Problem-solving ability using mathematical modeling strategy on model eliciting activities based on mathematics self-concept

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Abstract. The purpose of this study is to test the effectiveness of problem-solving skills using mathematical modeling strategy on MEAs and to describe problem-solving skills based on the mathematics self-concept. This research uses a quantitative method followed by descriptive with research variables are problem-solving ability and mathematics self-concept. Data collection techniques used in this study are documentation, tests, questionnaires, and interviews, then processed with a classical completeness test, t-test, proportion test, and linear regression test. We find that the ability of problem-solving with mathematical modeling strategy on Model Eliciting Activities achieved completeness. The ability to solve problems with mathematical modeling strategies on Model Eliciting Activities is better than conventional learning models. Student’s mathematics self-concept has a positive effect on problem-solving ability by 31.2%. There are two subjects with high mathematics self-concept categories have high and low problem-solving skills, and two subjects with medium and low mathematics self-concept groups have medium and low problem-solving skills.

1. Introduction
Lesh and Zawojewski [1] defined mathematical problem solving as the process of interpreting a situation mathematically, which usually involves several iterative cycles of expressing, testing, and revising mathematical interpretations and of sorting out, integrating, modifying, refining clusters of mathematical concepts from various topics within and beyond mathematics [2]. According to Polya [3], the problem-solving ability is the ability to find solutions to all problems through the steps of problem-solving quickly and easily [see also 4]. Furthermore, Polya [3] devised four steps problem-solving process formulated problem-solving steps are understanding the problem, devising a plan, carrying out the plan, and looking back. Problem-solving is one aspect of high levels thinking ability is a very important ability [5]. Although problem-solving ability is fundamental and useful and is closely related to daily life, but the problem-solving ability of Indonesian students is still relatively low [6, 7, 8]. This statement is reinforced by a preliminary study conducted by [9], which declares that student’s problem-solving abilities are still low because students tend to feel difficulties when given non-routine problems.

In a relationship between mathematics and problem-solving ability, a strategy is needed to bridge abstract concepts with real-world problems that are applied to problem-solving problems, because problem-type problem-solving in its solution requires specific steps. Following [10] states that problem-solving is the focus in the study of mathematics that includes a variety of problems with various ways of solution, so we need an effective strategy for improving students’ skills in problem-solving ability. One of the problem-solving approach that enables students to develop
problem-solving ability is mathematical modeling strategy. Mathematical modeling is commonly regarded as the art of applying mathematics to a real-world problem to understand the problem [11]; therefore, mathematical modeling is closely related to problem-solving. The statement is also supported by the results of research conducted by [12], which states that mathematical modeling strategy can improve problem-solving ability.

Mathematical modeling strategy is a strategy that focuses on the process of making a model of real problems in real life so that it is easy to find a solution. There are some reasons why problem-solving skills are essential to develop for students. This skill is helping students to get a better insight into mathematical concepts and communication [13]. Problem-solving develops student’s mathematical abilities, comprehensively [14, 15, 16]. It can stimulate students to solve more challenging problems [2, 3, 11, 12]. The process of solving problems using mathematical modeling according to [15] is to identify, define, compile, and solve mathematical models, and interpret the results into real situations. We developed the four steps of the mathematical modeling strategy used in this study [14, 17]. First, understanding the real problem. Second, build the mathematical model. In the second step, one must do the translation of real problems into mathematical language. Steps to be covered include identifying all quantities involved in the problem, select variables and constants, and giving a symbol. The process of constructing mathematical models takes into account the laws, theorems, and conditions that apply to problems. The selection of applicable laws and theorems shows the relationship between the involved variables and constants. The third step is to determine the model solution. And the last step is to interpret model solutions in the form of problem solution. Figure 1 shows a mathematical modeling strategy scheme, according to [14, 17].

![Figure 1. Mathematical Modeling Strategy](image)

In learning mathematics, students' mental state is one of the essential aspects [5]. In addition to problem-solving skills, there are psychological aspects that contribute to the success of a person in completing a task well. The mental issue is mathematical self-concept. Most of the policy to include self-concept as one of the most important goals in education [18]. According to [19], mathematical self-concept is an aspect of learning related to personal beliefs related to the world of mathematics with a set of ideas, judgments, beliefs, and attribution that a person has built during his learning process in the school environment. Reyes argues that specifically, one's self-concept of mathematics refers to perceptions or beliefs in its ability to succeed in mathematics or beliefs in learning mathematics [20]. Low self-concept makes students have difficulty in solving problems given by the teacher; more specifically, one of the subjects that are considered difficult by students is mathematics. Someone who has high confidence to succeed in learning mathematics will have a positive self-concept; conversely, if they feel less confident in their ability to mathematics, they have a negative self-concept.

