

Students' creative thinking skills in solving mathematical logic problem with open-ended approaches

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Abstract. Mathematical logic is one of the important mathematics lessons to improve reasoning in solving daily problems. Creativity is needed in solving mathematical logic problems. This research aimed to analyze students' creative thinking skills in solving mathematical logic problems. The approach used in this research is the open-ended approach. This research is a qualitative descriptive study. The subjects in this research were students at Mathematics Educations study program in Faculty Education and Teacher Training at State Islamic Institute of Jember. Data collected in this research are test results with open-ended question types, interview results, observation results, and documentation during the research activities. The data analysis technique used in this research is the Miles and Huberman analysis model. The result of data analysis showed that the levels of students creative thinking skills were classified as follows: 8.33% of the students categorized as "*Slightly creative*"; 30.56% of the students categorized as "*Moderately creative*"; 41.67% of the students categorized as "*creative*"; and 19.44% of the students categorized as "*very creative*". From these results it appears that most of student have the creative thinking skills. This means that the open-ended approach can be used as a reference in teaching and learning activities to increase the ability to think creatively.

1. Introduction

Learning is the activity of students in building meaning or understanding. Thus, teachers need to give encouragement to students to use their authority in developing ideas and skilled in thinking. Thinking skills must be maintained by students to answer the challenges of education in the current global era. The thinking skills consisted of 1) critical thinking skills and problem-solving; 2) collaboration skills; 3) communication skills; 4) creative and innovative thinking skills [1]. Therefore, learning designs are required to encourage and improve students' thinking skills. According to Hobri, learning that can improve students' creative thinking skills is by giving them open-ended problems [1].

According to the constructivists' viewpoint, learning aims are to build understanding. In this case, learning is not emphasized to gain a lot of knowledge but more importantly to provide information through students' schemata [2]. Based on constructivist philosophy, there are several approaches to learning, including 1) discovery, 2) problem-solving, 3) problem posing, 4) investigation, 5) open-ended approach, and 6) realistic approach [3]. In this study, the approach used is the open-ended approach.

An open-ended approach is an approach presenting a problem that has more than one method or correct solution [3]. This open-ended approach is not oriented towards the final result but rather prioritizes how students develop methods, ways, or approaches to each problem given to help them in improving their creative thinking. Creative thinking is one's ability to search for and find new or



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original ideas (originality or novelty) for the person concerned even though for others it is a familiar thing, flexibly and fluency, which is useful or able to be applied [4]. This is similar to Shimada [3] in determining the evaluation criteria of open-ended problem, namely 1) fluency defined as the ability to use several methods to find the solution; 2) flexibility is the ability to find different mathematical ideas, and 3) authenticity intended to measure the authenticity of students' ideas in presenting correct answers.

According to Markaban [3] mathematical logic can help improve students' reasoning abilities in solving problems. Besides improving students' reasoning abilities, this material can also be applied directly in real life and when studying other subjects. For the first-semester students of Mathematics Education Department, Mathematical logic is one of the essential materials as a tool to understand the subsequent course, especially in proving each theorem or the properties in the next mathematics subject. Accordingly, researchers chose mathematical logic to find out the creative thinking abilities of students in the Mathematics Educations study program in Faculty Education and Teacher Training at State Islamic Institute of Jember.

Some prior studies supporting this study include 1) Widiartana [5] stated that learning mathematics with an open-ended approach had a positive influence on students' logical thinking abilities; 2) Titikkusumawati et al. [6] claimed that learning mathematics through a semi-structured problem posing with open-ended problem design can improve students' creative thinking abilities; 3) Romli et al. [7] expressed that student learning resources designed with an open-ended approach can improve students' creative thinking abilities; and 4) Wijaya [8] stated that open-ended tasks could promote student's mathematical creativity. Starting from the background above, the purpose of this study is to describe the students' creative thinking abilities with an open-ended approach in solving mathematical logic problems.

