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Improving student's mathematical creative thinking and habits of mind using a problem-solving approach based on cognitive thinking stage

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Abstract. This research is a pre-post-test experiment that aims to examine the role of the problem-solving approach (PSA) and students' cognitive intelligence on mathematical creative thinking abilities (MCTA) and mathematical habits of mind (MHoM). This study involved 50 8th grade students. The instruments used were TOLT test, MCTA test, and MHoM scale. This research found that students at the age of 13-14 years are at the stage of formal, transition, and concrete thinking. Whereas MCTA students who receive learning with PSA achieve better grades than students taught by the scientific approach (SA). The MCTA level of students who receive PSA is good and sufficient for students who receive SA. Both groups of students are still aware of some difficulties in completing MCTA tasks, such as solving problems improperly, in more than one way, and or in different ways. The MHoM results of the two students were not different, they were at a good level. Based on the cognitive thinking stage, it was found that there were significant differences in the improvement of MCTA between the two classes, there was a certain stage of thinking in the MCTA of the two classes, and there was no interaction. While for MHoM there is no difference in terms of approaches and stages of thinking, and there is no interaction. In Other findings, there is no relationship between MCTA and MHoM.

1. Introduction

Every learning system encourages students to be able to think creatively. **Creative thinking ability (MCTA) is an important ability possessed by** students to deal with everyday problems, especially in learning activities [1]. MCTA consists of four activities, namely 1) fluency 2) flexibility, 3) originality cover, 4) elaboration [2]. The activities or components of the MCTA describe HOTS in mathematics. By establishing creativity as HOTS, students are expected to have the ability to solve various unexpected problems in the future [3]. MCTA in learning mathematics will stimulate students' ability to find various ideas or solutions in solving mathematical problems [4]. This shows that CT is the essence of mathematics [5]. Then so that students have the MCTA, students must master mathematical content, have good thinking habits, and certain cognitive learning readiness. This is certainly related to the concept of mathematical habits of mind (MHoM) and students' formal operational thinking.

MHoM as a habit of thinking flexibly, managing and listening empathically, asking questions, solving problems effectively, using past knowledge for new situations, communicating, thinking correctly, using all the senses when gathering information, trying various ways and generating ideas-new ideas, responding, taking risks, being responsible, having a sense of humor, getting interactive



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thinking with others, being open and trying continuously [6]. MHoM will help students to become competent, creative, and independent people and responsible for their activities. The discussion on MHoM will use a related theory, namely the development of the cognitive stages of Piaget. The development of cognitive stages is divided into sensorimotor (0-2 years), preoperative (2-7 years), concrete operations (7-12 years), and formal operations (12 years - adults) [7]. Measuring the cognitive stage of students can use the test of logical thinking (TOLT) [8].

The importance of MCTA and MHoM students is not following conditions in the field, ie the results of the study show that MCTA students are classified as low [9-13]. Then the results of other studies show that students' MHoM is relatively low [10].

Exploring MCTA students need to develop a learning model that can find mathematical problem-solving solutions that are easy, flexible, and up to date [14]. Mathematical creativity will be difficult to develop if one is limited to rule-based implementation without recognizing the essence of the problem that must be solved [5]. So the development of MCTA must be carried out in conjunction with MHoM students to meet the required needs. In this case, the authors consider that the problem-solving approach (PSA) is the right solution. This approach focuses on activities on MCTA, then is followed by strengthening skills and developing other abilities. PSA can be applied to anticipate problems that arise during the mathematics learning process and can generate creative ideas for students [1]. Based on the explanation, the purpose and formulation of the problems in this study are a) measuring the percentage of the concrete, transition, and formal stages of students using TOLT; b) measure the learning outcomes of MCTA and MHoM students who use PSA; c) analyze the difficulties experienced by students in completing MCTA questions referring to their cognitive stage; and d) determine the existence of an association between MCTA and MHoM whose learning uses PSA.

