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Creative Thinking Process In Solving Mathematical Problems Geometry Topics In Terms Of Students' Spatial Abilities

Rizki Dwi Siswanto[1], Dadan Dasari[2], Agus Hendriyanto[3]

[1]Department of Mathematics Education
Faculty of Teacher Training and Pedagogy, Universitas Muhammadiyah Prof. Dr. HAMKA
Jakarta, Indonesia

[2]Faculty of Mathematics and Science Education
Universitas Pendidikan Indonesia
Bandung, Indonesia

[3]Department of Mathematics Education
Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia
Bandung, Indonesia

[1]rizkidwisiswanto@uhamka.ac.id
[2]dadan.dasari@upi.edu
[3]agushendriyantio@upi.edu

Abstract – Spatial abilities and creative thinking skills are interrelated. Therefore qualitative research with transcendental phenomenology design tries to analyze students' creative thinking processes in terms of their level of spatial ability. A total of 30 participants from a public junior high school in Jakarta were involved in this study, and from selected 11 subjects representing high, medium, and low levels of spatial ability. The data obtained are processed in a way that refers to the Miles & Huberman stage with triangulation techniques to achieve saturated data. It is concluded that only students with high levels of spatial ability have creative thinking skills. The entire creative thinking process carried out can be described well in this study. The thought processes are the introduction, incubation, illumination, and verification stages.

Keywords – creative thinking process; geometry; mathematical problems; spatial abilities

I. Introduction

The essential function of education is to form individuals who can be confident, curious, creative, innovative, and able to understand differences [1]. Creative thinking skills are part of High Thinking Order Skills (HOTS). Krulik et al. [2] state that creative thinking is the highest level of thinking in HOTS by producing new and original solutions. Individuals who can think creatively tend to build new ideas and come up with various original solutions [3]. There is a statistically significant association between creative thinking and student learning achievement and its implications for education as a whole [4].

Mathematics education in schools aims to develop students' reasoning so that students can become individuals who are trained in their way of thinking, consistent, active, creative, independent, and have problem-solving abilities, which are very useful in social life. The current approach in mathematics education promotes the teaching of creative thinking to develop a deep conceptual understanding of mathematics [5]. Some even argue that the essence of mathematics is creative thinking, not just arriving at the correct answer [6]. That is, the mathematics learning process that takes place in the classroom must be able to encourage the development of student's creative thinking skills. According to the perspective of Wallas's theory in his book "The Art of Thought", Wallas [7] developed a model of creativity in four stages, namely: preparation, incubation, illumination, and verification. The creative thought process in a person or student will be able to be characterized and seen from the results. People who are creative in thinking will be able to perceive things the same from a different point of view from the views of people in general.

Mathematical problem-solving research that discusses mathematical creativity has been carried out [8], and one of them is the ability to ask problems as a creative ability [9]. Thus, creativity is seen by assigning tasks in the submission of a problem. Mathematics is broadly divided into four fields: geometry, algebra, analysis, and statistics.

Geometry is an object that is always found in daily activities because almost all visual objects around us are part of geometry. This suggests that geometry is the most crucial part of life. Agustini, et al. [10] argue, "Learn about geometry not just learn about formula, but we can learn other subjects to solving problems of geometry". Logically, geometry is one of the branches of mathematics given since primary education. Jelatu, et al. [11] suggest that geometry is one of the essential fields taught from primary education to higher education in the Indonesian curriculum. Therefore, Ma et al. [12] argue, "Geometry is one of the most important topics in mathematics". According to Fajriah [13], geometry is part of the scientific branch of mathematics that examines shapes, positions, and spatial properties. Through geometry, students can train logical, systematic and creative thinking skills.

In studying geometry, it takes the ability to describe something in mind and transform it into a solid form, commonly called visualization. Every one can imagine an event well. Even by imagining, someone will be faster to understand the event. As stated by NCTM [14], one of the reasons for giving geometry in schools is that children can use visualization and spatial skills and geometric modelling to solve problems. In line with NCTM's opinion, the curriculum in Indonesia requires children to master the material of field geometry and space geometry which in it also requires spatial skills. According to Gardner [15], spatial ability includes the ability to reveal the space-visual world precisely, which includes the ability to recognize the shape of an object precisely, make changes to an object in its mind and recognize the change, imagine a thing or thing and pour it into a tangible form, reveal data in a graph with balance, relationships, colors, lines, shape, and space. Spatial abilities have their characteristics with other cognitive abilities. Characteristically, spatial abilities are divided into (1) spatial perception; (2) spatial visualization; (3) mental rotations; (4) spatial relations, and (5) spatial orientation. All these abilities need to be mastered to learn geometry. Therefore, spatial ability is crucial in studying mathematics, especially geometry materials.