2. Methodology

This research is a qualitative descriptive study. The subjects were first-semester students of the Mathematics Educations study program in Faculty Education and Teacher Training at State Islamic Institute of Jember. The data was collected by a test using open-ended questions, interviews, observation, and documentation [9]. The method used for determining the subjects was a purposive sampling method, in which resulted in three students who have high, medium, and low mathematical abilities. Data analysis techniques used in this study were data condensation, data display, and conclusion drawing/verification [10].

The answers to the open-ended question were examined and marked according to the creative thinking criteria. This data is used to determine the level of creative thinking ability of first-semester students in the Mathematics Educations study program in Faculty Education and Teacher Training at State Islamic Institute of Jember. The analysis refers to aspects of creativity, namely fluency, flexibility, and novelty of the answers [4]. The level of creative thinking skills can be determined from the table below [11].

Table 1. Level of Creative Thinking Skills

Level	Criteria	Category
4	Very Creative	Fluency, Flexibility, Novelty
3	Creative	Flexibility, Novelty; Fluency and Flexibility; Fluency and Novelty.
2	Moderately Creative	Novelty; Flexibility.
1	Slightly Creative	Fluency.
0	Uncreative	Does not meet any category of creative thinking skills

3. The Result

The results of this study are descriptions of students' creative thinking abilities in solving mathematical logic problems. This research begins with the implementation of the test using open-ended questions. Next is exploring the students' answers to observe their creative thinking skills. One of the fluent thinking ability indicators is the richness of their description with many ideas about a problem. The other one is how fluent they described their ideas. A description containing consideration to situations that are different from those given by others shows a flexible thinking ability. This step was carried out in the classroom by taking random students' answers and discussing them together. Selected answers were presented and responded by other students. If there are different answers or opinions, then the answers are written on paper to compare the answers. From this activity, the researcher can observe the students' thinking process. The following example is a student answer which is different from others.

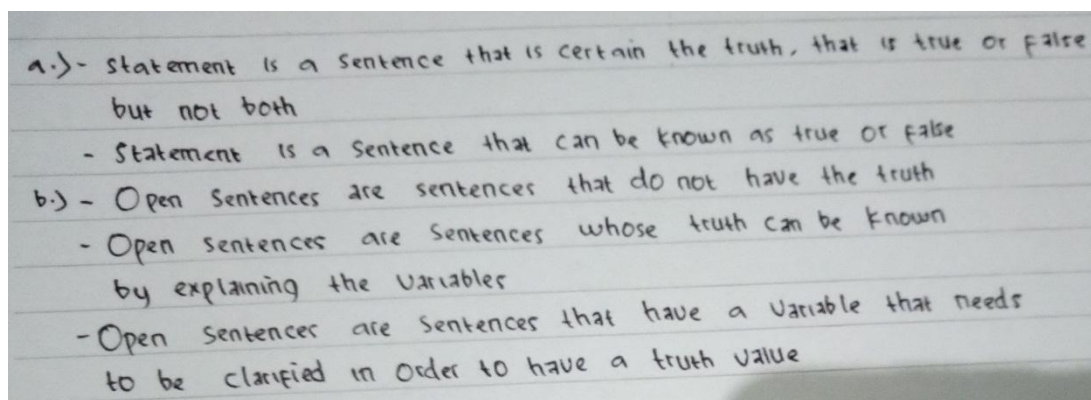


Figure 1. The student's answer to problem 1

It appears that there are two different answers. This is a description of fluent thinking skills indicators. The work also shows that they have tried to provide various interpretations of the problem. While in the discussion, they have tried to give any considerations to situations that are different from other group members. Both of these descriptions are indicators of flexible thinking skills.

Next, the interview was held to collect students' responses to the implementation of the test that used an open-ended approach. It aims to determine the students' creative thinking abilities. Interviews were conducted with three students who had high, medium and low ability, respectively named as YAR, MA, and AF.

The following conversation is the interview with YAR.

Lecturer : "What do you think of the test questions with the open-ended approach that you just took?"

YAR : "Interesting, Sir. I felt free to answer every given problem without referring to only one correct answer or one exact way. Also, there was a discussion section. I got a lot of knowledge from my friends' opinions through this discussion."

Lecturer : "Have you ever had a test like that before?"

