Mathematical creative thinking level on polyhedron problems for eight-grade students

Y Junaedi¹, Wahyudin² and D Juandi²

¹ Departemen Pendidikan Matematika, Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia, Jl. Dr. Setia Budhi No. 229, Bandung 40154, Indonesia
² Departemen Pendidikan Matematika, Universitas Pendidikan Indonesia, Jl. Dr. Setia Budhi No. 229, Bandung 40154, Indonesia

E-mail: yusupjunaedi@upi.edu

Abstract. Mathematical creative thinking is needed by students in addition to other abilities because it can provide broad thinking to get new ideas or new solution of mathematical problems solving. The aim of this research is to describe mathematical creative thinking level on polyhedron problems for eight-grade students. This research was conducted at a senior secondary school in Indonesia with a total of 35 students in year 8. This type of research is a case study with inductive data analysis techniques which include: data reduction, data display, drawing conclusions and verification. The research instrument consisted of 4 test descriptions based on the aspects of mathematical creative thinking ability, interview guidelines and documentation. The result of this research concluded that students with a high level of mathematical creative thinking ability tend to solve polyhedron problems in the aspects of originality, fluency, flexibility, and elaboration. Students with a medium level of mathematical creative thinking ability tend to give one overall correct answer to polyhedron problems in the aspects of originality, fluency, flexibility, and elaboration. Students with low level mathematical creative thinking ability tend to give incorrect answers to polyhedron problems in the aspects of originality, fluency, flexibility, but in the elaboration aspect, it gives one correct answer even though it is not detailed.

1. Introduction

Polyhedron is a part of geometric material that needs to be studied because it can train the ability to think logically, systematically, and turn on creativity in developing innovation [1]. Mathematical creative thinking ability on polyhedron material is important because it requires reasoning and originality of student thinking without any examples of previous solutions and the goal is for students to gain confidence about their mathematical abilities, become good mathematical problem solvers, be able to communicate and reason mathematically [2].

Creative thinking can be defined as a combination of logical thinking and divergent thinking that is based on intuition but has a purpose [3]. In philosophy, creative thinking is possible because philosophical questions are open-ended questions which means that investigating the nature of the problem is the beginning of the effort and the way in which it is followed is often much more interesting than the end result [4]. Mathematical creative thinking is the ability in mathematics which includes four aspects, namely fluency, flexibility, originality, and elaboration. Fluency is the student's ability to solve math problems, or questions, appropriately. Flexibility is the student's ability to generate ideas, answers,
or questions that vary but must still refer to the problem given. Originality is the ability of students to answer mathematical problems using their own language, way or ideas so that other people never think of these ideas. Elaboration are students' ability to develop answers to problems, their own ideas, or the ideas of others [5].

Basically, most people are creative but have different degrees or levels because each person has the ability to think differently so that it shows the existence of a level of creative thinking ability [6]. Based on the level of differences in students' mathematical creative thinking abilities, research on the Analysis of Students' Creative Thinking Ability in Solving Problems in Triangular Materials in Junior High School, which stated that students with high levels of mathematical creative thinking abilities were able to achieve and fulfill aspects of fluency, flexibility and originality. Students with medium levels of mathematical creative thinking abilities who are able to fulfill the fluency aspect by completing two solution ideas. Meanwhile, students who have a low level of mathematical creative thinking abilities have not shown answers on aspects of fluency, flexibility, and originality [7].

In addition, other research is about the Mathematical Creative Thinking Process of Students Following the Creative Problem Solving Learning Model states that the fluency aspect, it can be completed by several students with a high level of mathematical creative thinking abilities. Meanwhile, students with a medium level of mathematical creative thinking abilities do not understand the meaning of the problem even though they know the concept of the area of a rectangle and a triangle. In the aspect of flexibility, some students with medium mathematical creative thinking abilities can understand the meaning of the problem but have not been able to find the measurements contained in the image based on the clue. In the aspect of originality, some students with high mathematical creative thinking abilities tend to be able to solve problems correctly using their own ideas. However, some students with medium and low creative thinking abilities find it difficult to find other ideas to solve problems. In the aspect of elaboration, students are asked to represent images into mathematical sentences or other forms to make it easier to understand. In this condition, some students still misinterpreted the picture [8].

