Level of Students' Creative Thinking in Solid Geometry

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Abstract. Creativity is an important aspect to face the global challenges. Creative thinking skill is a skill that is needed in this era to face problems in all aspects of modern life. Creative thinking is a thinking style which allows individuals to produce new products, find new solutions, and new ideas. The purpose of this study is to identify the level of students’ creative thinking in solid geometry. This research is a qualitative descriptive research. The subjects of this research were three students from 8th grade student of SMP N 8 Purwokerto Banyumas regency. The students were classified to high-ability, moderate-ability, and low-ability. The data were collected through creative thinking test and interview. There are three aspects of creative thinking: fluency, flexibility, and novelty. Based on the results, three subjects didn’t fulfill novelty, students who had low-ability had creative thinking level 0 (Not Creative), students who had moderate-ability had creative thinking level 1 (Almost Not Creative), and students who had high-ability had creative thinking level 2 (Quite Creative).

1. Introduction
Education is the key to create qualified people who can provide a better change for the nation and country. New ideas can create a change so there are innovation from the old ideas that already exists. New ideas can be realized if someone were able to take advantage of creativity in him. Creativity is the important component for nation advancement [1]. Through their creative thinking, students will see things differently than most students in general and summarize unusually. Creativity is an essential feature of personality that is used in everyday life [2]. One of the main purposes in mathematics learning is developing creative thinking skills [3]. The same thing is expressed by [4] that one of the abilities of mathematical thinking needs to be developed early on is ability to think creatively.

Creativity is a mental process that generates novel, unique, and intuitive solutions to a given problem [5]. Students are able to look at mathematical problems from different perspective through creative thinking so they can give a diverse answer in problem solving. It gives a good impact for students because students can find the most effective and efficient way of solving mathematical problems. Learning to know our creativity ability is one of the most significant aspects of our life, for everything we do, is affected by our thinking abilities [6].

Creative thinking skill is one of the most necessary skills in solving a problem [7]. Creative thinking will be trained when students are faced with problem-solving. Problem solving provides many opportunities for students to explore their competencies. This also provides an opportunity for improving students' creative thinking skills. Nevertheless in developing the creative thinking skills, students have many difficulties. Students are still focused on examples from the teachers and feel...
confused when there are new problems that are different from the examples. Students must use their creative thinking skills to solve new problems by using their knowledge.

Due to difficulty of describing structure of mathematical creativity and its characteristics, defining mathematical creativity is a challenging task [8]. Creativity is not an invention that no one has ever known before, but that creativity product is something new to oneself and should not be something new to another or the world [9]. Creativity is not only obtained from teacher, but also obtained from other places [10]. Mathematical creative thinking as the ability to analyze problems given from different perspectives, look at patterns, differences, and similarities, generates some ideas, and chooses the right method for solving non-routine mathematical problem [6].

There is significant influence between creativity and achievement of junior high school student [11]. It means if student’s creativity is improved, then student’s achievement will be improved too. In addition, there is significant influence between creativity and achievement of 7th grade junior high school student [12]. Based on these two researches, it can be concluded that student’s creativity influences student’s achievement. It means that if the learning achievement is low, then students' creativity is low too.

The percentage from the result of UN 2016/2017 at Banyumas showed that the test result of solid geometry material is 46.73%, it is lower than the result of the others material. It shows that the student's achievement on solid geometry material is low, so it means that the student's creativity is low too. In the learning of geometry, needs student’s creativity to solve the problem [13]. Creativity in mathematics classrooms is not just about what pupils do but also about what we do as teachers [14]. The important tasks of teachers is to identify and develop mathematical creativity [15]. To assess their capabilities in creative thinking, teacher could use level of students' creative thinking [16].

Creativity in mathematics is often looked at as the exclusive domain of professional mathematicians [17]. The ability to think creatively mathematically was the ability to find solutions math problems that were easy, flexible, and new [18]. The creative thinking is the main component of the creativity, and the main factors of the creativity in mathematics are the sensitivity toward the problems, the fluency and flexibility of thinking, the originality, the perspicacity and the ingenuity [19].

