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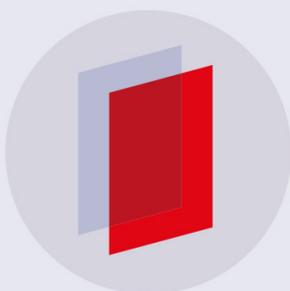
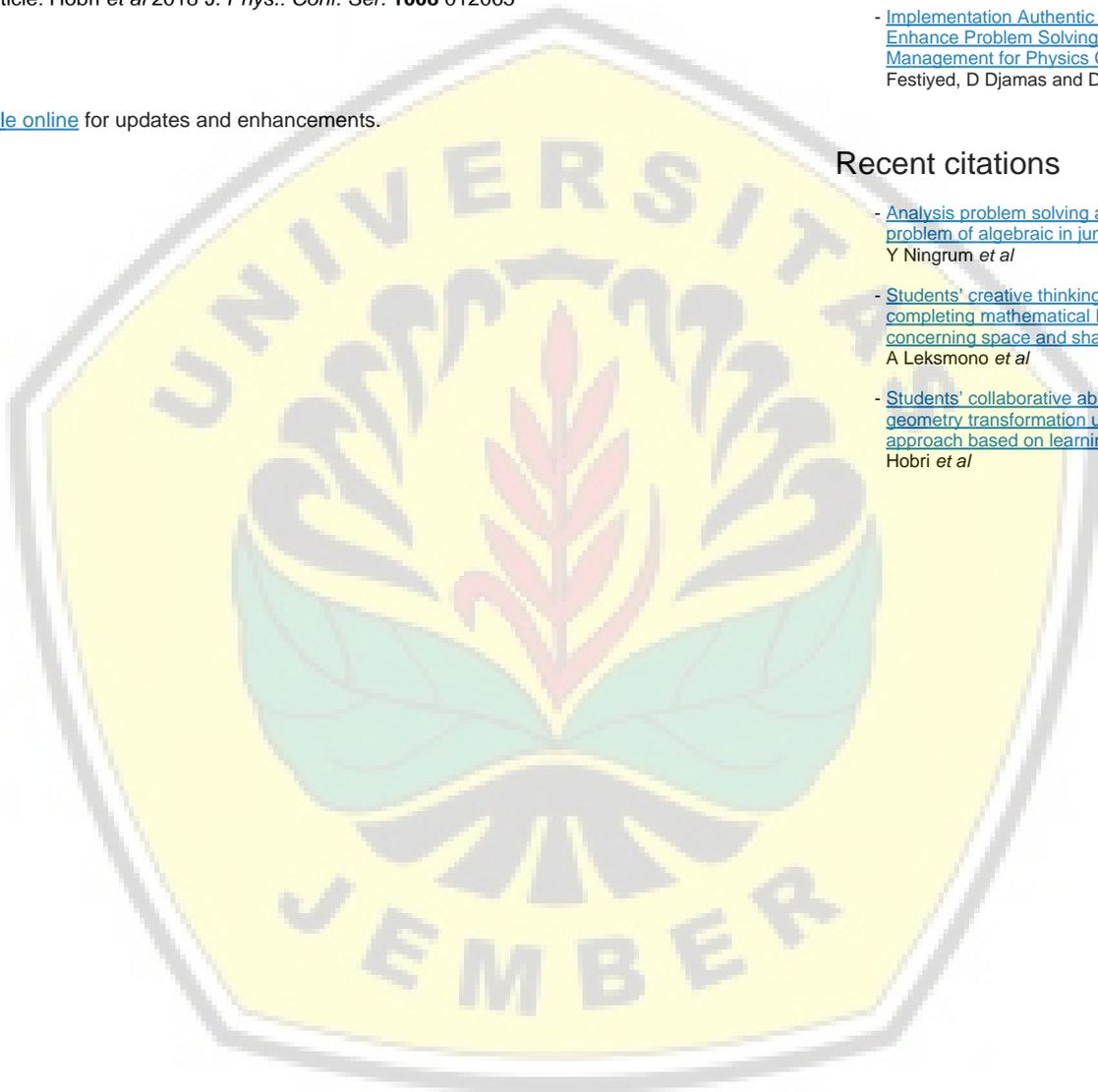
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Analysis of students' creative thinking level in problem solving based on national council of teachers of mathematics

