Designing teaching materials based on process skills approach to mathematical representation ability in polyhedron

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Abstract. The purpose of this study was to develop the didactical design of teaching materials based on process skills approach to mathematical representation ability in polyhedron. The didactic design was made in the form of module for grade VIII based on the Didactical Design Research (DDR) stage, namely the didactic situation analysis stage before learning, the metapedadidactic stage, and the retrospective stage. At the stage of the didactic situation analysis resulted in a learning obstacle, didactic anticipation of teaching materials in the form of mathematics modules based on mathematical representation abilities and the results of validation of modules by experts. In the metapedadidactic stage, the responses of teaching material users were obtained to 26 students and one mathematics teacher in SMPN 1 Waled. While the results of filling out the questionnaire by the teacher obtained very positive response criteria and the results of the response questionnaires filled out by students obtained positive response criteria. In the retrospective stage, anticipation of user responses is obtained after the teaching materials are implemented. The results of module validation by four experts are categorized as very valid.

1. Introduction

Learning activities cannot be separated from the standard competencies that have been set, the National Council Teacher Mathematics (NCTM) recommends five main standard competencies in mathematics learning, namely problem solving, communication, connection, reasoning, and representation [1]. One of the standard competencies, which is the focus of researchers, is the ability of mathematical representation. This issue related to other studies that is mathematical representation ability enriches students' mathematical knowledge to solve everyday problems especially in mathematics problem [2-7]. The essence of mathematics, which is an abstract science, can be facilitated and clarified through the form of interpreting students' thoughts from their representation abilities [1] [8-9]

Representation is an explanation of objects and symbols [10] not only for result (or new construction) but also refers the process of students thinking and understand the concept [11]. Mathematical representation is the ability to restate mathematical problem through selecting, interpreting, translating, and using object (graphics, tables, images, diagrams, formulas, equations) to express problems [12]. Moreover, mathematical representations the ability to create a model of a problem into the form of a new well in verbal, written or graphic [13]. In other words, mathematical representation can be used as a tool to express mathematical concept and find a solution to a problem.

However, in the reality, the students' mathematical representation ability is still low. The results of research that has been conducted by Yazid stated that students grade VIII in SMPN 1 Jepara still have
difficulties in learning the concept of geometry, including the volume of 3D [14]. One of the materials studied by students of class VIII SMP is polyhedron. Representative skills are needed to help students solve 3D shapes problems because the application can contain visual representations and images. One of the reasons for the low ability of student representation is that the learning process carried out by teachers in the classroom often does not involve students.

The low ability of representation of students is also reinforced by the results of studies preliminary who conducted research in SMP N 1 Waled. The ability of 34 students VIII C in making mathematics representations was tested. The result displayed in table 1.

| Ability Indicator | Problem Indicator | Number of Students Who Answer | (%) |
|-------------------|-------------------|-------------------------------|-----|
| Representing data or representation from a diagram, graph, or table representation. | Convert questions into tabular form and solve the problems that are asked. | 22 | 64.7 |

In the teaching preparation, teachers select, modify, design student learning activities [15]. Learning activities cannot be separated from learning resources, for example teaching materials. All forms of material that are arranged systematically that allow students to learn are called teaching materials [16]. One of the choices of teaching materials according to the needs of students is the module. Modules include teaching materials that are arranged systematically in language that is easily understood by students according to their level of knowledge and age [17].

Teaching materials made should be equipped with an approach or skill, for example a process skills approach. The process skills approach is an approach aimed at developing a number of mental and physical abilities whose sources are based on existing and existing basic abilities of students or abilities that can help students develop their thinking [18]. To achieve the predetermined competency standards, the teaching materials not only contain knowledge but also contain knowledge and attitude skills [16].

Several studies related to the development of teaching materials have been carried out. Nuraeni et. al. developed student activity sheets based on the traditional “Gobak Sodor” game based on the learning obstacle with DDR stages on rectangular material [19]. Habsah develops Realistic Mathematics-Based teaching materials Oriented to Mathematical Reasoning and Mathematical Communication in grade VII [20]. Gazali develops teaching materials for junior high school students based on Ausubel learning theory [21]. The research related to the design of teaching materials based on the process skills approach to the mathematical representation ability of the Polyhedron has never been done.