Research which are related to the level of creative thinking has been carried out by several previous researchers. One of them by [3]. The difference is researchers did not review the level of creative thinking from students' anxiety levels in this study. Then the other research was conducted by [20]. The difference is that research aims to describe the characteristics of the level of student creative thinking in mathematics.

According to [3], level of creative thinking was stage of thinking hierarchical based on the product of mathematics creative thinking that was viewed from aspect of creativity. There are three aspects of creative thinking: fluency, flexibility, and novelty. Fluency is shown when students fluently generate ideas in solving problems. Flexibility is shown when students generate some ideas that are used to solve problems. Novelty is shown when students give unusual and different answers than most people. The aspects of creative thinking as shown on Table 1.

| Aspect  | Criteria(s)                                      |
|---------|--------------------------------------------------|
| Fluency | Students can solve the problems smoothly and correctly. |
| Flexibility | Students can solve the problems in various steps. |
| Novelty | Students can solve problems in new steps and these steps are not commonly used. |

Creative thinking is thinking that is original and reflective and that produces a complex product. Those levels are also not easily predictable or identified in the learning process [21]. The characteristics of the levels of creative thinking as shown on Table 2 contained a different primary aspect for each level [3].
Table 2. Characteristics of student’s creative thinking level.

| Level             | Characteristic of Creative Thinking Level                                      |
|-------------------|--------------------------------------------------------------------------------|
| Level 4 (Very Creative) | The subject fulfills the fluency, flexibility, and novelty aspect.             |
| Level 3 (Creative)     | The subject fulfills the fluency and novelty aspect.                           |
| Level 2 (Quite Creative) | The subject fulfills the fluency and flexibility aspect.                       |
| Level 1 (Almost Not Creative) | The subject fulfills the fluency aspect.                                        |
| Level 0 (Not Creative)  | The subject doesn’t fulfill any aspect of creative thinking.                   |

2. Research Method

The research approach is qualitative research which aim to identify the level of students’ creative thinking in solid geometry. Sampling methods in this study using purposive sampling. The subjects of this research were three students from 8th grade student of SMP N 8 Purwokerto Banyumas regency. The analysis was conducted on the high-ability student, moderate-ability student, and low-ability student. The selection of the research subject was based on: (1) subjects have received a lesson about solid geometry; (2) subjects have taken the test of creative thinking skill; and (3) subjects have communication skill in both oral and written.

The data were collected through creative thinking test and the task-based interview to the 8th grade students. The main instrument at this research was the researcher. The secondary instrument at this research were the task of problem solving and the guide of interview. The problem-solving task was used to identify the level of students’ creative thinking. The data of this research must be valid so that researchers conduct methodological triangulation. In methodological triangulation, data valid when there are no significant differences between test and interview. The students’ work was analysed by identifying the correctness of the answer, then checking for aspects of creative thinking (fluency, flexibility, and novelty) in problem solving. Data analysis uses three steps, namely data reduction, presentation, and conclusion.

3. Results and Discussions

The data were collected through creative thinking test and the task-based interview. The data were analysed after it were collected. The result of this research described the level of creative thinking students in solid geometry. The answers from low-ability students, moderate-capable students, and high-ability students can be analysed as follows.

All of three subjects were asked to answer this question: A bathtub has a length of 80 cm, a width of 50 cm, and a height of 70 cm. The water height in the bathtub is 30 cm. Then 3 iron cubes with a length of 20 cm were inserted into the bathtub. What is the final water height in the bathtub after the 3 cubes were inserted?

Based on the test results, it showed that low-ability student could analyse and write information into mathematical symbols. However, she wasn’t able to understand the problem. Subject who had low-ability could not solve the problem correctly. She only added the initial water height to the cube height to calculate the final water height after the iron cubes were inserted. It was shown in Figure 1. She didn’t give another step to solve the problem. She didn't have interest in finding other ways to solve this problem.
Translate
1) Cuboid : p = 80 cm, high water in tub = 30 cm (initially)
   l = 50 cm       P cuboid = 20 cm
   t = 70 cm
   high water in tub = 30 cm + 20 cm = 50 cm

Figure 1. Low-ability student’s solution.

