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Learning Obstacles and Didactical Anticipation for Slow Learners in Polyhedron Learning

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ABSTRACT

The objectives of this study are to determine students' prior knowledge, the learning obstacles they have experienced, develop hypothetical didactic designs, and anticipate the didactic implications for students' learning process. This study uses a qualitative method within the DDR (Didactical Design Research) framework. This study was carried out by giving written tests to the students, conducting interviews with the students and the teacher, and observing the students' learning process. The participants in this study are students in 8th grade who studied the rectangular and triangular shape topic, and students in 9th grade who studied the polyhedron topic. Based on the data, the students' prior knowledge is not sufficient for learning the polyhedron topic. There are four characteristics of students' learning obstacles: epistemic, psychological ontogenic, conceptual ontogenic, and instrumental ontogenic. The hypothetical didactic design is based on slow learners' prior knowledge, their learning obstacles, student interview results, and teacher interview results. Didactical anticipation, designed hopefully, could help students connect prior knowledge to new knowledge and address the learning obstacles they face.

INTRODUCTION

Learning is fundamental to the growth and development of human mental functions [1]–[3]. The learning process does not always follow the teacher's plan. Teachers play a very important role in guiding students to develop their abilities. Therefore, every student is expected to be able to apply their abilities to deal with everyday problems more independently and effectively [4]–[6]. Teachers must know the objectives of the learning that will be carried out and how to assess students [7].

Authentic assessment refers to the degree of success in achieving the main objective of teaching students optimally, thereby preventing teachers from misdiagnosing students' learning difficulties [8]–[11]. One cause of learning difficulties is the instantaneous delivery of mathematical concepts as ready-made products, which limits students' understanding of the mathematical context. If mathematical concepts are presented directly in final results, students may experience difficulties in learning mathematics [12]–[14]. Therefore, mathematics should not be seen as a product but as an activity.

Students will encounter several difficulties during the learning process. These difficulties will cause students to face obstacles in learning. There are three types of learning obstacles that can occur in the learning process, namely ontogenic obstacles, epistemological obstacles, and didactical

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obstacles [15], [16]. Ontogenic obstacles are learning obstacles that arise from children's mental readiness [17]. Epistemological obstacles stem from students' learning difficulties, arising from their limited and incorrect understanding of the material being studied [18]. Didactical obstacles are those that arise from the methods or media teachers use in the learning process [19].

The results of the initial observations conducted by the researchers showed that students were given questions related to the formulas for the area and perimeter of quadrilaterals and triangles. The students' responses varied; some did not dare to express their opinions. Some students dared to express their opinions, but were incorrect in stating the formulas. Some students made mistakes in stating the area and perimeter of rectangles. When asked to state the formula for the area of a plane figure, the students stated the formula for the perimeter of the plane figure in question. Another response was that some students were wrong in stating the area of one type of plane figure, but used the formula for a different type. The following is one of the students' responses:

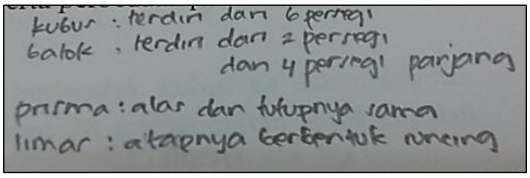

Figure 1. One of the Students' Responses Regarding the Characteristics of Flat Shapes

Based on Figure 1, students are still unable to understand the characteristics of flat-sided shapes when asked about them. Another finding is that some students experience difficulties and make mistakes in determining the base and height of a triangle [20]. The study found that students encounter obstacles in every lesson on triangles, so they will always need guidance in determining the base and height of a triangle.

This study will focus on students who are classified as slow learners. Slow learners are students who do not have special needs but are otherwise normal, with below-average abilities, or are unable to achieve learning objectives. According to Setyaningsih et al. [21], some characteristics of slow learners include having failed a grade, needing more time to understand the subject matter, and lacking enthusiasm in carrying out learning activities.

Researchers observed that slow learners are still not adequately facilitated by teachers. Another finding from the researchers' observations, particularly regarding students classified as slow learners, was that teachers did not allow slow learners to present their answers in front of the class.

The role of teachers in guiding and helping students who experience learning obstacles is to prepare for the responses given during the learning process [22]. Therefore, according to the researchers, it is important to focus the analysis of learning obstacles on students who are classified as slow learners.