The learning model chosen to overcome the student’s problem-solving ability must be a learning model that can bring up positive mathematical self-concepts of students so that it will have an impact.
on students' ability to solve problems. Efforts are made to achieve satisfactory learning outcomes, and students can master the learning material is the use of learning models that can improve students' problem-solving abilities. One of the appropriate learning models is the MEAs. Research related to MEAs has also been carried out by previous researchers. Based on research [21] revealed that MEAs are a good learning model. The results of [22] show that MEAs aided by student worksheets are effective on student’s mathematical communication skills.

The MEAs model requires students to develop mathematical models, which are conceptual systems so that students can gain a variety of mathematical experiences [23]. MEAs are a learning model for understanding, explaining, and communicating the concepts contained in a presentation through the process of mathematical modeling [24]. Chamberlin and Moon [23] implement MEAs in several steps, namely (1) the teacher reads a newspaper article simulation related to the context of the lesson for students, (2) students respond to aperception questions based on the article, (3) the teacher read a statement about a problem and make sure each group understands what is asked, (4) students try to solve the problem, and (5) students present their work in front of the class. The purpose of this study was to: (1) determine the achievement of classical learning completeness students' problem-solving abilities of students with mathematical modeling strategies on the Model eliciting Activities; (2) knowing the achievement of problem-solving abilities with mathematical modeling strategies in the Model Eliciting Activities and conventional learning; and (3) describe student’s problem-solving abilities with mathematical modeling strategies in the Model Eliciting Activities based on students' mathematical self-concept.

2. Methods
The research method used in this study is a quantitative method followed by a descriptive research design used the Posttest-Only Design with Non-equivalent Groups. The study design chosen was a concurrent embedded, which is a form of research design that combines two kinds of research data which includes the data of quantitative and qualitative research simultaneously in a single stage of collecting data [25]. Because the priority in this research is in the quantitative stage, the main data in this study is quantitative, while qualitative data is used as supporting data.

The population in this study are students of class XI of SMK Negeri 1 Bumijawa in the even academic year 2018/2019. Two sample classes are XI TKJ 3 as a control class and XI TKJ 4 as an experimental class, respectively. The subjects in this study are six students of class XI TKJ 4 SMK Negeri 1 Bumijawa. By using a purposive technique on the results of student’s mathematical self-concept scale data so that six students are chosen consist of 2 students from an upper group of mathematical self-concepts, two students from the middle group of mathematical self-concept, and two students from the lower group of mathematical self-concept.

Research variables in this study are problem-solving ability and mathematics self-concept of students. The data collection method used is the method of documentation, test, questionnaire self-concept mathematics, and interviews. The data is used as supporting data, which is the background of this research. The test method is used to collect data on problem-solving abilities after mathematical learning by using mathematical modelling on MEAs and conventional. The questionnaire method is used to measure students' mathematics self-concepts, which are then used to group students into groups of high, medium, and low. The interview method in this study was conducted in an unstructured way to obtain data about problem-solving abilities with mathematical modeling strategy in terms of students' mathematics self-concepts.

3. Result and Discussion
The initial ability data is used to find out whether the experimental class and the control class have the same initial conditions. The results of normality and homogeneity test from the initial data of the experimental class and the control class indicate that the initial data of the two classes is normally distributed and has the same variance. Furthermore, the two average data tests for the initial problem-solving ability of the experimental class and the control class did not differ significantly. Based on the
results, it can be concluded that there was no significant difference between the initial ability of problem-solving students of the experimental class and the initial ability of problem-solving students of the control class.

### Table 1. Descriptive statistics of initial data.

| Class    | n  | Mean | s  | Min | Max |
|----------|----|------|----|-----|-----|
| Experiment | 27 | 66.37 | 13.7 | 38 | 99 |
| Control   | 25 | 71.96 | 8.2  | 52 | 85 |

Posttest data of problem-solving ability were analyzed to obtain a picture of the condition of students in the experimental class and the control class after participating in learning. Posttest data of problem-solving ability obtained were then analyzed descriptively first. Table 2 presents descriptive statistics about the posttest of problem-solving ability.