Hobri¹, Suharto¹ and Ahmad Rifqi Naja¹

¹Department of Mathematics Education, University of Jember, Indonesia

Email: hobri.fkip@unej.ac.id

Abstract. This research aims to determine students' creative thinking level in problem solving based on NCTM in function subject. The research type is descriptive with qualitative approach. Data collection methods which were used are test and interview. Creative thinking level in problem solving based on NCTM indicators consists of (1) Make mathematical model from a contextual problem and solve the problem, (2) Solve problem using various possible alternatives, (3) Find new alternative(s) to solve the problem, (4) Determine the most efficient and effective alternative for that problem, (5) Review and correct mistake(s) on the process of problem solving. Result of the research showed that 10 students categorized in very satisfying level, 23 students categorized in satisfying level and 1 students categorized in less satisfying level. Students in very satisfying level meet all indicators, students in satisfying level meet first, second, fourth, and fifth indicator, while students in less satisfying level only meet first and fifth indicator.

1. Introduction

Mathematics is one of the most important subjects that is so instrumental in advancing the civilization of a nation, mathematics can be interpreted as a study of patterns and relations, a path or thinking pattern, an art, a language, and a tool, therefore mathematics is not a solitary knowledge, but its existence to assist human beings in understanding and mastering various other problems by Jihad [3]. Problem solving is a process that students take to solve a problem so that the problem will not be a problem for him anymore by Hudojo [2]. Problem solving in NCTM naturally develops students' ability in solving problems through their exploration of mathematical knowledge by Xie [10]. Therefore, problem solving has a very important role and is the core to mathematics learning by Ninik *et. al.* [7] and also there is some results about creative thinking skills in [11, 12, 13].

The expected problem solving is problem solving which is involving and exercising creativity. The statement is supported by one of the ideals of mathematics learning formulated by Ministry of Education and Culture's regulation number 59 of year 2014 which reads "students are able to have creative attitude and behavior in solving problems" by Ministry of Education and Culture [4]. So, it can be concluded that creativity becomes an important discussion because it has a share in achieving education's goals by Febriyanti *et. al.* [1]. However, creativity in problem solving is rarely noticed in mathematics learning by Prianggono [8]. Sometimes teachers emphasize more to memorize formulas in order to solve problems such as math. Although sometimes this method is considered to be more instantaneous but it actually inhibits the development of students' reasoning and creativity. Whereas it has been emphasized that one of the objectives of learning mathematics by the government is that students are able to have creative attitude and behavior in solving problems. The goal of mathematics learning, especially problem solving, is to build new mathematical knowledge through problem



solving, solving problems that arise in mathematics and in other contexts, able to apply and adapt various appropriate strategies to solve a problem and to monitor and reflect on the process of solving mathematical problems by NCTM [6]. Therefore, we should start to abandon those bad learning habits and turn to the learning ways that can develop and enhance the creativity of students.

Senior High School is one level of education which is equivalent to SMK or MA in Indonesia. Learning in senior high schools equip their students with science knowledge that will benefit them to study in college. According to National Ministry of Education's regulation, several mathematical subjects for high school skills include conceptual comprehension, problem solving, reasoning, mathematical communication, and mathematical utility by National Education Standards Agency [5]. This capability is aligned with the five standard mathematical learning processes formulated by NCTM namely: problem solving, reasoning, communicating, making connections, and presenting. To be able to realize the learning process that uses this standard, qualified teachers are required to be able to improve students' skills in these five aspects.