The following are interviews with S1 research subjects:

R : How do you calculate the final height of water?
S1 : By adding the initial water height with the height of the iron cube inserted. So, 30 cm is the water height and 20 cm is the cube height. So the final water height is 30 + 20 = 50 cm

R : How many cubes are inserted in the bathtub?
S1 : There are three cubes.

R : How do you calculate the final water height if only one iron cube is inserted? Is the method same?
S1 : (unable to answer).

R : What is the volume of the cubes which are inserted in the bathtub?
S1 : (confused and unable to answer).

Based on the interview results, subject seems to be still unsure of the answer. Subject could not explain the volume formula of cuboid and cube because she forgot it. She was asked to explain the steps of the answer. She explained that the final water height was obtained from added the initial water height to the height of the cube. When she was asked to measure the final water height when only one cube was inserted, she was confused and unable to answer. Subject did not understand the problem given. Subject could not solve the problem correctly and she could not give another step to solve the problem.

Based on analysis of test result and interviews, subject who had low-ability did not fulfill any aspect of mathematics creative thinking. Therefore this subject got Level 0 (Not Creative).

Subject who had moderate-ability could solve the problem correctly. He could analyse and write information into mathematical symbols. His first step, he calculated the volume of the bathtub. Then he calculated the volume of water, and the volume of 3 cubes. After those steps, he tried to find the final water height. He also could solve it with appropriate steps. However, he did not give any other steps to solve the problem. Subject only used one step and did not search the other ways to solve the problem. It was shown in Figure 2.
The following are interviews with S2 research subjects:

R: Do you know how to calculate the volume of cuboid and cube?
S2: By multiplying the length, width, and height of the cuboid or cube.
R: How do you solve this problem?
S2: I calculated the volume of water in the bathtub, which is $80 \times 50 \times 30 = 120,000$. Then added with the volume of the cube entered is $3 \times 20 \times 20 \times 20 = 24,000$. After that, I try to find the water height.

Based on the interview, subject could explain how to calculate the volume of cuboid and cubes. Subject solved the problem by calculated the water volume in the cuboid first. Then he calculated the volume of three iron cubes inserted. The next step, he added the water volume and volume of three cubes, and calculated the final water height. He solved the problem correctly. However he was not able to provide another steps to solve the problem. He fulfilled the fluency aspect because he could solve the problem smoothly and correctly. He could not provide a variety of other answers so that he did not fulfill the flexibility aspect.

Based on analysis of test result and interviews, subject who had moderate-ability only fulfilled the fluency aspect. Therefore this subject got Level 1 (Almost Not Creative).

Subject who had high-ability could analyse and write information into mathematical symbols. The way she wrote information from questions was better than moderate-ability and low-ability students. Subject who had high-ability could solve the problem correctly. She also solved the problem with the appropriate steps as shown in Figure 3.
Translate:
Given: cuboid  
\( p = 80 \text{ cm} \)
\( l = 50 \text{ cm} \)
\( t = 70 \text{ cm} \)
\( t_{\text{water}} = 30 \text{ cm} \)

cube \( s = 20 \text{ cm} \)

Ask: \( t_{\text{water}} \) final?

Answer:
\[ V_{\text{water rise}} = V_{\text{cube}} \]
\[ P\times l \times t_{\text{increase}} = 3 \text{ s}^3 \]
\[ 80 \times 50 \times t_{\text{increase}} = 3 \times 20 \times 20 \times 20 \]
\[ 4000 \times t_{\text{increase}} = 24,000 \]
\[ T_{\text{increase}} = 6 \text{ cm} \]
\[ T_{\text{final}} = 30 + 6 = 36 \text{ cm} \]

**Figure 3. High-ability student’s solution 1.**

She searched water height by comparing the volume of water that rose with volume of 3 cubes. After the height of the rising water is found, then added with the initial water height. So, she calculated the height difference then added to the initial water height.

