and relationships.[26,27,28]

METHOD

This research uses a descriptive qualitative approach with the Didactical Design Research (DDR) method to understand the learning barriers of students' algebraic thinking in learning square and rectangular flat shapes. DDR focuses on designing learning designs that can overcome students' learning barriers through cycles of planning, teaching, and didactical analysis.[29] The research subjects consisted of 30 grade II students of SDN 4 Argasari Tasikmalaya district and their class teacher. Of the 30 students, 6 students who experienced complex learning difficulties were selected by taking into account the students' previous academic achievements, input from the teacher and students being able to express their ideas. The following is a picture of the determination of the subjects interviewed in figure 1.

Data were collected through tests, interviews, observations, and documentation, then analyzed descriptively qualitatively with a focus on students' difficulties in understanding the concepts of square and rectangle. The analysis followed the DDR steps, namely prospective analysis (analysis of the didactic situation before the implementation of learning); metapedadidactic analysis (analysis of the didactic-pedagogical situation); and retrospective analysis (which links the first stage with the second stage).[30,31] The following research implementation scheme is shown in figure 2.

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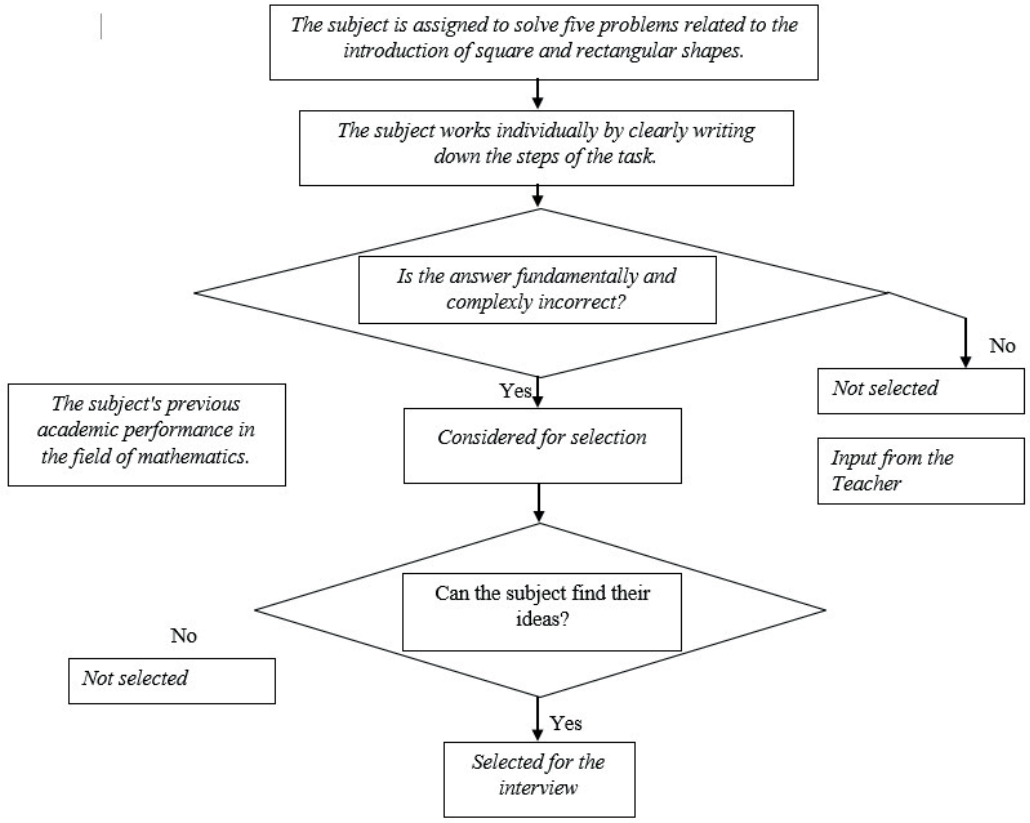

