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ANALYSIS OF UNDERGRADUATE STUDENTS' CREATIVE MATHEMATICAL THINKING ABILITIES

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Abstract: This research aimed to analyze undergraduate students' mathematical creative thinking abilities (MCTA). This study employs a qualitative descriptive method, with the research subjects being Mathematics Education Study Program students. Tests and interviews were the instruments used for mathematical creative thinking ability. The results of the research show that students' mathematical creative thinking abilities vary, as many as 20% are in the low category (CCTA < 33%), 60% are in the medium category (CCTA between 33% and 67%) and 20% are in the high category (CCTA > 67 %). Understanding mathematical concepts, learning experiences, and motivation all have an impact on students creative mathematical thinking skills. It is hoped that the results of this research can be considered when designing learning that can develop students' mathematical creative thinking abilities.

Keywords: analyze, mathematical creative thinking abilities, undergraduate students'

INTRODUCTION

The ability to think creatively is one of the essential skills for learning mathematics in the 21st century. Creative thinking involves the ability to generate new ideas, see problems from different perspectives, and find innovative solutions (Siswono, 2018). In higher education, mathematical creative thinking becomes critical for students to face the increasingly complex and dynamic challenges of the future.

In both national and international literature, the importance of mathematical creative thinking has been widely acknowledged. According to Nadjafikhah & Yaftian (2013) mathematical creativity allows individuals to generate original ideas, see new relationships, and generate unconventional solutions. This ability is the key to dealing with unusual issues that require innovative approaches. In an age of globalization full of uncertainty, the ability to think mathematically and creatively becomes an essential capital for students to adapt and innovate in the face of change. Guilford (1967) emphasized that creative thinking is the ability to see a variety of possible solutions to a problem, which is a divergent form of thinking. Torrance (1974) defines creative thinking as the process of perceiving difficulties, problems, or gaps in information; making assumptions and formulating hypotheses; testing and altering hypotheses; and communicating results. This definition

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emphasizes the aspects of fluency, flexibility, originality, and elaboration in creative thinking.

Silver (1997) proposes three main components of mathematical creative thinking: fluency, flexibility, and novelty. (novelty). Flexibility is defined as the ability to generate many relevant ideas or solutions. Flexibility involves the ability to generate different ideas and see problems from different perspectives. Innovation is defined as the ability to generate original and unusual ideas. Sriraman (2017) argues that mathematical creative thinking involves the ability to formulate mathematical hypotheses, find patterns and relationships, develop new methods, and find unconventional solutions. According to Sriraman, mathematical creative thinking also involves an incubation process, i.e., a period of reflection and embedding of ideas before reaching insights or solutions. Leikin (2009) proposed three criteria for evaluating creativity in a mathematical context, namely novelty, flexibility, and flexibility. (fluency). Innovation refers to the originality of ideas or solutions; flexibility refers to the diversity of approaches or representations; and smoothness refers to the amount of idea or solution produced.

Based on the various opinions of the experts, it can be concluded that the ability to think mathematically creatively involves several key indicators, among others: 1. Fluency: the ability to produce many relevant ideas, solutions, or alternatives. 2. Flexibility: the capacity to generate different ideas, see problems from different points of view, and change approaches when necessary. 3. Novelty or originality: the capability to produce new, unusual, and unique ideas. 4. Elaboration: The ability to develop, add details, and enrich ideas or solutions. Empirical research has shown that creative mathematical thinking has a positive impact on learning achievements in mathematics. Nurmasari et al. (2014) found a significant correlation between the ability to think mathematically creatively and the student's mathematical learning achievement. Students with high mathematical creative thinking abilities tend to demonstrate a better understanding of concepts and are able to solve math problems more effectively. The findings underline the importance of developing mathematical creativity to support success in learning mathematics.

Research conducted by Hwang et. al. (2007) in Taiwan shows that students tend to have difficulty generating original and varied ideas for solving mathematical problems. Similarly, a study conducted by Kandem & Gür (2007) in Turkey also found that students' levels of mathematical creative thinking were still low, especially in terms of flexibility and originality. Research conducted by Sriraman (2017) revealed that mathematical creative thinking involves the ability to formulate math hypotheses, find patterns and relati onships, develop new methods, and find unconventional solutions. Meanwhile, (Haavold, 2018) highlights the importance of flexibility in mathematical creative thinking, i.e., the ability to change approaches or strategies when facing a deadlock.