Once the types of learning obstacles faced by slow learners have been identified, several solutions will be provided. The solutions provided will be in the form of didactical anticipation. However, the solutions provided will not only focus on didactical anticipation, but also pedagogical anticipation [23]. The didactical anticipation to be displayed depends on the results of the analysis of students' learning obstacles. Therefore, the type of didactical anticipation that will be displayed will be determined by the results of the types of learning obstacles that are most prominent in slow learners[24].

Didactical anticipations will be formulated based on the learning obstacles faced by slow learners. Researchers hope that all students will also understand the concepts that slow learners do.

However, concepts not yet understood by slow learners have two possible paths to understanding for other students. These two possibilities are that other students already understand them or do not yet understand these concepts. Therefore, the anticipated measures are expected to guide slow learners in overcoming the obstacles they face during learning activities and guide other students in optimizing their understanding of the concepts. Therefore, this study aims to identify the dominant learning obstacles for slow learners in learning flat-sided shapes and to develop appropriate didactical anticipations to improve students' conceptual understanding and mathematical reasoning optimally.

METHODS

The research method used was DDR (Design Didactical Research). The stages carried out based on the DDR design were 1) Analysis of the didactical situation, the researcher compiled the material, analyzed the concepts, compiled the test instruments, conducted tests on the students, and analyzed the students' answers, 2) Metapedagogical analysis, in which the researcher analyzed students' prior knowledge, analyzed students' learning obstacles, developed a hypothetical didactical design, and made predictions about student responses, 3) Retrospective analysis, analysis of the didactical situation, linking response predictions and anticipations [25].

The research instrument was a written test consisting of two types: a prerequisite knowledge test to assess students' prior knowledge before learning flat-sided shapes, and a learning obstacle test to assess the obstacles students faced after learning flat-sided shapes.

The prerequisite knowledge test consisted of 10 essay questions administered to 26 eighth-grade students at Junior High School 12 and 27 students at Junior High School 29. The following are the indicators of the prerequisite knowledge test questions used in this study.

1. Identify objects around you that are flat shapes (triangles and quadrilaterals).
2. Identify types of triangles and quadrilaterals based on their characteristics.
3. Identify types of triangles.
4. Calculate the perimeter of flat shapes in general.
5. Calculate the perimeter of quadrilaterals (squares, rhombuses, parallelograms, trapezoids).
6. Determine the difference between the perimeter and area of a known rectangle.
7. Determine the area of a triangle by determining the base and height of the triangle.
8. Calculate the area of quadrilaterals (rectangles, trapezoids, kites) and triangles.
9. Calculate the surface area of rectangles to answer questions in everyday life.
10. Calculate the perimeter and area of combined flat shapes.

The learning obstacle test consisted of seven essay questions administered to 29 students at Junior High School 12 Bandung and 28 at Junior High School 29 Bandung. The following are the indicators of the learning obstacle test questions used in this study.

1. Write down objects around you that are cubes or cuboids.
2. Determine the nets of cubes and cuboids from several known nets.
3. Determine the surface area of general shapes.
4. Determine the volume of cubes and cuboids.
5. Calculate the surface area of cubes and cuboids whose edge lengths are known.
6. Estimate the surface area and volume of irregular three-dimensional shapes.
7. Solve problems related to cubes and rectangular prisms.

The data analysis technique used in this study is a descriptive-qualitative approach. This analysis was conducted as soon as possible after the results and data collection were obtained [26]. The stages of data analysis in this study were 1) analyzing the results of the prerequisite knowledge test, 2)

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analyzing the results of the learning obstacle test, 3) analyzing the learning plan and student worksheets in the prepared didactical design, and 4) analyzing the didactical anticipation of slow learners.

RESULTS AND DISCUSSION

This section presents the results of the study based on the stages of data analysis conducted in accordance with the Didactical Design Research (DDR) framework. The findings are discussed to describe students' prerequisite knowledge, learning obstacles, and the effectiveness of the proposed didactical design in supporting slow learners. The analysis is organized into several subsections, beginning with an examination of students' prerequisite knowledge.

1. Prerequisite Knowledge for Slow Learners

The following table presents the average percentage of correct answers for each test question for both schools. These data provide an overview of students' prerequisite knowledge before learning polyhedron concepts.