Figure 1. Selection of Interviewed Research Subjects

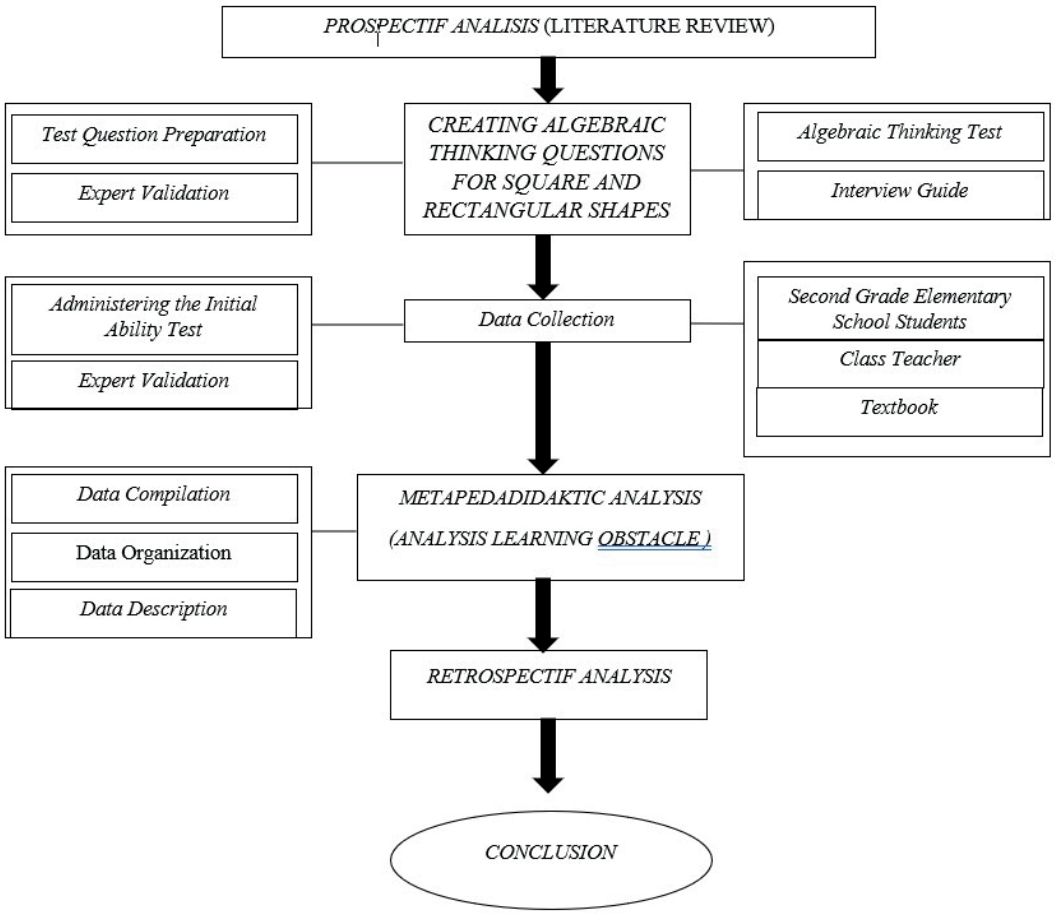

Figure 2. Schematic of Research Implementation Procedure

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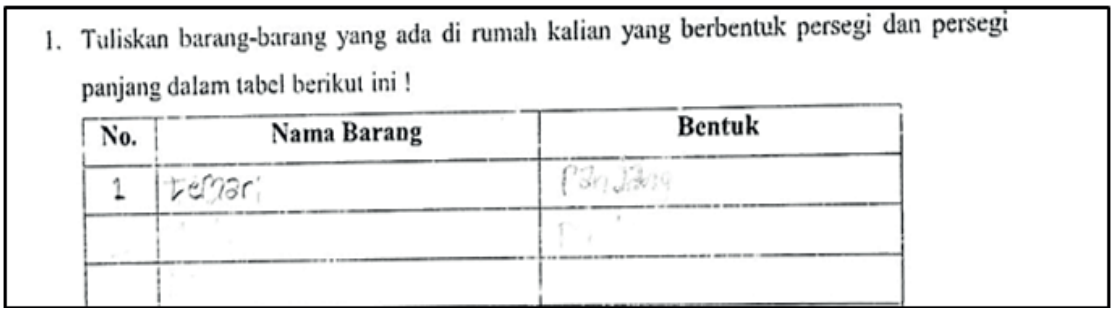
RESULTS