YAR : "Not yet, Sir. I have never worked on a question that can be solved by more than one way or method to find the right answer."

Lecturer : "Were you able to find more than one answer?"

YAR : "Yes, although it required a longer time. But with the discussion after working on the test, I could get more answers."

Lecturer : "Well, now I want to ask, how do you solve the problems in the test?"

YAR : "For problems 1 and 2, I could finish them, Sir, even though my answers were just like that since I was still confused at that time. For problem 3, I could not work on it, Sir. I just wrote back the problem. For problems 4 and 5, I could answer them, Sir."

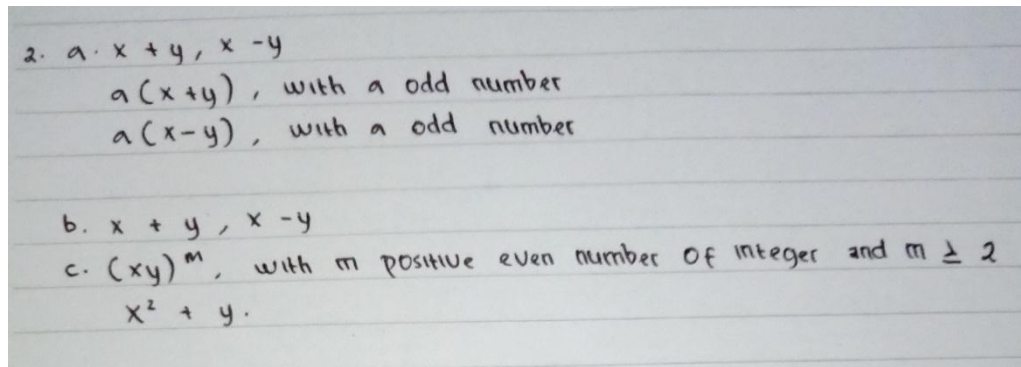


Figure 2. YAR's Answer on Problem 2

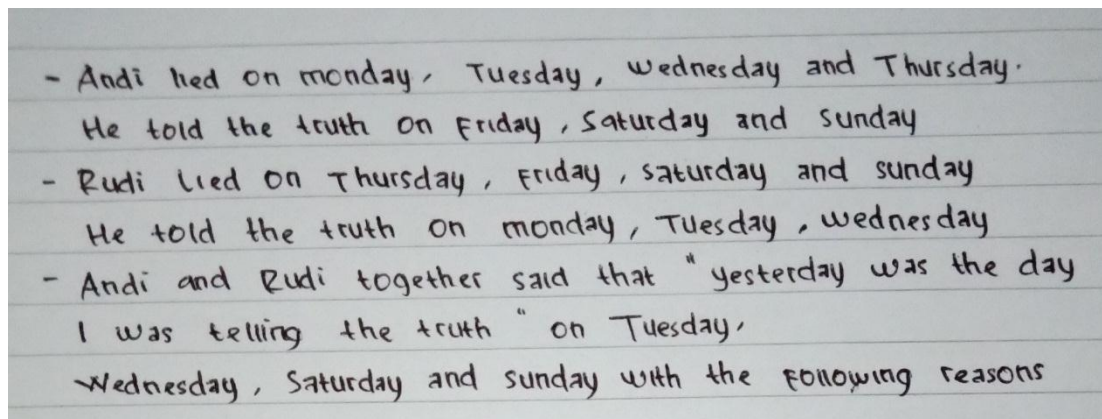


Figure 3. YAR's Answer on Problem 3

Based on Figure 2, it appears that YAR tried to give several answers to the given problem. Unfortunately, he could not find the answer to problem 3 as presented in Figure 3. This means that YAR's creative thinking skills have not been seen. The indicators that appear are only fluent thinking skills, especially related to presenting some answers to the given question.