Table 1. Average Percentage of Student Answers on the Prerequisite Knowledge Test

Item Number	Average Percentage
1	47,32 %
2	54,04 %
3	33,61 %
4	40,01 %
5	40,27 %
6	39,45 %
7	14,21 %
8	20,22 %
9	22,26 %
10	14,69 %

Based on Table 1, the highest percentage was for question 2, at 54.04%. The indicator for question number 2 was to determine the type of quadrilateral based on known properties. Most students were able to determine the types of quadrilaterals that matched the known properties. The lowest percentage of students with correct answers was seen in question number 7, which was 14.21%. The indicator in question 7 asked students to write the area of a triangle by finding the base and the height. Only a few students understood the concept of determining the base and height of a triangle. A unique finding was observed in test question number 5, with an average percentage of 40.27%, an average of 24.56% for Junior High School 12, and 55.93% for Junior High School 29, with the indicator being the calculation of the perimeter of a quadrilateral. In question number 5, students were asked to determine the perimeter of several types of quadrilaterals with specified side lengths. The diversity of students' answers regarding the perimeter of a square is presented in Table 2.

Table 2. Diversity of Students' Answers about the Perimeter of a Square

No.	Diversity of Students' Answers
1	$s^2 \times s^2$
2	$s \times s \times s \times s$
3	$s + s + s + s$
4	$s \times s$

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Based on Table 2, slow learner students at Junior High School 29 answered correctly about the perimeter of a square. However, students only added up three random sides of other flat shapes, and some did not respond. Meanwhile, at School A, students gave varied responses. Some students multiplied the four known sides of a quadrilateral to calculate its perimeter. The following are the students' responses to question number 5.

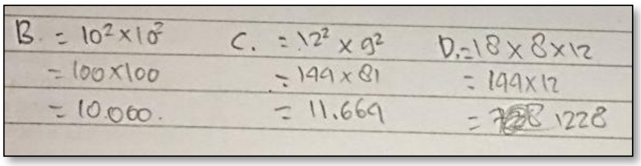

Figure 2. Response of One Student to Question Number 5

Based on Figure 2, which contains questions about the perimeter of quadrilaterals and triangles, students respond by calculating the perimeter of quadrilaterals and triangles by multiplying each side. The following presents additional findings regarding the prerequisite knowledge for question number 6.

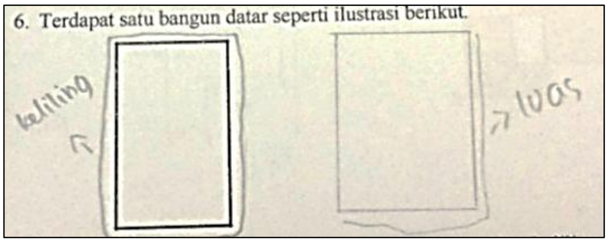

Figure 3. Response of One Student to Question Number 6

As shown in the image above, the answer to question 6 indicates that students are confused when distinguishing between the perimeter and the area of a rectangle. Based on the students' arrows, there is no difference between the perimeter and the area of a rectangle. The following presents the prerequisite knowledge for question number 7.

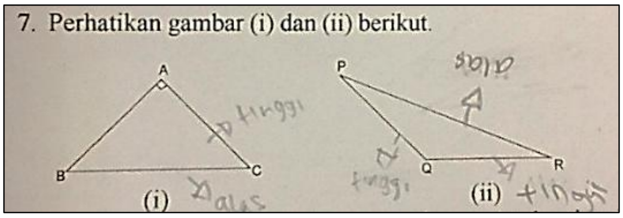

Figure 4. Response of One Student to Question Number 7

Students were asked to determine the area of a triangle, but before doing so, they needed to identify its base and height. Based on Figure 4, the students did not understand which sides served as the base and the height. This lack of understanding was evident from their answers, which were mostly guesses about which sides represented the base and the height. The findings regarding students' prior knowledge for question 8 indicate that students perform multiplication and addition operations at random to determine the areas of triangles and quadrilaterals. The findings for question 9 indicate that students do not pay sufficient attention to changes in units of measurement in the questions. Finally, the findings for question 10 are that students perform addition operations on each side of a mixed flat shape to calculate its perimeter.