This study found five main obstacles experienced by Grade 2 students in understanding the introduction of square and rectangular flat shapes. First, students had difficulty understanding the context and content of story problems, indicating weak reading comprehension skills. Second, students had difficulty representing story problems into mathematical form, indicating the need for improvement in converting text information to mathematical symbols. Third, obstacles arise in performing measurements and calculations, where students lack skill in understanding the concepts and properties of flat shapes. Fourth, students experience challenges in communicating answers, both orally and in writing, which indicates weak mathematical communication skills. Fifth, students have difficulty generalizing answers from story problems, indicating the need for a deeper understanding of the application of mathematical concepts in various situations.

Understanding the Context and Content of Story Problems

In this finding, students showed difficulty in understanding the context and content of the story problem. For example, S[6] did not fully understand the instructions given in the problem.



1. Tuliskan barang-barang yang ada di rumah kalian yang berbentuk persegi dan persegi panjang dalam tabel berikut ini !

No.	Nama Barang	Bentuk
1	lemari	

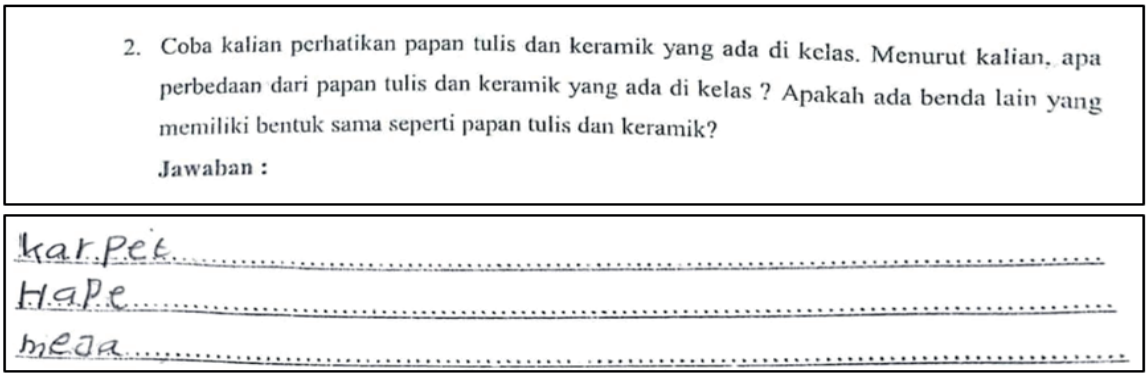
Figure 3. S_6's answer to Q_1

In the completion of Q_1, S_6 showed that she did not understand the meaning of the question Q_1, which asked students to write down items in the house with square and rectangular shapes. S_6 only wrote down the name of one item, a cupboard, and noted that its shape was long, without mentioning a more specific geometric shape such as square or rectangle. This answer shows that S6 did not fully understand the context and content of the problem and had difficulty in identifying and classifying the geometric shapes requested. This is reinforced by S_6's expression as follows:

- P: Why did you answer number one long?
- S_6: Because the cupboard is long.

So, S_6 did not understand the difference between a description of a precise geometric shape (such as a square or rectangle) and a description of size or dimension in general. S_6's answer showed that she associated the term "long" with the shape of the cupboard without connecting it with a more specific geometric term.

The same thing was shown by S_1 in Q_2. S1's answer directly wrote the name of the object such as carpet, cellphone, table without giving additional information about its shape.