The design of teaching materials is structured as a didactic design. The design of this study includes showing direct evidence of the focus of learning [22], namely the learning obstacle experienced by students. The didactic design is assembled in a Didactical Design Research (DDR). According to Suryadi, DDR is a design of teaching materials that can assist students in learning which is structured based on student learning obstacles [23]. By identifying the learning obstacle experienced by students, an alternative is prepared so that students no longer encounter obstacles in existing concepts. With a didactic design that is oriented towards research on the obstacles experienced by students in one particular mathematical concept, it is hoped that other obstacles will no longer appear in further learning. So that the objectives of learning mathematics as one of the learning objectives can be realized properly.

Based on the description that has been stated above, the authors are interested in conducting research that aims to design teaching materials based on the learning obstacle experienced by junior high school students related to mathematical representation skills based on a process skills approach on polyhedron.

2. Methods

The method used in this research is qualitative which aims to design teaching materials. The design of this study was Didactical Design Research (DDR). DDR is a design of teaching materials that is structured based on student constraints. So that in this study is to compile a didactic design based on the
identified learning obstacle related to the material of polyhedron. According to [24] didactical design research basically consists of three stages, namely:

2.1 Analysis of the didactic situation before learning in the form of a Didactic Hypothesis Design including Didactic and Pedagogical Anticipation (ADP).

The activities carried out at this stage are (1) determine the material that will be used as research material, (2) collecting literature regarding the material that has been determined, (3) developing instrument to measure mathematical representation, (4) conducting a preliminary test of 26 students to find out the difficulties of students regarding the polyhedron material, (5) analyze the results of the initial test to identify student difficulties regarding the material circle, (6) arrange a didactic design according to students' difficulties regarding circle material.

2.2. Methapedadidactic analysis

Methapedadidactic analysis activities carried out in this study are: implementing the didactic design that has been compiled, analyze the situation and student responses when the didactic design is implemented. This research is limited to the methapedadidactic analysis stage due to time constraints. The subjects in this study were divided into two, namely the subject of identification of the initial learning obstacle and the subject for the implementation of the didactic design carried out in grade VIII of the even semester at SMPN 1 Waled.

2.3 Retrospective analysis

Retrospective analysis namely the analysis that links the results of the didactic situation analysis hypothesis with the results of the methapedadidactic analysis. The instruments used in this study were test instruments and non-test instruments. The test instrument was used to identify the initial learning obstacle and the final learning obstacle. The test is in the form of a description consisting of six questions where the questions use four indicators of mathematical representation. Meanwhile, the non-test instruments were interviews and questionnaires. The interview was conducted after the students had carried out the initial test to determine the student's response and to find out the learning obstacle to the tests that had been carried out. Then the questionnaire was used to determine the validity of teaching materials and teacher intervention.

3. Result and discussion

Based on the results of interviews with teachers and the results of test questions, it can be concluded that students still have difficulty learning the material of polyhedron, especially questions of mathematical representation. In addition, students usually do not write down the problem-solving process but are more concerned with the final result. Even though in learning the teacher has used teaching materials, this has not been able to overcome the learning difficulties of students in studying polyhedron, because the teaching materials used by the teacher do not involve students so that students cannot interact with teaching materials. In addition, the design of teaching materials that are less attractive also reduces students' interest in understanding the polyhedron material. One of the efforts to overcome students' learning difficulties in studying the material of polyhedron is by designing teaching materials that are tailored to the needs of students.

The teaching materials to be made are in the form of polyhedron module based on process skills and mathematical representation abilities. This module is made based on the barriers to learning experienced by students, especially learning barriers that make students' low representation ability and ultimately students are more concerned with results than the process when students work on questions. The teaching materials that are made are expected to be able to overcome student learning difficulties, especially related to the polyhedron material.

