The creative thinking process of junior high school students in solving mathematical problems

D Rupalestari¹, D Juandi¹, and A Jupri¹
¹Mathematics Education Department, Universitas Pendidikan Indonesia, Jl. Dr. Setia Budhi No. 229, Bandung 40154, Indonesia
*destyrupalestari@upi.edu

Abstract. This study aims to describe students’ creative thinking process in solving mathematical problem. This study used descriptive qualitative method. The data were collected by using written test and interview. The test used six creative thinking questions that each two of them covered one of four indicators of mathematical creative thinking. The research subjects were five 8th grade students who have prior knowledge above the Minimum Mastery Criterion value taken from two research classes. The result shows that students can understand all the questions that indicate fluency, flexibility, and originality by read the questions repeatedly, write important information of questions on another paper, redraw, and imagine the problems situations in daily life. Students can give ideas well on fluency and originality questions by recall and carry out the knowledge but some students don’t provide different solution on flexibility questions. Students do the illumination process well by show the ability to count and carry out well-generated ideas. Students can solve the problem by using the trial and error method in any situation. Furthermore, the verification process is carried out by do a recalculation, read the question to adjust the purpose of the problem, and use other strategies to have the same answer.

1. Introduction
Preparing individuals who have creativity is important because if a person has the ability to think creatively, then they can solve their complex problems in real life with various ways [1],[2]. The demand for educational institutions today is to prepare graduates to develop their creativity (the product of creative thinking) to become more prominent. The current educational institutions also emphasize students to master various thinking skills such as critical thinking, creative thinking, and problem solving skills [3],[4]. This is in line with the objectives of 2013 curriculum in Indonesia that requires students to have 4C skills, namely creative thinking, critical thinking, communication, collaboration.

Creative thinking has two main approaches, namely process and product [5]. Creative thinking from product or outcome view is students’ solutions in emphasizing aspects of fluency, flexibility, originality and elaboration in solving problems [2], [5]–[7]. Creative thinking from the viewpoint of the process is the student's response in solving a problem using the appropriate method.

The process of creative thinking is different for each person. Creative thinking processes include preparation, incubation, illumination, and verification [8]–[11]. In the process of creative thinking, the preparation stage occurs when students are confronted with a problem then tries to understand the problem presented through an activity gathering data or information related to the problem. The incubation stage occurs when students do mental activities that are not realized may occur. Students do activity to think of various ways in order to solve the problem. Then the illumination stage is the stage
where students find a problem solving. While the verification stage is an activity where students re-examine the resolution of problems that have been obtained which requires students' critical thinking. At this stage, students are reviewing their creative ideas obtained. The review is examining the creative ideas that are produced turn into convergent thoughts so that the best creative thinking ideas appear rationally.

Many studies that examine the ability to think creatively. Research conducted by [12] who examined the creative thinking processes of students who participated in creative problem solving learning explained that the students' creative thinking processes qualitatively viewed from the level of their creative thinking on the material area of rectangles and triangles. Research conducted by [13] on seventh grade junior high school students using a combination of the Wallas model and creative problem solving found that there were 18.18% of creative students, 68.18% of students were less creative and 13.64% of students were not creative in posing problems. The difference in students' creative thinking processes in each group is that students with less creative and non-creative groups tend to understand the instructions of information well (the preparation stage), students with non-creative groups need a relatively long time to come up with ideas (incubation stage), students at creative groups apply ideas with the correct solution, whereas students in the less creative groups apply ideas with wrong solutions (illumination stage), and students in the creative group improve their work by reworking the questions to the right, while students in the less creative groups improve by replacing answers, and the group of students is not creative in changing questions without trying to find a solution first (verification stage).

Meanwhile, another research is related to giving open questions. Research conducted by [12] about the high school students' mathematical creative thinking abilities through open ended learning on two linear equation system material results that open ended approach can improve students' mathematical creative thinking abilities. In addition, creative thinking process of gifted students shows the indicators of creative thinking that arise when gifted students solve open ended problems. They are indicators of fluency, flexibility, elaboration, and integration. Meanwhile, originality indicator have not yet emerged because the test results show the similarity of the completion patterns used by the two gifted students [12]. Based on this research, it can be concluded that by giving open problems students can demonstrate their creative thinking abilities.