Based on several studies, it has different results and difficulties in measuring students' mathematical creative thinking abilities. This is influenced by the different abilities of each student, both in understanding the material and different experiences in working on non-routine problems. So that some students with medium and low levels of mathematical creative thinking experience some difficulties, such as difficulties in bringing up ideas or ideas to solve aspects of fluency, are still fixated on one way and sometimes wrong in calculating problem solving in the aspect of flexibility, on aspects of originality some students have difficulty looking for other ideas to solve the problem. And in the elaboration aspect, some students are hampered in making details from the information presented in the problem and developing the ideas they have. Based on the description above, the researchers are interested in describe mathematical creative thinking level on polyhedron problems for eight-grade students. The questions of this research include:

a. What is the level of students' mathematical creative thinking ability based on aspects of originality on polyhedron problems?

b. What is the level of students' mathematical creative thinking ability based on aspects of fluency on polyhedron problems?

c. What is the level of students' mathematical creative thinking ability based on aspects of flexibility on polyhedron problems?

d. What is the level of students' mathematical creative thinking ability based on aspects of elaboration on polyhedron problems?

2. Method
This research used a qualitative descriptive and case study design. The research subjects consisted of 35 students of year 8 at a junior secondary school in Serang City, Indonesia. This research procedure includes four stages including: planning, implementation, data analysis and reporting. This research uses inductive data analysis techniques which are a way to find patterns and meaning data so that it can be
accepted by the public regarding the phenomena under investigation and analysis [9]. The steps in analyzing data include Data Reduction, Data Display, Conclusions Drawing and Verification.

The research instrument consists of 4 questions describing mathematical creative thinking abilities that measure aspects of originality, fluency, flexibility, and elaboration in polyhedron problems which are done for 80 minutes and other instruments such as interview guidelines and documentation. The research instrument was validated by three mathematicians consisting of two mathematics education lecturers and one mathematics teacher. The research test was tried out on non-sample students who had studied the polyhedron material. To find out the validity of the items can be seen in table 1.

| No | Coefficient of $r$ | $t_{score}$ | $t_{table}$ | Criteria | Index |
|----|-------------------|-------------|-------------|----------|-------|
| 1  | 0.79              | 7.17        |             | Valid    | High  |
| 2  | 0.78              | 6.93        | 1.70        | Valid    | High  |
| 3  | 0.77              | 6.71        |             | Valid    | High  |
| 4  | 0.66              | 4.89        |             | Valid    | High  |

In table 1, it can be seen that tests number 1 through number 4 has high validation. The reliability value of the mathematical creative thinking test is 0.74, which means that the test is reliable and can be used.

To see the level of students' mathematical creative thinking abilities, the following formula is used:

$$t = \frac{\bar{x} - \mu}{s / \sqrt{n}}$$

where $t$ is the value of the test statistic, $\bar{x}$ is the sample mean, $\mu$ is the population mean, $s$ is the standard deviation, and $n$ is the sample size.

| No | Aspects of mathematical creative thinking | Score | Ideal Score | Average |
|----|-----------------------------------------|-------|-------------|---------|
| 1  | Originality                             | 0 1 2 3 4 | 4  | 2.23  |
| 2  | Fluency                                 | 3 4 4 16 8 4 | 4  | 2.63  |
| 3  | Flexibility                             | 1 3 20 7 4 4 | 4  | 2.28  |
| 4  | Elaboration                             | 1 2 9 15 8 4 | 4  | 2.77  |

3. Result and Discussion

3.1. Mathematical creative thinking ability

In learning mathematics, the problems of daily life are often used as a learning resource that is used to develop and inspire students’ mathematical creative thinking abilities. Student character in creative thinking, mostly seen from the level of creative thinking ability that can be achieved in solving problems according to aspects of creative thinking abilities. To see the level of students’ mathematical creative thinking abilities, the following table 2 is presented

| Category Determination Criteria | Criteria | Level | Students |
|--------------------------------|----------|-------|----------|
| Scores ≥ Mean + SD             | Scores ≥ 12,61 | High  | 5        |
| Mean − SD ≤Scores < Mean + SD  | 7,22 ≤ Score < 12,61 | Medium| 24       |
| Scores < Mean - SD             | Scores < 7,22  | Low   | 6        |

Table 3 shows the mathematical creative thinking abilities of students with a high level of creative thinking as 5 students, medium level as 24 students and low level as 24 students 6 low students. Overall students are in the medium level of creative thinking. Based on the results of interviews with subject
teachers, some students with high creative thinking categories are students who have high initial math abilities and often become representatives in every mathematics competition. This is in line with research that says a significant correlation between students’ creative thinking and their learning achievement [10].