### Table 2. Descriptive statistics of posttest data.

| Class    | n  | Mean | s  | Min | Max |
|----------|----|------|----|-----|-----|
| Experiment | 27 | 71.72 | 16.3 | 28.0 | 97.6 |
| Control   | 25 | 64.05 | 19.9 | 31.7 | 96.3 |

We test the first hypothesis that the problem-solving ability of class XI on the counting rules, permutations, and combinations material with mathematical modeling on Model Eliciting Activities have achieved classical learning completeness. We use minimum criteria of student’s completeness that should reach at least 70%. From calculation with \( \pi_0 = 0.70 \) and \( z_{table} = 1.64 \), obtained \( z_{score} = 2.4 \). Based on test criteria of \( z < z_{0.5-a} \) then \( H_0 \) is rejected. It can be concluded that problem-solving ability in counting rules, permutations, and combinations using mathematical modeling on MEAs have reached classical completeness.

The second hypothesis test is conducted to test whether the achievement of students problem-solving ability using mathematical modeling strategy on Model Eliciting Activities is better than the achievement of problem-solving ability with conventional learning, based on a test with a significant level 5% using the Independent T-Test pr t-test, the value obtained significance 0.055 > 0.05, it means \( H_0 \) is rejected. So, the average problem-solving ability using mathematical modeling strategy on Model Eliciting Activities is better than the average problem-solving ability with conventional learning. In addition to the average test, a right-side proportion test was conducted to test whether the proportion of problem-solving ability using mathematical modeling strategy on Model Eliciting Activities was better than conventional learning, based on testing with significance level 5% using the right-side proportion test, with \( x_1 = 20, x_2 = 10 \), and \( z_{table} = 1.64 \), obtained \( z_{score} = 2.59 \). Based on the test criteria, because of \( z > z_{a} \), then \( H_0 \) is rejected. So it can be concluded that the proportion of problem-solving ability using mathematical modeling strategy on Model Eliciting Activities is better than the proportion of problem-solving ability with conventional learning. From both tests, problem-solving ability using mathematical modeling strategy on Model Eliciting Activities is better than problem-solving ability in the control group.

We use a mathematics self-concept questionnaire for experimental class before learning the material of counting rules, permutations, and combinations. We obtain a description of the condition of the student’s mathematical self-concept in the experimental class before being given treatment. The selection of research subjects in this study uses the classification od students' mathematics self-concept according to [26]. Based on the calculation of a Likert scale mathematics self-concept questionnaire, from 27 students in class XI TKJ 4, there were three students in the high group level, 19 students in the medium group level, and five students in low group level, see Table 3.
In the problem-solving ability of the high mathematics self-concept, based on the results of the interview about the posttest problem-solving ability, S-1 and S-2 can answer nine questions correctly out of 10 available items. Nine questions answered fulfill all indicators of problem-solving ability with mathematical modeling strategy, which is (1) identifying the elements that are known, asked, and all quantities involved in the problem by providing symbols, (2) formulating mathematical problems or compiling mathematical models, (3) applying a strategy to determine the model solution, (4) interpreting the model solution into a problem solution, while on unanswered problem does not fulfill all of the indicators. Based on the description of these two subjects, they did not answer question number 1b because of the lack of time management when working on problem-solving ability test questions.

In the problem-solving ability of the medium mathematics self-concept, based on the results of the interview about the posttest problem-solving ability, S-3 can answer seven questions correctly out of 10 available items, and S-6 cannot answer all the questions correctly. Three questions that were answered incorrectly indicate that S-3 has not been able to apply strategies to formulate mathematical problems or construct mathematical models, implement strategies to determine model solutions, and interpret model solutions into problem solutions. S-3 has not been able to understand the problems fully, so it is difficult to formulate a strategy or method used to solve the problem. S-3 can give symbols to the elements that are known in the problem but do not mention the description of the symbol. S-3 also deficient in understanding problems so that it is wrong to use concepts of permutation and combination because the problem should be solved by combination, not permutation. S-4 can correctly answer five questions out of ten available questions. The questions answered incorrectly indicate that in general, S-4 has not been able to fulfill two indicators of problem-solving ability using mathematical modeling strategy, which are implementing strategies to determine model solutions and interpret model solutions into problem solutions.

In the problem-solving ability of the low mathematics self-concept group, based on the results of the interview about the posttest problem-solving ability, S-5 and S-6 cannot answer all the available questions correctly. S-5 and S-6 both have immature concepts on the counting rules, permutations, and combinations so that they cannot formulate correctly the strategies that must be used when solving the problems. S-6 can identify the elements that are known from the problem and give a symbol, but for the next step, S-6 is not able to understand the concept of inclusion-exclusion well, so cannot yet apply rules to the problem.