She could give another step to solve the problem as shown in **Figure 4.**

**Figure 4. High-ability student’s solution 2.**

Subject who had high-ability could solve the problem correctly. The second way, she added the water volume and volume of three cubes, then look for height. This answer was similar to the answer of a moderate-ability student. Both ways are the right steps to solve the problem. The following are interviews with S3 research subjects:

\( R \) : How do you solve this problem?
\( S3 \) : I have two different ways to answer it and give the same answer.
\( R \) : Explain the first way!
\( S3 \) : The first way, I look for the water height difference. It means, from the volume of three cubes, then search the height when three cubes are inserted in cuboid. After that, the height is added to the initial water height in the bathtub.
R: How is the second way?
S3: I calculated the volume of water in the bathtub, then calculated the volume of three cubes. After that, I added all. Then I looked for the final water height.

Based on the interview, subject who had high-ability answered questions with confidence. She explained how to solve the problem in two different ways. The first step, the height difference was searched then added it to the initial water height. The second step, she added the volume of water and volume of three cubes, then look for the height. Then subject was asked how he found all the steps. He replied that the first step was obtained from tutoring outside of school. The second step is a commonly step which taught in class by the teacher. After conducting deeper interviews, it turned out that subject have not fulfilled the novelty aspect because even though her answer is different from the other students' answer, her answer is not new for herself. She solved the problem smoothly and correctly so she fulfilled the fluency aspect. She also fulfilled the flexibility aspect because she was able to solve problems with two different steps.

Based on the test and interviews, subject who had high-ability fulfilled the aspects of fluency and flexibility, but her solutions did not fulfill novelty. Based on the criteria, subject who fulfill the fluency and flexibility aspect got Level 2 (Quite Creative).

The characteristics of the level of creative thinking as shown on Table 3 contained a different primary aspect for each level. The difference is in the creative thinking aspects that consisted of fluency, flexibility, and novelty in problem solving.

| Subject       | Criteria                                                                 |
|---------------|---------------------------------------------------------------------------|
| Low-Ability   |                                                                           |
| Level 0       | Student could not solve a problem with more than one solution and could not represent another step to solve it. Her solution did not fulfill fluency, flexibility, and novelty. She also can’t pose the novelty and flexibility problems. Not all constructed problems fulfilled fluency, flexibility, and novelty. |
| (Not Creative)|                                                                           |
| Moderate-Ability | Student couldn’t solve a problem with more than one solution. The solution does not fulfill originality novelty. The constructed problem just fulfilled fluency without novelty and flexibility. |
| Level 1       |                                                                           |
| (Almost Not Creative)|                                                    |
| High-Ability  | Student was able to solve a problem with more than one solution, but her solutions did not fulfill novelty. She could represent another way to solve a problem. The constructed problems fulfill fluency and flexibility without novelty. |
| Level 2       |                                                                           |
| (Quite Creative)|                                                                                |

The results of this research indicated that there is a significant difference in the level of creative thinking from each student's ability. This results support the other studies where the conclusion of their research is student's creativity influences student's achievement. If student's achievement is low, then one of the influential elements is student's creativity and it can be said that student's creativity is low. In this research, from three subjects who had low-ability, moderate-ability, and high-ability did not fulfill the Level 3 (Creative) and Level 4 (Very Creative), so the level of students’ creative thinking were still low.

4. Conclusion
The aim of this research is to identify the level of students’ creative thinking in solid geometry. There are three aspects of creative thinking: fluency, flexibility, and novelty. The conclusions of this study are (1) students who had low-ability have level of creative thinking level 0 (Not Creative), (2) students who had moderate-ability have level of creative thinking level 1 (Almost Not Creative), (3) students who had high-ability level of creative thinking level 2 (Quite Creative).

From the results of this study, there are significant differences in the level of creative thinking of each student. High-ability student have higher level of creative thinking than other ability students. The results of this study can provide benefits for teachers to identify the level of creative thinking of students so that they can carry out better learning in accordance with the conditions of students. One of the elements that influences student achievement is creativity. Therefore, research in this field is very important.

