Analysis of Creative Thinking Process Based on Metacognitive with Project Work Models

Detalia Noriza Munahefi
Universitas Negeri Semarang
Semarang, Indonesia
detalia@mail.unnes.ac.id

Kartono
Universitas Negeri Semarang
Semarang, Indonesia

Budi Waluya
Universitas Negeri Semarang
Semarang, Indonesia

Dwijanto
Universitas Negeri Semarang
Semarang, Indonesia

Abstract* - One learning model that encourages students to develop mathematical creative thinking is the project work model. One of the factors that influence differences in mathematical creative thinking processes is metacognitive. Therefore, the aim of this study is to analyze students' mathematical creative thinking abilities based on metacognitive levels through the project work learning model. The research method used in this study is a combination of explanatory sequential design research methods. The research sample was taken through simple random sampling, where the sample was divided into experimental and control classes. While the technique of selecting research subjects for qualitative data collection is purposive sampling, namely subjects based on metacognitive, divided into high, medium, and low levels. The average value of the mathematical creative thinking test of the experimental and control classes was carried out by the comparative test results obtained in table 1. Based on table 1 Sign value 0.01 < 0.05 so that there is a difference in the average between the experimental and control classes. The average of the experimental class is 62.97 while the control class is 54. Metacognitive as one of the components that affect the ability of mathematical creative thinking. Stages of mathematical creative thinking process in students with metacognitive levels consist of understanding the problem, formulating problem solving strategies, implementing problem solving strategies, evaluating problem solving solutions.

Keywords:* *creative thinking mathematic, metacognitive, project work

I. INTRODUCTION

Mathematics as a science education where one of the main objectives of science education is to raise creative and productive individuals who can meet the needs of our lives and connect science with everyday life. This is in line with one of the goals of national education, which is to develop the potential of students to become capable, creative and independent human beings. Bart, Hokanson, Sahin, & Abdelsamea (2015) stated that creative is becoming an increasingly important area in the field of education. Fatah, et al (2016) also stated that creativity was the focus of learning, especially in mathematics. Mathematical creativity at the school level according to Shriki (2010) was expected to be able to offer new insights in solving mathematical problems. In addition, Wessel (2014) stated that creativity in mathematics can encourage students to use new and unusual strategies in solving problems.

Individual creative ideas emerge in mathematics learning not suddenly but after various processing of symbols, facts, and investigation of problems through a certain set of processes. Therefore creativity is the result of creative thinking processes. The creative process of creative thinking according to Krulik and Rudnick (1995) involved the stage of synthesizing ideas, arousing or constructing ideas, and implementing ideas. Treffinger & Isaksen (2005) consisted of: (1) understanding the problem including the stages of finding goals, finding data or facts and finding problems as target questions, (2) generating ideas, and (3) planning actions by analyzing, developing choice of ideas as appropriate, prepare a choice or alternative to increase support and value. Wallas as quoted by Solso, Maclin, and Maclin (2008) explained that there are four stages in the creative process, namely preparation, incubation, illumination, and verification.

Students have different mathematical creative thinking processes. This is in line with Maharani, Sukestiyarno, and Waluya (2019) who stated that differences in mathematical creative thinking processes are due to differences in levels of motivation, background, attitudes towards learning, and different responses to the classroom environment. Students need self-regulation to be able to learn discipline in managing and controlling themselves and emphasize self-initiative. Research on mathematics learning shows that self regulated learning (SRL) has an effect on mathematical performance (Fast, Lewis, Bryant, Bocian, & Cardullo, 2010). Hadwin & Oshige (2011) stated that SRL is a learning process that actively monitors and regulates metacognitive, motivational, and behavioristic aspects. Therefore this study groups students' mathematical creative thinking abilities based on metacognitive levels.

Students are encouraged to be actively involved in learning so as to foster mathematical creative thinking abilities. (Kwan & Wong, 2014; Tandiseru, 2015; Tunca, 2015) stated that a mathematics learning environment that encourages students to actively participate in open investigations and explore various techniques and solutions can have a major impact on students' critical and creative thinking skills. One learning model that encourages students to be involved in open investigations is the project work model. Project Work encourages students to focus on the problem solving process, so students must explore various information in order to determine their own mental concepts by following the instructions compiled by the teacher that lead to the achievement of learning goals. Based on the description above, the purpose of this study is to analyze students' mathematical creative thinking abilities based on metacognitive levels through the project work model.