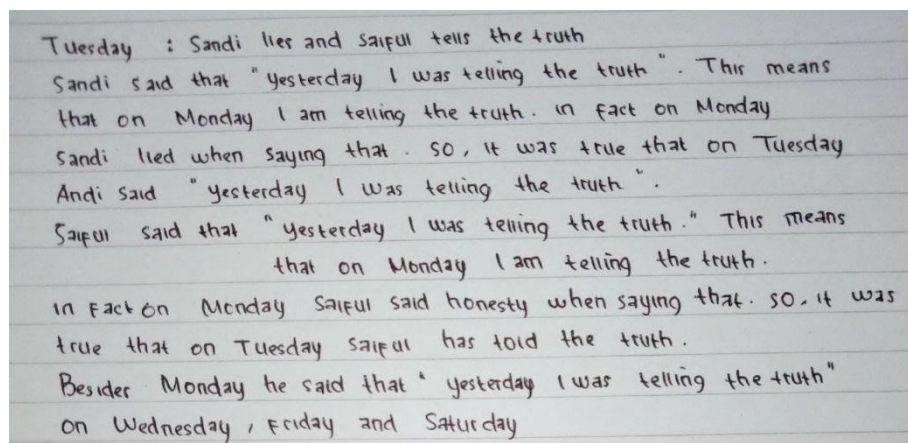


Figure 4. First Answer of YAR on Problem 4

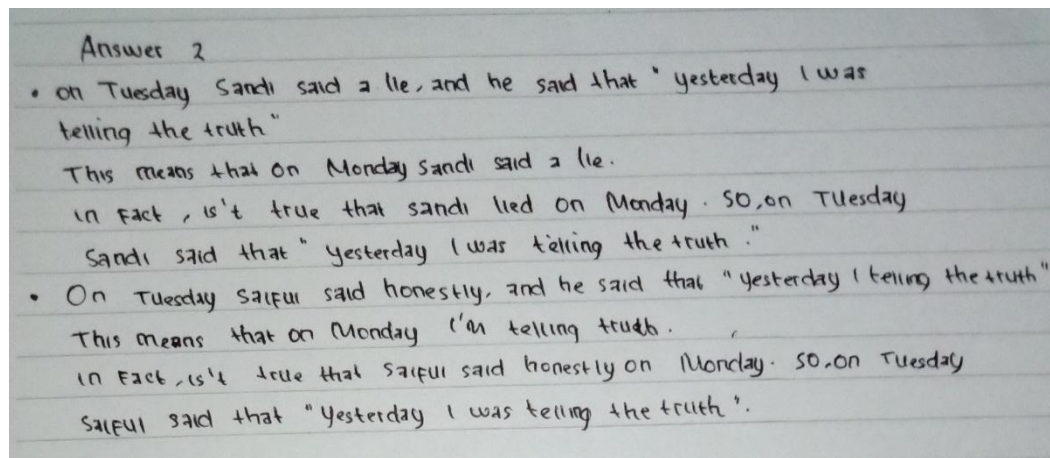


Figure 5. Second Answer of YAR on Problem 4

In Figures 4 and 5, it can be seen that YAR can find more than one answer. This shows that YAR's creative thinking skills can be observed. First, presenting some answers to a question and having many ideas towards a problem are the indicators of fluent thinking skills. Second, providing a variety of interpretations of a problem is an indicator of flexible thinking skills. Last, thinking of problems that have never been thought of by others is an indicator of original thinking.

