An Analysis of Metacognition and Mathematical Self-Efficacy Toward Mathematical Problem Solving Ability

M B Susilo¹, H Retnawati²
¹Graduate Program of Mathematics Education, ²Department of Mathematics Education, Faculty of Mathematics and Natural Science, Yogyakarta State University

Abstract. Mathematical problem solving ability was required in NCTM in addition to the ability of connection, communication, and mathematical representation. In other side, metacognition plays a important role in the process of solving problems in mathematics. Another factor predicted having important role in setting the cognitive processes of students in problem solving is self-efficacy. The main purpose of this study was to measure the relationship about metacognition and mathematical self-efficacy towards mathematical problem solving ability. The samples of this study are 345 students grade X of Senior High School in Kediri, East Java, Indonesia. The result of this study indicated significant relationship between metacognition and mathematical self-efficacy toward mathematical problem solving ability. It was concluded that metacognition and mathematical self-efficacy influence the mathematical problem solving ability.

1. Introduction
Problem solving ability is one of the most important abilities in learning mathematics. Mathematical problem solving ability is a capability that required in NCTM in addition to the ability of connection, communication, and mathematical representation. Mathematical problem solving ability is one aspect that is assessed in the national exam. The problem that becomes the focus to be solved by the students are the problem are not routine. The problem are like an opinion Liljedahl, Santos-Trigo, Malaspina, & Bruder [1] “Problems, then, are tasks that cannot be solved by direct effort and will require some creative insight to solve”. The solution of the problems are not obtained using a standard formula but requires more in-depth analysis. In solving the problem requires an ability such as opinion Gupta [2] “Problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills”. The problem that requires problem solving ability is the HOTS (High Order Thinking Skills) model, which is like Retnawati's opinion, "... that HOTS demand for more complex thinking in dealing with situations or solving a problem"[3]. Broadly speaking, problem solving ability is the ability to solve non-routine problems involving knowledge and skills. In the context of learning mathematics, problem solving ability is the ability of students in solving problems that are not routine.

According to Flavell [4] metacognition is “an individual’s awareness, consideration, and control of his or her own cognitive processes and strategies”. In line with Flavell, Dean & Kuhn explains that metacognition “...is defined in similar terms as awareness and management of one's own thought, or thinking about thinking” [5]. Opinion Flavell and Dean have similarities in aspects of awareness and control of a person's cognitive process. While Koriat, Ackerman, Adiv, Lockl, & Schneider argue that “Metacognitive monitoring refers to the subjective assessment of one’s own cognitive processes and knowledge” [6]. Schneider & Artelt define “Metacognition refers to people's knowledge of their own information-processing skills, as well as knowledge about the nature of cognitive tasks, and of strategies for coping with such tasks” [7]. Based on the opinion of some experts it can be concluded that
metacognition is a person's awareness in controlling and evaluating the cognition process. In metacognition there are elements of monitoring, control, and evaluation of a person's cognition process.

Bandura defines self-efficacy as self-confidence in a person's ability to deal with a problem [8]. Mathisen & Bronnick argue that “Self-efficacy as the belief in one’s ability to produce lots of ideas” [9]. Bandura and Mathisen's opinion has similarities in aspects of self-confidence over the ability possessed by someone. A slightly different opinion is delivered by Van Dinther et. al. [9] “Self-efficacy as a belief of personal competence acts upon human behaviour in different ways”. In line with Van Dinther, [10] argue that “Self efficacy is the belief that one can succeed in performing particular behaviors”. Based on the opinions of some experts it can be concluded that self-efficacy is a belief in self-ability in dealing with various situations and conditions.