II. METHODS

The research method used in this study is a combination of explanatory sequential design research methods. Explanatory sequential design begins with quantitative data collection that provides an overview of the research problem followed by qualitative data collection to help explain or elaborate quantitative results. Quantitative data were obtained from mathematical creative thinking ability test results while qualitative data were obtained through observations and interviews with research subjects at each metacognitive level.

The study was conducted on high school graduate students. The research sample was taken through simple random sampling. This sampling technique provides an equal opportunity for each member of the population to become a research sample. The research sample is divided into two classes, namely the experimental class and the control class. The treatment given to the experimental class is learning with the project work model while the control class uses conventional learning models.

The technique of selecting research subjects for qualitative data collection is purposive sampling. Purposive sampling is researchers intentionally choose individuals to study and understand central phenomena. Taking the subject of this study is based on metacognitive levels. Researchers divide metacognitive levels into three levels, namely high, medium, low. Each of these levels was selected three research subjects to be analyzed mathematical creative thinking processes.

III. RESULTS AND DISCUSSION

A. Results

The average value of the mathematical creative thinking test of the experimental and control classes was carried out by the comparative test results obtained in table 1. Based on table 1 Sign value 0.01 < 0.05 so that there are differences in the average between the experimental and control classes. The experimental class score is 62.97 while the control class is 54. Therefore the experimental class average is higher than the control class.

Regression analysis to test the effect of metacognitive on mathematical creative thinking abilities. Table 2 shows the significance values in the linearity test to test eligibility. The significance value of 0.043 <0.05 so that there is a metacognitive influence on the ability to think mathematically creative. The regression model of the metacognitive influence on mathematical creative thinking ability is $\hat{Y} = 33.769 + 0,397X$.

Table 1. t-test of Two samples

Levene's Test		t-test for Equality of Means			
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
.218	.642	-2.656	56	.010	-8.971
		-2.561	41.388	.014	-8.971

Table 2. Linearity Test

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	549.96	1	549.95	4.45	.043[a]
Residual	4.077.02	33	123.55		
Total	4.626.97	34			

Based on questionnaires, students with low, medium and high metacognitive levels were obtained. Each metacognitive level was chosen by three research subjects for in-depth research into mathematical creative thinking processes. The nine subjects were observed and interviewed related to the stages of creative thinking in each of the research subjects. The group with high metacognitive levels is called ST, the group of subjects with moderate metacognitive levels is called SS. Whereas the group with low metacognitive levels is called SR. The following describes the mathematical creative thinking process at each level of metacognitive.

Figure 1 shows how ST subjects tried to understand the problem. ST write down the components of the problem in detail. ST is able to identify questions that will be solved in these questions. Figure 1 shows that ST writes in detail all the components of the problem, scales the graph based on the problem description, and writes the components of the problem.

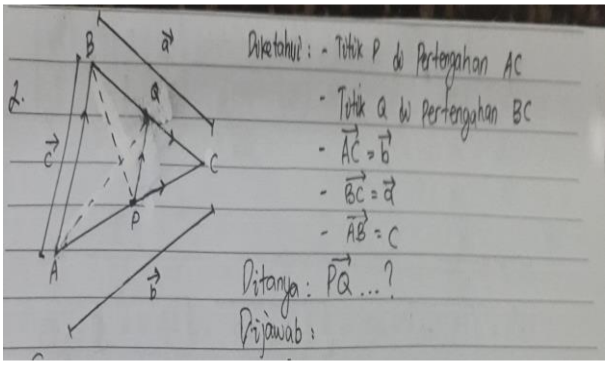

Figure 1. ST subjects Understanding Problems

The following are excerpts of interviews with ST to find out the next steps taken after ST understands the problem. Based on excerpts from observational interviews it was found that the steps that ST did in order to determine the problem solving strategy were to recall the concepts that had been learned. Because the level of difficulty of the questions is quite high, the ST for a moment ponders various appropriate completion steps. ST also connects various concepts that have been learned in solving these problems.