2. Coba kalian perhatikan papan tulis dan keramik yang ada di kelas. Menurut kalian, apa perbedaan dari papan tulis dan keramik yang ada di kelas ? Apakah ada benda lain yang memiliki bentuk sama seperti papan tulis dan keramik?

Jawaban :

karpet
Hape
meja

Figure 4. S_1's answer to Q_2

In addition, S_1 also did not answer the question about the shape of ceramics and blackboards, which is an important part of the problem. The conclusion from this situation is that S1 had difficulty in understanding and following the problem instructions thoroughly. S1 did not seem to be able to connect the information about

geometric shapes with the objects mentioned and did not include relevant information other objects. This can be seen from the interview with S1 as follows:

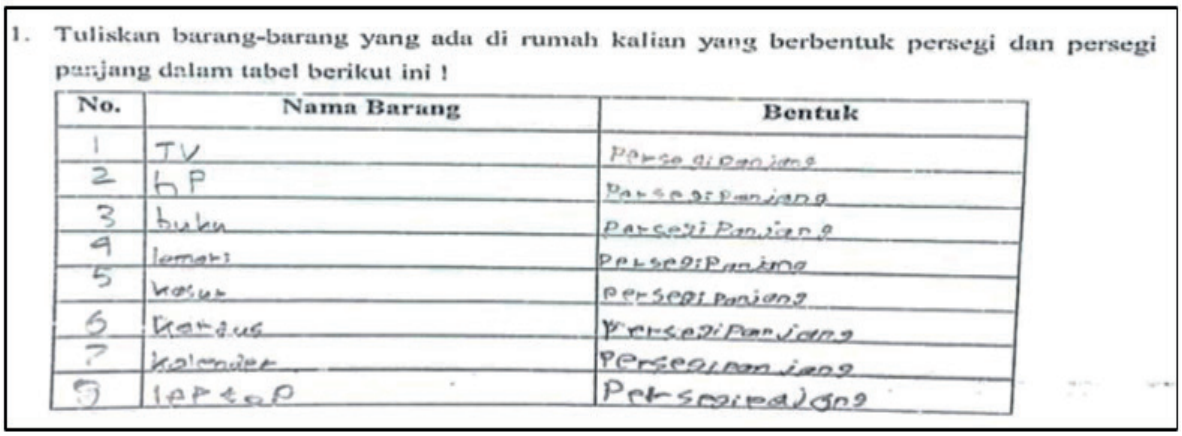
- P: Why did you answer number two carpet, phone, and table?
- S_1: The same shape as the blackboard.

So, S_1 seems to associate the objects with a similar shape to the blackboard, but did not explain in detail or accurately the geometric shapes requested in the problem. This suggests that students may not have fully understood or followed the problem instructions appropriately, as well as having difficulty in identifying and classifying objects based on specific geometric shapes.

Students' low understanding of the context and content of story problems is the main factor that causes them to have difficulty in understanding the problem as a whole. This limitation hinders students' ability to capture the intent of the problem, which in turn impacts their inability to identify the steps of solution and represent the information into an appropriate mathematical form. Therefore, improving their understanding of the context and content of the problem is essential to help students overcome their learning barriers.

Representing Story Problems into Mathematical Forms

In the second finding, many students had difficulty in translating the story problem into the correct mathematical form. S_2, for example, only correctly wrote down rectangular objects, in accordance with the question's instructions which asked to find objects with this shape. S_2 did not include objects that were square, even though the question also asked to include objects with square shapes at home.



1. Tuliskan barang-barang yang ada di rumah kalian yang berbentuk persegi dan persegi panjang dalam tabel berikut ini !

No.	Nama Barang	Bentuk
1	TV	Persegi panjang
2	HP	Persegi panjang
3	buku	Persegi Panjang
4	lemari	Persegi Panjang
5	kasur	persegi panjang
6	karpet	Persegi Panjang
7	kalender	Persegi panjang
8	lapto P	Persegi panjang

Figure 5. S_2's to Q_1

When confirmed, S_2 understood the meaning of the problem. P then continued with questions about the purpose of the problem, and the student explained that the task was to find objects that were square and rectangular. However, when the researcher asked why students only wrote down rectangular objects, students answered that what came to mind at that time was only a rectangular shape. The following is S_2 's statement:

- P: What does the question mean?
- S_2: Looking for objects that are square and rectangular
- P: But why did you write only rectangular objects?
- S_2: Because that's what I thought, ma'am.

