Students’ creative thinking process in completing mathematical PISA test concerning space and shape

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Abstract. This study aims to describe the creative thinking process of junior high school students in solving PISA-level Mathematics questions on space and shape. This research is descriptive qualitative research. The subjects were 2 students from Public Junior High School 1 of Banyuwangi, 2 students from Public Junior High School 1 of Giri-Banyuwangi, and 2 students from Public Junior High School 1 of Rogojampi-Banyuwangi. The data analyzed was the results of creative thinking tests and student interviews. The results of this study indicate that high-ability students have creative thinking skills at a very creative level. Students with abilities are having creative thinking skills at the creative level. Students with creative thinking ability for low-level creative thinking in categories not creative.

1. Introduction
Since 2000, Indonesia’s participation in PISA indicates that Indonesia has experienced very little improvement in the quality of education. Assessment results in mathematics and science for 15 year olds from 72 OECD countries conducted in 2015 demonstrates that Indonesia is ranked 62, far behind Vietnam already which has exceeded top 10 ranks along with Singapore at the first rank [1]. The PISA test can be used as a reference because increased ratings in PISA test can increase the average final score of a country, which is positively correlated with an increase in GDP (Gross Domestic Product) [2].

Mathematics is considered as the mother of all sciences because it is a tool which solves problems of every other science. Therefore it is very necessary to master mathematical concepts. The concept of mathematics is based on previous concepts. As a result, understanding the wrong concept will produce errors in understanding the concept further.

The educational problem in Indonesia is currently related to the results of national examinations and the lack of attention of teachers to efforts aimed at developing creativity of students. Teacher’s creative idea is needed to change the learning practices for more interesting and effective learning experience, while inviting students to be more active. Based on the results of the national examination in 2015-2017, there was a decrease in the achievement results of students in Public Junior High School 1 of Banyuwangi, Public Junior High School 1 of Giri, and Public Junior High School 1 of Rogojampi.

The steps of creative thinking include synthesizing ideas, building ideas, planning the application of ideas, and applying these ideas to produce something new [3]. The students are better focused on mathematical thinking and understanding of the concepts they have and respond to their understanding through instruction [4]. The thinking process is a mental activity used to formulate and solve problems, make decisions, and understand problems [5]. The thinking process is based on 1) specifying, 2) generalizing, 3) guessing, 4) convincing [6]. The process of requesting this question requires a high degree of mathematical creativity, in addition to understanding the material as well as creativity in
composing questions. This is what causes the improvement of students' creative thinking ability through learning problem posing. These findings are in line with the results of the studies which revealed that posing problems can improve students' creative thinking ability [7-11]. The improvement of the ability of mathematical creative thinking of students who received problem posing learning with manipulative media aid was higher than the ability of the students who received problem posing learning without the aid of manipulative media [12]. PBL model is an alternative learning model that can improve students' creative thinking skills. By using PBL, students are given the opportunity to think creatively. This learning model is believed to be able to improve student learning creativity [13].

Creative thinking is related to all of the perspectives, and a strong belief in any particular perspective may result in a tendency [14]. Students of academic level were only able to achieve smoothness and flexibility aspects well. But the originality of students at the academic level was not yet well structured. In contrast to high academic level students who were already able to build unusual ideas, intelligent ideas that were different from the way in general. Therefore, students of high academic level have been able to reach the aspect of originality which was the highest aspect in the ability of mathematical creative thinking [15]. Indicators of mathematical creative thinking is fluency, flexibility, and originality [16, 17].

Developed the test of mathematical creativity by indicating aspects of fluency, flexibility and originality [18]. The ability of students' creative thinking ability taught using PBL is higher than the students' creative thinking ability by conventional learning. Therefore, it can be said that PBL Model has a good influence on students' creative thinking ability in mathematics [19]. OQALE stages are proven to bring students to observing, questioning, analyzing, associating, and expressing and able to enhance creative thinking skills, mathematical students [20]. Find new alternative to solve the problem, can only be fulfilled by 29.4% of the class. This indicator sure is the hardest for this class’ students to fulfil. Finding a new way other than ways that found in students’ book or teachers taught is not an easy task because it requires a deep understanding of the theory which is used to solve the given mathematical problem and other knowledge that relates to it [21]. No student met the flexibility component because students solve the problem in one way or in two ways but by using the same ways. The creativity of students in posing the problem depends on the experience of students in learning mathematics. The more students experience in learning mathematics the more creative the students are also in posing the problem.

Beside the learning experience, the students' creativity in posing the problem also depends on the students' way in posing the problem. Some are guided by the answer first, and also directly pose the problem by looking at different points of view from a known problem [22]. The strength of scientific approach in building mathematical creative thinking ability lies with flexibility indicator. However, scientific approach still fails to build the novelty indicator. Therefore, the teaching and learning using scientific approach should be performed optimally and by actively involving students in order for it to be able to improve students’ mathematical creative thinking ability [23].