3.1. Learning obstacle in polyhedron

Here is an overview of the results of test o measure mathematical representation ability:
Problem 1

Three cuboids with each volume 960 cm³, 2430 cm³, 150 cm³ and have different length, width and height. The first cuboid is 8 cm and 6 cm wide and high. The second cuboid is 18 cm and 15 cm long and wide. Meanwhile, the third cuboid has a length and height of 10 cm and 3 cm. Make the data into tabular form then count each of the unknowns from the cuboid!

Learning obstacle that experienced by the students are not able to make a table of the statement that there is in question. Obstacle have resulted in students not to use the formula so that students are not able to resolve the problems that exist. Figure 1 shows the obstacles experienced by students in working on question problem 1.

![Figure 1](image)

Students did the calculation as multiplication and division correctly. However, the student’s answer becomes inappropriate because immediately calculate the width times length, students also do not use formulas when solving questions.

Problem 2

The diagonal length of a cube is 15 cm. Sketch the image of the cube and calculate the length of the edge!

The results of the observations in the form of a test representation ability test to solve questions in number 2 can be seen in the table 2.

| Ability Indicator | Problem Indicator | Number of Students Who Answer Wrong Percentage |
|-------------------|-------------------|-----------------------------------------------|
| Draws geometric shapes to clarify problems and facilitate resolution. | Draw a cube and its diagonals to calculate the edge length. | 29 | 85.29 |

The barrier to learning for most students in question number 2 is that they are unable to draw a cube with its diagonal to help solve the problem. Students have not been able to calculate the length of the edge. This shows that students are unable to answer questions. Regarding the results of the answers which indicate a learning barrier, the following is an analysis of the student's answer sheet when answering question problem 2.

![Figure 2](image)
The student is not able to draw a cube with its diagonal to solve the problem. The mistake in answering problem 2 might be the students not knowing the part of the cube.

**Problem 3**

*From the cube image below, find the parts of the cube and determine the number!*

![Cube for problem 3](image)

**Figure 3.** Cube for problem 3.

The results of the observations in the form of a test representation ability test to solve questions in number 3 can be seen in table 3.

| Ability Indicator                                    | Problem Indicator                                    | Number of Students Who Answer Wrong | Percentage (%) |
|------------------------------------------------------|------------------------------------------------------|-------------------------------------|----------------|
| Use visual representations to solve problems.        | Determine the number and parts of the cube by looking at the picture | 19                                  | 55.9           |

The learning obstacle of most students in question number 3 is that they are not able to say the parts of the cube by looking at the image representation. This shows that students are incomplete in answering questions. Even though the material on the elements of 3D shapes has been given since elementary school. This indicates that students need to be reminded of the prerequisite material. Regarding the results of the answers which indicate a learning barrier, the following is an analysis of the student's answer sheet when answering question problem 3.

![Example of student answers in working on problem number 3](image)

**Figure 4.** Example of student answers in working on problem number 3.

Student already know the parts of the cube by looking at the picture in the question in problem 3. However, student have not written them completely so that students are not able to count the sum of the parts of the cube.
Problem 4

Draw nets of cuboid and pyramid!

The results of the observations in the form of a test representation ability test to solve questions in number 4 can be seen in table 4.

Table 4. Representation mathematics ability from question number 4.

| Ability Indicator     | Problem Indicator      | Number of Students Who Answer Wrong Percentage |
|-----------------------|------------------------|-----------------------------------------------|
| Make geometric pattern drawings. | Painting cuboid nets and pyramid. | 25 | 72.5 |

The learning obstacle of most students in question number 4 is the inability to draw geometric pattern pictures. This shows that students are incomplete in answering questions. This indicates that students need to practice making geometric pattern drawings. Regarding the results of the answers which indicate a learning barrier, the following is an analysis of the student's answer sheet when answering question problem 4.

Figure 5. Example of student answers in working on problem number 4.