Teacher: What are the next steps you take to find a solution to the problem?

ST: I try to recall the material and formula that I learned earlier. Then I reasoned to relate it to the problem I was having.
Teacher: What are the difficulties you face when trying to find a solution to the problem!
ST: The difficulty level of the questions given is quite high
Teacher: How do you deal with it!
ST: I pondered for a moment how the right steps in solving the problem. I was curious and kept thinking about how the solution would be if faced with a difficult problem. Therefore, I imagined various solutions to the settlement strategy with the concepts I had learned in order to obtain the right way.

The next step ST did in solving mathematical creative thinking problems was to determine a solution strategy. Figure 2 below shows how ST formulate problem solving strategies. ST is able to identify the problem in a vector projection sketch where there is $\bar{b}$ which is projected against $\bar{a}$ so the result is vector $\overline{b_1}$. Therefore ST can find a solution through the application of the orthogonal vector projection concept.

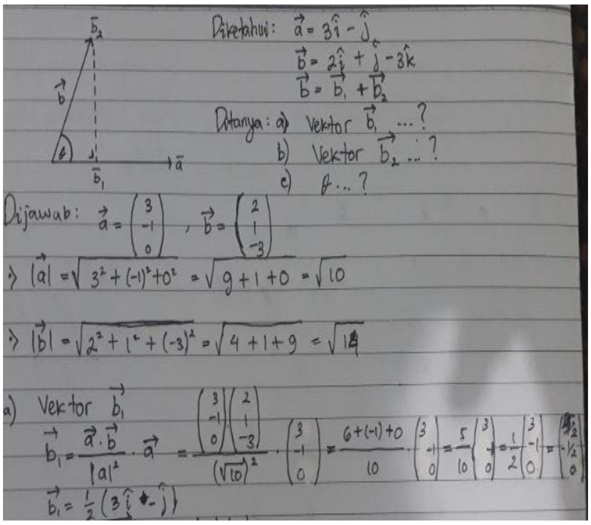

Figure 2. ST Implementing a Problem Solving Strategy

The next step taken by ST after finding a solution of the problem based on interviews and observations is to check the solution obtained. Figure 3 below shows how ST check problem solving. ST subjects use different resolution strategies to check the solution to the problem. Based on Figure 3 the same results are obtained despite using different strategies.

Teacher: What is the purpose of using several problem solving strategies?
ST: To be able to convince me that my calculation results are correct.
Teacher: What if the results you get are different?
ST: I will monitor each sequence of steps to solve the problem
Teacher: What are the steps you take so that you get a solution to the strategy that is different from the solution to the problem obtained?
ST: I am trying to find simpler completion steps through concepts that I have known for a long time but were not discussed in the material.

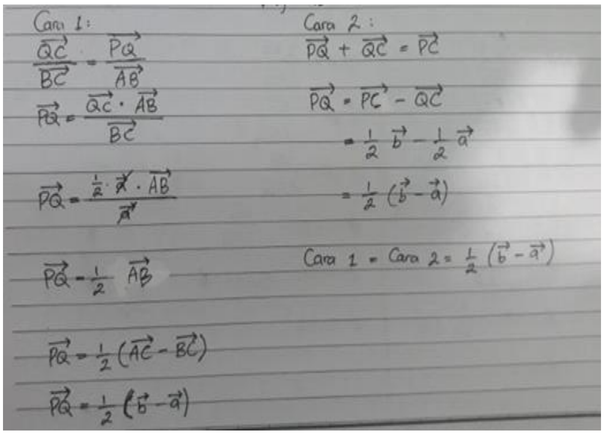

Figure 3. ST Checking Resolution

The first step taken by SS to solve mathematical creative thinking test questions is to understand the problem. Figure 4 shows how SS understood the problem. SS mention the components of the problem in detail. Furthermore, SS were also able to identify questions on the question. Figure 4 also shows that SS were able to draw on the basis of the problem description and write the components in the picture.