Proposes the indicators to assess students' creative thinking using problem submission and problem solving [24]. To assess creative thinking of children and adults is often used The Tolerance Tests of Creative Thinking (TTCT). Three key components assessed in creativity use TTCT include fluency, which refers to the number of ideas made in response to a question. In this case, students are able to provide variations in answers to solving problems smoothly, flexibility which indicates the extent to which students are able to produce variations of answers with different approaches in solving problems and creating novelty, that is students are able to create new, unique, and different answers.

The indicators used in the package of creative thinking tests are fluency, flexibility and novelty. These indicators are presented in table 1.

| No | Criteria | Indicator |
|----|-----------|-----------|
| 1  | Fluency  | - Students are able to understand the information contained in questions with various interpretations  
    |           | - Students are able to identify what is known and unknown from the problem  
    |           | - Students are able to explore and translate the information on the problem according |

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The TTCT assessment can also classify the level of students' creative thinking abilities. The level of creative thinking comprises of 5 levels, namely level 4 (very creative), level 3 (creative), level 2 (fairly creative), level 1 (hardly creative), and level 0 (not creative) [25]. These levels of creative thinking are theoretical-hypothesis, meaning that it is developed based on known theories and is a hypothesis that requires empirical verification in the field (at school). Based on the levels of creative thinking, there are several levels of students' creative thinking abilities which can be seen in table 2.

| Level    | Category         | Characteristic                                                                 |
|----------|------------------|-------------------------------------------------------------------------------|
| LCTA 4   | Very Creative    | Students are able to show fluency, flexibility, and novelty or novelty and flexibility in solving problems |
| LCTA 3   | Creative         | Students are able to show fluency and novelty or fluency and flexibility in solving problems |
| LCTA 2   | Creative Enough  | Students are able to show novelty or flexibility in solving problems           |
| LCTA 1   | Less Creative    | Students are able to show fluency in solving problems                         |
| LCTA 0   | Not Creative     | Students are not able to show the three aspects in solving problems           |

The widely acknowledged steps in solving mathematical problems is put forward by Polya, in his book "How to solve it". The four steps of solving mathematical problems according to Polya are (1) understanding the problem, (2) making a plan, (3) implementing the plan, and (4) rechecking [26]. Space and shape content refers to the geometry curriculum concerned with finding similarities and differences, recognizing shapes in different representations and different dimensions, understanding the nature of objects and their relative positions, and their relationship between visual representations and real objects.

2. Method
This research was qualitative descriptive research. In this study qualitative and quantitative data were analyzed based on aspects of the creative thinking process. The subjects were chosen from 3 different schools. These schools were namely Public Junior High School 1 of Banyuwangi with 2 students in class IX-D, Public Junior High School 1 of Giri with 2 students of class IX-A and Public Junior High School 1 of Rogojampi, with 2 students in class IX-C. The rationale in determining the research subjects was the need for involving students at various levels of critical thinking skills. Students who had different abilities were selected through the PISA test answer sheet, the results of which were discuss with the mathematics teacher to better understand their students' thoughts through spoken and written communication. Furthermore, interviews were conducted with the subject.

The data that had been obtained from the answer sheet of the PISA test was analyzed by checking the truth of the answers made by the students. The analysis results were the basis to determine the aspects of students' creative thinking, namely fluency, flexibility and originality. To find out the creative thinking process of students, the researchers analyzed the student test answer sheet and conducted an interview, where the analysis included data reduction, data exposure and drawing conclusions.
3. Result and Discussion

Students with high, medium and low math abilities were used in this study in determining aspects and categories of creative thinking. Students were given creative thinking tests, namely completing PISA test questions, space & shape content and conducting interviews. The student's creative thinking process can be described based on the results of tests and interviews with the research subjects.

The results of the study obtained S1 with high mathematical abilities having a very creative category and fulfilling aspects of creative thinking fluency, flexibility and novelty. Another student, S2, with high mathematical abilities had creative categories and fulfilled aspects of creative thinking fluency and novelty. S3 with moderate mathematical skills had a very creative category and fulfilled the aspects of creative thinking processes fluency, flexibility and novelty. S4 with moderate mathematical skills had a fairly creative category and fulfilled the aspects of the creative thinking process flexibility and novelty. S5 with low mathematical abilities had a category that was not creative or unable to fulfil the aspects of fluency thinking, flexibility and novelty. S6 with low mathematical abilities had a category, indicating that he was not creative and unable to fulfil the aspects of fluency thinking, flexibility and novelty. Based on the results of test and interview, the process of creative thinking on each research subject can be analyzed as follows:

