Generative learning model to improve mathematics problem solving skills on polyhedron

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Abstract. The purpose of this study was to develop valid, practical and effective generative learning instruments to improve the mathematics problem solving skills. This research was development research using Thiagarajan, Semmel & Semmel’s 4D model consisting of designing, defining, developing, and disseminating stages. However, this study was limited to the validation stage. The instruments developed were lesson plan, student worksheet, and mathematics problem solving test. Data collection techniques used were questionnaires and tests. The participants are 24 year 8 students in one of secondary school in Pidie, Aceh, Indonesia. The validity data of learning instruments were obtained based on expert validation while the validity data of the test were derived based on students' answers. The results of this study showed that the learning instruments developed was valid, with the score for (a) lesson plan was 4.54 (excellent category), (b) student worksheet was 4.32 (good category), and (c) the test of mathematics problem solving skills was 4.4 (good category). Furthermore, the developed test of mathematics problems solving skills showed that the average results of validity and reliability were categorized into the high criteria, difficulty index into medium criteria and differentiation index into good criteria.

1. Introduction
Mathematics is one of the subjects playing an important role in education. It is taught in educational institutions, from elementary to university levels. One of the objectives of mathematics subjects as stated in the Standard of Mathematics Subject Content of Junior High School is that students can solve mathematics problems including the ability to understand problems, design mathematics models, solve models and interpret the solutions [1]. Therefore, the mathematics learning that we do must be oriented to problem solving [2,3], and it is should be teacher's goal help students understand and resolve the problems as most problem solving in mathematics learning is about the problems in everyday life.

Problem solving is the process of applying the previously acquired knowledge to new and different situations [4]. ”Problem solving is the heart of mathematics” meaning that the fundamental of mathematics is problem solving [5]. Recognizing the importance of mathematical problem solving skills, the teachers are required to deliver learning that makes students more active and free to express ideas and reasons for the given problems. Therefore, students will better understand the knowledge that formed themselves and the learning process will be more optimal.

One of the efforts that can be done is through developing learning instruments of generative learning model. Generative learning theory is developed to explain the cognitive processes that occur during learning [6]. It defines learning as a generation of knowledge of “the creation of new understanding” [7]. Generative learning is a learning model emphasizing the active integration of new
knowledge by using the students’ initial knowledge so that students express what they have acquired in their own words [8].

There are four stages in the generative learning model, namely the exploration stage, the focusing stage or introduction of concepts, the challenge stage, and the application stage [9]. In the first stage, the teacher guides students to explore the initial knowledge, ideas, or concepts derived from daily experiences or gained from previous levels of learning. In the second stage, students are given the opportunity to express their ideas about the concepts being studied. In the third stage, the teacher gives students the opportunity to compare their opinions with other students' and express the superiority of their opinion of the concept being studied. In the last stage, students are given the opportunity to test alternative ideas that they build to resolve the varied issues. In this learning process, students are active in the discussion because it is another way of deepening the understanding of concepts through social interaction [10].

Considering the background described above, this study aimed to develop valid, practical and effective generative learning instruments to improve the mathematical problem solving skills.

2. Method

The type of this study is a Research and Development using the 4-D model. This model consists of four development stages of Define, Design, Develop, and Disseminate [11]. However, this study was limited to the Develop stage.

In the first stage, the learning conditions should be defined. Considering the five steps of the defining phase [11] that have been performed, it was concluded that most students were having difficulty in understanding and solving problems of the polyhedron. This is because students had difficulty in determining the mathematics model and they did not understand the problems so that the significant information not being used to solve the problem. Therefore, problem solving is hard for students.

The participants in this study were 24 Year 8 students in one of secondary school in Pidie, Aceh, Indonesia. Students’ ability and interest were varied. The common teaching method used in the school was lecturing, discussion and solving problems together. Concept analysis and task analysis generated an instructional objective, that is learners can solve problems related to cubes and cuboids through generative learning.

The next stage of the development is Design. There are four steps in the Design stage, namely criterion-test construction, media selection, format selection, and initial design. Through the four steps, the initial learning instruments were developed. The learning instruments developed was lesson plan, student worksheet, test questions and self-efficacy questionnaire [12]. However, this paper will only discuss the lesson plan, student worksheet, and test questions. The lesson plan was developed based on the generative learning model syntax, whereas student worksheet and test questions were developed based on the indicators appropriate to mathematics problem solving.