3.2. Discussion

3.2.1 The level of students’ mathematical creative thinking ability based on originality aspects. Originality aspect is a person’s ability to produce different problems or refer to the originality of the ideas produced [8]. To find out the mathematical creative thinking skills in the originality aspect of the polyhedron test, students are asked to make two problems (questions) related to the diagonal area of the cube and solve them correctly independently. The following is a mathematical creative thinking test on the aspects of originality and the answers of students with high, medium and low levels of creative thinking.

1. Look at the following cube image.

   ![Cube Image](image.png)

   The length space diagonal of the cube is $\sqrt{27}$ cm. Ask two problems related to the area of the diagonal area contained in the cube, then answer these problems.

   **Figure 1. Test of mathematical creative thinking ability on the originality aspect.**

Based on figure 2, the results showed that students with a high level of mathematical creative thinking abilities tended to be able to complete the problem in the originality aspect completely by compiling two problems (questions) regarding the area of the diagonal plane on the cube and solving them correctly. Following are the answers of students with a high level of creative mathematical thinking.

Based on figure 3, The steps to solve it are by applying the known information to determine the size of cube’s edge, determining various the size of face diagonal. Then arrange two problems related to the diagonal area of the cube. Next, calculate the two diagonal areas by operating the side lengths multiplied by the diagonal length of the plane to obtain two diagonal areas on the cube. Then, the students’ answers are presented with a medium level of mathematical creative thinking.

Based on figure 2, The steps to solve it are by applying the known information to determine the size of cube’s edge, determining various the size of face diagonal. Then arrange two problems related to the diagonal area of the cube. Next, calculate the two diagonal areas by operating the side lengths multiplied by the diagonal length of the plane to obtain two diagonal areas on the cube.

Based on figure 3, Students with a medium level of mathematical creative thinking abilities tend to be able to solve an alternative answer on the aspect of originality by compiling a problem (question) regarding the area of space diagonal and solving it correctly. This happened because some students misunderstood the meaning of the questions, and experienced difficulties in arranging problems (questions) related to the area of space diagonal cube. This is in line with research that say students with a medium level mathematical creative thinking find it difficult to understand problems and find it difficult to find other ideas to solve problems [7].
In english

Number 1

Noted that:

space diagonal = \sqrt{27} = s\sqrt{3} = \sqrt{27}

\[ s = \frac{\sqrt{27}}{\sqrt{3}} = \sqrt{9} = 3 \text{ cm} \]

face diagonal = \( s\sqrt{2} = 3\sqrt{2} \)

face diagonal = AF, AH, EB, ED, DG, HC, GB, CF

Asked: a. L. ADFG?  
    b. L. BCEH?

Answer:

a. L. ADFG = AD.AF = 3. \( s\sqrt{2} = 9\sqrt{2} \text{ cm}^2 \)

b. L. BCEH = BC.EB = 3. \( s\sqrt{2} = 9\sqrt{2} \text{ cm}^2 \)

**Figure 2.** The answer of high level student’s mathematical creative thinking test.
Translation

a. Note that:
- cube’s edge = 3 cm
- \( BH = DH^2 + BD^2 \)
- \( (\sqrt{27})^2 = s^2 + (s\sqrt{2})^2 \)
- \( 27 = s^2 + s^2 \cdot 2 \)
- \( 27 = 2s^2 \)
- \( s^2 = \frac{27}{3} = 9 \)
- \( s = \sqrt{9} = 3 \text{ cm} \)

b. \( L.BCEH = BC.CH = s\sqrt{2} \cdot s = 3^2 \sqrt{2} = 9\sqrt{2} = 12.72 \text{ cm} \)

Figure 3. The answer of medium level student’s mathematical creative thinking test

Students with a low level of mathematical creative thinking abilities tend not to be able to provide answers to aspects of originality correctly because they misunderstand the sentences in questions, experience difficulties due to the lack of information provided, and arrange problems that are not in accordance with instructions on aspects of originality such as determining the size of cube’s edge, determines the volume of the cube and determines the number of face diagonals cube. This is in line with research that says students with low levels find it difficult to understand the problem and estimate the solution [11].
Translation
Note that: space diagonal = \( \sqrt{27} \) cm

Asked:

a. what is the volume of the cube?

b. what the face diagonal cube is?

Answer:

a. The volume cannot be calculated because only the diagonal is known

b. The diagonal face cube cannot be calculated because the lengths cube’s edge are not known

Figure 4. The answer of low-level student’s mathematical creative thinking test.

3.2.2. The level of students' mathematical creative thinking ability based on fluency aspects. In the aspect of fluency, it measures students' ability to find various ideas in solving problems related to the concept of the surface area of the cube so that they can produce various answers. In this case, students were asked to find various sizes of gift cubes that could be wrapped in rectangular wrapping paper so that there was no leftover wrapping paper. Following are the results of the analysis of students’ answers based on their level of creative thinking abilities.