1. The Creative Thinking Process of S1

| No. | The Steps of Solving Polya |
|-----|----------------------------|
| 2.  | Step 1. Understanding the Problem (Restate the problem in your own words) |
|     | Known: |
|     | \[ A D \angle 120^\circ \] |
|     | Asked: |
|     | How much the length of AB? |

**Figure 1.** Polya’s creative thinking level on the 2nd question

Question number 2 for step 1 understand the problem. S1 made a rectangle and there was AOB right triangle inside it. As shown on figure 1, S1 combined 3 two-dimensional objects, in which they were rectangle, right triangle and trapezoid. S1 also wrote 120° as the angle placed on AOD. In step 2 which was making the plan of problem solving, we can see that S1 made 3 different formulas on this second step. In the first formula, S1 made a concept about straight angle, in which if \( \angle AOB \) and \( \angle AOD \) were summed, the result would be 180°. S1 formulated \( a + b = 180^\circ \) and her straight-angle image. The second formula was S1 made the area formula of right triangle. However, the writing error was done by S1 in giving the symbol on the area formula of right triangle. After conducting an interview, S1 pointed out that it was a writing error. The base was supposed to be multiplied with the height on that right triangle, it was not side (S) times side (S). “The biggest part of creative thinking lays on a habit” [27]. The third formula wrote by S1 was a comparison of special angles on right triangle with 30°, 60°, 90° as its angles. S1 wrote
AB: AO: BO = \sqrt{3}: 2: 1. The following is a part of interview carried out with S1 which showed that he could restate question number 2.

P: triangle AOB has symbol “o”, was it a letter or number?
S1: It was O, Sir.
P: It was similar to zero, why did you place it inside the triangle?
S1: Definitely Sir, since I am used to placing it there.
P: It should be placed outside as we are able to differentiate the symbol of number or letter. Like the symbols of letter you made, in which they were A, B, C, D.
S1: Yes, Sir.

The third step was to implement the plan, S1 searched for \( \angle AOB \) by referring to the straight-angle formula that she had made. After the value of AOB was obtained, then S1 looked for the value of AB using a comparison of its special angles that were 30°, 60°, 90°. S1 used comparison of \( AB: AO = \sqrt{3} : 2 \), thus \( \frac{AB}{AO} = \frac{\sqrt{3}}{2} \). However, S1 wrote \( \frac{AB}{AO} = \frac{\sqrt{3}}{2} \), according to S1, although it was turned back and forth between the left and right segments, it would be the same way to do it and the value obtained was the same. The answers made by S1 fulfilled the aspects of flexibility and novelty. Students tend to be confident and challenged to do the tasks given quickly and immediately correct the answers correctly [3]. The fourth step was to re-check, S1 re-calculated the AB value using the \( \frac{AO}{2} = \frac{AB}{\sqrt{3}} \) formula. S1 wanted to convince himself of the answers she had made to find the value of AB and made conclusions related to the special triangle with an angle of 90°: 60°: 30° has a comparison as \( \sqrt{3} : 2 : 1 \).

2. The Creative Thinking Process of S2

In Figure 2 above, step 1 was to understand the problem. S2 made a flat trapezoidal shape then determined the size of the angles that were \( \angle CAB \) and \( \angle ACB \). The question made by S2 was to determine the angle \( \angle ABC \). Step 2 was to make a plan of problem solving. S2 determined the formula for the number of angles in a triangle which value was 180°. The formula made by S2 was used to make a comparison of the angles on the sides of a right triangle. Step 3 was to implement the plan, S2 summarized the three angles on the right triangle, in which the result of the sum was 180°. After obtaining the value of \( \angle ABC = 60° \), then S2 entered the size of each inner angle on the right triangle. S2 could not obtain a new idea, because the S2 could not solve the question if what was known was the value of the length of one side of the triangle only. Based on the explanation of S2 during the interview, S2 only could answer the question if the known one was 2 sides namely base and height from right triangle. Whereas, the question asked about hypotenuse.
3. The Creative Thinking Process of S3

**Figure 3.** Polya’s creative thinking level on the 4th question

In the stage of understanding the problem on question 4, S1 could compose the question by writing what was known and asked correctly. Question number 4 on the item of known, S3 drew circle and create central angles as well as circumference angle. Then, she gave a symbol of letter to each angle point. Circumference angle ACB was 40° and the length of OB = 14 cm. S3 on the item of asked wanted to find out the area of segment AOB. In step 2 of making a plan of problem solving, S3 created a formula of the central angle of circle and circle area which was used to find segment area. S3 could create combination of three different formulas correctly. In step 3 of implement the plan, S3 did a calculation to find the central angle of circle at first. To clarify the answer, the calculation of central angle used the formula of \( \text{central angle} = 2 \times \text{circumference angle} \) rewrote by changing the description of circumference angle with \( \angle ACB \). After obtaining circle area, S3 found out the central angle of circle by creating the formula of central angle at first. After obtaining circle area, S3 found out segment area and then drawing the conclusion correctly.

