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The development of mathematical learning material based on model-eliciting activities (MEAs) approach to improve mathematical problem-solving skill of students of grade X of Senior High School Padang

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The development of mathematical learning material based on model-eliciting activities (MEAs) approach to improve mathematical problem-solving skill of students of grade X of Senior High School Padang

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Abstract. Mathematical problem solving skill is a very important ability in mathematics learning. This skill is used in learning and solving problems. In fact, problem-solving skill of students can be enhanced. Students should get the opportunity to develop their skill in problem solving. One of the efforts to improve problem-solving skill of students is to develop mathematics learning material based on Model-Eliciting Activities (MEAs) approach. The purpose of this study is to produce mathematics learning material based on MEAs approach, which are valid, practical and effective. This developmental research uses the Plomp's model consisting of three phases: preliminary, prototyping, and assessment stage. Subjects of this study were students of grade X of Senior High School Padang state. The results of data analysis from validity of the instrument was showed that mathematics lesson equipment based on MEAs approach has fulfilled valid criteria in terms of content and construct. The lesson equipment has been considered as practical in terms of feasibility, convenience, and time because they can be applied in mathematics learning activities. The lesson equipment has also been effective since they can enhance problem solving skill. Based on these results, it can be concluded that mathematics lesson equipment based on MEAs approach, which were implemented to students of grade X in the first semester was valid, practical, and effective.

1. Introduction

Mathematics is a subject that has significant role in education. By learning mathematics, students can develop logical, critical, analytical, systematic and creative thinking ability as well as cooperative skills [1]. In addition, one of purposes of learning mathematics is to develop students' problem-solving skill both in mathematics context and outside mathematics (real life, science and technology), which consists of some phases, such as: understanding the problem, constructing mathematical models, simplifying the models and interpreting the solution from mathematics into real world [2]. Furthermore, in the process of teaching and learning mathematics in school, teachers should pay attention to five mathematical thinking skills, including problem-solving skill [3]. Therefore, it can be said that problem-solving skill is a skill that has to be possessed and developed by students.

The importance of problem-solving skill was also stated by [4] that problem-solving skill is the heart of mathematics. Problem-solving skill is indispensable not only for someone who will learn mathematics in the future but also for people who will apply it in other fields and daily life [5]. So, problem-solving skill is not only used by students in learning mathematics but also in their daily life to

solve any problems or obstacles that they face. By applying some phases of problem-solving skill, such as: understanding the problem, devising a plan, carrying out the plan and looking back the solution [6], students are expected to develop curiosity and motivation and can be a creative, logic and systematic thinking student's in order to solve and face any problems in their daily life.

Problem solving can be seen as a process that integrated in every part of mathematics learning, which also provides skill as a context. Problem-solving skill also can be learned to find out the solution of a problem that cannot be solve immediately [6]. Similarly, [7] and [8] said that problem solving is effort to solve a new problem by using knowledge, skill and understanding that are already possessed.

Old perspective about mathematical problem solving was stated by [9]) that problem solving is a process to develop skills through a learning, which at the beginning consists of concepts and procedures followed by exercises in solving word problems and then transforms to enrich experience by applying competence in solving a new and non-routine problem. Similarly, [10] also stated that problem solving involves high level of mathematical thinking, such as: visualisation, association, reasoning, manipulation, abstraction, analysis, synthesis and generalisation.

There are four indicators of problem-solving skill that are used in this study, namely: (i) students are able to identify unknown aspects that are asked and the sufficiency of aspects that are needed; (ii) students are able to formulate mathematical problems or construct mathematical models; (iii) students are able to apply strategies to solve any problems either in or outside mathematics; and (iv) students are able to explain and interpret the solution of problems [3].

There are many students facing difficulties to solve mathematical problems. These difficulties closely related to mathematical problem-solving skill. The result of interviews with teachers revealed that students always got confused while doing word problems or non-routine problems, which need analysing skill. The students do not understand the problems well so that they cannot explore the steps needed to solve those problems. This leads to the unsatisfactory problem-solving skill. For example, when a teacher presents a mechanistic problem, students can complete it immediately. However, when learners are given questions non routine problem or problems to solve requires analysis then learners look confused in understanding and solving the problem. Only a few people can do the problem. The other students are just waiting for an answer from their friends.