2. Method

This research is a pre-post-test experimental design that aims to analyze the role of PSA on MCTA and MHoM students. The population in this study were private junior high school students in the city of Bandung, this study involved 50 eighth grade students who were divided into experimental and control classes. The instrument used was a Test of Logical Thinking (TOLT), MCTA test of 4 questions, MHoM scale of 30 items. The following sample items are MCTA, TOLT, and MHoM scales. As for examples, the test instruments are listed in the Figure 1 and Figure 2 respectively.

A block measuring 24 cm x 20 cm x 25 cm contains water as high as 20 cm. Then slowly inserted an iron pyramid-shaped object with a side length of 6 cm and a height of 10 cm into the beam.

- Sketch the situation!
- Determine the height of the water increase after adding 1 and 2 of the pyramid.
- Check the amount of pyramid put in water:
 - so that the water surface is below a height of the beam
 - so that the water level is as high as the beam
 - so that water will be spilled.

Figure 1. Test instrument on students' mathematical creative thinking ability (fluency)

The Flower SeedsItem 6

A gardener bought a package of 21 seeds. The package contents listed:

- 3 short red flowers
- 4 short yellow flowers
- 5 short orange flowers
- 4 tall red flowers
- 2 tall yellow flowers
- 3 tall orange flowers

If just one seed is planted, what are the chances that the plant that grows will have red flowers?

- a. 1 out of 2
- b. 1 out of 3
- c. 1 out of 7
- d. 1 out of 21
- e. Other

Reasons:

1. One seed has to be chosen from among those that grow red, yellow, or orange flowers
2. $\frac{1}{4}$ of the short and $\frac{4}{9}$ of the tall are red.
3. It does not matter whether a tall or a short is picked. One red seed needs to be picked from a total of seven red seeds
4. One red seed must be selected from a total of 21.
5. Seven of the twenty-one seeds will produce red flowers.

Figure 2. Test instrument of TOLT

Related to the instrument of habit of minds, as for examples the non-test instruments are listed in the Figure 3

<u>Note:</u> <u>QO: quiet often</u> <u>O : often</u>		<u>ST: sometimes</u> <u>S : seldom</u>	<u>QS: quiet seldom</u>		
<u>No</u>	<u>Activity, Feeling, or Opinion</u>	<u>QO</u>	<u>O</u>	<u>ST</u>	<u>S</u> <u>QS</u>
1	I try to solve the difficult problem of SLETV even if it takes more time				
2	I am confused when my friend draws the graph equation of a line unusually.				
3	I try to complete a difficult problem of line equation by using various strategies				
4	I am reluctant to review the truth of completion of SLETV problem that has been solved				
5	I realize difficulty to imply SLETV concept in daily life problem				
6	I avoid solving the problem of SLETV having many solutions				
7	I can receive different ideas when we are discussing a difficult problem of SLETVm				
8	I think my failure experience in solving a difficult problem will motivate me to learn better				

Figure 3. Mathematical Habits of Mind Scale

3. Result and Discussion

The provision of cognitive thinking stage tests, one of which uses TOLT, is a benchmark that students' cognitive thinking patterns can vary. From Table 1, the cognitive thinking stages of grade 8 middle school students aged 13-14 years as many as 50 people who were tested using the TOLT instrument produced 3 groups, namely formal (2%), transition (18%), and concrete (80%). This becomes a reference in the statistical test of student learning outcomes based on the cognitive thinking stage.

Table 1. Recapitulation of Cognitive Thinking Stages Students use TOLT

Learning	Cognitive Thinking Stage						Total
	Formal	%	Transition	%	Concrete	%	
PSA	0	0	4	16	21	84	25
SA	1	4	5	20	19	76	25
Total	1	2	9	18	40	80	50

Student MCTA achievement scores, MCTA N-Gain, and MHoM are presented in Table 2. Table 2 shows that the students' initial MCTA scores were at a low level with the two MCTA differences from the start. In the post-test MCTA grades, students who received PSA were at a good level and students who received the SA were at a sufficient level. In MCTA gain experiment class students get better results than control class students. As for the MHoM results, the two classes have almost the same value, with a good level.

