Analysis of Student's Mathematical Creative Thinking Ability in Solving Open-Ended Problems in Terms of Cognitive Style

Nabilla Nur Amanah[1*)], Siti Inganah[2]
[1,2] Universitas Muhammadiyah Malang
*) nabillanuramanah@gmail.com

Abstract
The standards of education in the 21st century can think creatively. The ability to think creatively is an important aspect that must be developed and trained through problem-solving, one of which is open-ended. This study aimed to analyze students' creative thinking skills in solving open-ended problems in terms of their cognitive style. This descriptive qualitative study was conducted at SMP Muhammadiyah 1, Sumberpucung. The instruments used in this study were the GEFT to classify students with FI and FD cognitive styles, an essay test to measure students' mathematical creative thinking abilities, and an interview guide. The subjects of this study were students with FI and FD cognitive styles. Based on the GEFT test, it was found that out of 28 grade VIII students of SMP Muhammadiyah 1 Sumberpucung, 39.28% had the FI cognitive style, and 60.71% had the FD cognitive style. Four subjects with different cognitive styles were selected for interviews, and the results obtained were I1, I2, D1, and D2 at level 3 of the ability to think creatively, namely, creative. The four subjects met the indicators of fluency and flexibility but still lacked the originality indicator.
Keywords: Mathematical Creative Thinking Ability; Open Ended Problems; Cognitive Style; FI; FD

Introduction

The 21st century is a century of changing times marked by various advances in science and technology that have made life more complex and where ways of life are increasingly competitive. Therefore, it is necessary to increase human resources (HR), especially in the field of education, to strive for the development of a new civilization in an increasingly advanced order of life to be able to compete in a world without borders (Nuryani et al., 2019; Somantri, 2021). In the 21st century, students must have a high performance and deep mastery of learning materials to face complex challenges. Education standards in the 21st century can think creatively (Haryanti & Saputra, 2019). Every individual needs the ability to think creatively to deal with life's problems, and this ability is generally obtained in the world of education, the education we get valuable knowledge (Tambunan, 2016). The ability to think creatively is an important aspect that must be developed and trained by students and educators at the elementary, secondary, and tertiary levels (Prasetyo et al., 2021; Rasnawati et al., 2019).

Creative thinking is the most important aspect of learning mathematics because students' creative thinking skills can be applied to solving complex mathematical problems in life (Rohman et al., 2021). Thinking creatively is needed to solve current and future problems and find new solutions to make life more productive (Astuti et al., 2020). Mathematical creative thinking ability is finding solutions or expressing different ideas when solving mathematical problems (Triyani & Azhar, 2021). The Torrance Tests of Creative Thinking (TTCT) provide three separate verbal creativity assessments: fluency, flexibility, and originality (Torrance, 2018). One approach to learning mathematics involves students actively and creatively producing creative ideas through problem-solving (Hendriana & Fadhillah, 2019). Mathematical problem-solving can be presented in various formats, one of which is open-ended (Setiawan & Hariastuti, 2021).

Students' creative thinking ability can be measured by asking open-ended questions. Questions with multiple solutions, such as open-ended questions, can be used to measure creativity in mathematics (Yunadia et al., 2023). Open-ended problems refer to learning that presents problems using different ways of solving (flexibility) and various solutions (multiple answers) (Hasyim & Andreina, 2019). There are three open-ended aspects of learning mathematics: 1) a problem may have a solution, but it is possible to receive answers in various ways; 2) a problem may have several different solutions; and 3) from one problem to another or a development approach (Becker, 2006). In solving mathematical problems, everyone has different types and styles of creative thinking, where individual differences can be expressed in the form of cognitive types known as cognitive styles (Napfiah, 2018).

Cognitive style is an individual characteristic that reflects how to obtain, organize, and represent information to solve a problem (Mirlanda et al., 2019; Priyono, 2020). Psychologically, cognitive style is divided into two areas: field-independent (FI) cognitive style and field-dependent (FD) cognitive style (Tsurayya & Ningrum, 2021). Students with a field-dependent cognitive style (FD) have high problem-solving abilities and calculated thinking skills when solving mathematical problems. However, students with a field-independent (FI) cognitive style have weak problem-solving skills and can usually think analytically using conceptual thinking processes when solving mathematical problems (Hajar et al., 2018; Mawardi et al., 2020). The student’s cognitive style was measured using the Group Embedded Figure Test (GEFT) developed by Witkin (Witkin et al., 1977).