Metacognition is an important aspect of the learning process. Metacognition plays a major role in the process of solving problems in mathematics. Like opinion Pannequin, Sorel, Nanty & Fontaine [11] “Metacognitive knowledge and metacognitive skills are linked to problem-solving performance”. In addition to metacognitive ability, another factor suspected to play a role in setting the cognitive processes of students in problem solving is self-efficacy. [12] "A strong sense of efficacy facilitates cognitive processes and performance in a variety of settings, including quality of decisionmaking and academic achievement". This opinion is reinforced by the results of Kitsantas et.al research where the mathematical self-efficacy and mathematical problem-solving abilities depicted by mathematics learning achievement have a high correlation index \((r = 0.54, p < 0.001)\) [13]. Thus the outline of self-efficacy beliefs facilitate the cognitive processes of students in the process of solving problems which further able to improve student academic achievement in the process of learning mathematics.

The results of TIMSS 2015 [14], Indonesian students are ranked 45 out of 50 countries. It shows that Indonesian students are still weak in terms of solving math problems. These weaknesses are seen in solving non-routine problems which require in-depth analysis. Based on these facts it is suspected that the low ability of problem solving of students' math is related to low mathematical self-efficacy and metacognition of students. The purpose of this research is to know the empirical relationship between metacognition and self-efficacy to students problem solving abilities. Having known these empirical relationships, teachers can design learning tools and mathematics textbooks that can accommodate aspects of student mathematical self-efficacy and metacognition. So, it is expected to be able to improve students' ability in solving mathematical problems which can further improve student achievement in mathematics.

2. Method

This is a survey study to analyze metacognition and mathematical self-efficacy toward the mathematical problem solving ability. The population in this study are 345 students grade X of Senior High School in Kediri Regency, which most of the population come from rural. Determination of sample research using technique proportionate stratified random sampling. The sample is divided into three level that is high, medium, and low by using the average data of National exam of mathematics 2017. Then, to determined the size of the sample has used the Slovin formula.

| Level  | Population (N) | Sample (n) |
|--------|----------------|------------|
| High   | 645 students   | 26%        | 88 students |
| Medium | 927 students   | 37%        | 127 students |
| Low    | 952 students   | 38%        | 130 students |
| Total  | 2524 students  | Total (n)  | 345 students |

Non-test instruments are used to measure students' metacognition and mathematical self-efficacy in the form of questionnaires. The questionnaires used to measure students' metacognition were the
Metacognitive Awareness Inventory (MAI) questionnaire developed by Schraw and Denisson [15] with various context adjustments ie problem solving. Consisting of 30 items of statement in the form of 16 positive statements and 14 negative statements. Student mathematics self-efficacy questionnaires were used to measure students' mathematical self-efficacy in learning mathematics. A metacognition questionnaire is in the form of a checklist (√) using a Likert scale consisting of 5 criteria, always (A), often (O), sometimes (S), rare (R), and never (N). But the mathematics self-efficacy questionnaire using Bandura’s scale from 1 to 9 level to countering the level of student’s mathematical self-efficacy.

The test instrument is used to measure the ability to solve mathematical problems. The math problem solving test uses two essay questions. The mathematical problem-solving indicators correspond to the Krulick and Rudnick versions of the problem-solving model Read, Exploration, Select a Strategy, Solve the Problem, and review. The validity of the test and non test instruments in this study used content validity by two expert judgements from Yogyakarta State University. While specifically for mathematical self-efficacy and metacognition instruments using construct reliability.

| Table 2. Reliability Criteria. |
|--------------------------------|
| Reliability Value | Classification |
| (α or r₁₁) >0.8 | Very high |
| 0.6 < (α or r₁₁) ≤ 0.8 | High |
| 0.4 < (α or r₁₁) ≤ 0.6 | Medium |
| 0.2 < (α or r₁₁) ≤ 0.4 | Low |
| (α or r₁₁) ≤ 0.2 | Very low |

With the results of the calculation of the reliability of the instrument can be seen in the table below.

| Table 3. Reliability Statistics of Instruments. |
|-----------------------------------------------|
| Variables | Cronbach's Alpha | N | Reliability Information |
| Metacognition | 0.813 | 30 | Very high |
| Mathematics self-efficacy | 0.863 | 30 | Very high |

Questionnaires of mathematics self-efficacy and metacognition were shared with respondents at the first meeting. While the mathematical problem solving test is given at the second meeting for each sample class. Respondents filled out mathematics self-efficacy questionnaires and metacognition with time allocation of 30 minutes each. While at the second meeting allocated 60 minutes for two math problem solving tasks.