This answer shows that although the student understands the question's instructions in general, he still has difficulty in remembering or identifying the specific shape of a square. Students' ability to represent story problems into mathematical form is still relatively weak, because they face difficulties in connecting abstract concepts with relevant geometric objects. Students often struggle to understand how the elements in the story problem can be transformed into appropriate symbolic or visual representations, such as drawing flat shapes or using appropriate formulas. This limitation indicates that their understanding of the relationship between mathematical concepts and real objects is not strong enough, so they are not able to apply these concepts effectively in solving problems.

Perform Measurements and Calculations

At this stage, some students, such as S_1, had difficulty in performing measurements and calculations, for example, when instructed to measure the square and rectangle drawings they had made, students did not understand how to measure the shapes and tended to fill them in carelessly without relevant measurements.

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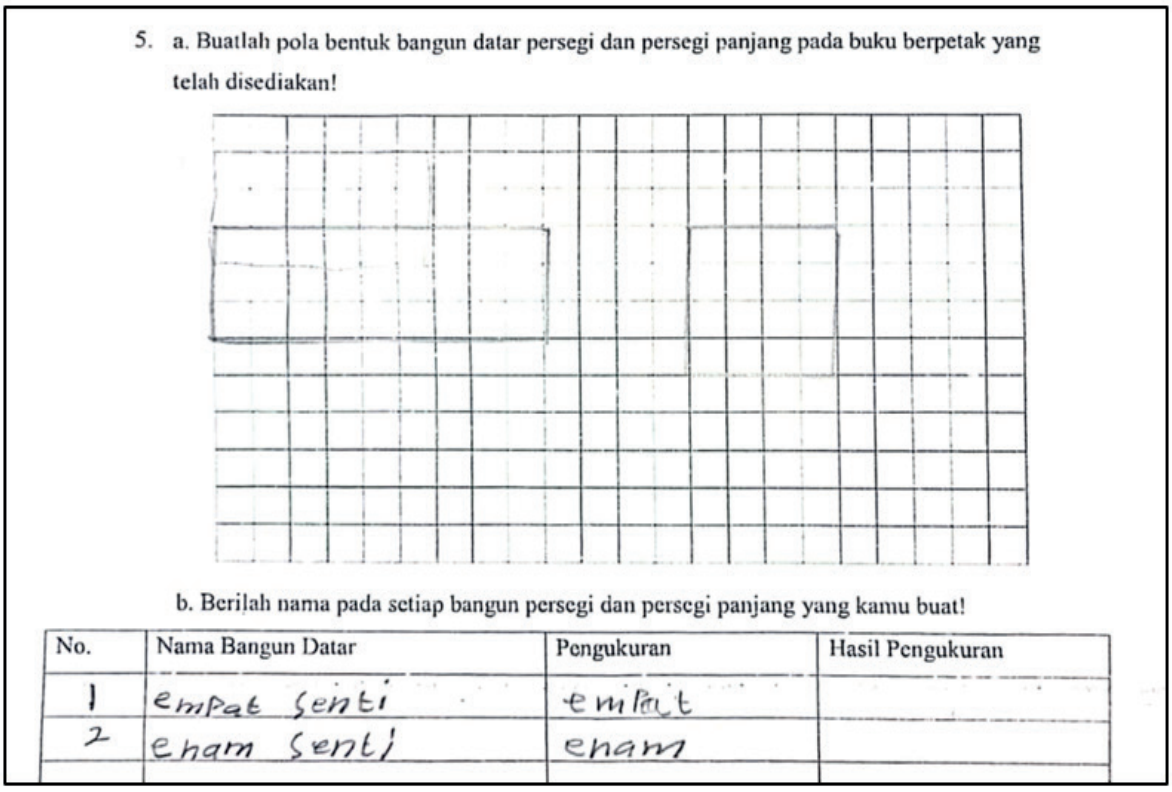


5. a. Buatlah pola bentuk bangun datar persegi dan persegi panjang pada buku berpetak yang telah disediakan!

b. Berilah nama pada setiap bangun persegi dan persegi panjang yang kamu buat!