Despite this, developing mathematical creative thinking skills in students still faces many challenges. According to research conducted by Anwar et. al. (2016), students' mathematical creative thinking ability is still not optimal. Students are often trapped in rigid thinking patterns and restricted to the procedures they have been taught. They have difficulty generating original ideas and seeing problems from different perspectives. This condition can be caused by various factors, such as a lack of in-depth understanding of mathematical concepts, learning still dominated by a

teacher-centered approach, and limited opportunities for students to explore and find varied solutions.

According to the literature study, the ability to think mathematically is an important aspect that students must develop. A comprehensive analysis of students' mathematical creative thinking abilities can provide valuable information for educators in designing effective learning. With a deep understanding of student's level of mathematics creative thinking ability, the factors that influence it, as well as appropriate learning strategies, it is expected to create an enabling learning environment to optimize students' creative potential in math.

In recent years, research into students' mathematical creative thinking ability has grown. Research conducted by (Firdausi et al., 2018) revealed that students' ability to think mathematically creatively can be enhanced through problem-centric learning and encouraging exploration. Similarly, Sari et al. (2018) found that project-based learning can enhance students' abilities of mathematical creative thinking, especially in terms of versatility and authenticity.

Given the importance of mathematical creative thinking and the challenges faced in its development, a comprehensive effort was needed to analyze and enhance such skills in students. The study aims to conduct an in-depth analysis of students' ability to think mathematically and creatively. The results of the research are expected to contribute to the development of the theory and practice of learning mathematics in colleges that focus on improving the ability to think mathematically creatively. The findings of this research can also serve as the foundation for advanced research that investigates innovative strategies to maximize students' creative mathematical thinking potential.

In practice, this research can provide valuable input to college faculty and policymakers in designing curricula and learning that are more responsive to the need to develop mathematical creative thinking skills. As a result, students will be better prepared to face complex challenges in the future and contribute creatively in various aspects of life.

METHOD

This research employs qualitative descriptive methods to examine students' capacity for mathematical creativity (Creswell & Creswell, 2014). Qualitative research is chosen because it allows researchers to acquire a deep understanding of a phenomenon through exploration, description, and interpretation (Nassaji, 2015). The subject of the research was a student of the Mathematical Education Study Program at one of the universities in Indonesia. The subjects of this research consisted of 10 students, 3 of whom had low thinking abilities, 5 of them had medium thinking abilities, and 2 of them had high levels of thinking ability. Data collection was carried out through mathematical creative thinking skills tests and semi-structured interviews. Semi-structured interviews allow researchers to ask open and flexible questions while still having general guidance on topics to be explored (Galletta, 2013). The interview guide was developed based on indicators of mathematical creative thinking capabilities that covered smoothness, flexibility, novelty, and detail. The interviews are conducted individually, with a duration of approximately 30-45 minutes for each student.

The mathematical creative thinking test consists of four questions that measure the fluency, flexibility, novelty, and elaboration

aspects of mathematical creative thinking. These issues are adapted from instruments developed and validated by experts. The interviews were conducted to dig deeper into the students's mathematical creative thinking processes in solving these issues. The four mathematical questions, which measure the student's creative thinking ability in solving geometry problems, are derived from the indicators of creative thinking presented in Table 1.

Table 1 Indicators of Creative Thinking Ability

Number of Test	Indicators of Creative Thinking Ability	Aspecs of Creative Thinking Ability	Indicator of Test
1	Fluency	Students can provide many ideas, many answers, and many problem-solving solutions smoothly.	Determine the garden's area in the form of an equilateral triangle with a circular pond in the middle.
2	Flexibility	Students can generate a variety of ideas, answers, or questions and see a problem from different perspectives.	The bisector separates the garden into two sections of equal size. There are at least two ways.
3	Originality	Students are able to create new and unique expressions.	Describes an illustration of a garden where there is a path connecting three trees in each corner with a pond.
4	Elaboration	Students are able to enrich and develop an idea or product.	Determine the area of the garden that can be planted with flowers outside of ponds and paths.

For data on students' creative thinking abilities, use the following percentage formula (Putra et al., 2018):

$$Percentage = \frac{Score}{Maximum\ Score} \times 100\%$$

The categorization of high or low creative thinking abilities is based on table 2 below (Putra et al., 2018):

Table 2 Criteria for Creative Thinking Ability (CCTA)

Percentage (%)	Criteria
68 - 100	High
33 - 67	Medium
< 33	Low

The obtained data was qualitatively analyzed using thematic analysis techniques. Data analysis steps include data reduction, data presentation, and drawing conclusions. The results of the data analysis are presented as qualitative descriptions with

interview quotes to support the research findings. To maintain the validity and credibility of the research results, triangulation and member checking were carried out. Triangulation involves the use of multiple data sources (tests and interviews) and multiple perspectives (students and researchers) to check the consistency of findings (Merriam & Tisdell, 2016). Member checking involves asking students to review and provide feedback on the researcher's interpretation of the data obtained. The results of data analysis are presented in the form of rich and in-depth qualitative descriptions, accompanied by direct quotes from interviews to illustrate emerging themes (Creswell & Creswell, 2014). Research findings are also discussed in relation to relevant literature.