Teaching and learning mathematics in the classroom can be enhanced to develop problem-solving skill, for instance by using Model-Eliciting Activities (MEAs) approach. MEAs is a learning approach to understand, explain and communicate concepts embedded in a problem with the model of [11]. Learning with MEAs approach is started with realistic problems in order to stimulate the interest of the students. This interest will allow them to easily understand the problems because those problems are related with students' daily life. After the students understand problems, it is expected that they can determine and explore the steps to solve problems. There are six principles in learning with the approach of MEAs, namely: 1) The meaningfulness principle, 2) The model construction principle, 3) The self-evaluation principle, 4) The model documentation principle, 5) The simple prototype principle, and 6) The model generalization principle [11].

The learning with MEAs approach needs students to work in a group of 3-4 students [12]. Working in groups allows students to discuss and communicate their ideas as well as to listen to their peers' opinions. The main feature of MEAs is the activity to construct mathematics models. Constructing mathematics models need a strong concept in understanding problems so that students can simplify their thinking [13]. Mathematics models can be defined as representing a situation or things mathematically. By modelling, the students will be used to the modelling steps, such as: simplifying the problem; constructing mathematics models; transforming and finding the results by using the models and interpreting the results. These steps of modelling are in line with Polya's problem-solving steps so that using the phases of MEAs approach is expected to enhance student's problem-solving skill. Previous studies, such as: [14] and [15], both stated that MEAs approach can develop students' problem-solving skill. Similarly, [16] also stated that MEAs approach can develop representing and problem-solving skill. On the other hand, the same opinion is also stated by [17] and [18].

Teaching and learning process by using MEAs approach in the classroom will run well only if the teacher prepares a well-organised lesson plan. Besides that, the handout, such as student's worksheet is needed to support the learning. However, the lesson plan and student's worksheet that are available in the school cannot fully facilitate students to develop their problem-solving skill. Therefore, the development of lesson plan and student's worksheet using MEAs approach is needed.

This study has the purpose to design lesson plan and student's worksheet by using MEAs approach so that lesson plan will be designed by including the steps and principles of MEAs approach. On the other hand, student's worksheet consists of guidances and the collection of problems, which are not only routine problems but also non-routine problems. student's worksheet also consists of problems that relate to students' daily life so that they can easily understand what the problem is asked them to do. Additionally, student's worksheet provides students with instructions that can guide them to solve the problem step by step, such as: understanding the problem and constructing mathematics models of the problem so that students can represent the ideas of the problem into pictures; symbols and mathematical equation, which will lead them to the solution. Using student's worksheet based on MEAs approach is expected to enhance students' mathematical problem-solving skill.

This study will elaborate the characteristics of learning equipment based on MEAs approach to enhance problem-solving skill of X (tenth) grade students, which is valid and practical as well as to investigate the effectiveness of learning equipment based on MEAs approach to enhance students' problem-solving skill.

2. Research Methods

This study is a developmental research. The developmental model used in this study is adapted from Plomp's model, which consists of three phases, such as: preliminary phase; development or prototyping phase; and assessment phase. In the first phase or initial investigation phase, the needs and context analysis are implemented. In the second phase (prototyping phase), a design, development and formative evaluation are implemented. Formative evaluation steps are started by self-evaluation, expert review, one-to-one evaluation, small group evaluation and field test. Next, in the third phase (assessment phase), a semi-summative evaluation in the form of assessment of learning is held [19].

The mathematics learning equipment based on MEAs approach was applied in X (tenth) grade of senior high school in Padang. The subject of this research are students from X grade of SMAN 3 Padang on period of July – December 2017. The characteristic of this research subjects are students that have different learning ability (high, medium, low). There are several instruments used in this study, such as: questions list; check lists; validation sheets; observation sheets; questionnaires and test. Prior to the use, all instruments are validated by experts.

The data as the results of the study is analysed based on its type. For example, qualitative data is analysed based on qualitative paradigm and also quantitative data is analysed based on quantitative paradigm. Finally, the results of the study are categorised and concluded qualitatively.

3. Results and Discussions

3.1. Results of Preliminary Research

In the preliminary phase, the identification and analysis of needs for development of learning equipment based on MEAs approach are held. There are three analysis performed, namely: needs analysis; curriculum analysis and concepts analysis. Needs analysis revealed that students require a new learning approach in addition to conventional learning that is commonly used in the school, which is able to optimise students' mathematical problem-solving skill. Besides, students also need learning equipment for the teaching and learning process runs systematically in order to achieve the learning goals.