This study aims to analyze the creative thinking process of students in terms of their level of spatial ability. This research must be carried out to identify student characteristics related to their creative thinking and spatial abilities. The results of this study can be used as a reference for educators to determine the appropriate learning model to improve students' creative thinking and spatial abilities.

II. Research Methodology

The research was conducted by referring to the standards set in qualitative research with an approach design in the form of transcendental phenomenology. Phenomenology as a qualitative method focuses on the human experience as a topic according to its frame of reference, namely concerning the meaning and how that meaning is obtained through experience. Furthermore, Husserl (in [16]) explained that in transcendental phenomenology, there are four conceptual components, namely intentionality, noema and noesis, intuition, and intersubjectivity.

The researcher always acts as a critical instrument in the entire series of research processes, from data collection to conclusion. Meanwhile, other auxiliary instruments, such as interview guidelines, observation sheets, and test questions, have been tested for credibility through expert validation. Data collection techniques used include observation (think aloud) and interviews. The test questions tested include spatial ability test questions and creative thinking test questions. Researchers use triangulation techniques to achieve saturated data, namely source and method triangulation. Researchers not only compare data obtained from interviews and observations but also compare data from each research subject.

The study subjects were selected from 30 participants at one of the state junior high schools in Jakarta City. The selection of subjects is through snowball sampling after the category of each level of spatial ability is known. Categorization of spatial abilities refers to the Norm Reference Assessment (NRA), which is formed in three levels: high, medium, and low. The NRA compares learners' scores with relative standards or norms. Meanwhile, the data analysis technique used refers to the opinion expressed by Miles & Huberman [17], where the analysis consists of three streams of activities that coincide, namely: data reduction, data presentation, and concluding / verification.

III. Result and Discussion

The research started by giving all research participants spatial ability test questions. The spatial ability test results showed that most students had moderate spatial abilities (n=16). Meanwhile, the number of students with high and low spatial abilities is 9 and 5, respectively. Next, researchers took one by one participant from each category to see the critical thinking process in solving geometric problems in building flat-sided spaces. In the end, researchers needed 3 participants in the high category, 3 in the medium category, and 5 in the low category. The creative thinking skills test questions given to the research subjects have been adjusted to the indicators of creative thinking skills consisting of flexibility, fluency, elaboration, and originality. Flexibility is the ability to change the direction of one's thinking or change the point of view. Fluency in thinking is the ability to generate many ideas from one's thinking quickly. Elaboration is the ability to develop ideas and add or detail the details of an object, idea or situation so that it becomes more interesting. Originality is creating a unique idea or sparking an original one.

The questions given (Figure 1) can be used to measure each of these indicators so that it can be seen how the student's creative thinking process occurs when solving the problem. Next, a description of the conclusions of each category in the creative thinking process will be displayed, which includes four stages: preparation, incubation, illumination, and verification.

On one occasion, you were asked to do several experiments to create a cube skeleton from a wire. If in each experiment, a wire with a length of 120 cm is given, determine how many times the experiment you will do and how many cubes you can form in each experiment if the experiment must meet both of the following conditions.

1. The length of the ribs of the cube should not be less than 2 cm
2. The volume of the cube in each experiment must be the same

Fig. 1. Display of creative thinking test questions

3.1. Findings

- Students with High Spatial Ability

Technically, the third subject in this category can be seen as meeting all four indicators of creative thinking in this case. He not only gives answers about how many cubes there are in each experiment but also can solve problems uniquely and see every detail of the problems that arise. On his answer sheet, he wrote down the number of experiments and the number of cubes in each experiment (see Figure 2). When asked to explain what he wrote (Figure 2), he was able to explain that the number of cubes in each experiment can be searched by dividing the length of the wire (120 cm) by the number of ribs of the cube (n=12) and its multiples (24, 36, 48 and 60). Then when deepened, why only up to 60 and not be passed on with the next multiple? "Because there is a requirement that the length of the ribs should not be less than 2 cm, and the whole cube should be the same", he explained.