No.	Nama Bangun Datar	Pengukuran	Hasil Pengukuran
1	empat senti	empat	
2	enam senti	enam	

Figure 6. S_1's to Q_5

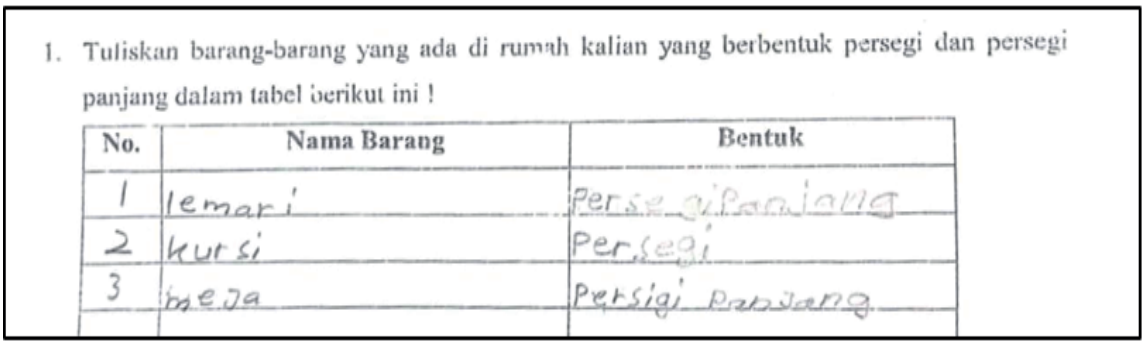
In solving Q_5, S_1 had difficulty when asked to measure square and rectangular flat shapes and then enter the measurement results into a table containing columns of flat shape names and measurement results. S_1 not only filled in the measurement results in the column that should be filled with the name of the flat shape, but also made mistakes in measuring the flat shape. The measurement results entered were inaccurate and did not match the actual shape. This error showed that S1 did not fully understand how to fill in the table correctly and experienced confusion in distinguishing between different columns. In addition, the difficulty in making precise measurements reflects a lack of understanding of the basic concepts of measurement and geometric shapes. This can be seen from the interview with S1 as follows:

- P: In question number five, where did you answer four centimeters?
- S_1: By measuring

From the statement S_1 explained that the answer 4 cm in question number 5 was obtained by measuring. However, the measurement results were not as expected, and S_1 seemed to be careless in making measurements.

Communicating the answer orally or in writing

Almost all research subjects showed difficulties in communicating answers, both orally and in writing. For example, S_1 had difficulty when asked to explain the answer verbally, even though he had written the answer on the answer sheet. Similarly, S_5 felt confused in writing the answer. When interviewed, S_5 just smiled in confusion.



1. Tuliskan barang-barang yang ada di rumah kalian yang berbentuk persegi dan persegi panjang dalam tabel berikut ini !

No.	Nama Barang	Bentuk
1	lemari	Persegipanjang
2	kursi	Persegi
3	meja	Persigi Panjang

Figure 7. S_1's to Q_1

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- P: If you understand question number one, what does it mean?
- S_1: Hmmmm.... (S_1 seems confused)

This incident shows that students still have difficulty in communicating answers orally, even though they have written them down, as in S_1. S_5's confusion in writing and answering during the interview indicates a lack of concept understanding and confidence. These difficulties emphasize the importance of strengthening mathematical communication skills and concept understanding through a more interactive learning approach.

Generalizing Answers to Story Problems

In solving Q_4, S_5 was able to list the names of the objects from the picture. However, S_5 did not include information about the geometric shape of each object, and did not provide reasons for the answers that had been written down.