2. Learning Obstacles for Slow Learners

The written test on learning obstacles consists of 7 questions. The first question is about examples of flat-sided cubes and blocks in everyday life. The second question is about cube and block nets. The third question is about the surface area of cubes and blocks. The fourth question is about the volume of cubes and blocks. The fifth question is about the surface area and volume of cubes and blocks. The sixth question is about estimating and calculating the volume of irregular shapes. The seventh question concerns solving everyday problems involving cubes and blocks. The average percentage of correct answers per question is presented below.

Table 3. Average Percentage of Student Responses on the Learning Obstacle Test

Item Number	**Average Percentage**
1	55,43 %
2	82,12 %
3	46,27 %
4	32,68 %
5	72,88 %
6	30,58 %
7	40,57 %

Based on Table 3, the highest percentage of correct answers was for question 2. For question number 2, the average percentage of correct answers from both schools was 82.12%. The indicator in question number 2 was to determine the nets of cubes and blocks from several known nets. Most students were able to find the correct nets of cubes and blocks. It can also be seen that the lowest percentage of correct answers was for question number 6. For question number 6, the average percentage of correct answers from both schools was 30.58%. The indicator in question number 6 is to estimate or determine the volume of irregular objects based on the volume of blocks. Students were asked to determine the relationship between the rise in water in the aquarium and the volume of stones placed in the aquarium, and to calculate the volume of the stones. Students understood the relationship between the rise in water and the volume of stones in the aquarium, but they were still unable to write it down in a correct sentence. The mistake that many students made in part b was that they used the wrong formula to calculate the volume of the stones.

The following is an explanation of the learning obstacles faced by slow learners on other questions [other than numbers 2 and 6]. On question 1, with an average percentage of 55.43%, students were unable to identify the properties of cubes and blocks correctly, or to find everyday objects with shapes like cubes and blocks in everyday life. Question number 3, with an average percentage of 46.27%, found that students did not understand how to determine the total area of the faces of a cube net, and some students did not write their answers on the answer sheet. After confirming through interviews with students who did not provide answers, the students stated that they did not understand how to answer question number 3. Question 4, with an average of 32.68%, found that some students still did not understand the relationship between the volume of water in the aquarium and the volume of the aquarium itself. Slow learners from both schools gave various answers, some stating that the aquarium volume was 1 liter or 20 liters, and some did not provide an answer. Question 5, with an average of 72.88%, revealed that the obstacle students encountered was that they still did not understand the surface area of a block correctly. The last question, with an average of 40.57%, revealed that the obstacle encountered by students was that some calculated the stone's volume incorrectly, and some did not write down their answers.

3. Didactical Design for Slow Learners

Based on discussions with mathematics teachers and a review of flat-sided solid figures, the lesson plan for cubes and blocks was divided into three sessions. The activities in the first session involved discovering the properties of cubes and blocks, calculating the lengths of the diagonal faces and spatial diagonals, and calculating the areas of the diagonal faces based on the known edge lengths of cubes and blocks. The activities in the second session consist of finding and drawing nets of cubes and blocks, understanding and finding the general formula for the surface area of cubes and blocks. The activities in the third session focus on understanding the general formula for the volume of cubes and blocks, and on calculating the volume of irregular shapes.

The first meeting discussed the properties of cubes and blocks. At the beginning of the meeting, students were given examples of cubes and blocks. Then, several students were asked to name objects in the shape of cubes and blocks that they had encountered. The process of associating objects around them with cubes and blocks aims to help students begin to understand examples of cubes and blocks and their differences. Then, to confirm the correctness of the cube- and block-shaped objects, the characteristics of cubes and blocks were introduced.

Students are asked to find the properties of cubes and blocks with their groupmates. This activity aims to train students to discover the properties of cubes and blocks independently.