Table 2. Description of MCTA, MHoM and Perception on PSA

Variables	Stat	Problem Solving Approach (PSA)				Scientific Approach			
		Pre-Test	Post-Test	N Gain	n	Pre-Test	Post-Test	N Gain	n
MCTA IS : 44	$\bar{X}$	3.08	31.8	0.70	25	4.56	25.64	0.54	25
	%	7%	72.27%			10.36%	58.27%		
	S	2.06	5.61	0.13		3.74	6.92	0.17	
MHOM IS : 136	$\bar{X}$		88,28		25		87,12		25
	%		64.91%				64.06%		
	S		10.59				8.15		

The statistical test of the differences in the independent sample t-tests to see their significance with the results in Table 3. MCTA and N <Gain> MCTA students who received PSA were significantly better than students who received SA, this shows PSA has an advantage over SA [10,15]. While the MHoM data test results showed no significant differences for the two classes. the same achievement between innovative learning and ordinary learning [10].

Table 3. Testing Hypothesis of Mean Difference of MCTA and MHOM

Variables	Teaching Approach	$\bar{x}$	SD	n	Sig (2-tailed).	Sig(1-tailed).	Interpretation
MCTA	PSA	31.80	5.61	25	0.001	0.000 < 0.05	MCTA _{PSA} > MCTA _{SA}
	SA	25.64	6.91	25			
N-Gain MCTA	PSA	0.7	0.13	25	0.000	0.000 < 0.05	N-Gain MCTA _{PSA} > N-Gain MCTA _{SA}
	SA	0.47	0.16	25			
MHOM	PSA	88.28	10.59	25	0.666	0.333 > 0.05	No difference MHoM _{SA} and MHoM _{SA}
	SA	87.12	8.15	25			

After testing the normality of student learning outcomes both classes are normally distributed. Then the average difference test is performed using the Two-Way ANOVA test based on the formal, transition, and concrete thinking stages in Table 4.

Table 4. Summary of Two Way ANOVA test base level TOLT of students' MCTA and MHoM

Variables	Normality		Levene's Test	Tests of Between-Subjects Effects		
	PSA	SA		Approach	TOLT	Approach*TOLT
MCTA	0.200	0.200	0.229 > 0.05	0.037 < 0.05	0.029 < 0.05	0.098 > 0.05
MHoM	0.200	0.200	0.097 > 0.05	0.120 > 0.05	0.101 > 0.05	0.118 > 0.05

Based on Table 4. From Levene's Test data Sig. = 0.229 > 0.05, it can be concluded that the variance of the results of MCTA and MHoM students are both homogeneous classes. Then the results of processing about the effect of the learning approach on the results of MCTA are that there are significant differences between the MCTA students of the experimental class and the control class at the significance level of 5%. Whereas for MHoM there is no significant difference between the MCTA students of the experimental class and the control class based on the approach.

Next, we can see the effect of cognitive thinking stages on students' MCTA and MHoM results. From Table 4 for MCTA sig. = 0.029 < 0.05 means that there is at least one group of students with a certain TOLT whose MCTA results are significantly different from other TOLT at the sig level of 5%. As for MHoM sig. = 0.101 > 0.05 means that there is no significant difference in the increase in MCTA between the thinking levels of the two classes.

On the interaction effect between the approach and TOLT result, in Figure 4 for MCTA and MHoM as well as from Table 4 sig. 0.098 and 0.118 > 0.05. This means that there is no significant difference between the difference in learning outcomes (MCTA and MHoM) obtained by PSA in the formal cognitive, transition, and concrete stages with students who obtain SA in the formal, transition, concrete stages at 5% sig.