RESULTS AND DISCUSSIONS

The following are the results of the mathematical creative thinking ability scores of 10 students based on the formula for determining the percentage of creative thinking ability.

Table 3 Percentage of Mathematical Creative Thinking Ability (MCTA) Score Results

Number	Respondent	MCTA Percentage	MCTA Criteria
1	ANN	75%	High
2	AF	72%	High
3	ZN	65%	Medium
4	MN	63%	Medium
5	DFS	58%	Medium
6	WD	54%	Medium
7	AS	47%	Medium
8	CSA	42%	Medium
9	WS	32%	Low
10	FTR	25%	Low

The research results show that the level of students' mathematical creative thinking abilities varies. According to data analysis from the mathematical creative thinking ability test, as many as 20% of students are in the high category, 60% are in the medium category, and 20% are in the low category. These results indicate that the majority of students have sufficient creative mathematical thinking abilities but still need to be improved. This finding is in line with research conducted by Firdaus et al., (2018) who found that the level of students' mathematical creative thinking abilities was in the medium category.

Students with high mathematical creative thinking abilities perform exceptionally well in terms of fluency, flexibility, and novelty. They are able to produce many diverse and original ideas for solving mathematical problems. For example, in a problem that asks students to find various ways to calculate the area of a triangular garden outside the pool, students with high creative thinking abilities can provide more than three different methods, including the formula for the area of a triangle, the Pythagorean formula, and even other methods. Students with high creative thinking abilities can also employ unconventional methods, such as applying

the principle of proportionality. This is in accordance with research conducted by Sari et al. (2018) who found that students with high creative thinking abilities were able to produce many varied and original ideas for solving mathematical problems. One example of an answer to a question in the novelty category by students who have a high level of creative thinking ability can be shown in Figure 1 below.

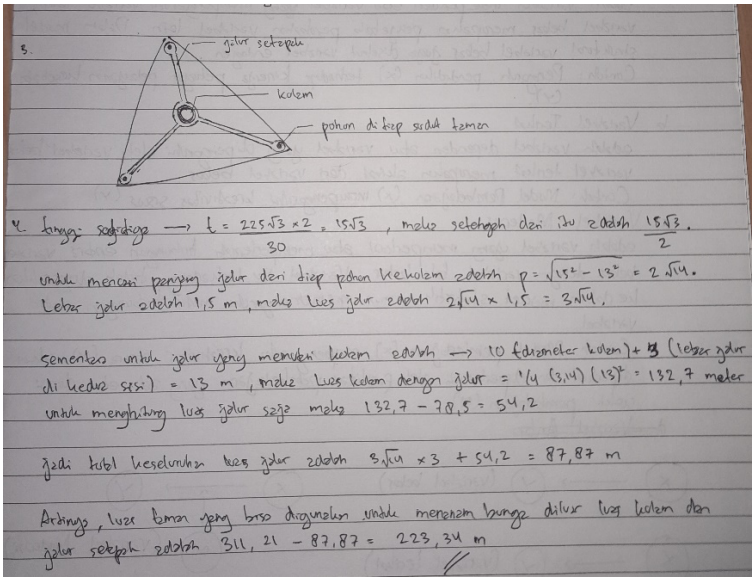

Figure 1 Results of The Subject's Work on Novelty Category

Apart from that, students with high creative mathematical thinking abilities also show flexibility in changing approaches or strategies when facing difficulties. They are not fixated on one way of solving problems but can adapt and look for other alternatives. This is seen when they face complex or unfamiliar problems, where they can modify or combine various techniques to find a solution. This finding is supported by research conducted by Faturohman & Afriansyah (2020), which revealed that students with high creative thinking abilities are more flexible in exploring various problem-solving strategies.

On the other hand, students with moderately creative mathematical thinking abilities tend to produce ideas that are quite diverse but less original. They can provide several different approaches or solutions, but most of them are still conventional or commonly used. For example, in questions that ask students to find alternative ways to prove a theorem, students with moderate creative thinking abilities can provide two or three proof methods, but most still follow the proof pattern that is often taught in lectures. This is in line with research findings conducted by Purwaningrum (2016), which show that students with moderate creative thinking abilities are able to produce several different, but less original, ideas.