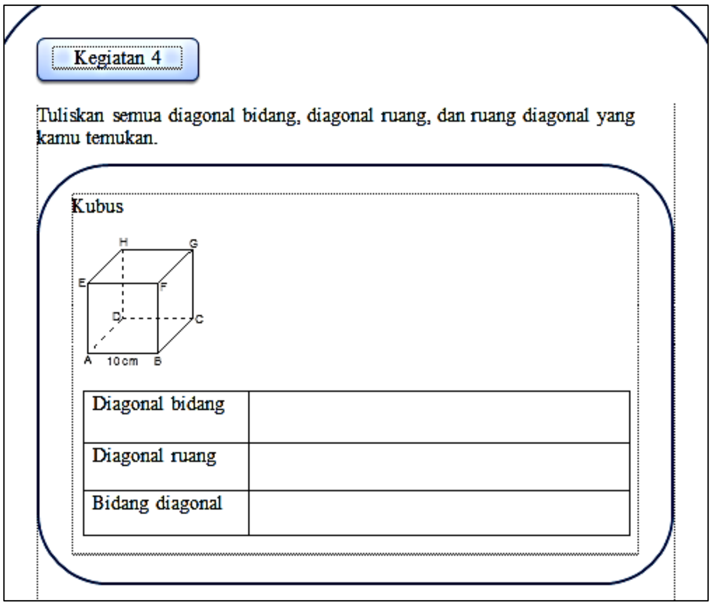

Figure 5. One of the LKS Designs about Cubes

Based on the image above, after students understood the properties of cubes and blocks, the examples of objects around them mentioned by the students were revisited to ensure they satisfied those properties. The interview results showed that the students understood the properties of cubes but were unable to give examples of objects around them that were cube-shaped.

The second meeting discussed nets and the surface area of cubes and blocks. At the beginning of the meeting, students were asked to work with their neighbors to find the nets of cubes from cube-shaped objects. They did this by cutting or trimming several edges to form cube nets. Based on the test results, it was evident that the students already knew the nets that formed cubes. At this stage, the students were expected to find cube nets that were different from those of their classmates. The purpose of finding cube and block nets was to help students learn about the various cube nets that could be formed.

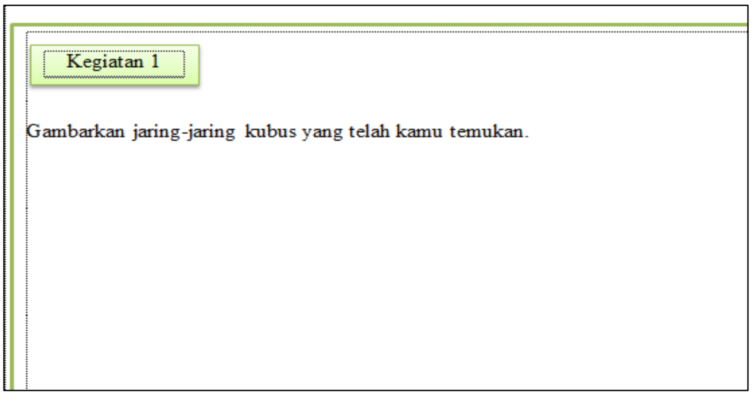

Figure 6. One of the Worksheet Designs is about Cube Nets

Based on the image above, after students find the cube nets, they are asked to calculate the total area of all the faces. Based on the test, it appears that some students do not yet understand how to determine the total area of all the faces of the cube's net. The researcher anticipates this by reminding students of the previous lesson about the properties of cubes, namely their faces. This anticipation is done by reminding students which parts of a cube act as faces and the shapes of those faces.

The students were guided in determining and calculating the surface area of a cube, and the researcher hoped they would understand it correctly. Similarly, for the surface area of a rectangular prism, the steps taken were the same as those for the surface area of a cube. At the end of the meeting, the researcher guided the students to write down the conclusions from the lessons learned in that meeting.

The third meeting discussed the volume of cubes and blocks. At the beginning of the meeting, the researcher asked the students to pay attention to the pictures provided on the student worksheets.

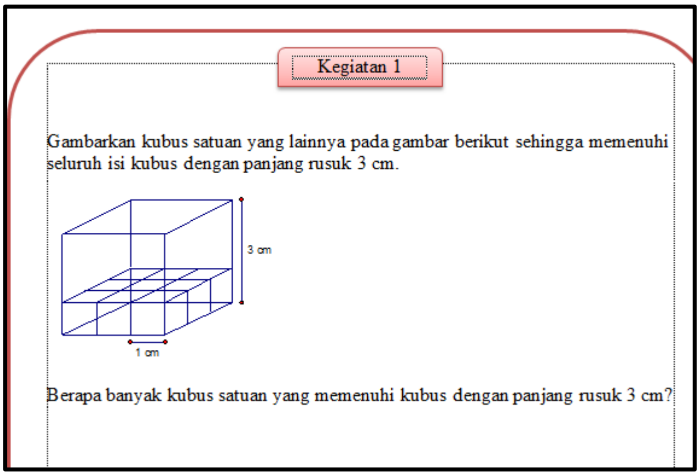

Figure 7. One of the Designs for Cube Volume

Based on the image above, researchers guided students in concluding the volumes of cubes and blocks, helping them develop a clear understanding and remember it for a longer period through the experience of discovering it together with their groupmates.