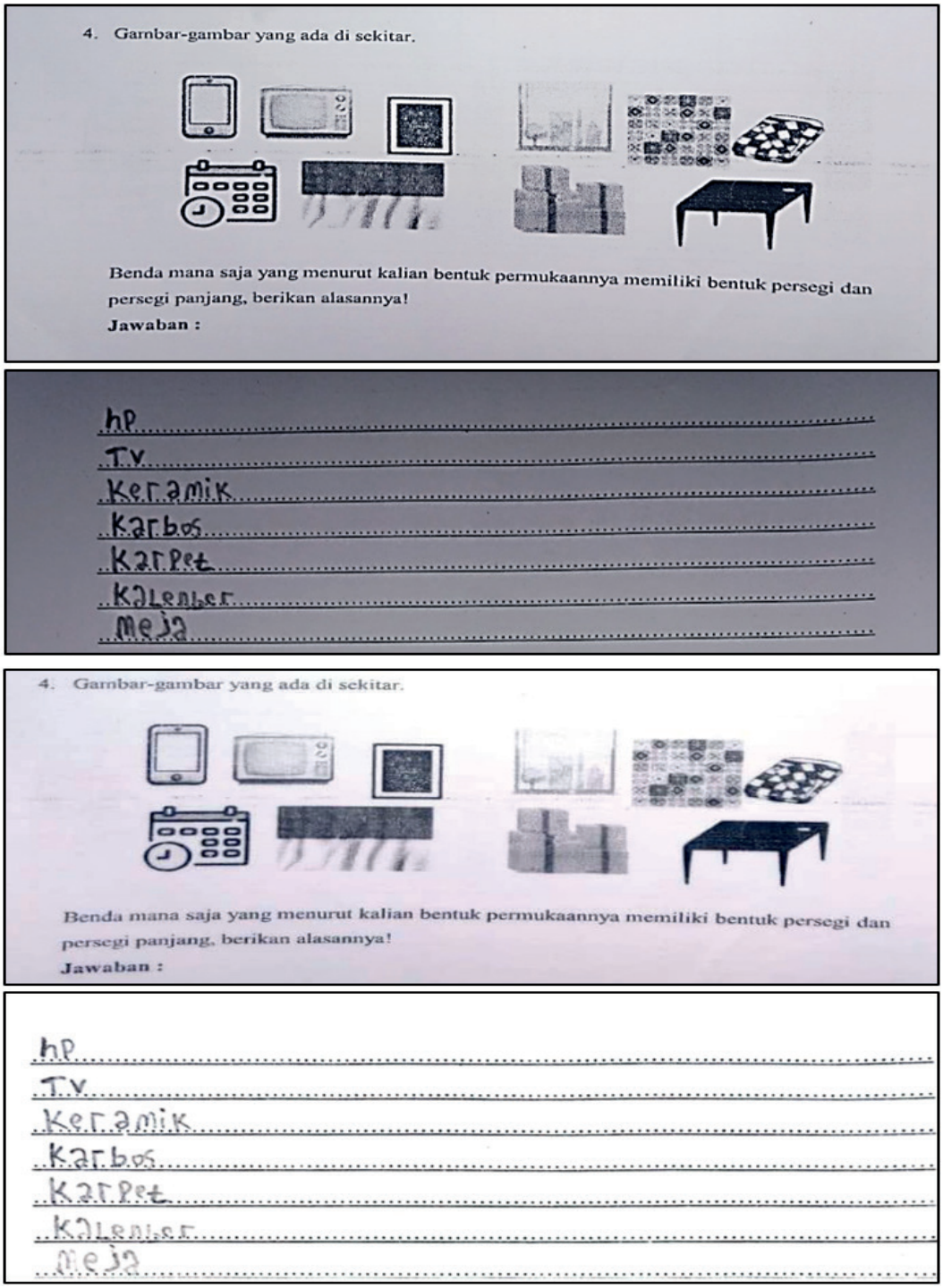

Figure 8. S_5's to Q_4

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S_5 had difficulty in generalizing the concepts he had learned. When asked to provide the reason for his answer, S_5 only focused on writing the name of the object without providing further explanation.

