The development of learning instruments based on an open-ended approach to improve students' problem-solving skill

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Abstract. Mathematics subject aims to help students to improve their problem-solving skill. One of the potential approaches that could be applied by teachers in mathematics teaching and learning process is the open-ended learning approach. This study aimed to develop the valid learning instruments on topics quadrilaterals based on open-ended approach, which included lesson plans, student worksheet, and test questions. The study focussed on Year 7 of one of the junior high schools in Banda Aceh, Indonesia. This study is a development research, which implemented a 4D model, consisting of four stages (Devine, Design, Development, and Disseminate). However, only the first three stages were conducted in this research. The validation process involved four validators specialized in mathematics education (two lecturers and two teachers). The finding showed that the average validation score of the developed instruments was 3.54, which indicated that the instruments were valid. Further studies to know the effectiveness and practicality of the instruments need to be conducted.

1. Introduction
Problem-solving skill is fundamental in mathematics, both for those studying mathematics and for those applying the skills in other fields of study and everyday life [1,2,3]. Five standards of mathematical skills must be mastered by students, namely problem-solving, communication, connection, reasoning, and representation [4]. Problem-solving is an essential part of the mathematics curriculum in relation to the learning process; students may gain experiences using their existing knowledge and skills to be applied to non-routine problem-solving. Problem-solving is an attempt to find a solution of a problem to achieve a certain goal that is not immediately achievable [5]. Therefore, problem-solving is a higher level of intellectual activity. To solve the problem, one can use certain steps that he or she controls. One of the causes of the poor quality of students' mathematics understanding in elementary and junior high schools is that teachers mostly focus on the exercises of solving procedural and calculation problems instead of understanding the mathematics concepts [6].

There are several steps of the problem-solving process as proposed by experts, which are then used to measure problem-solving skills. The steps are; Firstly, (a) reading and thinking, (b) exploring and planning, (c) selecting a strategy, (d) finding and answering, and (e) reflecting and extending [7]. Secondly, (a) understanding of the problem, (b) devising a plan, (c) carrying out the plan and, (d) looking back [8]. Thirdly, (a) recognition, (b) definition, (c) formulation, (d) test, (e) and evaluation [9]. In this study, the Polya stages were used since they are simple and implicitly cover all stages of problem-solving.

One way to improve students' mathematics problem-solving skills is by implementing the open-ended approach in teaching and learning process. Mathematics learning using open-ended questions is one of the representative methods to improve students' problem-solving skills [10, 11]. The purpose of the open-ended approach is to help develop the creative activities and students’ mathematical mindset.
through problem-solving simultaneously [12]. An open-ended approach is a learning approach presenting a problem that has more than one correct method or solution, allowing students to acquire the knowledge or experience of finding, recognizing, and solving problems using several techniques [10].

Open-ended problem is a problem that has many solutions or resolution strategies [13]. Open-ended problems are divided into three parts, namely: (a) the problem with one answer to many ways of solving; (b) the problem with one solution to many answers; (c) problem with many solutions and also many answers. Based on those three opinions above can be stated that presenting the open-ended problem can provide stimulation to the students to improve the way of thinking so that students have the freedom to express the exploration’s result of reasoning power and the analysis to solve a problem actively and creatively. Thus, open-ended problems can train students' mathematical literacy skills themselves. In this study, the researcher uses the problem with one solution to many answers and problems with many solutions as well as many answers. According to Takahashi [13], there are several benefits to using open-ended problems in mathematics learning. First, students become more active in expressing their ideas. Second, students have more opportunities to use their knowledge and skills comprehensively. Third, students have abundant experience in the process of finding and receiving approval from other students for their ideas.

The open-ended learning is divided into two stages. The first stage is the teacher provide a problem, students write down ideas, summarize, and discuss the results of individual answers in the groups. The second stage: presenting of group work results [14]. Learning with open-ended approach is arranged in two stages, at stage one: students solve the problem given by the teacher at the beginning of the learning, the students are given blank paper to write their ideas, the papers are collected by teachers to generate the conclusions of the individual response, the students discuss the results of individual work in groups, students write down the results of group discussions. During the second stage: the results of each group are presented and discussed and then the learning is concluded [15]. Learning can be implemented well if it is based on appropriate learning materials and assessment instruments. Therefore, it needs to start by a valid learning instrument.

2. Method
The type of research used in this study was Research and Development. The learning instruments development model used was to modify the Four D model [16]. This model consisted of 4 stages: Define, Design, Develop, and Disseminate. This development study was limited to the Define, Design and Development stages. In the Define stage, the researcher collected information to determine the characteristics of learning instruments to improve students' problem-solving skills. At this stage also conducted an early curriculum analysis with the help of mathematics teachers to identify the mathematical material needed for the learning instruments development. The design stage was the stage of designing an instrument that would be used in mathematics learning. At this stage, there were four activities, namely the preparation of tests, the selection of formats, the selection of media in accordance with the characteristics of learning materials, and the making the early design. At this stage produced the draft 1 which was then subsequently refined at the development stage.

The development stage was the stage of validating learning instruments by experts by providing a questionnaire for each learning instruments, with a scale of 1 to 5 (invalid to valid). Learning instruments had been validated in two revisions by four validators (two lecturers and two mathematics teachers). The criteria used for assessing the learning instruments were based on Plomp and Nieveen [17] as shown in Table 1.

| Score | VS | Criteria |
|-------|----|----------|
| 4 ≤   | < 5| Highly valid |
| 3 ≤   | < 4| Valid |
| 2 ≤   | < 3| Less valid |
| 1 ≤   | < 2| Not valid |
3. Result and discussion
This research is a prototyping phase of the development of learning instruments based on the open-ended approach to improve students’ problem-solving skills on topic quadrilaterals, which aimed to produce the valid learning instruments. The learning instruments were expected to be a reference for teachers in classroom learning, especially on the quadrilaterals topics. The research procedure used was 4D development study [16].