4. Didactical Anticipation for Slow Learners

Teachers design lesson plans by forming several groups at each meeting. The purpose of dividing students into several groups is to reduce the frustration of students who are eager in answer questions and express their opinions, by allowing them to do so. Based on the researcher's observations at the participating schools and previous experience, students who are active in answering questions sometimes feel frustrated because they are not allowed to express their opinions.

The teacher will then ask several students who have not been active during the lesson to answer questions. This practice often reduces students' enthusiasm for participating in subsequent discussions. Therefore, dividing students into several groups is expected to prevent a decline in students' learning motivation. Below, the researcher discusses the anticipation in each meeting.

In the first meeting, in activity 1, the teacher asked students to name objects in everyday life that are cubes and blocks. Before activity 1, the teacher showed the students the framework of cubes and blocks to the students in the class. The teacher took this step as an anticipation to guide students in giving examples of objects that are correctly shaped as cubes and blocks.

In the first meeting, the teacher facilitated students' recognition in cubes and blocks and their discovery of their properties concretely through real objects and building frames. This strategy is in line with research findings that show that concrete and varied learning methods can help students understand geometric concepts, given that many students experience difficulties in geometry due to limited visual experience and low understanding of abstract concepts In addition, other studies also show that the use of strong visual and manipulative representations is an important strategy to help students who have difficulty learning geometry so that abstract concepts become easier to understand [27]–[29]. In the context of slow learners, who often need more time to achieve basic understanding, direct guidance from teachers in explaining plane diagonals, space diagonals, and the properties of diagonal planes provides opportunities for students to connect real objects with mathematical representations, which is a form of effective didactical anticipation to minimize conceptual misunderstanding [30].

Activity 2 is about discovering the properties of cubes and blocks. The teacher mentions the characteristics of flat-sided shapes by pointing to the cube and block frames. The teacher conducts this activity to guide students in discovering the properties of cubes and blocks. In Activity 5, students are asked to calculate the lengths of the face and space diagonals, as well as the areas of the diagonal faces of cubes and blocks. The teacher begins by guiding students in finding a way to calculate the length of the face diagonals. The teacher guides students to calculate the face diagonal by asking them to focus on one of the triangles formed by two cube edges and one face diagonal. The teacher asks students to continue the steps in calculating the length of the space diagonal. The teacher walks around the classroom to help students when they encounter difficulties.

The teacher guides students to identify the type of flat shape formed by a diagonal plane on a cube. Students' responses will likely vary regarding the type of flat shape they know. The teacher guides students to re-examine the properties of the diagonal planes that are formed. After that, the teacher asks students to recall the areas of the flat shapes formed. At the end of the session, the teacher guides students in writing conclusions based on the material covered in the first session.

In the second meeting, the main activities were finding and drawing cube nets and calculating surface area. The teacher's anticipation included checking the concrete objects brought and guiding students in the steps of measuring edges, which was very important for slow learners. In mathematics education literature, it is known that learning strategies that use spatial models and teaching aids can minimize difficulties in learning geometry by converting abstract representations into concrete ones that are easier for students to understand [31], [32]. Understanding nets requires spatial visualization skills, which often pose an obstacle for many students in geometry because they have difficulty transforming three-dimensional objects into two-dimensional representations [33], [34]. By guiding students to mark the areas and recall the formula for each area, teachers indirectly help students build visualization skills and reduce the conceptual prerequisite errors that slow learners often experience. Focusing on prerequisite concepts before calculation demonstrates the application of scaffolded instruction, a didactical approach based on tiered support that is known to be effective for students with learning obstacles [35], [36].

After the students find the nets of cubes and blocks, the teacher guides them to calculate the total area of all the faces on the nets they have found. The teacher prepares for this by guiding students to write numbers on each face of the cube nets. The teacher guides students in recalling the shapes of a cube's faces, reminding them of the formula for the area of a face and how to calculate it. This preparation is done so the teacher can guide students in acquiring the prerequisite knowledge and correcting any misconceptions.