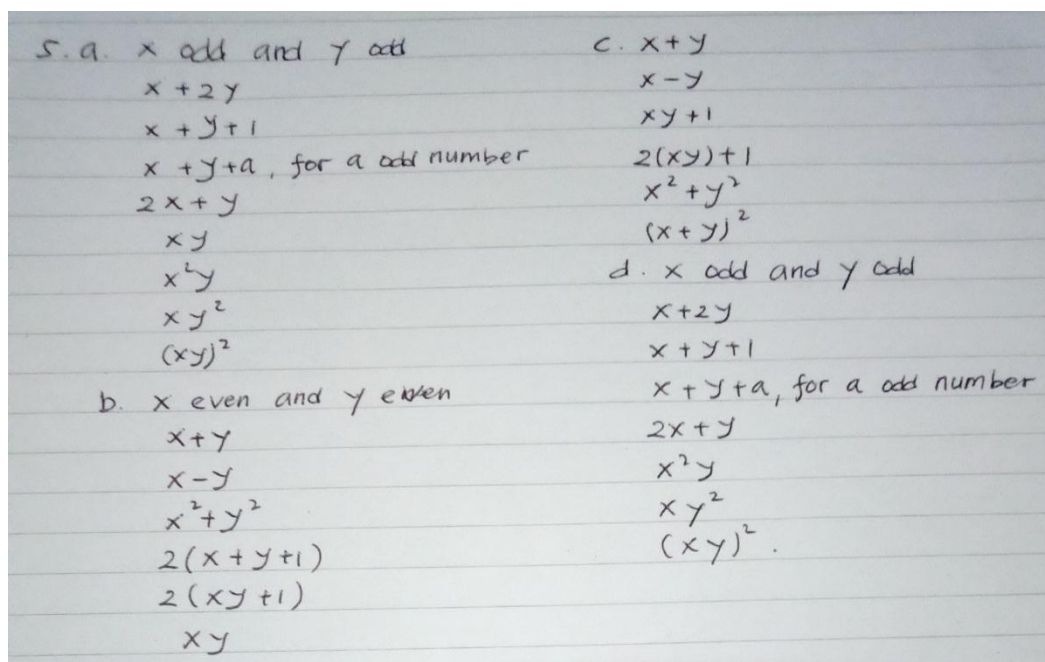


Figure 6. YAR's answer on problem 5

Figure 6 illustrates that YAR can obtain more than one answer. This shows that YAR's skill to think creatively can be observed, that is to provide some answers to a question, have different methods to solve a problem, and think of problems that have never been thought of by anyone else which are respectively indicating the fluent, flexible, and original thinking skills.

Based on the YAR's answers above, it can be observed that in problem 1, problem 2, and problem 3, YAR can give several answers to a given question. It means that YAR has fluent thinking skills [4]. For problem 4 and problem 5, YAR presented some answers to a question and had many ideas on a

problem, provided various interpretations of a problem, and thought of problems that have never been thought of by others. It means that YAR included in the category of having fluent, flexible, and original thinking skills [4]. In conclusion, YAR's level of thinking is at level 4 meaning very creative [11].

Next, the results of the interview with the MA.

Lecturer : "What do you think of the test questions with the open-ended approach that you just took?"

MA : "I think it's good, although it's complicated but it's challenging to answer"

Lecturer : "Have you ever had a test like that before?"

MA : "Not yet".

Lecturer : "Were you able to find more than one answer?"

MA : "Yes, sir, some can or may not".

Lecturer : "Well, now I want to ask, how do you solve the problems in the test?"

MA : "I can work on problem 1 and problem 2, but I can only find one answer. For problem 3, I can't, sir".

below are the MA's answers on the test.

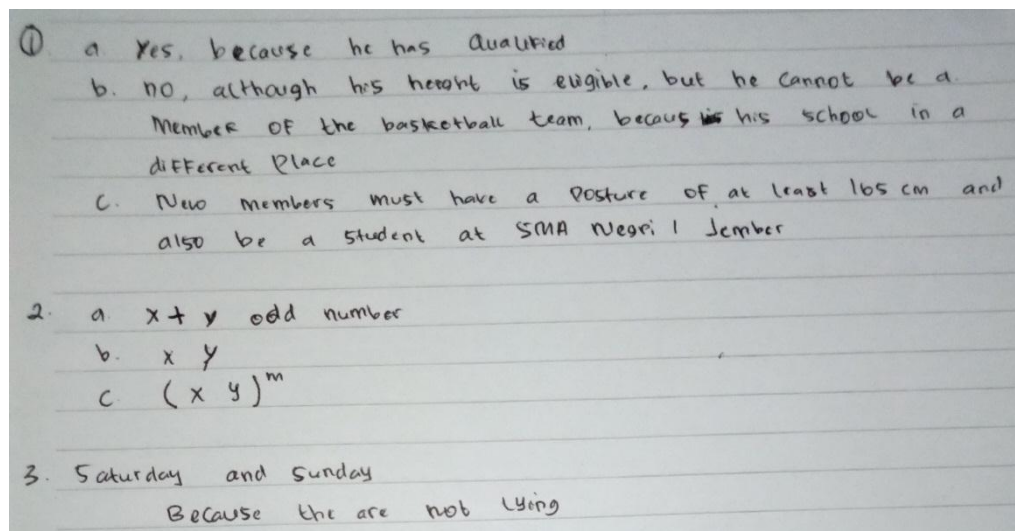


Figure 7. MA's answers on problems 1, 2, and 3

Lecturer : "How did you solve problem 4 and problem 5 on the test that you took earlier?"

