Assessment for learning of mathematics

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Abstract. In the 21st century assessment is not only done at the end of learning, but also can be integrated directly in the learning process, called assessment for learning. This study explores the effect of it implementation in the process of mathematics learning. The main purpose of this research is to describe the achievement of learning objectives which consists of understanding concepts, reasoning, problem solving, and communicating ideas. Design research, which consists of three steps, preliminary research, prototyping stage, and assessment phase, is the method chosen for designing assessment for learning. The design is tested to 36 students. The implementation of assessment for learning is carried out in three activities. The results of the implementation of it on the achievement of learning objectives are as follows: at the first meeting 6 of 9 groups succeeded. In the second activity all groups achieved the learning objectives, and in the third activity 7 out of 8 groups also did it. This indicates that the implementation of assessment for learning can achieve the learning objectives that have been set very well. Because of that, effect of the design most learners can achieve the learning objectives that have been set. Furthermore, the design facilitates learners to be actively involved in learning activities so that it makes a good interaction between educators with learners, fellow learners, and the atmosphere created in the classroom becomes more positive.

1. Introduction

At present, Indonesia uses a curriculum known as the Curriculum 2013 (K13). It explains that assessment consists of three forms, namely assessment as learning (AaL), assessment for learning (AfL), and assessment of learning (AoL). This is in line with Berry [1] who divides it into three, as explained. AoL is carried out to measure students’ achievement of the competencies that have been set. AoL is an assessment that is usually done by educators in the form of tests conducted after learning is done, for example daily tests, midterms, semester exams, and national exams. AfL allows educators to use the condition information of students to improve learning, while AaL allows students to see the achievements and progress of learning to determine their next learning target.

According to Frey and Schmitt [2], class assessment generally uses written tests after learning is complete. Assessment that is carried out during the learning process can be an information material by educators to recognize and respond so as to improve student learning as long as the learning process[2,3] conducted by Kartowagiran and Jaedun [4] which found that most educators did not understand the demands of the assessment requested by the K13 known as authentic assessment. Authentic assessment is a means to improve learning based on the condition of students in the learning process known as assessment for learning (AfL)[5,6]. AfL is not provided for examination of achievements after the educator completes teaching. However, AfL can be used to obtain information that can help educators plan effective learning, especially for students [5,7,8,9].
This study aims to design AfL that is integrated with learning activities. Lesson plan is one of the materials that can see whether the quality of assessment planning shows good categories, or needs improvement. Aspects of assessment design in lesson plan still need improvement, because it does not indicate that assessment is integrated with learning activities generally [4]. One principle of assessing the achievement of competencies by students is integrated and systematic, meaning that assessment is not separate from learning activities and is carried out in a planned and gradual manner. AfL design is limited on the subject of sine rules and cosine rules. Learning sine rules and cosine rules is generally done by memorizing patterns, then practicing some problems related to the material and ending with an exam. Students who are active in mathematics lessons not only learn mathematics as a product, but also learn it as a process. It would be better for educators not to present the material in its finished form, because students do not learn mathematics by only accepting and memorizing it, but must learn meaningfully [10]. Thus, this research focuses on: (1) how is the design of assessment for learning (AfL) on the learning of sine rules and (2) whether the design of AfL can help educators’ direct students to achieve mathematical competence in the material of sine rules and cosine rules.

2. Methods

2.1. Research Method
This research method is qualitative research in the form of design research. This model is one of methods that answer research objectives in the field of education to develop instructional theory based on the development of theory-driven and empirically based experiments [11]. Based on the formulated characteristics, Plomp [12,13] defines design research as: A systematic study of designing, developing and evaluating educational interventions (such as programs, strategies and learning materials, products and systems) as a solution to solving complex problems in educational practice, which also aims to advance our knowledge of the characteristics of these interventions and their design and development processes.

2.2. Developing Plan
In this study, researchers used the steps of implementing the design research Plomp’s model [12,14]: preliminary research; prototype stage; and the assessment phase described as follows:

Preliminary research: Needs and context analysis, literature review, develops a conceptual and theoretical framework for research. Prototype stage: Initial stage of this part is to design learning trajectory. The process consists of three stages: 1) set learning objectives; 2) determine learning outcomes; and 3) set assessment criteria. The next step is to design an assessment for learning which is consists of 3 aspects: concept construction; problem solving; and feedback. Each draft of the assessment prepared includes predictions and anticipations that arise, so that ongoing learning can achieve predetermined mathematics learning objectives. Assessment Phase: Semi summative evaluation to conclude whether the solution or intervention is in accordance with the desired and propose recommendations for the development of the intervention model.