The questionnaires revealed that students liked to work in group, had high spirit to study and were more interested to solve problems relating to daily life. Regarding student's worksheet, questionnaires also revealed that students prefered student's worksheet with certain features, such as it had interesting and attractive display, was dominated with blue colour, the paper size used was A4 paper size, and

was accompanied with illustrations that was matched with the handouts. Based on the results of the needs analysis, it is required to develop learning equipment based on MEAs approach that will be designed in the development phase.

Next, in the curriculum analysis, data revealed that there was order of the basic competence. There was also an adjustment of teaching materials due to the applicable rules policy. Assessment of teaching materials indicated the needs to do a change of sequence to adjust the interrelationship between each concept and basic competencies.

The last part of the preliminary analysis was conceptual analysis. This analysis revealed information about the content and sequence of teaching materials, total meetings for each basic competency, and indicators of achievement of competence. This information was needed in the designing of student's worksheet.

3.2. Results of Prototyping Phase

There were two prototypes designed in this study, the first was the prototype of lesson plan based on the MEAs approach and the second was the prototype of student's worksheet based on the MEAs approach. The form of lesson plan based on the MEAs approach, was the same as the regular lesson plan, but in the core activities, the learning process refered to the six principles of MEAs approach, such as: reality, model construction, self-assessment, construct documentation, effective prototype, and construct share ability and reusability. Learning activities in the MEAs approach-based lesson plan consisted of preliminary activities, core activities and closing activities. Preliminary activities were initial activities in one meeting, which were aimed at generating motivation and focusing the attention of students to actively participate in the learning process. Learning activities were accompanied by time allocation to facilitate teachers to implement the learning process.

Next, core activities were the learning process to achieve learning objectives. The core activities were started by the teacher while explaining the lesson material briefly, then students were confronted with some contextual problems related to the material being studied. Afterward, teachers asked students to discuss in groups. Students discussed all the information from the problem in student's worksheet and constructed the models based on what was known in the problem. The students must be confident with the models they created. They should be able to measure the feasibility and usefulness of problem solutions without the help of teachers. The students further documented the models and solutions they created and they must be sure that the models should be easily interpreted by others. The last stage of learning was to communicate the models for which they got responses from other groups. Learning ended by concluding activities, which could be done in the form of making a summary or conclusion about the material that has been learned. Lastly, the teacher informed the material to be learned at the next meeting.

At student's worksheet design stage, there were three characteristics that needed to be considered, such as: content, language and display aspect. The content aspect began by providing contextual problems that existed in everyday life. Additionally, student's worksheet provided students with instructions that can help them to solve problems. The first instruction asked students to understand the problem by identifying what was known and asked from the problem. The second instruction asked students to plan the solution by constructing the mathematical models of the problem. The third instruction asked students to solve the problem using the models that have been found. At the end of each student's worksheet, there were exercises to be done by the students.

Regarding the display, student's worksheet consisted of cover, introduction, table of contents, questions and bibliography. Cover contained the identity/title of student's worksheet based on the MEAs approach, subject headings studied, identity columns of students containing names and classes as student's worksheet owners. Type of writing used in the title of student's worksheet was Comic Sans MS with size 20. For the identity of students and class information as well as semester, the type of writing used was Comic Sans MS with size 18.

The third aspect was the language aspect. The language used was adjusted to the rules of writing with enhanced spelling. In addition, the language used was also communicative and in accordance

with the level of understanding of junior high school students so that the presentation of the material on student's worksheet can be understood well by students. The questions in student's worksheet were arranged with clear sentences in order to lead students to get the expected answers. The result of this design was called prototype 1. The next activity, after lesson plan and student's worksheet was completed, was to conduct a formative evaluation of the learning equipment. Formative evaluation was preceded by doing self-evaluation to the designed learning equipment. The purpose of this self-evaluation was to see the completeness of the MEAs stages and principles. Another purpose was to check if there were still typing errors and lack of punctuation, capitalisation, spaces between words and so forth.

The results of self-evaluation of lesson plan revealed some mistakes, such as: typing errors, the missing of spaces between each word, and misuse of capital letters. Another mistake was the missing of full stops at the end of the sentence. Furthermore, the size of the letters used was still small that is 11 so that the size was changed to 12. On the other hand, the mistakes found in student's worksheet were typing errors and the missing of spaces between each word. Another mistake was that there was too big space where students writed the solution of the problem. The errors in the lesson plan and student's worksheet were then revised. The revised result of this learning equipment was called prototype 2.