MA : "I do it according to what I get and I understand when studying in class, sir. For problem 4, I can't do it, I didn't go in when the material is. For problem 5, I can do it. I found four answers".

Here are the MA's answers on problem 4 and problem 5.

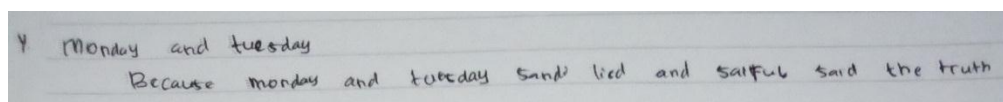


Figure 8. MA's answer on problem 4

Handwritten mathematical solutions for problem 5, showing three different approaches (a, b, c) to solve for x and y .

a. $x + y + 1$
 $x + y + a$, for a odd number
 xy
 $(xy)^m$

b. $x + y$
 $x - y$
 xy
 $x^2 y$

c. $x + y$
 $x - y$
 $xy + 1$
 $x^2 + y^2$
 $x + y + 1$
 $x + y + a$, for a odd number
 xy
 $(xy)^2$

Figure 9. MA's answer on problem 5

From the interview results dan figure 7, illustrates that MA can obtain only one answer. This shows that MA's skill to think creatively can be observed, that is to think for themselves solutions to existing problems. From the figure 9 illustrates that MA can obtain more than one answer. This shows that the creative thinking skill of the MA can be observed, that is to provide some answers to a question, and have different methods to solve a problem.

Based on the MA's answers above, it can be observed that in problem 1, problem 2, and problem 3 can be answered by the MA with a single answer that is the result of the MA's own thinking. It means that YAR has Novelty thinking skills [4]. For problem 5, presented some answers to a question and had many ideas on a problem, and provided various interpretations of a problem. It means that MA included in the category of having fluent and flexible thinking skills [4]. In conclusion, MA's level of thinking is at level 3 with creative criteria [11].

Furthermore, the results of the interview with AF.

Lecturer : "What do you think of the test questions with the open-ended approach that you just took?"

AF : "Good, because it has more than one answer".

Lecturer : "Have you ever had a test like that before?"

AF : "Not yet, sir".

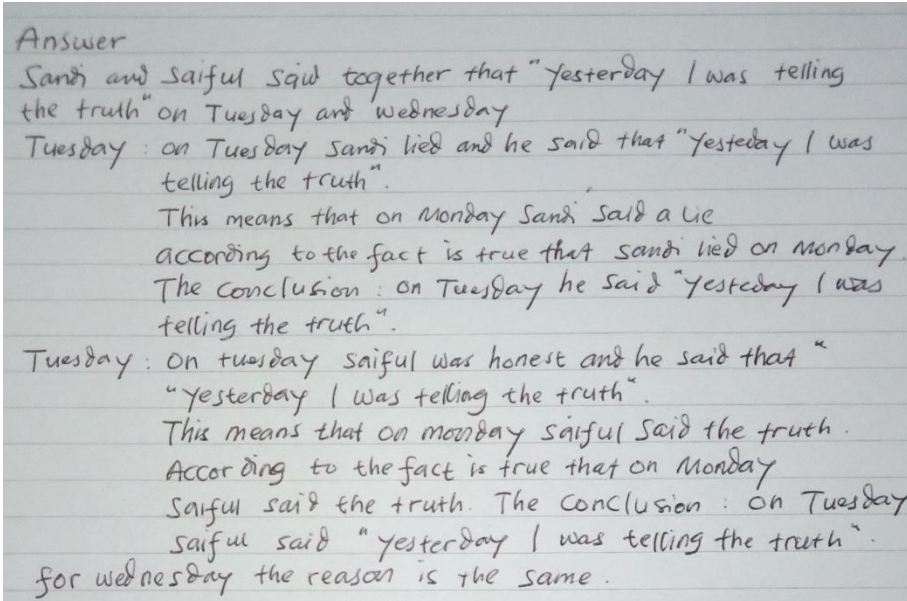
Lecturer : "Were you able to find more than one answer?"