After that, the teacher guided the students to find the general formula for the surface area of a cube. Then the teacher gave examples of problems related to the surface area of a cube to help the students better understand it. Next, the activity of finding the surface area of a block was the same as the activity of finding the surface area of a cube. At the end of the meeting, the teacher guided the students in summarizing the material learned in the second meeting.

In the third meeting, before conducting activities, students were shown a large cube model consisting of small cubes to build spatial imagery. This approach is relevant to research that emphasizes the importance of developing spatial visualization skills in geometry learning, especially when students are asked to understand three-dimensional volume and structure [37], [38]. The approach of using real objects and manipulative scenarios helps students make motor and visual connections that support abstract cognitive processes, which are often a major obstacle for slow learners [39], [40]. Furthermore, by providing variations in edge length in the form of numbers and letters, teachers help students improve their flexibility in symbolic thinking, an important skill in dealing with complex and different types of mathematical problems. This approach is in line with differentiated learning efforts that provide opportunities for all students to achieve a form of conceptual understanding that suits their pace and abilities [41], [42].

The teacher guides students to find the volume of a cube. The teacher prepares cubes of various sizes so that students have more diverse knowledge and can work together and help each other. The teacher guides students in the relationship between many cubes and the length of the cube's edges, so that students can find the formula for the volume of a cube. After students find the formula for the volume of a cube, the teacher asks students to determine the volume of a cube with a known edge length in the form of letters, not numbers. The teacher does this activity so that students no longer feel strange or unfamiliar when faced with edge lengths written in letters.

The steps for finding the volume of a block are the same as those for finding the volume of a cube. After students have found the volumes of the cube and the block, the teacher asks them to practice solving various types of questions. The variety of questions is expected to help students better understand what they have learned and remember the lesson for a longer period of time.

In general, the strategies used by teachers in this study, namely the use of concrete media, group division, step-by-step guidance, and reinforcement of prerequisite concepts, are forms of didactical approaches recommended in geometry learning studies. The literature on mathematics education shows that slow learners often experience learning obstacles, particularly in visualization, conceptual abstraction, and spatial reasoning [43], [44]. Therefore, the use of approaches that emphasize concrete experiences, manipulative visualization, and repetition of concepts can reduce these obstacles and increase student engagement and motivation to learn [45], [46]. Other studies also confirm that geometry learning enriched with teaching aids and visual media helps students connect abstract concepts with real experiences, thereby improving conceptual understanding[47], [48].

Dividing students into groups in each meeting is not only a classroom management strategy but also an effort to increase each student's participation, especially for slow learners who often lag in large-class discussions. The collaborative approach is supported by research findings that state that collaboration and group discussions can increase motivation and engagement in solving geometry problems, which are often challenging for students with slower learning abilities [49], [50]. Social interaction in groups also provides opportunities for slow learners to receive peer scaffolding from their classmates, thereby strengthening their understanding of concepts through dialogue and discussion [51], [52].

The above discussion shows that the didactical anticipation used by teachers in teaching flat-sided shapes has been strategically positioned to minimize various learning obstacles faced by slow learners, particularly limitations in spatial visualization, understanding abstract concepts, and symbolic skills. The integration of concrete media, a tiered approach, intensive guidance, and collaborative strategies shows strong coherence with the findings of contemporary mathematics education research, which emphasize the importance of visualization, manipulation, and differentiation in overcoming difficulties in learning geometry [31], [53].

CONCLUSIONS AND SUGGESTIONS

This study concludes that slow learners still experience difficulties in identifying flat shapes in everyday contexts, distinguishing between perimeter and area, understanding related formulas, and applying these concepts in problem-solving situations. These difficulties indicate limitations in students' prerequisite knowledge and conceptual understanding in polyhedron learning.

The findings also reveal that ontogenic, conceptual, instrumental, and epistemological obstacles are the dominant challenges faced by slow learners. However, didactical obstacles were not prominent during the learning process. This suggests that students' learning difficulties are mainly influenced by internal cognitive and conceptual factors rather than instructional procedures.

The proposed didactical design, supported by student worksheets, structured learning activities, and step-by-step guidance, has effectively anticipated these learning obstacles. Therefore, teachers are encouraged to implement differentiated and scaffolded instructional strategies to support slow learners. Future studies may further explore adaptive learning models and long-term interventions to enhance students' mathematical understanding.

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