According to [7], creative thinking is not only in posing mathematical problems, but also emphasizes mathematical problem solving. Therefore researchers interested to do a research about students' creative thinking processes in solving mathematical problems.

2. Methods
This research is descriptive qualitative research that aims to describe creative thinking process of public junior high school students. The research subjects were 8th grade students of one of public junior high school in Pangkalpinang. Techniques for collecting data are through test and interview. To know the creative thinking process of students, it used 4 stages which are preparation, incubation, illumination, and verification. The test used 6 creative thinking questions that each two of them covered one of four indicators of creative thinking. Test has been validated by using AnatesV4. Interview was used to know what process which is not seen by the test only such as the way students construct their cognitive abilities and determine the factors that influence students’ process of creative thinking in solving problem.

3. Result and Discussion
Based on the research results, it’s found several things that occur in the students’ process of creative thinking, namely the process of understanding the problem, incubation, illumination and verification. In addition, it was also found how students in constructing their cognitive abilities in each process of creative thinking. The result of this study is shown by Tabel 1.
### Table 1. Students creative thinking process

| Result type                  | Stages    | Description                                                                                                                                                                                                                                                                                                                                 |
|------------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| General                      | Preparation | Students can understand the problem well in building creative thinking skills indicators of fluency, flexibility and originality. Students are also able to identify important and unimportant information in the problem and make examples and not examples of answers for understanding the purpose of the problem. |
|                              | Incubation | Students can carry out the process of reflection to come up with the idea of completion in a variety of different ways for each student. However, students often have difficulty in obtaining several methods of solving problems with indicators of flexibility. |
|                              | Illumination | Students can communicate ideas well and clearly in writing and verbally without having difficulty in calculations for the ideas that have been generated.                                                                                                                                  |
|                              | Verification | Students can verify the results in various ways but some answers still have not produced the answers that meet the originality indicator.                                                                                                                                             |
| The process of constructing mathematical cognitive abilities | Preparation | Read questions repeatedly, write down or describe important information of the questions on another paper, imagine the situation of the problem with daily life.                                                                                                                      |
|                              | Incubation | Take time to think, redraw information about problems (pictures), remember the subject matter that has been learned in school and elsewhere such as mathematical concepts and principles related to the material, and change data into pictures or also mathematical models. |
|                              | Illumination | Perform a careful calculation according to the ideas generated, do trial and error.                                                                                                                                                                                              |
|                              | Verification | Check the truth of the answer by doing a recalculation, re-reading the questions (adjusting the purpose of the questions), using another strategy with the same answer.                                                                                                               |

In the preparation process, the five students did not write down the information that was known and asked on the questions on the answer sheets provided, but directly answered the questions according to the strategy the students chose which shown by picture on figure 1. After the interview, students can already understand the problem well on each indicator of creative thinking which seen from the results of interviews conducted by giving questions that sometimes trap students to answer with incorrect answers, but students can answer the question correctly. The data obtained at the preparation stage of the interview process is that students can understand the problem well but do not write down the information that is known and asked for on the answer sheet of the test but on another sheet of paper and the student's way of understanding the questions is to read the questions repeatedly. The following figure 1 shows the students' answers of question number 3.
The question of number 3:
Asti was assigned by his teacher to make at least 4 quadrilaterals from paper. Asti has to make a quadrilateral that has an area of $120 \text{ cm}^2$. Determine what quadrilaterals Asti can make and the required lengths of sides!

![Figure 1. Student's answers of question number 3](image)

Based on figure 1, besides it shown that student did not write down the information that was known and asked on the questions on the answer sheets provided, student also can not solve question by a formal strategy. The student answered the question correctly by doing trial and error and doing an algebraic strategy. These strategies are in line with [14] that found that more than half of research subjects used informal guess-and-check strategies in solving geometry problems.

The thinking process consists of 3 steps of formation, namely the formation of understanding, forming opinions and forming conclusions [15],[16]. Therefore, without forming good understanding one cannot form an appropriate conclusion. Based on [12], the way students construct cognitive abilities at the preparation stage are by formulating important information about questions and rereading questions can be categorized at a high mathematical ability level and used by students with very creative abilities. The purpose of reading is to establish the intent of the writer by using information available in the text and assisted with the knowledge and experience of previous readers [17],[18].