In this research, problem which was used is open middle contextual type problem. The school chosen as the research location is SMA Negeri 1 Situbondo, this school is one of the best senior high schools in Situbondo. Subjects in this research is the class XI MIPA 1 SMA Negeri 1 Situbondo. The purpose of this research is to determine the level of creative thinking ability of students in solving mathematical problems based on NCTM (National Councils of Teachers of Mathematics)

2. Research Methods

The type of research used is descriptive research with qualitative approach. The subjects of the study were the students of class XI MIPA 1 SMA Negeri 1 Situbondo, which consists of 34 students. To achieve the objectives of this research, research procedure is conducted. Research procedure consists of some steps that need to be done sequentially. The first step is making research instruments which are test and interview guidelines. The test instrument contains a mathematical functions subject problem based on NCTM that serves to measure the creative thinking level to solve mathematical problems of students. Problem which was used is an open middle contextual type problem which was arranged for students to find or use a variety of strategies to solve the given problem. The next step is validity testing. Validation was performed on both instruments by two lecturers of FKIP Mathematics University of Jember and one mathematics teacher of SMAN 1 Situbondo. If it meets the criteria specified then the instrument can be said to be valid and can be used. However, if it is not yet valid, it will be revised and re-validated until the instrument is valid. The third step is determining location and subject of research and data collecting. In this step location and subject of research is determined and then data which were needed for the research were collected. The data were collected at SMAN 1 Situbondo with the subjects of research were 34 students of class XI MIPA 1 SMAN 1 Situbondo. The data were collected by conducting test to 34 students of class XI MIPA 1 with an open middle contextual mathematics function subject problem which has been compiled based on NCTM. The students answer then analysed in order to determine their creative thinking level in problem solving and then some students are interviewed as sample to strengthen and enrich the analysis result. As we know, the earlier commonly used methods to identify and measure this are CAMT, TTCT and Silver's statement about the most suitable approach to identify students creative thinking. The latest research about creative thinking levelling in problem solving in Indonesia used three components of creative thinking (fluency, flexibility, and novelty) as theoretical basis and develop it as indicators to measure students' creative thinking level in solving and posing mathematical problem which is divided into 5 level by Siswono *et. al.* [9].

In this research, in order to analyse and determine the level of students' creative thinking in problem solving, researcher combine theories and indicators by earlier researcher with NCTM's mathematics problem solving's goals. This action results indicators of problem solving's goals based on NCTM and creative thinking level in problem solving based on NCTM which are presented in Table 1 and Table 2.

Table 1: Indicators of problem solving's goals based on NCTM's achievements

No	Goals of Problem Solving Based on NCTM	Indicator(s)
1.	Solve problems that arise in mathematics and in other contexts.	Create mathematical model of a contextual problem and solve it correctly.
2	i. Apply and adapt various appropriate strategies to solve the problem and ii. Build new mathematical knowledge through problem solving	a) Solve problem using various possible alternatives b) Find new alternative(s) to solve the problem c) Determine the most efficient and effective alternative for that problem.
3	Monitor and reflect on the process of solving mathematical problems	Review and correct mistake(s) on the process of problem solving.

In the Table 1, the meaning of new alternative solution(s) in this research is another alternative that teachers have never taught to students or not present in their mathematics students' book.

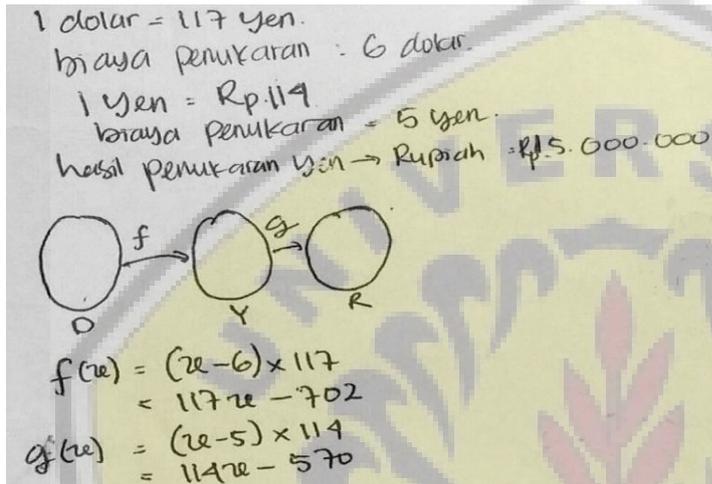
Table 2: Indicators of creative thinking level in problem solving based on NCTM