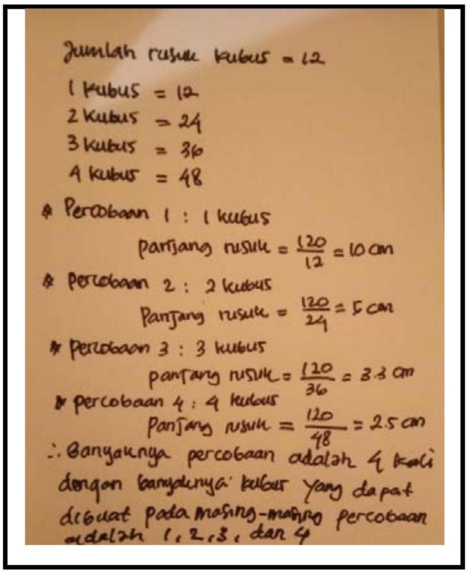

Fig. 2. Visual answers to one of the subjects with high spatial ability

From the whole set (observations and interviews) on this subject, the creative thought process can be described as follows. In the preparatory stage, the subject seeks to collect information or data to solve the problem by reading the questions several times and marking the crucial questions. Then he tried to think of an alternative solution to the problem by drawing a cube and calculating the number of cube ribs to ensure that the number of ribs was 12 as he had previous knowledge. The incubation stage was shown in a short time after he wrote down a conclusion about the number of ribs of the cube and then passed on at the illumination stage by writing down multiples of 12. Finally, the verification stage is shown by matching findings with written conditions until concluding.

- Students with Moderate Spatial Ability

The conclusion of the subjects of this level can be described as that of them can be seen only two of the four indicators appear how subjects in this category answer by multiplying integers more than 2, i.e. 3, 4, and 5, by the number of ribs (n=12) so that the conclusion obtained is an experiment of 3 times with the number of cubes 3 and 2. "When the length of the ribs is 4 or 5, the number of cubes that can be made is only 2. If the rib length is 5 cm, the wire is used up without students, but when the rib length is 4 cm, it still leaves a wire 24 cm long". From this description, it is known that the subject understands the problem but how to solve it only by formal means. Based on this, the indicators that appear are only elaboration and originality.

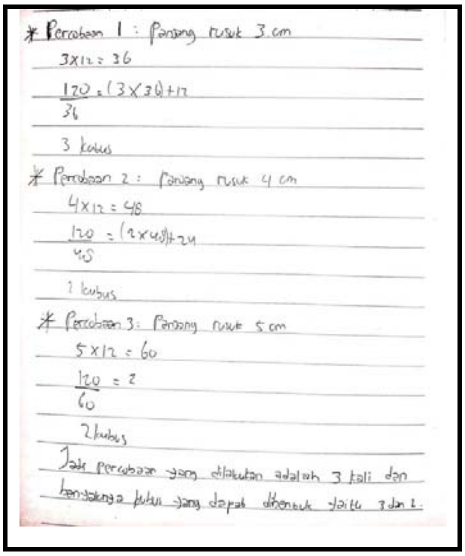

Fig. 3. The visual answer of one of the subjects with moderate spatial ability

The results of observations and interviews can be explained the creative thinking process that occurs in this subject, namely: 1) the preliminary stage, to understand the problem, begins with reading the whole question and then repeating the important parts several times before they copy it in a note paper. The essential parts are the length of the wire, the core of the question, and the two conditions; 2) incubation, in some time (±30 seconds) after understanding the problem of being able to execute the computation; 3) illumination, embodied in an activity of counting at each predetermined rib length; and 4) verification, repeatedly verifying the suitability between inferences, computations, and questions.

- Students with Low Spatial Ability

Classically subjects at low spatial levels write down information in the "known and asked" section (Figure 4). They cannot accept that one cube is one of the forms that can be created. This they concluded based on the second condition, "all cubes must be the same size," the answer of one of the subjects at the interview. This condition indicates that students experience learning obstacles in the form of epistemological obstacles. Then the answer is shown only about how many cubes are in each experiment (Figure 3). When confirmed, why is the rib length only 2 and 5? "Because 10 can only be divided by 2 and 5 only," explains one of the subjects. From this, it is also known that the inscription "2 rib lengths and 5 rib lengths" in question is the length of the ribs that can be made, namely 2 cm and 5 cm, so that the cubes that can be formed are only 5 cubes and 2 cubes in each experiment. From his writing style, it is indicated that the subject also has ontogenic obstacles. In addition, the answer given ignores condition 1.