Much research has been conducted on students' creative mathematical thinking abilities. As has been done by (Rohman et al., 2021; Susilawati et al., 2020) examined

students' creative mathematical thinking abilities in solving mathematical problems in terms of self-concept. Analysis of students' mathematical creative thinking abilities through open-ended questions has been done by (Ramadhani & Nuryanis, 2017; Wahyuni & Palupi, 2022). Based on the description above, through open-ended problems, students' creative thinking abilities can be analyzed. FI and FD cognitive styles can influence differences in students' creative thinking abilities. In previous research, an analysis has been carried out related to creative thinking abilities through open ended questions in terms of self-concept. Therefore, this study analyzed the ability of students' creative thinking in solving open ended problems in terms of cognitive style.

Method

This research was a descriptive qualitative study, with the subjects being grade VIII students of SMP Muhammadiyah 1 Sumberpucung. Researcher conducted research directly to obtain maximum and accurate data. This research was conducted in three stages: preparation, research, data processing and conclusion. In the preparation stage, the researcher created essay test sheets in the form of open-ended problems that were validated beforehand, prepared GEFT test sheets, and prepared interview sheets that were validated beforehand.

The second stage is the implementation of research at SMP Muhammadiyah 1 Sumberpucung. In the first meeting, the researcher will give the GEFT to all students in the class in the first hour, and then they will be given an open-ended problem test in the second hour. The data obtained were analyzed after the two tests were conducted at the first meeting. At the second meeting, the researcher chose two students from all subjects who represented each cognitive style: one student with the FI cognitive style and one with the FD cognitive style. Selected students will be interviewed to verify the results of the tests that have been carried out previously and to bring up indicators of mathematical creative thinking that did not appear in the results of the open-ended problem tests.

The third stage involved the researcher processing the data obtained in the field. At the data processing stage, the researcher analyzed the results of the students' work on the GEFT and open-ended problem tests. Based on the GEFT test analysis results, researchers can divide students into two groups: students with a field-independent (FI) cognitive style and students with a field-dependent (FD) cognitive style. The grouping of the two cognitive styles was based on the percentage score obtained from the GEFT test results, where the

maximum score that students obtained was 18 points. If the student scored ≤ 11 on the GEFT test, the student was placed in the FD Cognitive Style category. Students who scored >11, these students were included in the FI cognitive style category (Ridwanah & Masriyah, 2021).

After the students were divided into two groups, they were given an open problem test that had been checked for validity through the instrument validation test. In the open problem test, students are asked to find the number of materials needed to make a model of a building space according to the type of material used. The results of students' work on the open problem test were analyzed based on indicators of mathematical creative thinking ability. The following table shows the indicators of students' creative mathematical thinking abilities in solving problems:

Table 1. Indicators of Mathematical Creative Thinking Ability

Aspect	Indicator
Fluency	Students can generate many ideas by using words.
Flexibility	Students can generate ideas, switch from one approach to another, or use various strategies.
Originality	Students can generate ideas far beyond the obvious, mundane, banal, or established.

Source:(Torrance, 2018)

Based on the indicators of students' mathematical creative thinking ability, the results of student work were analyzed using the rubric for assessing students' mathematical creative thinking ability as follows:

Table 2. Rubric for Assessment of Students' Mathematical Creative Thinking Ability

Aspect	Score	Student responses to questions or problems
Fluency	0	Do not answer or give ideas that are not relevant to the problem.
	1	Presents an idea that is irrelevant to problem-solving
	2	It gives a relevant idea, but the answer needs to be corrected.
	3	Provides more than one relevant idea, but the answer is wrong
	4	Provides more than one relevant idea, and the solution is correct and precise.
Flexibility	0	Not answering or providing an answer in one way or more but all wrong
	1	Answer only one way, the calculation process and the results are wrong.
	2	Give answers in one way; the calculation process and the results are correct.
	3	Give answers in more than one way (various), but the results are wrong because there is an error in the calculation process.
	4	Give more than one (various) answer; the calculation process and the results are correct.
Originality	0	Did not answer or gave the wrong answer
	1	Answers are in their way but can't be understood.
	2	Give answers in their way; the calculation process is directed but still needs to be finished.
	3	Give answers in their way, but there is an error in the calculation process, so the result is wrong.
	4	Give answers in their way, the calculation process, and the results are correct.