Students with a high level of mathematical creative thinking abilities tend to be able to fulfill the fluency aspect by providing alternative answers to more than one size cube-shaped gift that can be wrapped in rectangular wrapping paper. The completion step begins with affixing the information known and asked. Next, determine the area of the wrapping paper using a rectangular area, and determine the surface area of the gift using the formula for the surface area of the cube. Next find the sizes of gifts by operating the division between the area of wrapping paper and the surface area of the gift. This step is taken several times to obtain various sizes of gifts that can be wrapped, provided there is no leftover wrapping paper.

Students with medium level mathematical creative thinking abilities tend to be able to answer questions on the fluency aspect by providing more than one alternative answer but the completion process given is incomplete. The completion steps taken by students with medium mathematical creative thinking abilities tend not to write down the formulas used in determining the rectangular size of the wrapping paper and the surface area of the gifts which are cubes. The following is an example of the answers of students with medium level creative thinking abilities.
Translation

Noted that: Paper surface area = \( l \times w \)
\[ = 90 \text{ dm} \times 40 \text{ dm} = 3600 \text{ dm}^2 \]

Asked: The surface area of cube?

Solution 1

The surface area of cube = \( 6 \times s \times s \)
\[ 3600 = 6 \times s^2 \]
\( 6 \times 600 = 6 \times s^2 = s = 10 \)
6 gifts if the size = 10 dm

The surface area of cube = \( 6 \times s \times s \)
\[ 3600 = 6 \times s^2 \]
\( 24 \times 150 = 6 \times s^2 \)
\( s^2 = 5 \)
\( s = 5 \)
6 gifts if the size = 10 dm

Solution 2

a. \( 900 \times 400 = 1 \)
\[ 450 \times 200 = 2 \]
\[ 225 \times 200 = 8 \]

Figure 5. The answer of low level student's mathematical creative thinking test.

Figure 5 shows a category student being able to solve a problem by giving them two correct gift sizes. But there is a mistake in the second way where rectangular gift paper is divided into several sizes to wrap a cube-shaped gift so this method is wrong.

Students with a low level of creative thinking abilities tend not to be able to answer questions on the fluency aspect correctly. This can be seen from the answer given that it is only able to determine the surface area of the wrapping paper (rectangle) without determining the sizes of the gift (cube) because there is an error in understanding the problem, the class uses the formula for the surface area of the cube. This is in line with research that says students find it difficult to understand information on questions because they are not used to doing exercises [12].

3.2.3. The level of students' mathematical creative thinking ability based on flexibility aspects. In the aspect of flexibility, students are asked to be able to solve problems about the concept of the volume of
a shape consisting of several shapes using various ways with different points of view. Following are the results of the analysis of students' answers based on their level of creative thinking abilities.

Students with a high level of creative thinking abilities tend to be able to answer questions on the flexibility aspect by providing two or more ways to determine the volume of the overall shape. The steps to solve it start by determining several types of shapes contained in the whole shape such as blocks, cubes, and pyramids. Provide numbering and write down the volume of each of the separated spaces. Next, determine the volume of the shape as a whole by adding up each volume contained in the shape of the room. Following are the answers of students with a high level of creative thinking abilities.

Translation

Task: Find the way to calculate the volume of shapes and sketch the shapes

1. Way 1: Formula $V_{a1} + V_{a2} + V_b + V_c$
2. Way 2: Formula $V_{a1} + V_{a2} + V_b + V_{c1} + V_{c2}$
3. Way 3: Formula $V_{a1} + V_{a2} + V_b + V_c$

Figure 6. The answer of low level student's mathematical creative thinking test.

Figure 6 describes the steps taken in solving problems in the aspect of flexibility by sketching. Next, determine what shapes are in the problem and break them into several shapes so that we get a way to determine the volume of the overall shape.

Students with medium mathematical creative thinking ability levels tend to be able to answer one correct way in determining the volume of the shape as a whole from the two ways given because in one of the other ways there are errors in determining the volume of the overall shape. Because in one way there is a mistake in the process of numbering and determining the shape of the space because one of the spatial shapes that contain the whole shape is not counted so that the method of determining the volume given is wrong.