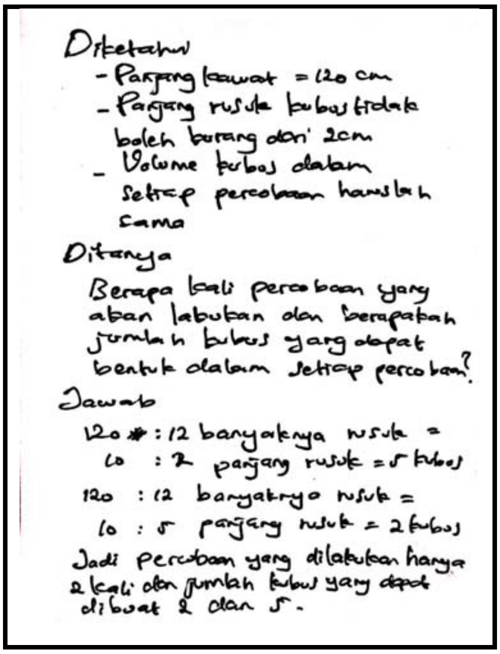

Fig. 4. The visual answer of one of the subjects with low spatial ability

From the whole set (observations and interviews) on this subject, the creative thought process can be described as follows. In the preparatory stage, the subject tries to collect information or data to solve the problem by writing down all the information they found when they first read the problem. The incubation stage occurs for quite a long time. The pause between the post-writing of information and the beginning of writing the computation occurs for 5 minutes. At the illumination stage, the activity carried out is to write down the length of the rib cube, which may be 2 or 5. The verification stage is carried out only on the computations, no longer caring about the essential components in the questions they pass.

3.2. Discussion

The above findings conclude that only students with high spatial abilities have creative thinking skills. As explained by Cotton [18], a person will have creative thinking if he meets 4 characteristics: fluency, flexibility, originality and elaboration. This follows the definition of creative thinking skills proposed by Munandar, where creative thinking skills are abilities based on available data or information to find many possible answers to a problem, where the emphasis is on the quantity, appropriateness, and diversity of answers [19]. This understanding shows that a person's creative thinking ability increases if he can show many possible solutions to a problem. Of course, all those answers have to fit the problem. So, not only does the number of answers that can be given determine a person's creative thinking ability but the quality or quality of the answers. In addition, the answer should vary. So, a person or student can be said to have creative thinking skills if they meet all the existing indicators.

Related to spatial ability, students with high spatial ability tend to easily adapt to new information, quickly respond to the task given, and dare to try. Meanwhile, students with low spatial abilities affect their ability to solve a problem according to the scope of their talent field, especially regarding speed. Students with low spatial ability will take longer to learn visual geometry than those with high spatial ability. This is in line with Adrian and Munadi's [20] research, which concluded that students with high spatial abilities tend to work independently, learn and respond with intrinsic motivation. While students with low spatial abilities need guidance during the learning process, examples or procedures that the lecturer has submitted are beneficial guidelines when doing exercises in designing a geometric construction design. The results of research by Siswanto [21]and Wahyuni [21] also stated that there is an association between spatial ability with students' mathematical creative thinking ability, meaning that the better the spatial ability that students have, the more students will tend to be able to think creatively in solving mathematical problems.

IV. Conclusion

Spatial ability has a connection to students' creative thinking skills. Those with high spatial abilities can quickly bring out their creative thinking skills when facing a problem. In this study, it has been shown that students with high spatial abilities can show their creative thinking ability by fulfilling the four indicators tested. The creative thinking process includes preparation, incubation, illumination, and verification.

Students collect as much related data as possible about the problem during the preparatory stage. The data is then processed analogically to respond to questions during the onboarding stage. At this stage, the student trains his mind to identify solutions by examining the relationship between the main problem, related problems, and available data. Then when the problem-solving process reaches the incubation stage and experiences an obstacle, students let their minds relax for a while. Nonetheless, their subconscious minds will continue to work automatically in search of improvement. The information that the mind receives incredibly affects the ongoing incubation process. The more details, the more material will have to be worked on during incubation—the process of unconsciously contemplating problems while performing other tasks. The incubation period that occurs in students with high spatial abilities is concise, and the inspiration obtained by students shows the end of this incubation period. This is the so-called illumination stage. The final stage is verification, where they test and critically assess the solution to the proposed problem.

References

[1] E. Ersoy and N. Başer, “The Effects of Problem-based Learning Method in Higher Education on Creative Thinking,” *Procedia - Soc. Behav. Sci.*, vol. 116, pp. 3494–3498, 2014, doi: 10.1016/j.sbspro.2014.01.790.

[2] S. Krulik, J. A. Rudnick, and E. Milou, *Teaching Mathematics in Middle School: A Practical Guide*. Allyn and Bacon, 2003.

[3] S. M. Ritter and N. Mostert, “Enhancement of Creative Thinking Skills Using a Cognitive-Based Creativity Training,” *J. Cogn. Enhanc.*, vol. 1, no. 3, pp. 243–253, 2017, doi: 10.1007/s41465-016-0002-3.