2.3. Implementation Stage
Opening learning activities of the material to 36 students, the researcher conveyed the purpose of learning to prove the rules of sine and the rule of cosine and solve problems related to them. To achieve this goal, the learning activities at this meeting are conducted with assignments, oral tests, and written tests.

3. Results and Discussion
The purpose of the first meeting on the implementation of assessment for learning is (1) understanding the concept of sine rules; (2) using reasoning on patterns and traits, manipulating mathematics in making generalizations and compiling sine rules; and (3) communicating ideas about the results of proving sine rules. Based on the learning objectives, learning activities are divided into two, namely
(1) constructing students’ knowledge, through the activity of identifying whether sine rules can apply to all triangular shapes as shown in Table 1 and (2) proving sine rules at any triangle ABC: 
\[ \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}, \]
shown in Table 2.

**Table 1.** Achievement of the sine rules goal

| Goals | Groups | Activity I | Activity II |
|-------|--------|------------|-------------|
| Achieved | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Not achieved | 2 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Achieved | 3 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Not achieved | 4 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Achieved | 5 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Not achieved | 6 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Achieved | 7 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Not achieved | 8 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Achieved | 9 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

The first meeting, the class was divided into 9 groups, each consisting of 4 students. In activity I 6 out of 9 groups succeeded in achieving the goals that had been written. Groups that did not reach the goal were groups 3, 5, and 8, Figure 1. Group 3 and group 5 did not reach the goal of activity I due to they chose arbitrary triangles that result in accuracy in measuring side length and angle in the triangle they described. Group 8 made a fatal mistake that the researcher did not notice when they were discussing. The mistake error in determines side a, side b, and side c in triangle ABC. so that the comparative calculation of each side and angle before it does not lead to the goal to be achieved. Activity II at the first meeting, all groups succeeded in achieving the learning objectives, so that the group that failed in activity I received confirmation again in activity II.

Next session, students were divided into 5 groups, each group worked on problems related to sine rules. The problems were given: 1) if two angles and one side are given (AAS and ASA); 2) if two sides of one angle are known (SSA); and 3) If one angle is known between two sides (SAS).

The third problem is yes-no question, can the triangle solve by the sine rule? After solve all of problem, they asked to make a conclusion. Because of their succeeded of solving the problems the sine rules, each group made a conclusion that the sine rule can be applied into three cases: 1) if two angles and one side are given (AAS and ASA); 2) if two sides and one angle are given, but the form have to SSA. Further, SAS form was discussed in the next meeting, the cosine rules.

**Table 2.** Achievement of the cosine rules goals

| Goal | Groups | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------|--------|---|---|---|---|---|---|---|---|
| Achieved | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Not achieved | ✓ |

The aim of assessment for learning in cosine rules are: (1) understanding the concept of cosine rules; (2) Using reasoning on patterns and traits, manipulating and compiling evidence of cosine rules; (3) communicating ideas about the results of proving the rules of cosines; and (4) solve problems related to cosine rules. Learning objectives (1), (2), and (3) are intertwined in one activity, and goals (4) in other activities, so the learning of cosine rules is divided into two activities. Activity I students are divided into 8 groups, each group has the task of determining the side length a at ∆ABC, if it is known the angle A, side b, and side c. Determining the a side starts in the form of a number, to a symbolic form so that the rule of \( \cos a^2 = b^2 + c^2 - 2bc \cos A \). One of the 8 groups formed cannot reach the cosine rule formula, Figure 2. The mistake that they made error in describing the form \( (c - b \cos A)^2 \) to be \( c^2 - (b \cos A)^2 \), so it does not reach the form \( a^2 = b^2 + c^2 - 2bc \cos A \). As
a result of almost all groups achieving their goals in activity I. Activity II was solving the problem related to the cosine rules. Every student did not face significant difficulties to solve some problems of the cosine rules.

Closing the implementation of assessment for learning is a form of feedback. Students conclude sinus rules and cosine rules, then knowing how they are applied in mathematics problems. Assessment for learning successfully achieves the learning objectives of mathematics that are set at the beginning of learning, understanding concepts, communicating ideas, and solving mathematical problems with the material that has been studied.

4. Conclusion
The results of the implementation of the assessment for learning show that almost all students achieve the objectives of learning mathematics on the topic of sine rules and cosine rule. Discussion activities carried out provide experience for students to be able to reject, accept, and communicate ideas in constructing the concepts of them. Learning activities that involve students in constructing the mathematical concept give their own meaning to students. Other than that, the results of the implementation of the assessment of learning also effectively provide information to teachers about students who need remedial and students who have achieved mathematics learning goals. If all students have achieved the learning objectives well, then the teacher can provide enrichment materials.

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