Next, the incubation process is carried out by students by providing problem solving arguments such as the stages of problem solving in the form of writing formulas used in solving problems. The incubation process is also carried out by drawing an object to present the information in the problem. Based on interview activities, the incubation process is carried out with contemplation to remember material related to the questions and experiences of students. This is in line with the students process of incubation stage that is students stop for a moment, trying to remember what has been learned to find a solution [18].

Based on the incubation process that students have been through, most students have difficulty in giving different ideas for completing the right solution. Meanwhile, according to [19], good problem solvers are those who use their experience to solve problems and provide varied solution strategies well. Students also only do a recall. Recall according to [20] and [21] is an activity carried out by remembering prior knowledge or experience by trying to imitate the methods that have been observed. Whereas one dimension of creative thinking is articulation, the process involves forming old and new knowledge, expanding current knowledge with the help of new knowledge, and building unusual relationships to produce authentic solutions with the help of imagination [22],[23]. If memories, perceptions, experiences, and associations contribute directly to creative imagination, creative thinking is increasingly developed [24].

The illumination process is done well by students for ideas that have been generated by students. The illumination process is carried out by carrying out the idea of completion and calculating until the end of the completion process. The calculation process is done well so that students solve the problem correctly even though the student answers do not meet the originality indicator. In the problem with fluency indicators, students use the trial and error method to solve the problem. According to [25], failure is a process of getting a better solution. This is in line with [26] where trial and error is one of the more efficient methods or strategies.
At the verification stage, students can already verify the mathematical solutions that have been produced until the students obtain the correct answer. Student activities to verify answers include recalculation, re-reading questions (adjusting the purpose of the questions) and answers, and using other strategies with the same answers. The following figure 2 shows the students' answers of question number 5 which shown the number of strategy student used.

The question of number 5:
On a weekend, Intan and her family visit a zoo. After walking around for 30 minutes, Intan saw an animal cage containing cows and an animal cage containing ducks. Intan looked at the legs and eyes of the animals and then counted them. The results obtained are as follows.

| Type of animal  | Number of eyes | Number of legs |
|-----------------|----------------|----------------|
| Duck (A) dan Cow (B) | 18             | 28             |

Based on this information, determine the number of each animal with 4 different settlement strategies!

![Figure 2. Student' answers of question number 5](image)

The activity to check the answer shows that students do not easily believe the answers that have been produced before they have been validated according to their own methods. The students' activities are not different from [12] which states that one way students construct their cognitive ability to check the truth is to do a calculation in another way. Likewise with the results of research from [27] which aims to see students' creative thinking processes seen in students' cognitive styles where the way students impulsive cognitive style in verifying answers is to recalculate answers and students' reflective cognitive style by re-reading and recalculating answers.

4. Conclusion
Students creative thinking process in this study are: 1) Students can understand all the questions that indicate fluency, flexibility, and originality well by reading the questions repeatedly, writing down important information in the questions on other papers, re-describing, and imagining events or situations in the problems in everyday life. 2) Students can provide ideas on problems with indicators of fluency and originality, and flexibility by remembering the knowledge students have but still have difficulty in giving different ideas for solving problems with flexibility indicators, 3) Students also carry out processes illumination where shown by the ability to count and carry out well-generated ideas. Students can solve problems with the trial and error method if there are obstacles to the process of completion, and 4) Students in verification stage verify the answer in different ways, namely doing recalculation, re-reading questions to adjust the purpose of the problem, and using other strategies with the same answer so students are confident of the answers given, but most students have not been able to provide final answers that meet the aspects of originality to the fullest.