The suggestions based on this research are teachers can provide challenges, open-ended problems, and ask students to solve problems with various kinds of solutions, so that students will be trained to improve their creativity in solving mathematical problems. Students are given the opportunity to be involved in solving challenging problems, which can enhance students' creativity. It means students are encouraged to reflect on their own ideas. Teachers make a plan and implement comfortable learning where students dare to convey their ideas. The results of this study can be a reference for other researchers to develop learning models that enhance student creativity.

References
[1] Amalina I K, Amirudin M and Budiarto M T 2018 J. Phys.: Conf. Ser 947 012012
[2] Svecova V R 2013 Support of Pupil’s Creative Thinking in Mathematical Education 5th World Conference on Educational Sciences 116 pp 1715-1719
[3] Machromah I U and Usodo B 2016 Analyze of The Creative Thinking Level of Students Junior High School Viewed From Mathematics Anxiety 3rd International Conference on Research, Implementation and Education of Mathematics and Science pp 145-150
[4] Ulfah U, Prabawanto S and Jupri A 2017 J. Phys.: Conf. Ser 895 012097
[5] Yaftian N 2015 The Outlook of the Mathematicians’ Creative Processes World Conference on Educational Sciences 191 pp 2519-2525
[6] Idris N and Nor N M 2010 Mathematical Creativity: Usage of Technology World Conference on Educational Sciences 2 pp 1963-1967
[7] Natadiwijaya I F, Rahmat A, Redjeki S and Anggraeni S 2018 J. Phys.: Conf. Ser 1013 012011
[8] Nadjaﬁkhah M, Yaftian N and Bakhshalizadeh S 2012 Mathematical Creativity: Some Definitions and Characteristics Procedia - Social and Behavioral Sciences 31 pp 285-291
[9] Slameto 2010 Belajar dan Faktor-Faktor yang Mempengaruhi (Jakarta: Rineka Cipta)
[10] Bolden D S 2010 Pre-Service Primary Teachers’ Conceptions of Creativity in Mathematics Educ Stud Math 73 pp 143–157
[11] Andinny Y 2017 Pengaruh Kreativitas dan Minat Belajar Siswa Terhadap Prestasi Belajar Matematika Seminar Nasional Matematika dan Pendidikan Matematika pp 156-161
[12] Wilda, Salwa and Ekawati S 2017 Pengaruh Kreativitas dan Minat Belajar Terhadap Hasil Belajar Matematika Siswa Pedagogy Journal of Mathematics Education 2 pp 134-144
[13] Kuncorowati R H, Mardiyana and Saputro D R S 2017 J. Phys.: Conf. Ser 943 012005
[14] Rumanová L and Smiešková E 2015 Creativity and Motivation for Geometric Tasks Designing in Education Acta Didactica Napocensia 8 pp 49-56
[15] Nadjaﬁkhah M and Yaftian N 2013 The Frontage of Creativity and Mathematical Creativity Procedia - Social and Behavioral Sciences 90 pp 344-350
[16] Siswono T Y E 2014 Developing Teacher Performances to Improving Students Creative Thinking Capabilities in Mathematics International Conference on Research, Implementation and Education of Mathematics and Science pp 509-516
[17] Sriraman B 2005 Are Giftedness and Creativity Synonyms in Mathematics? The Journal of Secondary Gifted Education 17 pp 20-36
[18] Munahefi D N, Waluyo S B and Rochmad 2018 J. Phys.: Conf. Ser 983 012161
[19] Parcaru M A P and Florea O 2017 Methods for Creativity Stimulation of Students in Math Courses Transylvania University of Brasov Series VII: Social Sciences, Law, Brasov 10 pp 75-86
[20] Siswono T Y E 2009 Level of Student’s Creative Thinking in Classroom Mathematics Educational Research and Review 6 pp 548-553
[21] Siswono T Y E 2008 Model Pembelajaran Matematika Berbasis Pengajuan dan Pemecahan Masalah untuk Meningkatkan Kemampuan Berpikir Kreatif (Semarang: Unesa University Press)

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