[4] M. N. Anwar and M. Aness, “An Examination of The Relationship Between Creative Thinking and Academic Achievements of Secondary School Students,” *Int. Interdiscip. J. Educ.*, vol. 1, no. 219, pp. 1–4, 2012.

[5] E. Aizikovitsh-Udi and M. Amit, “Developing the Skills of Critical and Creative Thinking by Probability Teaching,” *Procedia - Soc. Behav. Sci.*, vol. 15, pp. 1087–1091, 2011, doi: 10.1016/j.sbspro.2011.03.243.

[6] T. Dreyfus and T. Eisenberg, “On Different Facets of Mathematical Thinking,” in *The nature of mathematical thinking*, Routledge, 2012, pp. 269–300.

[7] G. Wallas, *The Art of Thought*, vol. 10. Harcourt, Brace, 1926.

[8] E. A. Silver, “Fostering Creativity Through Instruction Rich in Mathematical Problem Solving and Problem Posing,” *ZDM*, vol. 29, no. 3, pp. 75–80, 1997, doi: 10.1007/s11858-997-0003-x.

[9] D. S. Balka, “Using Research in Teaching: Creative Ability in Mathematics,” *Arith. Teach.*, vol. 21, no. 7, pp. 633–636, 1974.

[10] R. Y. Agustini, D. Suryadi, and A. Jupri, “Construction of Open-Ended Problems for Assessing Elementary Student Mathematical Connection Ability on Plane Geometry,” *J. Phys. Conf. Ser.*, vol. 895, no. 1, 2017, doi: 10.1088/1742-6596/895/1/012148.

[11] S. Jelatu, Sariyasa, and I. Made Ardana, “Effect of GeoGebra-aided REACT Strategy on Understanding of Geometry Concepts,” *Int. J. Instr.*, vol. 11, no. 4, pp. 325–336, 2018, doi: 10.12973/iji.2018.11421a.

[12] H. L. Ma, D. C. Lee, S. H. Lin, and D. B. Wu, “A Study of Van Hiele of Geometric Thinking among 1st through 6th Graders,” *Eurasia J. Math. Sci. Technol. Educ.*, vol. 11, no. 5, pp. 1181–1196, 2015, doi: 10.12973/eurasia.2015.1412a.

[13] N. Fajriah, “Kriteria Berpikir Geometris Siswa SMP dalam Menyelesaikan Masalah Geometri,” *Math Didact. J. Pendidik. Mat.*, vol. 1, no. 2, pp. 110–115, 2015, doi: 10.33654/math.v1i2.11.

[14] R. D. Siswanto, “Asosiasi Antara Kemampuan Geometri Spasial Dengan Kemampuan Berpikir Kreatif Matematis Siswa,” *Kalamatika J. Pendidik. Mat.*, vol. 1, no. 2, pp. 141–146, 2016.

[15] R. D. Siswanto and Y. S. Kusumah, “Peningkatan Kemampuan Geometri Spasial Siswa SMP Melalui Pembelajaran Inkuiri Terbimbing Berbantuan GeoGebra,” *Jppm*, vol. Vol.10, No, no. 1, p. hlm. 42-51, 2017.

[16] D. Suryadi, *Landasan filosofis penelitian desain didaktis (DDR)*. Bandung: Pusat Pengembangan DDR Indonesia, 2019.

[17] M. Huberman and M. B. Miles, *The Qualitative Researcher’s Companion*. SAGE, 2002.

[18] K. Cotton, *Teaching Thinking Skills*. Northwest Regional Educational Laboratory, School Improvement Program, 1991.

[19] U. Munandar, *Pengembangan Kreativitas Anak Berbakat*. Jakarta: Rineka Cipta, 2009.

[20] A. Ardian and S. Munadi, “Pengaruh Strategi Pembelajaran Student-Centered Learning dan Kemampuan Spasial terhadap Kreativitas Mahasiswa,” *J. Pendidik. Teknol. dan Kejuru.*, vol. 22, no. 4, p. 454, 2016, doi: 10.21831/jptk.v22i4.7843.

[21] A. Wahyuni and D. W. Hidayati, “Pengaruh Kemampuan Berfikir Kreatif Berbasis ICT Terhadap Kemampuan Spasial Mahasiswa,” *J. Inf. J. Penelit. dan Pengabdi. Masy.*, vol. 6, no. 1, pp. 6–9, 2020, doi: 10.46808/informa.v6i1.165.