- P: Why didn't you write the reason for your answer?
- S_5: I don't understand mom, so I just wrote the object.

This shows that S_5 only remembered the surface information without being able to link the concept with the underlying reason. This limitation indicates that students have not achieved a deeper and more comprehensive understanding, especially in connecting basic concepts of flat shapes with more abstract reasoning, which is needed in the generalization process.

DISCUSSION

This study reveals various difficulties faced by students in understanding mathematical concepts, especially square and rectangular flat shapes, as well as algebraic thinking processes. These difficulties arise at various stages of learning, from understanding the context of the story problem, representing the problem in mathematical form, drawing flat shapes, to communicating and generalizing answers. These findings indicate a gap between students' understanding and curriculum expectations, reflecting the importance of a more contextualized and interactive learning approach. These findings will be combined with theory and previous research results to strengthen the analysis.

In the first point, understanding the context and content of story problems is an important first step in solving math problems. Desmita[32] asserts that elementary school students are at the concrete operational stage, so they more easily understand concepts through direct experience rather than through abstraction. This study also found that many students had difficulty understanding important elements in story problems, similar to the findings of[33], who stated that students often failed to capture important information in the problems. Piaget et al.[34] and Vygotsky[35] added that concrete learning and social interaction play an important role in accelerating students' understanding, supporting this study's finding that students often need direct assistance in understanding story problems.

At the stage of representing story problems into mathematical form, this study found that many students had difficulty. This finding is consistent with research[36,37], which shows that students still have difficulty translating story problems into mathematical form. Gagatsis[38] also revealed that mathematical representation facilitates problem solving, but many students fail to recognize key elements to translate into mathematical symbols. Cartwright[39] emphasized that fluency in using various forms of representation is an important indicator of mathematical thinking ability.

In terms of drawing and measuring flat shapes, the results of this study show that some students have difficulty drawing shapes with correct proportions and measuring dimensions appropriately. Piaget et al.[34] emphasized that spatial ability develops gradually and needs to be supported with adequate practice. This barrier, as seen in this study, is often due to a lack of practical practice and students' inability to use tools properly.[40] The ability to communicate answers is also a challenge for many students. Hodiyanto H[41] emphasized the importance of developing mathematical communication early on. This study found that students struggled to communicate their answers clearly, both orally and in writing. This supports the findings of[42], who emphasized that mathematical communication is very important in clarifying students' understanding and improving the flow of mathematical thinking.

Finally, the ability to generalize or draw conclusions from specific problems is an important aspect of mathematics learning. This study found that many students had difficulty generalizing, in accordance with the findings of[27,43] who emphasized the importance of reasoning skills in solving story problems. Piaget J[44] also asserts that generalization is part of higher cognitive development, and students' difficulties in generalizing indicate the need for a learning approach that is more focused on developing critical thinking skills,

Overall, this study shows that students' mathematics learning difficulties are not only caused by one factor, but are a combination of various aspects ranging from understanding story problems to the ability to generalize answers. Teacher support through contextual and interactive learning can be an effective solution in helping students overcome these difficulties.[45]

CONCLUSIONS

To overcome the obstacles found, a more contextual, interactive, and student-centered learning approach is recommended. This approach involves the use of concrete aids and activities relevant to everyday life, such as simulation and object manipulation, to help students understand the concept of square and rectangle more deeply. In addition, contextualized, open-ended didactical designs need to be designed, where students are given the opportunity to answer in various ways and justify their own knowledge. Providing intensive practice in representing story problems to mathematical symbols and encouraging communication and collaboration through group discussions are also important to improve students' ability to communicate and generalize their

answers. This approach can create a more effective learning environment in supporting the development of algebraic thinking skills.

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CONFLICT OF INTEREST

There is no conflict of interest.

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