The results of questionnaires and tests were analyzed using regression. In the univariate case was analyzed using Pearson product-moment statistics to determine the magnitude of the relationship between metacognition and mathematics self-efficacy with the ability to solve mathematical problems separately. While multiple correlation statistics and multiple linear regression in multivariate cases were used to determine how much relationship and influence between metacognition and mathematics self-efficacy with the ability to solve mathematical problems simultaneously. Regression model has passed the classical assumption tests that are linearity, normality, heteroscedasticity, and multicollinearity. So
that the regression model is feasible to use to estimate changes in the dependent variable caused by the independent variable.

**Table 4. Qualitative Criteria of Variables.**

| Interval                                      | Classification |
|-----------------------------------------------|----------------|
| $X > (\bar{X}_i + 1.8sb_i)$                  | Very High      |
| $(\bar{X}_i + 0.6sb_i) < X \leq (\bar{X}_i + 1.8sb_i)$ | High          |
| $(\bar{X}_i - 0.6sb_i) < X \leq (\bar{X}_i + 0.6sb_i)$ | Medium        |
| $(\bar{X}_i - 1.8sb_i) < X \leq (\bar{X}_i - 0.6sb_i)$ | Low           |
| $X \leq (\bar{X}_i - 1.8sb_i)$               | Very Low       |

Notes: 
$sb_i$ = Ideal Standard Deviation  
$\bar{X}$ = Average Ideal Score  
$X$ = Total Empirical Score

The conversion of quantitative data into qualitative data as shown in the table 4. This data conversion are used to categorize the scores that have been obtained in this study. the score indicates the position of metacognition, mathematical self-efficacy and student problem solving abilities of mathematics.

3. **Result and Discussion**

This research question whether there is a relationship between metacognition and mathematical self-efficacy to the mathematical problem solving ability. The statistical test that has been used to measure the magnitude of the relationship between metacognition and mathematical self-efficacy against mathematical problem solving ability is Pearson Product-Moment. The hypothesis in this research is a significant positive relationship between metacognition and mathematical self-efficacy against mathematical problem solving ability. Table 5 shows the relationship between research variables along with the means.

**Table 5. Means, Range and Correlations of study Variables (n = 345).**

| No. | Variables                     | Mean  | Range | Correlations |
|-----|-------------------------------|-------|-------|--------------|
|     |                               |       |       | 1  | 2  | 3  |
| 1.  | Mathematical Problem Solving  | 65.32 | 45-85 | 0.701** | 0.664** |
| 2.  | Ability                       | 103.23| 82-135|            | 0.669** |
| 3.  | Metacognition                 | 157.17| 100-230|           |           |
|     | Mathematical Self-Efficacy    |       |       |              |           |

**. Correlation is significant at the 0.01 level (2-tailed).

Average scores mathematical problem solving ability ($M = 65.32$) has shown students' ability in solving mathematical problems that have been given.

**Table 6. Qualitative Criteria of Mathematical Problem Solving Ability.**

| Interval       | Classification |
|----------------|----------------|
| 80 < X         | Very High      |
| 50 < X \leq 80 | High           |
| 40 < X \leq 50 | Medium         |
| 20 < X \leq 40 | Low            |
| X < 20         | Very Low       |

Based on the Table 6 students' mathematical problem-solving abilities are at high criteria. While for the results of each indicator of math problem solving ability can be seen in the Table 6.
Table 7. The Krulick & Rudnick’s Indicators of Mathematical Problem Solving Ability.

| Indicators       | Max Score | Scores | % Total Score | % Max Score |
|------------------|-----------|--------|---------------|-------------|
| Read and Thinking| 1648      | 1269   | 26            | 77          |
| Explore          | 1648      | 1232   | 25            | 75          |
| Select a Strategy| 1648      | 995    | 20            | 60          |
| Solve            | 1648      | 701    | 14            | 43          |
| Review           | 1648      | 663    | 14            | 40          |
| Total            | 4860      |        | 100           |             |