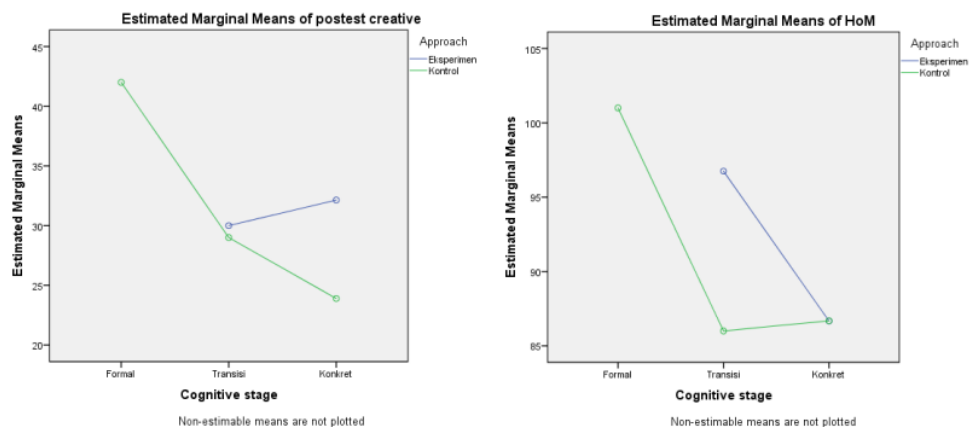


Figure 4. Interaction Curve

Furthermore analyzed the association between Mathematical Creative Thinking Ability and Mathematical Habits of Mind (Table 5).

Table 5. Association creative * HoM Crosstabulation PSA

Association MCTA	Association HoM			Total
	High	Medium	Low	
Low	0	3	2	5
Medium	1	5	2	8
High	1	8	3	12
Total	2	16	7	25

The correlation between MCTA and MHoM was carried out by contingency coefficient statistical tests with the results in Table 6. The results showed no correlation between MCTA and MHoM.

Table 6. Pearson-chi square test and contingency coefficient between MCTA and MHoM

Pearson Chi-Square	Df	Contingency Coefficient	Sig
0.954 ^a	4	0.192	0.917

In both classes, students were still aware of the difficulties in completing the MCTA assignment. The difficulty of students in completing MCTA assignments is illustrated in Table 7.

Table 7. Mean Score of Each Item of MCTA Test of Students

Teaching Approach	Statistic Descriptive	Indicators			
		Elaboration	Flexibility	Fluency	Originality
PSA	$\bar{X}$	8.56	7.32	9.16	6.76
	% of IS	71.33%	73.20%	76.33%	67.60%
SA	$\bar{X}$	6.92	5.48	7.4	5.84
	% of IS	57.67%	54.80%	61.67%	58.40%

Table 7 show that the achievement of PSA students in each indicator has reached a good level. While students in the SA on the indicators of elaboration, flexibility, and authenticity are at a sufficient and good level on the indicators of fluency. From the results of the observation, the perceptions of the two groups of students were still aware of some difficulties in completing MCTA assignments such as, (1) students had difficulty in finding answers in more than one way, but some students were already proficient in completing them; (2) most students have not been able to solve the problem, they have difficulty in finding the cut points with a slightly different form of inequality. This means they are difficult to see the problem with a different perspective; (3) most students have understood questions and can solve problems, but some students have difficulty in expressing new things to make conclusions; (4) story questions made by students are too simple, this shows they have difficulty in expressing and composing a story problem. (5) almost all students find it difficult to construct story problems into mathematical models and students find it very difficult to enrich and develop a product. Such experiences occur because students are not accustomed to solving non-routine problems [16-23].

4. Conclusion

This study found that students at the age of 13-14 years were at the stage of formal thinking, transitioning, and concretizing differently from Piaget's theory. Whereas MCTA and N <Gain> MCTA students who received learning with PSA achieved better grades than students taught by SA. Students who get PSA, their MCTA level are good. Whereas students who get SA, these MCTA levels are sufficient. Both groups of students are still aware of some difficulties in completing MCTA tasks, such as solving problems improperly, in more than one way, and or in different ways. At MHoM, although the first group students achieve better grades than the second-grade students, both grades are at a good

level. Based on the cognitive thinking stage, it was found that there were significant differences in the improvement of MCTA between the two classes, there was a certain stage of thinking in the MCTA of the two classes, and there was no interaction. Whereas for MHoM there are no differences in approach, stage of thinking, and no interaction. In other findings, there is no relationship between MCTA and MHoM.

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