AF : "I still don't understand, sir".

Lecturer : "Well, now I want to ask, how do you solve the problems in the test?"

AF : "I can't, sir. But I try to answer and can only do problem 1 and problem 2 and I'm not sure. For problem 3, I just wrote the problem and guessed that Thursday is the day where they are said together. For problem 4 and problem 5, I worked, but I'm not sure about the answer".

Below are the AF's answers on the test.



Answer

Sandi and Saiful said together that "Yesterday I was telling the truth" on Tuesday and Wednesday

Tuesday : on Tuesday Sandi lied and he said that "Yesterday I was telling the truth".

This means that on Monday Sandi said a lie

According to the fact is true that Sandi lied on Monday.

The conclusion : on Tuesday he said "Yesterday I was telling the truth".

Tuesday : On Tuesday Saiful was honest and he said that "Yesterday I was telling the truth".

This means that on Monday Saiful said the truth.

According to the fact is true that on Monday Saiful said the truth. The conclusion : on Tuesday Saiful said "Yesterday I was telling the truth".

for Wednesday the reason is the same.

Figure 10. AF's answer on problem 4

From the results of interviews with AF, it can be observed that for problem 1, problem 2, and problem 3, AF only answered with one answer and was wrong. So the skill to thinking has not been observed. For problem 4, it can be observed that AF can obtain more than one answer as shown in figure 10. This shows that AF's creative thinking ability can be observed, that is to provide some answers to a question. It means that AF included in the category of fluency [4]. Therefore, it can be said that AF's level of thinking is at level 1 with slightly creative criteria [11].

Furthermore, researcher identify the students' creative thinking skills through the results of student answers on the tests. From 36 first semester students of mathematic class it can be observed that 3 students are at level 1 which means they have slightly creative thinking skills, 11 students are at level 2 which means they have moderately creative thinking skills, 15 students are at level 3 which means they have the ability to think creatively, and 7 students are at level 4 which means they have the ability to think very creatively.

4. Discussion

Based on the results of the study, it was concluded that 3 students are at level 1. This means that 8.33% of students categorized as "Slightly creative". Then 11 students are at level 2 which means that 30.56% of students categorized as "Moderately creative". 15 students are at level 3 which means that 41.67% of students categorized as "creative". And 7 students are at level 4 which means that 19.44% of students categorized as "very creative". This shows that the open-ended approach can be used by teachers to develop students' creative thinking. This corresponds with the opinion of Dahlan, Nurhadi and Rohimah [12] who said that the open-ended approach has a positive effect on the ability to think creatively.

In addition, there are learning theories that support these results, namely constructivism learning theory. According to the opinion of constructivism, learning is a process of forming knowledge that must be done by students [13]. This means according to the characteristics of open-ended that learning must be student-centered. The same opinion is expressed by Piaget's theory [13] which suggests that knowledge owned by someone is the result of the construction of the person himself. So it is necessary for teachers to use a learning approach that can develop students' creative thinking. Therefore, the open-ended approach can be used as a reference in classroom learning.

5. Conclusion

Based on the results of the study and discussion, it was concluded that creative thinking skills can be observed and classified using the open-ended approach. From the observations of students' creative thinking skills, the average percentage of students' creative thinking skills were classified as follows: 8.33% of the students categorized as "*Slightly creative*"; 30.56% of the students categorized as "*Moderately creative*"; 41.67% of the students categorized as "*creative*"; and 19.44% of the students categorized as "*very creative*".

Furthermore, it is suggested that in giving assignments or exam questions to students using an open-ended approach to find out creative thinking skills. This means that the open-ended approach can be used as a reference in teaching and learning activities to increase the ability to think creatively.

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