Based on the Table 7, read and thinking indicator has allocated 26% of the total score and 77% of the maximum score for read and thinking. It shows that the ability of students is good enough in identifying and understanding the problems that are being done. In this case, students are also good enough in determining whether the information provided in the problem is lacking, enough or excessive. While to indicator of explore get allocation 25% from total score and 75% from maximum score explore indicator. This fact show that ability of student good enough in finding pattern or determine concept and principle what is in the problem. In this step students have been able to identify problems by representing it can be in pictures, concept maps, diagrams, tables and so forth. It aims to facilitate students in understanding the problem comprehensively. While for select a strategy indicator get allocation 20% from total score and 60% from maximum score select a strategy indicator. These facts show that the students' ability is good enough in making hypotheses about how to solve the problem, which is based on the discovery in the read and thinking and explore step. In this step most students have been able to determine what formula is appropriate to solve the problem although there are still not yet able to determine the appropriate formula to solve the math problem that is being done. While for solve and review indicators get 14% consecutive allocation of total score and 43% respectively and 40% from maximum score solve and review indicators. These facts show that the ability of students in the enough category in solving the problem in accordance with the method or formula that has been determined in the select a strategy step. besides the ability of students is still less in verifying the results of his work by testing the solution or re-checking and can conclude the results of the calculation by bringing back to the context of the problem. In addition, most students have not been able to expand in the use of other methods or formulas that might be used to find similar results.

The ability of students to work on HOTS type questions is still weak. This must be the teacher's attention in guiding students to improve mathematical problem solving abilities such as opinions expressed by retnawati et.al. in their research which states that "The results indicate that teachers' knowledge about HOTS, their ability to improve students' HOTS, solve HOTS-based problems, and measure students' HOTS is still low"[16]. The low ability of students in solving HOTS problems may be caused by the lack of teachers' ability to implement the 2013 curriculum that was announced by the government. This is in accordance with the research conducted by Retnawati et al. with the conclusions of the results of his research that is “... many teachers have not completely understood Curriculum 2013. The reason is that they are con- fused, afraid and not open their minds to the change; as a result, the effort to understand the curriculum are not maximal”[17]. In addition, the lack of supporting facilities such as limited learning media was allegedly the cause of students' low ability to solve non-routine problems. Like the opinion of retnawati et.at. "The teaching facilities in the form of learning resources and learning media are limited; as a result, the teachers are supposed to be creative so that the teaching and learning process can be well conducted "[17]. Another cause of the low ability of teachers in implementing the curriculum which results in low ability of students in solving mathematical problems is because of the government's inconsistency in implementing the curriculum. Like Retnawati et.al. "In
the past several years, there have been curriculum changes from Level Curriculum to the Curriculum 2013 to the Curriculum for the School Unit"[18]. So that teachers are confused in following government policies that often change in a not too long time. In addition, teachers also have difficulty in assessing students with a new curriculum as the results of research conducted by Retnawati et al. "The teachers have not fully understood the assessment system"[19].

While the average score of metacognition (M = 103.23) has shown students' awareness in organizing and evaluating their cognitive processes in solving mathematical problems. Based on the Table 8 metacognition scores of students are on the high criteria as well.

| Interval   | Classification |
|------------|----------------|
| 126 < X    | Very High      |
| 102 < X ≤ 126 | High       |
| 78 < X ≤ 102 | Medium     |
| 54 < X ≤ 78 | Low           |
| X < 54     | Very Low       |

Thus the aspects of awareness, control, monitoring, and evaluation of students' cognitive processes are quite good. While for the mathematics self-efficacy score (M = 157.17) has shown belief in the students' ability to solve the mathematical problems that have been given. The self efficacy score is in medium criteria as shown in the Table 9.

| Interval   | Classification |
|------------|----------------|
| 222 < X    | Very High      |
| 174 < X ≤ 222 | High       |
| 126 < X ≤ 174 | Medium     |
| 78 < X ≤ 126 | Low           |
| X < 78     | Very Low       |

This fact has shown that there are still many students who are less convinced of their own ability to organize, predict, and carry out the efforts required to achieve the goals and complete the tasks assigned. so students feel less confident in their ability that in reality most students are good enough in solving the math problems that have been given.