Students with a low level of mathematical creative thinking ability tend to give wrong answers on the flexibility aspect because they can only divide the number of spatial shapes such as cubes, blocks,
and pyramids and write down each volume formula without determining the volume of the shapes as a whole. In the problem of mathematical creative thinking in the aspect of flexibility, the average student has difficulty in sketching the shape of a space to obtain the overall volume of the shape in different ways. This is in line with research that says that the difficulty in identifying images is a common difficulty faced by some students in solving problems regarding geometric material [7].

3.2.4. The level of students' mathematical creative thinking ability based on elaboration aspects. In the elaboration aspect, students are given problems to calculate the maximum number of chocolate blocks that can be inserted into the cardboard box. In addition, students are asked to make a sketch so that they can detail the amount of chocolate that is put into the box without remaining. The following is presented a mathematical creative thinking test on the detail aspect. Following are the results of the analysis of students' answers based on their level of creative thinking abilities.

Students with a high level of mathematical creative thinking ability can solve problems in the elaboration aspect by providing two alternative answers in detail. Then answer the first question by making a sketch of chocolate on the cardboard based on the size and determining the position of the chocolate parallel and providing information on the arrangement of the chocolate found in the front, side and back positions. In the second answer, determine the maximum amount of chocolate that can be put into the cardboard by calculating the division operation between the volume of the cardboard and the volume of chocolate, both of which are in the form of blocks.

Students with a medium level of mathematical creative thinking tend to answer both problems in the aspect of detail but there is an error in one of the answers given. The final step taken is to make a detailed sketch of the chocolate on the cardboard and find out the reasons for determining the position of the chocolate parallel. Next determine the maximum number of chocolates that can be put into the box, but in the second answer, there is an error in counting the number of chocolates so that only one correct answer can be answered.

Students with a low level of mathematical creative thinking tend to be able to provide answers on the elaboration aspect but there is an error in one of the answers and do not completely write down the formula used in determining the maximum number of chocolates. Following are the answers of students with low creative thinking levels.

![Image](image.jpg)

**Translation:**

a. Sketch

b. There are maximum of 36 chocolates can fit in the box

Figure 7. The answer of low level student's mathematical creative thinking test.
Based on figure 7 it can be seen that the answer given is not complete with steps. This happens because students at a low level of mathematical creative thinking have difficulty making sketches so that they cannot understand the sketches they make, besides that students do not understand the meaning of the questions given even though they can count the number of chocolates that can be loaded in the box. This is in line with research which states that difficulties in understanding a given problem provide less structured, less detailed and less systematic solution steps [13].

4. Conclusion
Based on the results, we draw the following conclusions:

a. In solving the problem of mathematical creative thinking ability on polyhedron material in terms of originality aspects,
   i) Students with high level mathematical creative thinking ability tend to be able to compose two problems (questions) regarding the area of the diagonal plane on the cube and solve them correctly.
   ii) Students with medium level mathematical creative thinking ability tend to only be able to compose one problem (question) regarding the area of the diagonal plane on the cube and solve it correctly.
   iii) Students with a low level of mathematical creative thinking ability cannot construct problems (questions) regarding the area of the diagonal plane on the cube.

b. In solving the problem of mathematical creative thinking ability on polyhedron material in terms of fluency aspects,
   i) Students with high level mathematical creative thinking ability tend to be able to give answers of more than one gift size (cube) that can be wrapped by wrapping paper (rectangle).
   ii) Students with medium level mathematical creative thinking ability tend to give more than one answer but the completion process is incomplete.
   iii) Students with a low level of mathematical creative thinking tend not to give correct answers regarding the size of gifts (cubes) that can be wrapped by gift paper (rectangle).

c. In solving the problem of mathematical creative thinking ability on polyhedron material in terms of flexibility aspects,
   i) Students with high level mathematical creative thinking ability tend to be able to answer two different ways and even more in determining the volume of the shape as a whole.
   ii) Students with medium level mathematical creative thinking ability tend to answer one way that is correct from the two ways given because in one other way there are incorrect answers.
   iii) Students with a low level of mathematical creative thinking ability tend to give wrong answers because they only draw back a sketch of the spatial shapes on the problem and write down the volume without the correct completion process.

d. In solving the problem of mathematical creative thinking ability on polyhedron material in terms of elaboration aspects
   i) Students with high level mathematical creative thinking ability tend to be able to provide two alternative answers, namely making sketches and counting the maximum number of chocolates (small blocks) on cardboard (large blocks) in detail.
   ii) Students with medium level mathematical creative thinking ability tend to give two answers on the aspect of detail but there is an error in one of the answers.
   iii) Students with a low level of mathematical creative thinking ability tend to only give one correct answer even though they do not completely write the spatial form formula used.

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