However, students with moderate mathematical creative thinking abilities still show excellent divergent and convergent thinking abilities. They can explore several possible solutions and choose the most appropriate approach to solving the problem. However, their ability to develop and elaborate on these ideas is still limited. This finding is supported by research conducted by Supardi & Suhendri (2019), which found

that students with moderate creative thinking abilities were quite capable of divergent thinking but were lacking in idea elaboration.

Meanwhile, students with weak mathematical creative thinking abilities tend to struggle to generate diverse and original ideas. They are often fixated on one method of solving that has been taught, and they have difficulty seeing problems from different perspectives. When asked to provide alternative solutions, they tend to provide minor variations of the same method or even repeat similar answers. This finding is in accordance with research conducted by Machromah et al. (2015), which revealed that students with low creative thinking abilities have difficulty producing varied and original ideas.

Students with low mathematical creative thinking abilities also tend to be less flexible in dealing with new situations or unfamiliar problems. They often feel confused and don't know where to start when faced with problems that require a creative approach. As a result, they tend to give up more quickly or rely on instructions and guidance from lecturers. This is in line with research conducted by Nurhikmayati & Sunendar (2020), which found that students with low creative thinking abilities tend to be less flexible in dealing with non-routine mathematics problems.

The results of interviews with students provide deeper insight into the factors that influence their mathematical creative thinking abilities. Students with high creative thinking abilities generally have characteristics such as outstanding curiosity, the courage to take risks, and perseverance in facing challenges. They also tend to have a strong interest in mathematics, and they enjoy exploring mathematical concepts in depth. This finding is supported by research conducted by Arini & Asmila (2017), which revealed that internal factors such as motivation, interest, and self-confidence play an important role in developing creative mathematical thinking abilities.

Meanwhile, students with low creative thinking abilities often have negative perceptions of their mathematical abilities. They think that mathematics is a difficult and abstract subject, so they feel less confident in exploring and trying new approaches. Several students also revealed that they rarely had the opportunity to be involved in open-ended problem-solving activities that required creativity. This finding is supported by research conducted by Faturohman & Afriansyah (2020), which found that self-perception and learning experiences that are less supportive can hinder the development of mathematical creative thinking abilities.

These findings are in line with previous research, which emphasizes the importance of a learning environment that supports creativity. Research conducted by Apino & Retnawati (2017), shows that learning that is student-centered, provides autonomy, and encourages exploration can improve mathematical creative thinking abilities. In addition, exposure to open-ended problems, challenging assignments, and investigative projects can also stimulate students' creativity, as revealed in research conducted by Maharani et al. (2017).

The results of this research also show the need for a paradigm shift in mathematics learning in higher education. Instead of just focusing on mastering content, mathematics learning should place more emphasis on developing creative thinking abilities and problem-solving skills. Lecturers need to design learning activities that encourage students to think divergently, explore various approaches, and find innovative solutions, as suggested in research conducted by Suastika (2017).

This study's limitations include the relatively small sample size and being limited to one institution. Further research with a larger and more diverse sample can provide a more comprehensive picture of students' mathematical creative thinking abilities. In addition, this research only focuses on the cognitive aspects of mathematical creativity, so affective aspects such as creative disposition and other non-cognitive factors have not been explored in depth.

Nevertheless, this research provides an important contribution to the understanding of students' mathematical creative thinking abilities and the factors that influence them. These findings can be the basis for developing more effective learning strategies to improve mathematical creative thinking abilities in higher education. This way, students will be better prepared to face complex challenges in the future and become innovative problem solvers.

CONCLUSIONS

The results of the research show that students' mathematical creative thinking abilities vary, as many as 20% are in the low category (CCTA < 33%), 60% are in the medium category (CCTA between 33% and 67%) and 20% are in the high category (CCTA > 67 %). Students with high creative thinking abilities are able to produce many diverse and original ideas for solving mathematics problems. Meanwhile, students with medium abilities tend to be less original, and students with low abilities have difficulty generating diverse ideas. Understanding mathematical concepts, learning experiences, and motivation all have an impact on students creative mathematical thinking skills.

Comprehensive efforts are needed to develop students' mathematical creative thinking abilities, such as designing problem-centered learning, encouraging exploration, and providing opportunities for open-ended problem solving. Lecturers need to create a safe and supportive learning environment, provide constructive feedback, and appreciate students' creative efforts. Further research with larger subjects and exploring affective aspects is also needed. The development of these abilities needs to be integrated into the curriculum and mathematics learning in higher education so that students are ready to face complex challenges in the future.

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