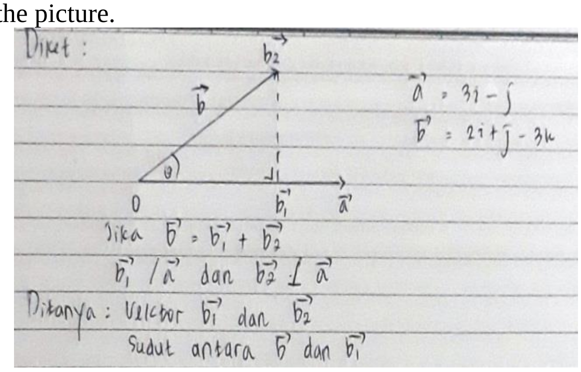

Figure 4. SS Understanding the Problem

Steps taken by SS after understanding the problem can be seen from the following interview excerpt. Based on the interview excerpt, it is known that the steps taken by SS in order to determine strategies for solving mathematical creative thinking problems are to recall concepts that have been learned. Then the SS also related various concepts that had been learned in solving the problem. Because the level of difficulty of the questions is quite high, the SS need quite a long time to be able to decide on the problem solving strategy used.

Teacher: What are the next steps you take to find a solution to the problem?

SS: I identified the relationship of each component to the problem. Then I try to connect with the concepts I have learned.

Teacher: What are the difficulties you face when trying to find a solution to the problem!

SS: I try to remember concepts I already understand and try to connect with the problem. Because the problem that I think is quite difficult, then I need a long time to decide on the settlement strategy that I use.

The next step SS after choosing a problem solving strategy is to apply it to find a solution to the problem. Figure 5 below shows how SS apply mathematical creative thinking problem solving strategies. Figure 5 shows the SS subjects able to translate the problem in a vector projection sketch. Therefore, SS subjects can find solutions through the application of orthogonal vector projection concepts.

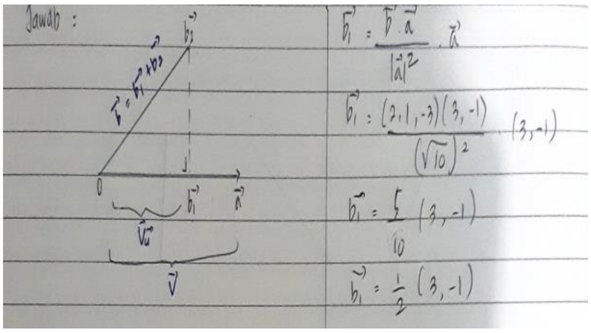

Figure 5. SS Implementing a Problem Strategy

The final step taken by SS in solving mathematical creative thinking problems is checking the solutions obtained. Figure 6 below shows that SS subjects did not check through the use of different settlement strategies. Figure 6 shows that SS found a vector solution $\overline{PQ}$ in only one way. Based on the interview excerpt it is known that SS did not have enough time to find a different settlement strategy. This can be caused by SS spending a lot of time at the stage of deciding to use problem solving strategies.

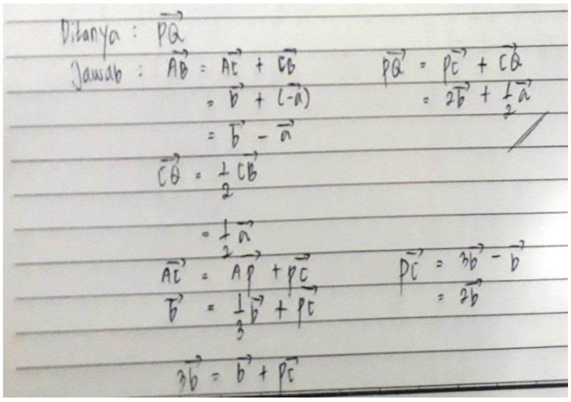

Figure 6. SS checking solution

Teacher: How do you check the solutions obtained?

SS: I did the recalculation

Teacher: Why don't you use another solution to check solutions?

SS: I did not have time to think of another settlement strategy.

The initial step taken by SR to solve mathematical creative thinking test questions is to understand the problem. Figure 7 shows how SR understood the problem. SS mention the components of the problem in detail. Furthermore, SS were also able to identify questions on the question. Figure 4 also shows that SS are able to draw on the basis of the problem description and write the components in the picture.

The steps taken by SR subjects after understanding the problem can be seen from the following interview excerpt.