Figure 5 appears that students still have difficulty drawing pyramid nets. The difficulty in drawing pyramid nets is due to the students' lack of understanding of the spatial nets.

3.2. Design of process skills-based teaching materials on the mathematical representation ability based on learning obstacle in polyhedron

Didactic design needs to be complemented with predictions regarding student responses that may appear when the initial didactic design is implemented.

Table 5. Didactical and pedagogical anticipation of problem 1.

| Learning Obstacle                                      | Didactical Anticipation                                      | Pedagogical Anticipation                              |
|--------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------|
| Students are not able to make tables from existing statements | Students are given a stimulus to make a table from a statement | The teacher guides students to make a table from a statement |
| Students are not able to perform algebraic calculations to calculate width dan height from a known volume of cuboids | Students are given a stimulus to calculate width dan height from the known volume of cuboids | The teacher reminds students about the stages of calculating algebraically |

Table 6. Didactical and pedagogical anticipation of problem 2.

| Learning Obstacle | Didactical Anticipation | Pedagogical Anticipation |
|-------------------|-------------------------|--------------------------|
| Students are not able to draw a cube with its diagonal. | Students are given a stimulus so that they can make a cube with a diagonal | The teacher guides the students to draw a cube with its diagonal |
Students are not able to calculate the length of the edge.

Students are reminded again about Pythagoras

The teacher helps students to recall the use of the Pythagorean formula.

Table 7. Didactical and pedagogical anticipation of problem 3.

| Learning Obstacle                                      | Didactical Anticipation                                      | Pedagogical Anticipation                                      |
|--------------------------------------------------------|--------------------------------------------------------------|---------------------------------------------------------------|
| The student is unable to count the sum of the parts of the cube | Students are given a stimulus to calculate the number of parts of the cube | The teacher guides the students to count the sum of the parts of the cube |

Before entering the 3D shapes material, students must understand the prerequisite material. At the time of analyzing the results of the trial, almost some students made mistakes in doing the questions in the prerequisite material stage. Hence, researchers provide prerequisite materials before entering the material to be taught as shown in figure 5.

In figure 6, students must be able to distinguish each form of surface on 3D shapes. The stimulus is given using objects that students often encounter in everyday life. After observing several polyhedrons, students are asked to name the elements such as the edges, sides, diagonals, internal diagonals, and vertices. Process skills that are grown at the apperception stage include observing and providing explanations or certain methods. Furthermore, to provide an understanding of the diagonals and internal diagonal, it is used the representation of nets and questions that construct knowledge as shown in figure 7. The process skills that are grown at this stage are predicting and predicting what will happen after making observations.
After students understand the prerequisite materials presented, the researcher also makes a didactic design that reminds students of the prerequisite materials such as the shape of a net in each surface of 3D shapes. This will make it easier for students to represent the surface area of a 3D shape. As for the form of the didactic situation design that is presented as shown in figure 8. Process skills that are grown at this stage are communicating, using words, symbols, or graphics to describe an object or action.

**Figure 7.** Side diagonals and space diagonals.

**Figure 8.** Polyhedron nets.

In figure 7, the design of the didactic situation is in the form of representing the shape of a flat side space through a net. Students make and write the shape of the flat surface 3D shapes of the nets presented. Polyhedron nets are a topic that students must master before studying surface area. The didactic situation to build the concept of surface area is shown in figure 8. The process skills that are grown at this stage are applying the concept to describe an event.
Furthermore, the design of the didactic situation related to the learning obstacle of building volume is to construct knowledge through a process skills approach as shown in figure 10. In constructing the volume of a prism, the cuboid volume approach is used.

At the end of each sub-topic of polyhedron (cubes, cuboids, prism and pyramids) a mathematical representation ability is given as shown in figure 11.

**Figure 9.** Surface area.

**Figure 10.** Volume of polyhedron.

**Figure 11.** Mathematical representation ability problems.
In Figure 10, the indicator of the ability to represent question number 9 is to draw geometric shapes to clarify the problem and facilitate its solution. Meanwhile, the indicator for question number 10 is: using a visual representation to solve the problem.