After self-evaluation was done, the next step was to validate prototype 2 to the experts. In this case, the learning equipment was validated by 5 people, consisting of 3 lecturers of mathematics, 1 lecturer of language and 1 lecturer of education technology. There were several suggestions from the validators. Firstly, mathematical validators of lesson plan suggested four points, such as: (1) the learning objective should show the learning process; (2) the assessment has not shown the problem-solving indicators; (3) preferably any problems written in lesson plan are not in bold; (4) it is better to remove "the next" word at the beginning of the activity in lesson plan. Secondly, the suggestion of the language validator was to pay attention to the sentence on the main competences, basic competences and learning goals as there were still the missing of full stop at the end of the sentence. Thirdly, the advice of educational technology experts was to add the source of learning. Meanwhile, the suggestions of a mathematical validator for student's worksheet were to correct the questions on student's worksheet because the questions still did not show the problem-solving indicators, to equate the type of writing used in each student's worksheet, to add attractive illustration relating to the material on the cover of student's worksheet. The suggestion of the language validator was to correct the greetings in the introduction of student's worksheet. The initial greeting should be capitalised and the wording in several sentences also needs to be corrected. Lastly, the advice of educational technology validator was to adjust the type of letters in each student's worksheet.

Learning equipment was then revised in accordance with the suggestions of the validators and re-shown to the validators. Afterward, the validators assigned mark to the existing learning equipment. The validation results of lesson plan revealed that overall average of mark of lesson plan based on the MEAs approach was 3.33, which could be concluded that this lesson plan has met the criteria of the validity. Based on the validation results in terms of content, the average mark obtained was 3.31, which could be interpreted as very valid. In term of the language, the average validity of student's worksheet was 3.25, which also could be interpreted as very valid. Lastly, based on aspect of typography, the average of validity obtained was 3.80 with very valid criteria. So, it can be concluded that student's worksheet based on MEAs approach was valid.

The next stage was to evaluate one-to-one evaluation. One-to-one evaluation was done with 3 students from grade X of Senior High School 3 state of Padang with different learning ability (high, medium, low). The selection of the three students was done by the researchers through the assistance of the grade X mathematics teacher. The purpose of this individual evaluation was to ask students' opinions about possible errors such as poorly understood grammar, misspelling, as well as the use of the term in each problem.

The next stage was to conduct a small group evaluation. This evaluation was conducted on 6 students who had high, moderate, and low ability from grade X-7 Senior High School 3 state of

Padang. The selection of six students was assisted by mathematics teacher at the school. The purpose of a small group evaluation was to identify the lack of learning equipment in terms of timelines and the implementation of learning outcomes. During the learning process in small groups, researchers were assisted by one observer who was tasked to record the implementation of the teaching and learning process by using the MEAs approach and to note the time spent. While doing the trial with small groups, there were some revisions in term of time spent. For example, at the first meeting, time required by students for presentation was only 5 minutes while the time designed on lesson plan was 10 minutes, so that a revision of time was made.

At the second meeting, there was a time revision when the participants worked on the exercises from 10 minutes to 15 minutes, while the time for presentation was changed from 10 minutes to 5 minutes. At the fourth meeting, there was an improvement over time on the lesson plan that was the change of the time to solve the 'problem 1' from 20 minutes to 25 minutes. Learning equipment that has been tested on small groups was revised based on the deficiencies and errors found. In Figure 1. we can see example of part of student's worksheet.