Teacher: What are the next steps you take to find a solution to the problem?

SR: I am trying to understand the relationship of

each component to the problem. Then I connect with the material that I have learned.
Teacher: What are the difficulties you face when trying to find a solution to the problem!
SS: The level of difficulty of the questions is high so it takes me a long time to decide to use a problem solving strategy.

Based on interview excerpts, it is known that the steps that SR take in order to determine strategies for solving mathematical creative thinking problems are understanding the relationship of each component to the problem. Then the SR lso relates to the material that has been studied. Because the level of difficulty of the questions is quite high then SR have difficulty to require a long time to decide on the use of problem solving strategies.

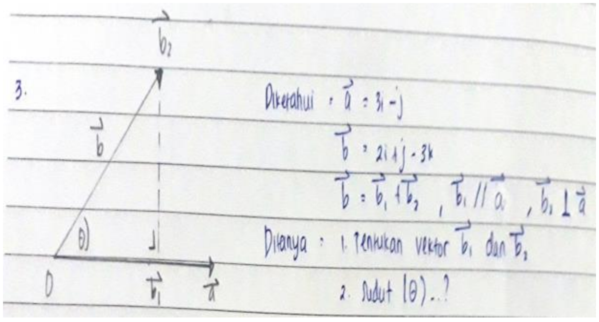
Figure 7. SS Understanding the Problem

The next step SR are implementing problem solving strategies to find solutions to problems. Figure 7 below shows how SR apply mathematical creative thinking problem solving strategies. Figure 7 shows the SR were able to apply concepts that were in accordance with the problem but the calculations made were incorrect.

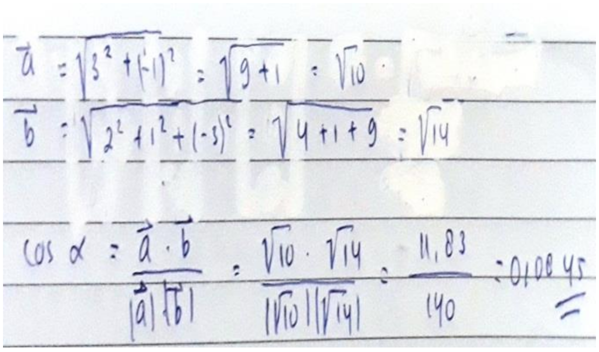
Figure 8. SS Implementing a Problem Strategy

The final step taken by SR in solving mathematical creative thinking problems is checking the solutions obtained. Based on the results of interviews and observations that the SR did not check the solution to solve the problem because the timing in solving the problem was not good so the SR subjects ran out of time.

IV. DISCUSSION

Students who are taught with project work models have higher mathematical creative thinking abilities than students who are taught with conventional models. The project work model is able to develop mathematical creative thinking skills. This is in line with Ummah, et al (2019) which states that project-based learning can increase mathematical creativity. Project work encourages students to develop mathematical projects that have different solutions to each other. Mathematical creativity at the school level according to Nadjafikhah (2012) is generally related to problem solving. Therefore, the students' mathematical creative thinking process can be obtained based on the results of the mathematical creative thinking test. Metacognitive as one of the factors that positively influences the ability to think creatively. Metacognition according to Ozsoy (2011) refers to a strategy of learning, planning, and validation of the learning process. Therefore differences in metacognitive levels result in differences in mathematical thinking abilities.

The process of creative thinking in students with high levels of metacogitive consists of understanding the problem, formulating problem solving strategies, implementing problem solving strategies, evaluating problem solving solutions. metacognition emphasizes the importance of controlling cognitive mind during problem solving, so metacognition can help students understand concepts (Mokos and Kafoussi, 2013). Therefore, students with high metacogitive levels can evaluate through the use of different problem solving strategies. The process of creative thinking in students with metacogitive levels is composed of understanding the problem, developing problem solving strategies, implementing problem solving strategies, and evaluating problem solving solutions. Students with a metacogitive level are evaluating problem solving solutions with careful recalculation. The process of creative thinking in students with low metacogitive levels consists of understanding the problem, developing problem solving strategies, implementing problem solving strategies. Students with low metacogitive levels do not do the evaluation because they need a long time to develop a strategy to solve the problem. Therefore students with low metacogitive levels are less thorough in doing calculations.