The third stage of the 4-D model is Develop. According to Thiagarajan et al. [11], this stage consisting of two steps, expert appraisal and developmental testing. In the expert appraisal step, the initial learning instruments that have been designed were validated to determine its quality. The validators in this study consisted of two mathematicians, two mathematics teachers, and one colleague who had attended various seminars. Based on the validation results of the lesson plan and student worksheet, the instruments were revised for subsequent use in the study.

3. Result and discussion

The developed learning instruments included: (1) lesson plan, (2) student worksheet, and (3) mathematical problem solving test. The learning instruments developed needs to be validated and the validity is measured based on the validity results [13]. Therefore, the initial product of these instruments was called Draft 1, and it was ready to be validated by the validators. In addition to these learning instruments, researchers also designed the instrument for assessment of the learning instruments. The assessment instruments consisted of the validation sheets of lesson plan, student worksheet and mathematics problem solving accompanied by assessment guides.
The validation process of the draft I was conducted to examine the content validity of the instruments developed. Learning instruments validation results were used to determine whether the learning instruments can be used or not. Suggestions from the five experts were used as a basis for the improvement of the instruments developed. Once the validators validated them, revisions were made following the feedbacks of the validators and Draft II was obtained. The validation result of Draft I is presented in Table 1.

**Table 1. Results of validators’ assessment toward the draft I of learning instruments.**

| Validated instrument                  | Average | Criteria |
|--------------------------------------|---------|----------|
| Lesson plan                          | 4.56    | Excellent|
| Student worksheet                    | 4.32    | Good     |
| Mathematical problem solving skill   | 4.4     | Good     |
| Average                              | 4.43    | Good     |

Based on the validator's assessment of the items on the mathematics problem solving skills, they fulfilled the content validity and can be used with little revision. The average score of validators' assessment for the lesson plan is 4.54 (excellent category), student worksheet is 4.32 with a good category, and the test of mathematical problem solving ability is 4.4 (good category). Overall, the average validation score for the learning instruments, including the lesson plan, student worksheet, and mathematics problem solving skills is 4.43 and falling into a good category (a scale of 5). Therefore, it was concluded that the learning instruments developed can be used with little revision.

**D. Comments and Suggestions for Improvement**

- **Lesson plan**
  - The sentences in the lesson plan do not clearly emphasize the activities of students and teacher.
  - The information in the questions is not systematic and appropriate.
- **Student worksheet**
  - The allocated time is not in line with the content presented.
  - Avoid using ‘follow the procedure…’
- **Mathematical problem solving skill**
  - The words or sentence has been revised.
  - The information given is complete and appropriate.
  - The sentences in the lesson plan have emphasized the activities of students and teacher.
  - The allocated time has been revised based on the content.
  - The words have been removed from the lesson plan.

**Figure 1. Validators’ comments to the test of mathematical problem solving ability**

Example of validators’ feedback or comment to the test of mathematical problem solving ability can be seen in Figure 1. Furthermore, the summary of validators' feedbacks toward the learning instruments is presented in Table 2.
Learning instruments developed as previously described, namely lesson plan, student worksheet, and the test of mathematics problem solving skills. In this research, lesson plan was designed to follow generative learning model to improve mathematics problem solving skills that were the exploration or preliminary stage, the focus or introduction stage, the challenge stage, and the implementation stage. Learning took place for four meetings with a time allocation of 2 x 40 minutes for each meeting. Based on the lesson plan validity results, it was valid with a minor revision. Student worksheet in this study is designed to encourage students actively in learning activities, practice the skills of learning, and develop problem solving skills and curiosity of students. From the validation result student worksheet obtained valid criteria with a minor revision. Figure 2 presents part of the developed lesson plan and student worksheet.

![Activity 2. Solving Problem Related to Volume of Cuboid](image)

Pak Erik is building a store. The dimension of the store is 4m × 7m × 3m with the thickness of the wall is 12cm. Pak Erik has made the foundation of his store using six pillars, the dimension of each pillar is 25m×30cm×3m. What is the minimum money needed by Pak Erik to build the wall?