Creative Thinking Level in Problem Solving Based On NCTM	Indicator(s)
Very satisfying	Students meet all indicators of achievement of problem-solving goals according to NCTM.
Satisfying	Students meet all indicators of: 1) Solve problems that arise in mathematics and in other contexts 2) Monitor and reflect on the process of solving mathematical problems But only meet some indicator(s) of: i. Apply and adapt various appropriate strategies to solve the problem and ii. Build new mathematical knowledge through problem solving.
Less satisfying	Students meet all indicators of: 1) Solve problems that arise in mathematics and in other contexts and monitor and reflect on the process of solving mathematical problems 2) Monitor and reflect on the process of solving mathematical problems.
Not satisfying	Students do not meet any indicators of achievement of problem-solving goals according to NCTM.

The final step is drawing conclusions. In this step researcher draw conclusions from data analysis' result which has been done before

3. The Results

The analysis result of students' answer using indicators of problem solving's goals based on NCTM's achievements showed that the percentage of students who meet the first indicator is 100 percent. All of the students are able to create mathematical model of a contextual problem and solve it correctly. The following is an example figure of the student's work that relates to the first indicator.



From this Figure 1, it is known that this student wrote down all of the known things in the given problem and what is asked there and made mathematical model of it in the form of mathematical functions. Some students also made composite function's figure of the given problem.

Figure 1: Student's work that relates to the first indicator

The second indicator, solve problem using various possible alternatives, can only be fulfilled by 97,1% of the class which means only one student who couldn't use more than one way to solve the given problem. The following figures are some alternatives which were used by the other 33 students to solve the given problem.

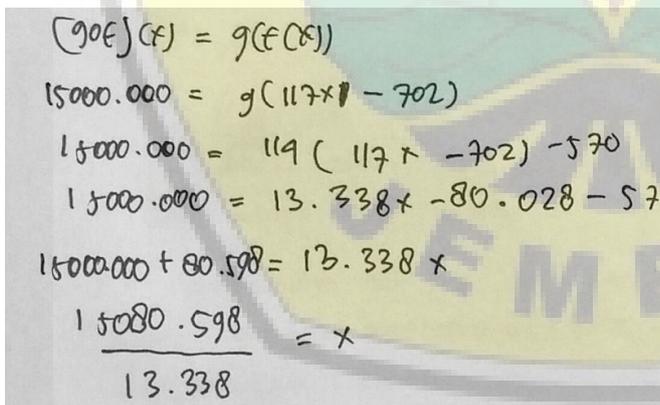


Figure 2: Alternative solution used by students (1)

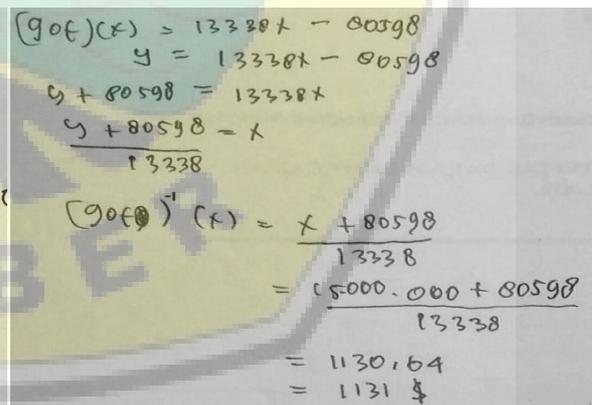


Figure 3: Alternative solution used by students (2)

$$\begin{aligned}
 f(x) &= 117x - 702 \\
 y &= 117x - 702 \\
 y + 702 &= 117x \\
 \frac{y + 702}{117} &= x \\
 \frac{x + 702}{117} &= f^{-1}(x) \\
 g(x) &= 114x - 570 \\
 y &= 114x - 570 \\
 y + 570 &= 114x \\
 \frac{y + 570}{114} &= g^{-1}(x) \\
 f^{-1}(x) \circ g^{-1}(x) &= \frac{x + 570}{114} + 702 \\
 &= \frac{x + 570 + 80028}{114} \\
 &= \frac{x + 80598}{114} \times \frac{1}{117} \\
 &= \frac{x + 80598}{13338} \\
 &= \frac{15.000.000 + 80598}{13338} \\
 &= 1131
 \end{aligned}$$