V. CONCLUSIONS

The project work model effectively develops mathematical creative thinking abilities so that mathematical creative thinking processes can be analyzed through the model. Metacognitive as one of the components that affect the ability of mathematical creative thinking. The stages of the mathematical creative thinking process in students with high and moderate levels of metacognitive consist of understanding the problem, formulating a problem solving strategy, carrying out the problem solving strategy, evaluating the problem solving solution. But there is an evaluation stage between students with high and moderate metacognitive levels. While the process of creative thinking in students with high metacogitive levels consists of understanding the problem, formulating a problem solving strategy, implementing a problem solving strategy.

REFERENCES

[1] Bart, W. M., Hokanson, B., Sahin, I., & Abdelsamea, M. A. (2015). An investigation of the gender differences in creative thinking abilities among 8th and 11th grade students. *Thinking Skills and Creativity*, *17*, 17-24.

[2] Fast, L. A., Lewis, J. L., Bryant, M. J., Bocian, K. A., Cardullo, R. A., Rettig, M., & Hammond, K. A. (2010). Does math self-efficacy mediate the effect of the perceived classroom environment on standardized math test performance?. *Journal of educational psychology*, *102*(3), 729.

[3] Fatah, A., Suryadi, D., & Sabandar, J. (2016). Open-Ended Approach: An Effort in Cultivating Students' Mathematical Creative Thinking Ability and Self-Esteem in Mathematics. *Journal on Mathematics Education*, *7*(1), 11-20.

[4] Gerhana, M. T. C., Mardiyana, M., & Pramudya, I. (2017, September). The effectiveness of project based learning in trigonometry. In *Journal of Physics: Conference Series* (Vol. 895, No. 1, p. 012027). IOP Publishing.

[5] Hadwin, A., & Oshige, M. (2011). Socially shared regulation:Exploring perspectives of social in self-regulated learning theory. *Teachers College Record*, *113*(2), 240 -264.

[6] Krulik, S., & Rudnick, J. A. (1995). *The New Sourcebook for Teaching Reasoning and Problem Solving in Elementary School. A Longwood Professional Book*. Allyn & Bacon, 111 Tenth St., Des Moines, IA 50309.

[7] Maharani, H. R., Sukestiyarno, S., & Waluya, B. (2017). Creative thinking process based on wallas model insolving mathematics problem. *International Journal on Emerging Mathematics Education*, *1*(2), 177-184.

[8] Mokos, E., & Kafoussi, S. (2013). Elementary Student'Spontaneous Metacognitive Functions in Different Types of Mathematical Problems. *Journal of Research in Mathematics Education*, *2*(2), 242-267.

[9] Özsoy, G. (2011). An investigation of the relationship between metacognition and mathematics achievement. *Asia Pacific Education Review*, *12*(2), 227 -235.

[10] Shriki, A. (2010). Working like real mathematicians: Developing prospective teachers' awareness of mathematical creativity through generating new concepts. *Educational Studies in Mathematics*, *73*(2), 159-179.

[11] Solso, R. L., MacLin, M. K., & MacLin, O. H. (2008). Cognitive Psychology

[12] Tandiseru, S. R. (2015). The Effectiveness of Local Culture Based Mathematical Heuristic-KR Learning towards Enhancing Student's Creative Thinking Skill. *Journal of Education and Practice*, *6*(12), 74-81.

[13] Treffinger, D. J., & Isaksen, S. G. (2005). Creative problem solving: The history, development, and implications for gifted education and talent development. *Gifted Child Quarterly*, *49*(4), 342-353.

[14] Tunca, N. (2015). The regression level of constructivist learning environment characteristics on classroom environment characteristics supporting critical thinking. *Eurasian Journal of Educational Research*, 60, 181 -200.

[15] Ummah, S. K., In'am, A., & Azmi, R. D. (2019). Creating Manipulatives: Improving Students' Creativity through Project-Based Learning. *Journal on Mathematics Education*, *10*(1), 93-102.

[16] Wessels, H. M. (2014). Levels of mathematical creativity in model-eliciting activities. *Journal of Mathematical Modelling and Application*, *1*(9), 22-40.