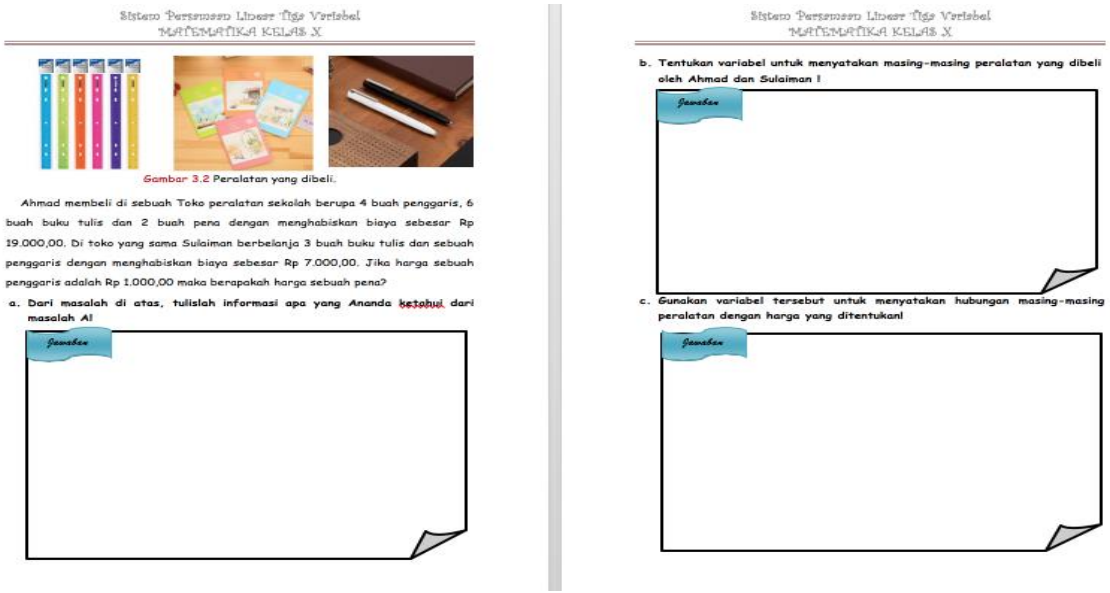

Figure 1. Example of Student's Worksheet.

The next phase was the assessment phase. In this phase, the testing of learning equipment to a large group of students of grade X-8 Senior High School 3 state of Padang was carried out. During the execution of the field test at the end of each session, the students were given 2 problem-solving problems. The assessment of this exercise was based on problem-solving rubric that was previously designed. The results of these exercises revealed that students' problem-solving skill increased from the beginning until the end of the meeting.

At the first meeting, the problem-solving skill of students for each indicator was still low because students were not accustomed to work on problem-solving problems. This can be seen from the percentage of problem-solving skills obtained for each indicator. The percentage of the indicator of understanding the problem was 18.1%. The percentage of the second indicator (devising a plan) was 33.6%. While the third indicator (carrying out the plan) obtained the percentage of 71.96%, the last indicator (looking back to the solution) obtained the percentage 14.65%. At the following meetings, the students were getting used to work on problem-solving problems, so that there had been an increase in problem-solving skill of students compared to the first meeting.

After the learning based on MEAs approach was completed, the questionnaires were given to teachers and students. The results of questionnaires filled by the teachers revealed that 86.1% of the convenience aspects were very practical, 75% of efficiency aspect was in the practical criteria, and

81.25% of appeal aspect also lied in the practical criteria. The equivalence aspect of student's worksheet was 91.7%, which lied in very practical criteria. Overall, the average of 83.5% was obtained. On the other hand, the results of questionnaires filled by students revealed that 80.2% of students were on practical criteria. Based on the questionnaires filled by the students, it was found that student's worksheet was easy to use; it was interesting and useful for the learning process. Additionally, based on the result of the anaysis of the observation sheet of lesson plan implementation based on MEAs approach filled by observer, it can be concluded that the implementation of lesson plan during learning was classified as practical with percentage of 82,78%.

After the learning was completed, then students were given a final test of problem-solving skill. Problems were given in accordance with the indicators of problem-solving skill. Students' answer sheets were assessed based on the assessment rubric. There were 36 students who participated in the final test. Based on the results of the final test conducted, there were 30 students who got the mark above the passing grade and there were 6 students whose mark was below the passing grade, with the percentage of classical completeness of 80%. From the results of the test conducted, there were more than 83.3% of the students whose mark was above the passing grade. This means that the learning equipment developed had been classified as effective to improve the problem-solving skills of students.

Finally, it can be said that the student's worksheet was developed, which started with the preliminary analysis phase, continued with the development phase, and the normative evaluation phase (self evaluation, one to ne evaluation, expert review, small group and field test) has contained principles of the MEAs approach. Student's worksheet that has been developed begins with the provision of contextual problems. Students are guided to present the model of the problem and ultimately result in a solution to the problem. So, it can be said that the student's worksheet has been in accordance with the MEAs approach.

4. Conclusion

Based on the results of this study, it was found that the designed learning material was in accordance with the data obtained in preliminary research. The developed equipment contained of the principles of the MEAs approach that was started with the contextual problems, then students constructed the models of the problems and lastly they socialised the models they created. Learning by using the equipment based on the MEAs approach had been able to improve problem-solving skill of students. This was because learning by using the MEAs approach made students get used to construct the model solution of the given problems. This happens because the students are accustomed to solving problems through the eliciting the model.

Learning materials that have been developed can be used as additional learning resources for teachers and students. Through learning material based on MEAs approach is expected to make the learning process more fun, make students to learn independently, accustomed to problem solving problems and more confident in solve a problem. Then, through this learning materials are expected to help teachers and learners in achieving the goals of learning. It is expected that the use of this learning material can also be used in other schools.

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