5. References
[1] Maharani H R 2014 Creative Thinking in Mathematics: Are We Able To Solve Mathematical Problems in a Variety of Way? Int. Conf. Math. Sci. Educ. pp. 120–125.
[2] Pehkonen E and Helsinki 1997 The state-of-art in mathematical creativity ZDM - Int. J. Math. Educ. 29, 3 pp. 63–67.
[3] McGregor D 2007 Developing thinking; developing learning (UK: McGraw-Hill Education)
[4] Trilling B and Fadel C, 2010 21St Century Skills: Learning for Life in Our Times Choice Rev. Online 47, 10 pp. 47-5788–47–5788.
[5] Haylock D W 1987 Mathematical creativity in schoolchildren The Journal of Creative Behavior.
[6] Krutetskii V 1976 The psychology of mathematical abilities in schoolchildren (Chicago: The University of Chicago Press).
[7] Silver E A 1997 Kreativität fördern durch einen unterricht, der reichist and situationen des mathematischen problemlözens und aufgabenerfindens ZDM - Int. J. Math. Educ. 29, 3 pp. 75–80.
[8] Wallas G 1926 The art of thought (New York: Harcourt, Brace and Company).
[9] Siswono T Y E 2010 Leveling Students’ Creative Thinking in Solving and Posing Mathematical Problem. Indones. Mathematical Society Journal on Mathematics Education 1 1, pp.17-40.
[10] Runco M A and Chand I 1995 Cognition and creativity Educational psychology review 7 3 pp. 243-267.
[11] Sitorus J 2016 Students’ creative thinking process stages: Implementation of realistic mathematics education Thinking Skills and Creativity 22 pp.111-120.
[12] Lisdiani D 2019 Proses Berpikir Kreatif Matematis Siswa yang Mengikuti Model Pembelajaran Creative Problem Solving (Doctoral dissertation, Universitas Pendidikan Indonesia).
[13] Amalina I K, Amirudin M and Siswono T Y E 2019. Kemampuan Berpikir Kreatif Siswa dalam Mengajus Masalah Matematika Semi-Terstruktur. Jurnal Riset Pendidikan dan Inovasi Pembelajaran Matematika (JRPIPM) 2 1 pp. 40-49.
[14] Jupri A and Syaodih E 2017 Between formal and informal thinking: The use of algebra for solving geometry problems from the perspective of Van Hiele theory Jurnal Pengajaran MIPA 21 2 pp.108–113.
[15] Arvianto I R 2018 Proses Berpikir Kreatif Mahasiswa dalam Mengajukan Masalah Matematika Ditinjau dari Perbedaan Gender JIPM (Jurnal Ilmiah Pendidikan Matematika) 6 2, pp.99-108.
[16] Suryabrata S 1990 Psikologi Pendidikan (Jakarta: CV Rajawali)
[17] Yazdanpanah K 2007 The effect of background knowledge and reading comprehension test items on male and female performance The reading matrix 7 2.
[18] Sari A P, Ikhsan M and Saminan S 2017 Proses berpikir kreatif siswa dalam memecahkan masalah matematika berdasarkan model Wallas Beta: Jurnal Tadris Matematika 10 1 pp.18-32.
[19] Prastiti T D, Tresnaningshih S, Mairing J P, Surabaya J M and Surabaya J M 2018 Tingkat kemampuan berpikir kreatif matematis siswa siswa sman di surabaya adMathEdu 8 1.
[20] Lee H J 2005 Understanding and assessing preservice teachers’ reflective thinking Teaching and teacher education 21 6 pp.699-715.
[21] Leung D Y and Kember D 2003 The relationship between approaches to learning and reflection upon practice Educational psychology 23 1 pp.61–71.
[22] Rhodes M 1961 An analysis of creativity The Phi Delta Kappan 42 7 pp.305-310.
[23] Sternberg R J 2009 Academic intelligence is not enough WICS: An expended model for effective practice in school and later in life Innovations in Educational Psychology p.403.
[24] Holt E 2018 Acknowledging Creative Thinking Skills Educating for a Creative Future (UK: Erasmus and The Steiner Waldorf Schools Fellowship.
[25] Swanson H and Collins A 2018 How failure is productive in the creative process: Refining student explanations through theory-building discussion Thinking Skills and Creativity 30 pp.54-63.
[26] Syahlan 2017 Sepuluh Strategi Dalam Pemecahan Indones. Digit. J. Math. Educ. 4 6 pp. 358–369.
[27] Sari F 2019 Proses Berpikir Kreatif Matematis Siswa SMP ditinjau dari Gaya Kognitif: Studi Kasus pada Kelas VIII untuk Materi Teorema Pythagoras (Doctoral dissertation, Universitas Pendidikan Indonesia).