Table 5 has shown that the correlation between mathematical problem solving ability and metacognition has a significant positive relationship (r = 0.701, P < 0.05). So, students who have good metacognition are sure to have good mathematical problem-solving ability as well. The results of this study is same from the results of research that has been done by Hoffman [20]. Hoffman has found that metacognition affects efficiency and accuracy in mathematical problem solving.

While the relationship between mathematical problem solving ability with mathematical self-efficacy has shown a positive relationship and significant (r = 0.664, P < 0.05). The results of this study are similar to the results of research that has been completed by Kitsantas et. al. [13] (r = 0.54, P < 0.001). Other than that, this result is in accordance with the research completed by Hoffman [20]. Students with high mathematics self-efficacy are able to solve more mathematical problems than students who have lower self-efficacy levels.

Interestingly, the relationship between metacognition and mathematics self-efficacy showed significant correlation (r = 0.669, P < 0.05). The results of this study reinforce the results of research that has been completed by Christopher A.Was et. al. (r = 0.50, P < 0.01) [21]. Thus, students who have high mathematical self efficacy, have a high awareness of metacognition as well. The results of a study
done by Cera et al. [22] also showed a significant positive correlation \( r = 0.357, P < 0.01 \) between self-efficacy to students' metacognition awareness. So, students who have good metacognition, tend to have a good self efficacy as well.

Multiple regression analysis in table 10 shows how big influence of predictor variable that is metacognition and mathematics self-efficacy to dependent variable that is mathematical problem solving ability. Table 10 shows the model of multiple regression linear equations, metacognition variable \( (t = 0.000 < 0.05) \) have a significant effect on the dependent variable mathematical problem solving ability. While the mathematical self-efficacy variable \( (t = 0.000 < 0.05) \) did significantly influence the mathematical problem solving ability. The results of this study simillar from the results of study that has been completed by Hoffman [20] which concludes that metacognition and self efficacy affect the accuracy and efficiency in solving math problems.

### Table 10. Standart Multiple Regression for MCG and MSE Toward MPSA \( (n = 345) \).

| No. | Variables                  | 1      | 2      | Mathematical Problem Solving Ability (MPSA) |
|-----|----------------------------|--------|--------|--------------------------------------------|
|     |                            |       |        | \( r \) | \( B \) | \( \beta \) | \( t \) | \( Sig. \) |
| 1.  | Metacognition (MCG)        | 0.669 | 0.701  | 0.354 | 0.465 | 9.632 | 0.00 |
| 2.  | Mathematical Self-Efficacy (MSE) | 0.669 | 0.664  | 0.110 | 0.353 | 7.311 | 0.00 |
| 3.  | Constants                 | 11.607 | 4.092  | 0.00  | 0.00  | 0.00  | 0.00 |

Note: \( p < 0.05 \) \( R = 0.749 \) \( R^2 = 0.560 \) \( Adj. R^2 = 0.558 \) \( F = 217.867 \) \( Sig. = 0.000 \) (Metacognition and Mathematical Self-Efficacy)

Correlation index score \( (R = 0.749 \ P < 0.05) \) shows a multivariate correlation index between metacognition and mathematical self-efficacy toward mathematical problem solving ability. These results indicate that metacognition and mathematical self-efficacy have a significant relationship to the mathematical problem solving ability if analyzed simultaneously. So students who have high metacognition and mathematical self-efficacy scores tend to have high mathematical problem solving skills as well.