The results of the descriptive data analysis, in general, showed that students in high mathematics self-concept groups did not feel difficulties significantly while working out the problem-solving ability test. However, the lack of proper time management was an inhibiting factor for S1 and S2. Students in the medium mathematics self-concept category S-3 and S-4, have not been able to compile mathematical models so well, so they cannot find the purpose solution. Students in the low mathematics self-concept group S-5 and S-6 have not able to understand the problem so well, so they cannot find a strategy or a way to solve the problem.

Table 3. Subjects of study.

| No | Students Code | Subjects Code | Group |
|----|---------------|---------------|-------|
| 1  | E-27          | S-1           | Upper |
| 2  | E-14          | S-2           |       |
| 3  | E-25          | S-3           | Middle|
| 4  | E-17          | S-4           |       |
| 5  | E-12          | S-6           | Lower |
| 6  | E-23          | S-7           |       |
4. Conclusion

Based on this study, a mathematical modeling strategy can be an alternative for developing problem-solving skills. We found that the problem-solving ability using mathematical modeling strategy on Model Eliciting Activities achieved classical completeness. The problem-solving ability using mathematical modeling strategy on Model Eliciting Activities is better than the conventional learning model. Two subjects with high mathematics self-concept categories have a high and middle problem-solving abilities. And the two subjects with medium and low mathematics self-concept categories have medium and low problem-solving abilities, respectively.

References

[1] Lesh R and Zawojewski J S 2007 In Lester F K (Ed.) Handbook of research on mathematics teaching and learning pp 763 (Charlotte: Information Age)
[2] Kuzle A 2007 Int. Electron. J. Math. Educ. 8 20
[3] Polya G 1988 How to Solve It: A New Aspect of Mathematical Method (NJ: Princeton)
[4] Dhamayanti A and Wijaya A 2018 J. Pendidik. Mat. 7 29
[5] Ulandari L Amry Z and Saragih S 2019 Int. Electron. J. Math. Educ. 14 375
[6] Wulandari N F 2015 In Proceeding Int. Conf. Res. Implement. Educ. Math. Sci. 5 17
[7] Putra A A and Subhan M 2018 Int. Electron. J. Math. Educ. 13 97
[8] Surya E and Putri F A 2017 J. Math. Educ. 8 85
[9] Fasni N Turmudi T and Kusnadi K 2017 Proceeding Int. Conf. Math. Sci. Educ 1 (IOP Publishing)
[10] Nurliastuti E Dewi N R and Priyatno S 2018 Prisma Pros. Semin. Nas. Mat. 1 99
[11] Cheng A K 2009 In Mathematical Problem Solving: Yearbook 2009, Association of Mathematics Educators (Singapore: World Scientific)
[12] Nursyarifah N Suryana Y and Lidinillah D A M 2016 J. Ilm. Pendidik. Guru Sekolah Dasar 3 138
[13] Ashim M Asikin M and Kharisudin I 2020 Unnes J. Math. Educ. Res. 9 216
[14] Rahman A A and Kharisudin I 2019 Unnes J. Math. Educ. 8 173
[15] Cahyono A N and Suyitno H 2018 Penyelesaian Soal Bertipe Pemodelan Matematika In Modul Pemodelan Dalam Pembelajaran Matematika untuk PPG Dalam Jabatan (Jakarta: Kemenristekdikti RI)
[16] Sutrisno H and Kharisudin I 2020 Unnes J. Math. Educ. 9 43
[17] Khasanah N Asih T S N and Kharisudin I 2020 Unnes J. Math. Educ. Res. 10 134
[18] Marsh H W and Craven R 1997 Academic Self-Concept: Beyond The Dustbowl in Handbook of Classroom Assessment: Learning, Achievement, and Adjustment 131
[19] Nuria G I Barona E G E G Nieto L J B Ignacio N G Nieto L J B and Barona E G E G 2006 Int. Electron. J. Math. Educ. 1 16
[20] Wilkins J L M 2004 J. Exp. Educ. 72 331
[21] Prasetyo A Dwidayati N K dan Junaeda I 2017 Unnes J. Math. Educ. 6 190
[22] Oktaviani R Suyitno H and Mashuri 2015 Unnes J. Math. Educ. 5 191
[23] Chamberlin S A and Moon S M 2008 Int. J. Math. Teach. Learn. 9 78
[24] Rahmawati D Darmawijoyo D and Hapizah H 2018 AKSIOMA: J. Program Studi Pendidik. Mat. 7 65
[25] Sugiyono P 2015 Metode Penelitian Kombinasi (Bandung: Alfabeta)
[26] Azwar S 2005 Penyusunan Skala Psikologi (Yogyakarta: Pustaka Pelajar)