Figure 4: Alternative solution used by students (3)

$$\begin{aligned}
 g(x) &= 114x - 570 \\
 15.000.000 &= 114x - 570 \\
 x &= \frac{15.000.570}{114} \\
 &= 131583,94 \text{ yen.} \\
 f(x) &= 117x - 702 \\
 131583,94 &= 117x - 702 \\
 x &= \frac{131583,94 + 702}{117} \\
 &= 1130,64 \text{ dolar} = \text{dibulatkan} = 1131 \text{ dolar} \\
 x &= 1131 \text{ dolar.}
 \end{aligned}$$

Figure 5: Alternative solution used by students (4)

$$\begin{aligned}
 g^{-1}(x) &= \frac{x + 570}{114} \\
 &= \frac{15.000.000 + 570}{114} \\
 &= 131583,94 \\
 &= 131584 \\
 f^{-1}(x) &= \frac{x + 702}{117} \\
 &= \frac{131584 + 702}{117} \\
 &= 1130,64 \\
 &= 1131 \$ \\
 \text{Jadi uang Jamer mula-mula} \\
 \text{sebesar } 1131 \$
 \end{aligned}$$

Figure 6: Alternative solution used by students (5)

$$\begin{aligned}
 g(x) &= (x - 5)114 \text{ (fungsi yen} \rightarrow \text{rupiah)} \\
 15.000.000 &= (x - 5)114 \\
 131579 &= (x - 5) \\
 x &= 131584 \text{ yen} \\
 f(x) &= x + 6 \text{ (fungsi yen} \rightarrow \text{dolar)} \quad (x = \text{yen}) \\
 \frac{131584}{117} + 6 &= 1127 + 6 = 1131 \text{ dolar, jadi, uang Jamer mula-mula adalah } 1131 \text{ dolar.} \\
 \text{Cara termudah adalah cara nomor III}
 \end{aligned}$$

Figure 7: Alternative solution used by students (6)

$$\begin{aligned}
 g^{-1}(x) &= \frac{x}{114} + 5 \text{ (fungsi rupiah} \rightarrow \text{yen mula-mula)} \quad (x = \text{rupiah)} \\
 &= \frac{15.000.000}{114} + 5 = 131579 + 5 = 131584 \text{ yen.} \\
 f(x) &= (x - 6)(117) \text{ (fungsi dolar} \rightarrow \text{yen)} \quad (x = \text{dolar)} \\
 131584 &= (x - 6)(117) \\
 1125 &= x - 6 \\
 x &= 1131 \text{ dolar, jadi, uang Jamer mula-mula adalah } 1131 \text{ dolar}
 \end{aligned}$$

Figure 8: Alternative solution used by students (7)

The number of ways students used to solve the given problem in the test is 7. In figure 2 student substituted value of the final money which is one of known things in problem to $g \circ f(x)$. In figure 3 student tried to find the inverse of $g \circ f(x)$ by defining it as a function y then arranging the

terms there so it becomes form of the equation of $x = y + \frac{80.598}{13.338}$ with x as the invers of $g \circ f(x)$ and y as the value of final money in Rupiah. In figure 4 student used the inverse properties of the composite function. In figure 5 student manually substituted the value of final money in Rupiah to $g(x)$ to find the value of its x then substituted that x value to $f(x)$ to find the value of initial money in Dollar. In figure 6 student manually substituted the value of final money in Rupiah to $g^{-1}(x)$ and the substituted its value to $f^{-1}(x)$ to find the value of initial money in Dollar. In figure 7 student manually substituted the value of final money in Rupiah to $g(x)$ to find the value of its x and substituted that x value to $f^{-1}(x)$ to find the value of initial money in Dollar In figure 8 student manually substituted the value of final money in Rupiah to $g^{-1}(x)$ to find the value of $g^{-1}(x)$ and then substituted its value to $f(x)$ to find the value of initial money in Dollar.