3.1 Define stage
In the Define stage, the researcher discussed the obstacles that teachers found when teaching quadrilaterals materials. It was considered important to obtain information about the conditions and attitudes of students during the process of learning mathematics in class. The results of the discussion with the mathematics teachers, it was known that the quadrilaterals material was a challenging and appropriate topic to develop open-ended based learning instruments to improve students’ problem-solving skills. One of the challenges that students often encountered was when deciding varieties of square and triangle planes. The learning material is a pre-requisite material before students learn topics of perimeter and area. Mathematics has a concept that is structured, logical, systematic and interrelated [18]. Students who had a poor understanding of the basic concepts would experience difficulties in understanding and learning new materials; thus resulting in low students’ problem-solving skills. Therefore, the learning instruments developed in this study consisted of the materials of the perimeter and area of the quadrilaterals.

3.2 Design stage
At the design stage, the learning instruments consisted of the lesson plan, student worksheets, and test questions, which were developed based on the analysis at the define stage. The results of the learning instruments at the define stage were called draft 1. The lesson plan was designed using open-ended learning steps, where the learning provided open-ended problems centered on students, encouraged students to learn, guided individual and group investigations, summarized and discussed problems and answers in groups, presented the results of group discussions and conducted class discussions with other groups. The learning process lasted for five meetings, with each meeting 2 x 45 minutes per lesson. In general, the lesson plan developed had aspects that were similar to typical lesson plans. Where at the learning step, the researcher combined all the steps into one stage. And at the motivation stage had a difference, which aimed to understand the area and perimeter concepts by asking problems a day. Here was an example of a problem to motivate students from a lesson plan.

“Dedi has two tiles as seen the following Figure 1, but Dedi does not know the area and how to determine the area of the tiles. Please help Dedi to determine the area of the tiles and how wide it is?”

![Figure 1. Two tiles that coincide with one side](image)

Design of test question should be relevant to the form of an open-ended question on quadrilaterals material. Table 2 shows the example of test questions developed.
Tabel 2. The sample of the developed test questions.

| Question | First revision | Second revision |
|----------|----------------|-----------------|
| 2        | A swimming pool is shaped like a shaded area below. Calculate the area and perimeter of the pool in your way! | Budi wants to make ceramics on the pedestal of swimming pool shaped rhombus with the area of 160000 cm². Calculate how much ceramics is required for the pool according to your way! |
| 4        | A garden is shaped rectangle with the area of 120 cm². If around the garden will be planted with protective trees with a distance between each tree is 2 m, how many stalks of protective trees are needed? | A garden is shaped rectangle with the area of 120 cm². If around the garden will be planted with areca nut trees with the distance between each tree is 2 m, how many stalks of areca nut trees are needed? |

Based on Figure 2, there were revisions of the test that would be given to the students. The revisions were based on the validator's suggestion. The first revision on questions number 2 and 4 shows that the questions have not been linked to pictures or illustrations in everyday life. Thus, it would improve students' problem-solving skills to solve the problems. Problem-solving is an attempt to find a way out of a difficulty to achieve a goal that is not immediately achievable [5]. The purpose of the open-ended approach is to help develop the creative activities and students' mathematical mindset through problem-solving simultaneously [12].

3.3 Develop stage
This stage related to the validation of product results developed. The developed learning instruments were validated in advance by experts (mathematics teachers, mathematical education experts). Table 3 shows the validation result of the learning instruments
Table 3. Learning instruments validation results.

| Product            | V1^a | V2^b | V3^c | V4^d | average | category |
|--------------------|------|------|------|------|---------|----------|
| lesson plan        | 0.87 | 0.86 | 0.86 | 0.80 | 3.39    | valid    |
| student worksheets | 0.93 | 0.96 | 0.90 | 0.92 | 3.71    | valid    |
| test questions     | 0.80 | 0.97 | 0.97 | 0.80 | 3.54    | valid    |
| Average            |      |      |      |      | 3.54    | valid    |

^a First Validator. 
^b Second Validator. 
^c Third Validator. 
^d Fourth Validator.

The analysis results of the learning instruments validation sheet were obtained an average value from the experts for the lesson plan of 3.39. This showed that the lesson plan with the open-ended approach was valid and could be used in the class learning process. The validation results of the students' worksheets received an average score of 3.71. This indicated that the students' worksheets with the open-ended approach were valid and could be used in the learning process in the class. The validation results of test questions got an average score of 3.54. This showed that the test questions that had been developed was valid and could be used in the learning process in the class. Overall learning instruments were obtained an average value of 3.54. This indicated that the overall learning instruments could be categorized as valid [17]. However, the score that was obtained on the questionnaire sheets had not reached the maximum value, that was 5, this was because the instrument was only revised twice in accordance with the validator's suggestion. Validity may affect the number of validators, the more validators, the more contents must be revised so that the higher level of the validity because it will provide more constructive advice from different perspectives for improving the instrument.

4. Conclusion

This study produced the valid learning instruments by implementing an open-ended learning approach on the topics quadrilaterals. The average validity score was 3.54, which indicated that, theoretically, the instruments were valid. When designing learning instruments using an open-ended approach, teachers are supposed to consider the relevancy of the topics to the approach due to the complex process of designing open-ended questions.

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