3.3. Designing teaching materials based on process skills against valid mathematical representation ability

Before teaching materials are implemented or used in learning, teaching materials are validated by experts. So that it can be seen whether the teaching materials that have been made are feasible or not. It is hoped that this teaching material can overcome the learning obstacle that occurs in subsequent lessons. Based on the total results of validation by experts, the value was 86.75%, which means it has very valid criteria.

In addition to providing an assessment of the teaching materials that have been made, the validator also provides input or suggestions for the teaching materials that have been made. After validation, the researcher made revisions according to the validator's input as described in Table 5. Based on the validator's input, the following will be given a revision of the teaching materials.

Table 8. Revision of validation of teaching materials based on validator suggestions.

| Validator | Revised Aspects                        | Pre-Revision Module                      | After Revision Module                      |
|-----------|----------------------------------------|------------------------------------------|--------------------------------------------|
| A         | Write the material discussed in the footer. | Have not written the material discussed on that page. | Already written the material discussed on that page. |
| B         | -                                      | -                                        | -                                         |
| C         | Inconsistent sentences or words.         | Inconsistent sentences or words.          | Sentences or words are consistent.         |
|           | Image neatness.                         | The neatness of drawing is not paid attention. | The picture has been tidied up.            |
| D         | Exercises                               | Less varied questions                    | The problem is more varied.               |

3.4. User validation data analysis (teachers and students)

User verification is carried out by the user with the aim of knowing the user's response to the module that has been created so that the module can be used in the learning process. In this study, the data obtained by the author were obtained from tests conducted at SMPN 1 Waled and a mathematics teacher in grade VIII SMPN 1 Waled.

The results of the combined response of students after using teaching materials are as follows:

\[
\text{Overall percentage} = \frac{690.27}{26 \times 32} \times 100 = \frac{690.27}{832} \times 100\% = 82.96\%
\]

The results of filling out the response questionnaire can be seen in Figure 12.
As for the response questionnaire data conducted by the mathematic teacher at SMP Negeri 1 Waled and data can see in table 6.

| Respondents | Score Achieved in Each Aspect | Expected Score on Each Aspect | Percentage of Responses in Each Aspect (%) |
|-------------|-------------------------------|-------------------------------|-------------------------------------------|
| Teacher     | 15 8 11 16 8 12              | 16 8 12                       | 93.00 100 91.00                           |
| Total       | 15 8 11 16 8 12              | 16 8 12                       | 93.00 100 91.00                           |

Information:
Aspect 1 is convenience
Aspect 2 is time efficiency
Aspect 3 is benefits

Based on the results of the calculation of the percentage of responses to teachers and students of teaching materials, the value of 94.66% was obtained with very positive criteria and 82.96% so that the teaching materials were in positive criteria.

4. Conclusion

Based on the results of the analysis and discussion in the previous chapter, the following conclusions were obtained. The learning obstacle found is divided into several types, namely (1) learning obstacle related to prerequisite material on 3D shapes (2) related learning obstacle. Presenting data or representation from a representation to diagram, graph, or table representation (3) related learning obstacle to draw geometric shapes to clarify problems and facilitate solving. (4) related learning obstacle. Using visual representations to solve problems. (5) related learning obstacle to make pictures of geometric patterns.

Teaching materials are prepared based on the learning obstacle obtained during the initial trials, the mathematical representation abilities developed, the presentation aspects of the components contained in the teaching materials, the process skills approach and the aspects contained in the teaching material validation sheet. This teaching material is categorized as valid from the results of the validator's assessment with a percentage of 86.25% which means that the teaching material is valid or can be used without revision.

Based on the results of the calculation of the percentage of responses to teachers and students of teaching materials, the value of 94.66% was obtained with very positive criteria and 82.96% so that the teaching materials were in positive criteria.
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Acknowledgment
The author would like to thank Universitas Swadaya Gunung Jati for providing research funding, Waled 1 Junior High School for being trustworthy partners so that this research can be completed well.