Based on the results shown in the Table 7, then the linear multiple regression equation obtained is

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MPSA = 11.607 + 0.354MCG + 0.110MSE + e
\]  \( (1) \)

\( e \) is another variable that does not include the predictor variable in this study. The score \( (R^2 = 0.560) \) shows the proportion of influence of predictor variable that is metacognition and mathematical self-efficacy is only 56%. Thus, metacognition and mathematics self-efficacy only affect 56% of mathematical problem solving ability. While the remaining 44% influenced by other variables that are not included in the multiple regression model that has been given. This is reinforced by the value \((F = 217.867 \ Sig. = 0.000 < 0.05)\) which indicates that the multiple regression model is feasible to be used to estimate the change of dependent variable that is mathematical problem solving ability.

Metacognition affects 32.60% of mathematical problem-solving abilities. This shows that metacognition plays a significant role in influencing problem-solving abilities for a student. Students who have good mathematical problem solving ability tend to have good metacognition as well. The meeting point of the relationship between metacognition and the ability to solve mathematical problems is HOTS problems where the problem of type HOTS requires good problem solving skills. metacognition is related to the ability of students to organize, and evaluate the results of thinking, while HOTS as conveyed by Apino & Retnawati "...HOTS in mathematics learning is important. It aims to develop students' ability to analyze, evaluate, and create, so that students have the critical power and creativity that can be used to solve problems in everyday life"[3]. Furthermore, the giving of HOTS type questions must be familiarized in the learning process in the classroom. So that students are able to develop mathematical problem solving skills, as Hadi et. al. which states that "The students' habits to
solve the HOTS problem need to be established along with development of appropriate mathematical teaching and learning strategies or methods"[23].

In the future teachers can develop media and learning tools that accommodate student’s metacognition and also using technology in teaching and learning mathematics[24]. Retnawati et. al. "The schools employed strategies by making efforts to provide the standard electronic equipment through collaboration with the students' parents and improving the curriculum content by adding information technology as a school subject”[27]. Metacognition is closely related to student’s ability to organize thoughts and evaluate the results of the thinking itself. So that with good metacognition, students can design a mathematical problem solving plan that they face well. In designing these mathematical problem solving plans students need learning steps that are closely related to learning trajectory. Like opinion Retnawati "The learning trajectory was designed based on the literature review toward multiple references with regards to theory and by considering the materials that the students had studied”[25].

While, mathematical self-efficacy has effect of 23.44% of mathematical problem solving ability. This shows that mathematical self-efficacy plays a significant role in influencing problem-solving abilities for a student. Students who have good mathematical problem solving ability tend to have good mathematical self-efficacy as well. Having known that self-efficacy has a positive and significant effect on student’s ability in solving mathematics problems, then in the future teachers can develop media and learning tools that accommodate student’s mathematical self-efficacy. Self-efficacy is related to students' beliefs about their abilities. In the context of mathematics learning, Self-efficacy is related to student’s self-confidence in solving mathematical problems they face. Based on the results of research on the level of student self-efficacy as shown in table 9, the average self-efficacy of students are still in the medium category. This reflects that most students are still not sure of their own abilities. so that students are not sure of being able to solve the mathematical problems they are facing. For this reason students need something that is able to increase confidence in their abilities, one of which is to strengthen students' understanding of the material. Like the opinion of Retnawati et. al. "To overcome the student’s difficulties associated with the nature of mathematics can be done by strengthening the student’s mathematical understanding of the mathematical concepts”[26].

4. Conclusions
Based on the data of the research results that have been shown, it can be concluded that metacognition and mathematical self-efficacy have significant effect on mathematical problem solving ability in case of univariate and multivariate model. Thus the teacher can develop learning tools and media that can improve student’s metacognition and mathematical self-efficacy so that student’s mathematical problem solving abilities can be improved as well. Based on the results of this study can be sure there are many other variables that affect the ability to solve mathematical problems in addition to metacognition and mathematical self-efficacy. Thus, the suggestion for further study is to better accommodate other factors that allegedly affect students' math-problem-solving abilities.

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