Source: Adopted from(Permata et al., 2022)

After the analysis, the scores obtained by the students were presented and divided into three categories of students' mathematical creative thinking abilities. The percentage values were calculated as follows:

$$Percentage = \frac{the\ total\ score\ obtain}{max\ score}\ x\ 100\% \quad (1)$$

The results of the percentage value of the test score for students' mathematical creative thinking abilities were categorized based on the following table:

Table 3. Category of Students' Mathematical Creative Thinking Ability

Percentage	Category
$x > 70\%$	High
$35\% < x < 70\%$	Medium
$x < 35\%$	Low

Based on the category of mathematical creative thinking abilities obtained through the results of open-ended problem tests, this will be confirmed again through interviews with representatives of subjects with different cognitive styles. The data obtained through tests and interviews will be analyzed more deeply so that conclusions can be drawn. The following is an interview guide that will be used.

Table 4. Interview Guidelines for Students' Mathematical Creative Thinking Ability

Aspect	Indicator
Fluency	Students' understanding of the problems given and the ideas students have in solving the problem plan.
Flexibility	Students' understanding of other alternatives in solving the problems given.
Originality	Students' understanding of the problems given and students' ability to find new alternatives according to the opinions of each student.

Through the results of the interviews, it is hoped that the researcher can identify indicators of students' mathematical creative thinking abilities that have yet to appear in the essay test. After obtaining the results of the interviews, the researcher analyzed the results of the essay tests combined with the interviews so that conclusions could be drawn regarding the level of student's creative thinking abilities. The ability to think creatively is divided into five levels: Level 1 (less creative), Level 2 (quite creative), Level 3 (creative), and Level 4 (very creative) (Siswono, 2008). The followings are the levels of mathematical creative thinking abilities and their characteristics:

Table 5. Levels of Mathematical Creative Thinking and Their Characteristics

Levels	Characteristics
Level 4 (Very creative)	Students can demonstrate Fluency, Flexibility, and Originality when solving and submitting problems.
Level 3 (Creative)	Students can demonstrate Fluency and Flexibility or Fluency and Originality when solving or submitting problems.
Level 2 (Pretty Creative)	Students can demonstrate Flexibility or Originality in solving or posing problems.
Level 1 (Less Creative)	Students can only demonstrate fluency in solving and posing problems.
Level 0 (Not Creative)	Students must demonstrate Fluency, Flexibility, and Originality in solving and submitting problems.

Source: Adapted from(Siswono, 2008).

Results and Discussion

Researchers have used the GEFT test instrument to measure the cognitive style of field-dependent (FD) and field-independent (FI) students. Based on the GEFT test, it was found that out of 28 grade VIII students of SMP Muhammadiyah 1 Sumberpucung, 39.28% had the FI cognitive style, and 60.71% had the FD cognitive style. Furthermore, all students were given a math essay test on geometrical material with two description questions. Essay tests were used to measure the students' creative thinking abilities. After grouping based on cognitive style and completing an essay test, four students were selected for the interview. The following subjects were selected.

Table 6. Interview Subject

No	Subject	Cognitive Style Criteria
1	I1	*Independent Fields*(FI)
2	I2	*Independent Fields*(FI)
3	D1	*Dependent fields*(FD)
4	D2	*Dependent fields*(FD)

Of the four selected subjects, two students were cognitive-style field-independent (FI), and two other cognitive-style students were field-dependent (FD)

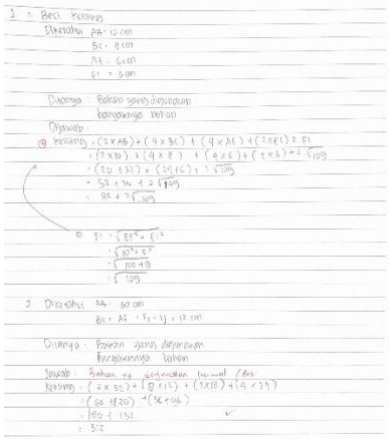
Based on the presentation of answers from the essay tests that have been given and subject interviews, the following results were obtained:

Table 7. Essay and Interview Test Results

subject	*Fluency*					*Flexibility*					*Originality*					Total Score	Percentage	Category
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4			
I1	-	-	-	-	√	-	-	√	-	-	-	-	-	-	√	20	83.33 %	High
	-	-	-	-	√	-	-	√	-	-	-	-	-	-	√			
I2	-	-	-	√	-	-	√	-	-	-	-	-	-	√	-	14	58.33 %	Medium
	-	-	-	√	-	-	√	-	-	-	-	-	-	√	-			
D1	-	-	-	-	√	-	-	√	-	-	-	-	-	-	√	17	70.83 %	High
	-	-	-	√	-	-	√	-	-	-	-	-	-	√	-			
D2	-	-	-	-	√	-	-	√	-	-	-	-	-	-	√	17	70.83 %	High
	-	-	-	√	-	-	√	-	-	-	-	-	-	√	-			