The third indicator, find new alternative(s) to solve the problem, can only be fulfilled by 29,4% of the class. This indicator sure is the hardest for this class' students to fulfill. Finding a new way other than ways that found in students' book or teachers taught is not an easy task because it requires a deep understanding of the theory which is used to solve the given mathematical problem and other knowledge that relates to it. For this class, ways that categorized as old way are: substituting value of the final money which is one of known things in problem to $g \circ f(x)$, finding the inverse of $g \circ f(x)$ by defining it as a function y then arranging the terms there so it becomes form of the equation of $x = y + \frac{80.598}{13.338}$ with x as the invers of $g \circ f(x)$ and y as the value of final money in Rupiah, and using the inverse properties of the composite function. While the other four such as shown in Figure 5, Figure 6, Figure 7, and Figure 8 are categorized as the new way.

The forth indicator, determine the most efficient and effective alternative for that problem, is fulfilled by 100% of the class. Most of them selected substituting value of the final money which is one of known things in problem to $g \circ f(x)$ as the most efficient and effective alternative for the given problem. The fifth indicator, review and correct mistake(s) on the process of problem solving, is fulfilled by 100% of the class. Making mistakes or errors while solving mathematical problems is common. Almost all of the students in this class made mistakes in the process of solving the problem given. The students' effort to fix can be seen from the stationaries' scribbles like pen and correction pen marks. They also admitted to having made mistakes while doing given math problem and have fixed them.

From the result of determining students' creative thinking level in problem solving of mathematics function problem which done at class XI MIPA 1 with 34 subject students hence got 10 student which categorized in very satisfying level, 23 students categorized in satisfying level and 1 person categorized in less satisfying level. If it is observed from the achievement of the indicator, it is found that 34 students meet the first indikator, 33 students meet the second indicator, 10 students meet third indicator, 34 students meet forth indicator, and 34 students meet fifth indicator. The following table will describe the summary of XI MIPA 1 students' achievements of problem solving's goals based on NCTM achievement indicators and the result of determining creative thinking level in problem solving based on NCTM.

Table 3: Creative Thinking Level Determination in Problem Solving Result of XI MIPA Students

No	Name	Indicator					Info	Level
		1 st	2 nd	3 rd	4 th	5 th		
1	A A	√	√	×	√	√	2W,2O,0N	Satisfying
2	A A F	√	√	×	√	√	3W,3O,0N	Satisfying
3	A Am	√	√	×	√	√	3W,3O,0N	Satisfying
4	A R F	√	√	√	√	√	4W,3O,1N	V. Satisfying
5	A A M	√	√	×	√	√	3W,3O,0N	Satisfying
6	A H	√	√	×	√	√	3W,3O,0N	Satisfying
7	A R P	√	√	√	√	√	5W,3O,2N	V. Satisfying
8	A E A	√	√	√	√	√	4W,2O,2N	V. Satisfying