4. The creative thinking process of S4

Subject S4 was not able to create a question on the second number, so that she did not do it. On the fourth question, on the first step, S4 was able to create a question by writing what he knew and was asked correctly. It is known that \( \angle ABC = 23° \) and \( \angle ABC = \text{circumference around} \). S4 also drew a circle with its central angle and circumference around and was asked \( \angle FOG \). In the second step, S4 made a concept that \( \angle DOE = \angle FOG \) and wrote the formula to find \( \angle DOE \) that was \( \angle DOE = 2 \times \angle ABC \). In the third step, S4 wrote the formula of \( \angle DOE = 2 \times \angle ABC \) and made its calculation correctly. Then, S4 wrote the formula to answer the questions she made that was \( \angle DOE = \angle FOG \) as well as the result was 46°. In the fourth step, S4 explained that \( \angle DOE \) and \( \angle FOG \) was an opposite angle and \( \angle DOE \) and \( \angle FOG \) had the similar values. S4 wrote that to find \( \angle FOG \), we have to know the angle \( \angle DOE \). Next, S4 calculated \( \angle DOE \) by using the formula she made and made the conclusion that was \( \angle DOE = 46° \).
5. The creative thinking process of S5
All of the questions were not able to be done by subject S5. The concept obtained from the school was not understood by him. Therefore, S5 was not able to apply it on the existing questions. Based on the interview with S5, subject S5 did not remember the formula. Thus, it can be said that S5 did not fulfill the three aspects of creative thinking.

6. The creative thinking process of S6

Subject S6 in creating questions of number 1A and 1B was not able to understand the problem existed. The concept mastery of S6 was not so good, in which in the step to understand the problem and make the solving plan, there was a mistake in applying the concept and its formula. Therefore, it influenced the process of applying the plan (answering the questions). We can see on the question of number 1A of the step to understand the problem, S6 wrote 125 m and on the kite figure, the number of 125 m was put in the sides. The number of 125 m was actually the diagonal kite.

When being interviewed, subject S6 gave the formula description above was the rectangular area, S6 wrote the rectangular area was $\text{Rectangular} = p \times l \times t$. S6 only remembered what was known based on his background knowledge. The basic mistake was the concept mastery that was not so good, did not understand the math formula. Thus, it can be said that S6 did not fulfill the three aspects of creative thinking.
thinking. Hereunder are the results of students’ creative thinking processes based on mathematical abilities can be seen there Table 3.

| Mathematical Ability | Code of Research Subject | Aspect of Creative Thinking | Category          |
|----------------------|--------------------------|----------------------------|-------------------|
|                      |                          | Fluency | Flexibility | Novelty |                      |
| High                 | S1                       | √       | √           | √       | Very Creative       |
|                      | S2                       | √       | -           | √       | Creative            |
| Medium               | S3                       | √       | √           | √       | Very Creative       |
|                      | S4                       | -       | √           | √       | Creative            |
|                      |                          |          |            |          | Enough              |
| Low                  | S5                       | -       | -           | -       | Not Creative        |
|                      | S6                       | -       | -           | -       | Not Creative        |

4. Conclusion and recommendation

The conclusion based on the results of the process of creative thinking and interviews with subjects with different mathematical abilities demonstrate that the research subjects are classified at medium and low creative thinking skills. The results of creative thinking processes are also different. High-level mathematics undergraduate, S1, has the ability to think very creatively, and high-level mathematics ability, S2, has the ability to think creatively. S3 with moderate mathematical abilities masters very creative thinking skills and moderate mathematical abilities. The undergraduate student has the ability to think quite creatively. The low mathematical ability, S5, possesses the ability to think creatively at not creative level and has low mathematical ability. S6 does not master creative thinking skills. The study has also found that students with high abilities have the same creative thinking skills. Likewise, the same thing applies to students who have moderate math skills. However, students with low creative thinking abilities have the same level of creative thinking, which is at not creative category. Demonstrating that not all students with high levels of mathematical ability have very creative thinking skills and not all students who are at middle and low level mathematical abilities have creative thinking skills. Fallacies in the mastery of concepts and application of mathematical formulas can influence students in solving problems in mathematics [28].

Stating that inaccurate understanding of a concept will result in a misunderstanding of the following concepts [29]. This study suggests that the students often read and work on PISA exercises concerned with space & shape content. This will result in better mastery of concepts and the ability to apply formulas. This will make it easier for students to make questions and solve problems. Suggestions from the result of this research that can be described by researcher are (1) To the next researcher, it is suggested to find literature as much as possible to strengthen the theory, (2) Solidify creative thinking level in problem solving of mathematical problems indicators in order to be able to analyze the level of creative thinking in problem solving better.

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