Information :
√ : score obtained

Table 6 shows the scores obtained by each subject, along with the categories of their creative thinking abilities. The score was obtained based on exposure to essay test answers and interview results. The creative thinking indicator consists of five scores, each with a different assessment category, according to what has been described in the research method. The table shows that participants had a cognitive style. Field-independent (FI) falls into a different category, namely I1, with a high-level category of creative thinking, and I2, with a medium-level category based on score acquisition. The I1 and I2 subjects have fluency abilities because they can provide multiple ideas relevant to solving open-ended problems. On the essay test answer sheets, I1 and I2 solved the problems using different methods. I1 solves both problems using the perimeter, whereas I2 solves problem 1 with the area and problem 2 with the perimeter.



Picture 1. I1 Answer Sheet

Picture 2. I2 Answer Sheet

The problem-solving process written by the subject with the FI cognitive style, as shown in Figures 1 and 2, is detailed. This is in line with the opinion of Wardani et al (2017) who stated that students with the FI cognitive style show an active attitude towards detailed

thinking to be able to solve the problems they face and find solutions. However, in the execution of I1, there needed to be an error in the writing sequence, namely, calculating the circumference and FI sections. However, the subject understood this and revealed in the interview that FI should have been calculated before calculating circumference. The final result of working on I1 for both problems was correct; thus, the score was 4. The I2 subject wrote down the answers in a detailed and sequential manner, but there were several things the subject missed, so the final result was wrong and received a score of 3. During the interviews, I1 and I2 explained the intent of the given open-ended problems and the ideas the subjects had in planning to solve these problems. Therefore, subjects with field-independence (FI) cognitive styles have the ability to be fluent in understanding the given problems and provide relevant solution ideas. This is in line with Syekhuddin et al (2022) who state that subjects with field-independence (FI) cognitive style can be fluent because the subject can understand the problem and convey many ideas for the correct and appropriate answers to solve the problem.

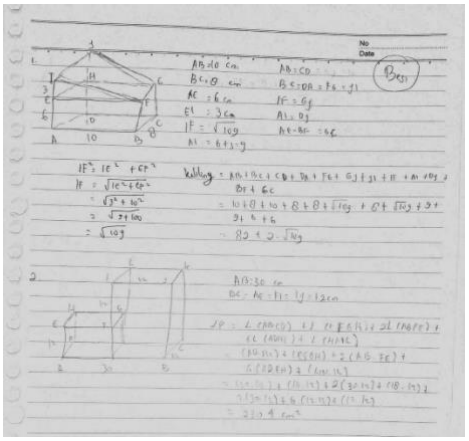
In the essay test answer sheet, the subject wrote down the solution in only one way for each number, and the answer from I1 got the correct result for both problems so that a score of 2 was obtained, while I2 got the wrong result so that a score of 1 was obtained. In the interview, the subject explained that solving open-ended problems could be done differently according to the materials used. The subject stated that if materials such as iron and wire were used, a method was used to calculate the circumference; if materials such as plywood and cardboard were used, a method was used to calculate the surface area of the shape. Thus, subjects with cognitive style Fields independent (FI) have flexibility because they can understand other alternatives and use various strategies to solve the given problems. This is in line with the statement of Syekhuddin et al. (2022), which states that flexibility subjects with the FI cognitive style are fulfilled because the subject can provide answers in different ways and mention various methods that can be used to solve problems as well as demonstrate knowledge of these methods.

I1 and I2 subjects wrote answers in their way according to their respective styles but were still based on geometric material. I1, in answering the problem, obtained the correct result so that a score of 4 was obtained, while I2 obtained the wrong answer so that a score of 3 was obtained. Even though the score obtained by the subject with the FI cognitive style was relatively high, the subject could not come up with ideas far beyond what was already evident. The subject still used ideas taught at school. This was revealed in the interview in

which the subject explained that he did not have his way other than the ways taught at school. Thus, the ability originality subject with cognitive style field-independence (FI) still needs to be improved. Based on the results of the I1 and I2 analyses, it can be concluded that the subjects had a cognitive style. Field-independent (FI) can think creatively mathematically at level 3, namely creative, because it can show indicators of fluency and flexibility.

The table shows that subjects with a cognitive style field-dependent (FD) fall into the same category, namely, D1 and D2, and fall into the category of high-level mathematical creative thinking skills based on the score. The D1 and D2 subjects have fluency abilities because they can provide multiple ideas relevant to solving open-ended problems. On the essay test answer sheets, I1 and I2 solve problems using the same method: solving problem 1 using the circumference and problem 2 using the area.