(The cost of a wall with dimension 1m×12cm×1m is Rp65,000.00 and the front side of the shop entirely using a metal door).

![Figure 2. Example of the problem on the developed student worksheet](image)

Mathematics problem solving test was designed to measure students' problem solving skills on polyhedron. The preparation of the test instruments of mathematical problem solving skills involved the preparation of test prediction and scoring rubrics. The items of the mathematics problem solving skills test were consulted to the supervisors and validators to obtain the content validity. From the results of the validation, the mathematical problem solving skills test acquired was valid with minor revision.

| No | Validity | Reliability | Difficulty index | Differentiation index |
|----|----------|-------------|------------------|-----------------------|
| 1  | High     | High        | Medium           | Fair                  |
| 2  | High     | High        | Medium           | Good                  |
| 3  | High     | High        | Medium           | Good                  |
| 4  | High     | High        | Medium           | Good                  |
| 5  | High     | High        | Medium           | Good                  |
| 6  | High     | High        | Medium           | Good                  |
| 7  | High     | High        | Medium           | Fair                  |
| 8  | High     | High        | Medium           | Good                  |
The items of mathematics problem solving skills test were tested to assess its validity, reliability, difficulty and differentiation index to examine the feasibility of the items. Therefore, the final product of the mathematics problem solving test is a set of questions meeting the valid, reliable, difficulty, and differentiation index of good or excellent. The results of test items validity, reliability, difficulty index, and differentiation index are presented in Table 3.

Based on Table 3, it can be concluded that the test of mathematics problem solving skills and reliability are classified as the high criteria, while difficulty index is classified as the medium criteria and differentiation index as the good criteria. Mathematics problem solving test items consists of pretest and posttest items, item 1, 2, 3, and 4 are the questions of pre-test while item 5, 6, 7, and 8 are the items of post-test. The correlation coefficient of validity test for the pretest items were 0.704, 0.853, 0.844, and 0.837 subsequently with the high and valid criteria. The result of reliability test for the items of mathematics problem solving skills test was 0.613 meaning the reliability is very high. The difficulty indexes of pretest items were 0.631, 0.623, 0.621, and 0.530, falling into for medium category. As for the differentiation index result for the pretest items were 0.310, 0.421, 0.510, and 0.405 categorized as the fair criteria for the item 1 and good criteria for items 2, 3, and 4.

The results of correlation coefficient calculation for the validity of post-test questions in the sequence were 0.794, 0.846, 0.780, and 0.864 with the high and valid criteria. The result of the reliability test for the items of the mathematics problem solving skills test was 0.623 meaning that its reliability is very high. The difficulty indexes of post-test items are 0.673, 0.644, 0.537, and 0.647 subsequently with the criteria for all questions is medium. As for the differentiation index, the results obtained the pretest items are 0.600, 0.496, 0.327, and 0.483 subsequently with fair criteria for item 3 and good criteria for item 1, 2, and 4.

Figure 3 presents one of student's answer to the posttest. As shown in figure 3, the student was able to solve the given problem by following the steps of problem solving approach: identify the issues, devise a plan, carry out the plan, and look back [2].

![Figure 3. Example of student’s answer to the mathematics problem skill test.](image)

Students' problem solving skills are excellent because the appropriate learning instruments used, one of which the learning instrument of the generative learning model. This is in accordance with a
study that revealed that there is an influence of the application of generative learning models on the mathematics problem solving skills [13]. In addition, the role of teachers and methods applied in learning influence students’ problem solving skills [14, 15]. This can be interpreted that the selection and application of a learning instrument to enhance students’ mathematics problem solving ability.

4. Conclusion
The mathematics learning instruments developed using generative learning model on the topic of polyhedron meets the criteria of validity. It shows that the average validation of experts is 4.43 of scale 5 (good category), the average score of the lesson plan is 4.54 (excellent category), student worksheet is 4.32 (good category), and mathematics problem solving skill test is 4.4 (good category). Overall, the developed learning instruments can be used with minor revision. Likewise, the test of the mathematical problem solving skill is also valid. The average results of validity and reliability are categorized into the high criteria, difficulty index into the medium criteria and differentiation into the good criteria. Therefore, the learning instruments using generative learning model on polyhedron that have been developed can be tested in the field as it has met all valid criteria.

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