9	ASI	√	√	×	√	√	3W,3O,0N	Satisfying
10	AN	√	√	×	√	√	3W,3O,0N	Satisfying
11	AW	√	×	×	√	√	1W,1O,0N	L. Satisfying
12	DBH	√	√	×	√	√	2W,2O,0N	Satisfying
13	DCMS	√	√	×	√	√	3W,3O,0N	Satisfying
14	DSP	√	√	×	√	√	3W,3O,0N	Satisfying
15	DP	√	√	√	√	√	5W,3O,2N	V. Satisfying
16	FSU	√	√	×	√	√	2W,2O,0N	Satisfying
17	FTM	√	√	√	√	√	5W,3O,2N	V. Satisfying
18	HR	√	√	×	√	√	3W,2O,1N	V. Satisfying
19	IA	√	√	×	√	√	2W,2O,0N	Satisfying
20	KRP	√	√	×	√	√	3W,3O,0N	Satisfying
21	MNA	√	√	×	√	√	3W,3O,0N	Satisfying
22	M. KKD	√	√	×	√	√	2W,2O,0N	Satisfying
23	MNR	√	√	√	√	√	6W,2O,4N	V. Satisfying
24	MRP	√	√	×	√	√	2W,2O,0N	Satisfying
25	NSTW	√	√	×	√	√	3W,3O,0N	Satisfying
26	NNDN	√	√	√	√	√	5W,2O,3N	V. Satisfying
27	RAP	√	√	×	√	√	2W,2O,0N	Satisfying
28	SN	√	√	×	√	√	3W,3O,0N	Satisfying
29	S.M. RD	√	√	×	√	√	2W,2O,0N	Satisfying
30	YAA	√	√	√	√	√	6W,2O,4N	V. Satisfying
31	YKP	√	√	×	√	√	3W,3O,0N	Satisfying
32	ZN	√	√	×	√	√	2W,2O,0N	Satisfying
33	ZR	√	√	√	√	√	4W,3O,1N	V. Satisfying
34	FIB	√	√	×	√	√	2W,2O,0N	Satisfying

Information:

Info : Additional info

W : Way(s)/ alternative solution(s)

O : Old way(s)/old alternative solution(s)

N : New way(s)/new alternative solution(s)

From the analysis result can be summarized information as follows:

- 1) Percentage of class XI MIPA 1 students who categorized in very satisfying level is 29.4%
- 2) Percentage of class XI MIPA 1 students who categorized in satisfying level is 67.6%
- 3) Percentage of class XI MIPA 1 students who categorized in less satisfying level is 2.9%
- 4) Percentage of class XI MIPA 1 students who meet the first indicator 100%
- 5) Percentage of class XI MIPA 1 students who meet the second indicator 97.1%
- 6) Percentage of class XI MIPA 1 students who meet the third indicator 29.4%
- 7) Percentage of class XI MIPA 1 students who meet the forth indicator 100%
- 8) Percentage of class XI MIPA 1 students who meet the fifth indicators 100%

4. Conclusion

Based on the result of the analysis and discussion, the determination of students' creative thinking level in problem solving based on NCTM in function subject can be concluded. Indicators of problem solving's goals based on NCTM achievements which are most fulfilled by students of class XI MIPA 1 SMAN 1 Situbondo are first, forth and fifth indicators that is 100% of students of this class are able to meet these indicators. While indicators of problem solving's goals based on NCTM achievements which are least fulfilled by the students of class XI MIPA 1 SMAN 1 Situbondo is third indicator that is only 29.4% of students of this class are able to meet this indicator. In first indicator, all students are able to fulfill it. In second indicator, there are five students who are able to fulfill it. In third indicator, all students are able to fulfill it. In forth indicator, all students are able to fulfill it. And in fifth indikator all studets are able to fulfill it. Students are not able to meet second indicator because they are unable to use more than one alternative solution to solve the given problem. While third

indicator can not be fulfilled because they are unable to find new problem solving solution that can be used to solve the given function subject problem. The least amount of alternative solutions used by students is 1 alternative solution, whereas the most amount of alternative solutions used by students are 6 alternative solutions. The number of most amount of new problem solving alternatives found by students to solve the given function subject problem are 4 new alternatives.

The number of students of class XI MIPA 1 who categorized in very satisfying level is as many as 10 students or 29.4% of the total students in the class, the number of students of class XI MIPA 1 who categorized in satisfying level is as many as 23 students or 67.6% of the total students in the class, the number of students of class XI MIPA 1 who categorized in less satisfying level is as much as 1 person or 2.9% of the total students in the class and no students of class XI MIPA 1 who is categorized in not satisfying level. Suggestions from the result of this research that can be described by researcher are (1) To the next researcher, it is suggested to find literature as much as possible to strengthen the theory, (2) Selecting classes for research's subjects with more heterogeneous math skills, (3) Solidify creative thinking level in problem solving of mathematical problems indicators in order to be able to analyse the level of creative thinking in problem solving better.

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