Picture 3. D1 Answer Sheet



Picture 4. D2 Answer Sheet

The problem-solving process written by the subject with the FD cognitive style, as shown in Figures 3 and 4, is a relatively detailed description. On the answer sheet, D1 uses the circuit method to solve problem 1 using the known edge length, but D1 substitutes the unknown FI value, so it is necessary to ask where the FI value is obtained. Regardless of the origin of the FI value, the results of the calculation of D1 for problem number 1 were correct, obtaining a score of 4. In answer number 2, D1 solves the problem in an area way. Still, the final result obtained is incorrect because D1 calculates the area of the lid shape, which should not be calculated to make the shape of the writing utensil, so a score of three is obtained. The subject can explain the problem ended given and the purpose of the problem, along with the ideas for solving the problem. Thus, subjects with cognitive style field-dependence (FD) have fluency because they understand the problems and can provide ideas in plans to solve them. This is in line with Syekhuddin et al. (2022), who stated that subjects with the FD

cognitive style tend to meet indicator fluency because they can write down and convey more than one idea of the correct answer according to the problem.

On the essay test answer sheet, the subject wrote down the solution in only one way for each number, and the answers from D1 and D2 received the correct result for problem 1, so they got a score of 2, while for problem number 2 they got the wrong result, so they got a score of 1. In the interview, the subject explained that solving open-ended problems could be done differently according to the materials used. Thus, subjects with field-dependence (FD) cognitive style have flexibility because they can understand other alternatives and use different strategies to solve the problems given. This is in line with the opinion of Napfiah (2018), who argued that subjects with the FD cognitive style could flexibly provide different answers or more than one for the settlement process.

The D1 and D2 subjects wrote their answers in their way according to their respective styles but were still based on geometric material. D1 and D2, in answering problem number 1, received the correct result, so they got a score of 4, whereas in answering problem number 2, they got the wrong answer, so they got a score of 3. Even though the score obtained by the subject with the FD cognitive style was relatively high, the subject needed help to come up with the correct idea, far beyond the obvious. The subject still used ideas taught at school. This is supported by the statement of Rosadi et al (2022), which explains that subject field-dependent (FD) tends to be able to apply existing structures and is better at solving questions whose examples are already in the book and have been explained by the teacher. In the interview, the subject explained that he could only solve the problem using methods taught at school. Thus, the ability of originality subjects with cognitive style field-dependence (FD) still needs to be improved. This is in line with the opinion of Syekhuddin et al. (2022), who stated that a subject with the FD cognitive style does not meet the indicators of originality because the subject still uses the same method as the previous one and does not try to use another method because he thinks that the method used is the easiest. Based on the analysis of D1 and D2, it can be concluded that the subjects had a cognitive style. Fields-dependent (FD) can think creatively mathematically at level 3, namely creative, because it can show indicator fluency and flexibility.

Students with FI and FD cognitive styles who are able to think creatively show a positive impact through the development of indicators of fluency and flexibility. Research shows that students with high fluency scores can produce more creative responses and are better at brainstorming, which is very important in problem solving scenarios (Fatmawati et

al., 2022; Meiarti et al., 2020). Flexibility can allow students to adapt their thinking strategies, leading to innovative solutions and better problem-solving skills (Meiarti et al., 2020). FI students often excel in generating many ideas independently, while FD students can collaborate well and produce creative solutions in a social context. Both have their own advantages that contribute to the overall creative thinking ability (Rukamana et al., 2020; Said et al., 2022).

Conclusions and Suggestions

Grade VIII students of SMP Muhammadiyah 1 Sumberpucung have significant differences in cognitive style; as many as 39.28% of students are cognitively style field-independent (FI), and 60.71% are cognitively style field-dependent (FD). Of the 28 students, the researcher chose two with different cognitive styles as research subjects to measure their creative thinking abilities through essay tests and interviews. Based on the results of essay tests and interviews, it was found that I1 and I2 subjects, who were subjects with the FI cognitive style, had level 3 creative thinking skills, namely creative. D1 and D2 subjects with the FD cognitive style also had Level 3 creative thinking skills, namely creative thinking skills. The four subjects demonstrated the fluorescence and flexibility of the indicator. Indicatorsoriginality needs to be improved. Based on the research results, students' creative thinking abilities must be improved again because their originality is still lacking, even if not seen.

This research is limited to analyzing students' creative thinking skills in solving open-ended problems in terms of cognitive style field-independent (FI) and field-dependent (FD); therefore, in future research, it is advisable to examine students' creative thinking abilities more deeply, and it is hoped that research can be carried out to improve students' creative thinking abilities, especially on indicator originality.

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