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How to Design Problem-Based Learning for Reasoning Ability?

Anggita Maharani [1*], Leo Waldy Yulius Putra[2]
[1,2]Universitas Swadaya Gunung Jati, Cirebon, Indonesia

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ABSTRACT

Objective: To get around students' reluctance, learning media is needed; one of them is the development of mathematics teaching materials. The development of teaching materials is needed to actualize subjects, especially mathematics, as a contextual subject. This goal is to improve students' reasoning abilities in understanding and solving the problems in daily life. The function of the model is as an intermediary between students' mathematical reasoning abilities and the questions presented in the development of teaching materials. More mathematical reasoning abilities are found in trigonometry material. Trigonometry is the science of measuring the angles and boundaries of triangles (used in astronomy and so on) in which there are solutions for other problems, such as measuring the height of mountains, buildings, towers, etc. **Method:** This research uses a qualitative method. **Results:** The teaching material Trigonometry research is valid for module material validation, graphics or media validation, and obtained from audience validation results. The three percentages are at a very valid validation level and can be used in schools. **Novelty:** After the application of this teaching material, the result was that students' mathematical reasoning abilities became better.

INTRODUCTION

Mathematics is a beneficial science for humans in daily activities. This knowledge is a compulsory subject from elementary school to university level. The National Education Standards Agency stipulates that starting from elementary school, students must be equipped with logical, analytical, systematic, critical, creative, and cooperative skills. The ability to learn mathematics is classified into five main competencies: understanding, problem-solving, communication, connection, and reasoning (Aguilar & Castaneda, 2021; Al-Mutawah et al., 2019; Marasabessy, 2021). The aim of learning mathematics in schools is to increase the sharpness of students' reasoning so that they can solve problems in daily life and improve their thinking skills in using numbers and mathematical symbols.

Mathematical reasoning ability is the ability to understand patterns of relationships between two or more objects based on rules, theorems, or proven propositions (Hasanah et al., 2019; Kadarisma et al., 2019; Lestari & Andinny, 2020; Lestari et al., 2022; Rizqi & Surya, 2017; Sandy et al., 2019; Saxton et al., 2019). This can be interpreted that mathematical reasoning skills need to be developed. However, there have been many research results showing that students' low mathematical reasoning was caused by the teacher only providing the subject with examples and routine problem exercises, but when given non-routine questions, students experienced difficulties when they had to start determining the solution (Fuadi et al., 2016; Indriati, 2018; Izzah & Azizah, 2019; Napitupulu et al., 2016; Nasution et al., 2019; Putri et al., 2019; Zubainur et al., 2020). Material that concentrates on non-routine problems is found in material on trigonometry. Trigonometry is a science that cannot be separated from high school mathematics because it is a source of arithmetic and geometry (Nanmumpuni & Retnawati, 2021; Sulastri & Arhasy, 2017; Zulmaulida et al., 2021).

Based on Huljanah's research at Al-Azhar High School with the identification of student work results, students made inappropriate procedural errors and problems with skill hierarchies even though students had studied the material (Huljannah & Sugita, 2015). These difficulties experienced by students are called learning obstacles. This proves that the student's learning is still categorized as "understanding," not developing material that has been understood or what is commonly called reasoning ability. A learning model that can develop students' abilities in reasoning is problem-based learning. What is meant is the Problem-Based Learning (PBL) model. PBL is beneficial in making students active (Kusuma & Candramila, 2017; Mardhiyana & Sejati, 2016; Masruro et al., 2021; Nisaâ et al., 2015; Nurdyansyah, 2018a; Samadun & Dwikoranto, 2022; Suwono et al., 2017; Thamrin et al., 2022; Uliyandari et al., 2021) because the learning situation is based on real-life problems so that students are responsive to the material they are learning. Problem-based learning effectively teaches higher-order thinking processes (Hidayati & Ratnawati, 2016; Ramdiah et al., 2018; Setiyani et al., 2017; Widiawati et al., 2018). To support problem-based learning and anticipate student learning difficulties by developing a learning planning process as a didactic design. Terms like this are called Didactic Design Research (DDR).

Didactic design research was initiated by the teacher's thought process, which occurred in three phases: Pre-activities, Activities, and Post-activity (Breda et al., 2017; Pino-Fan et al., 2018). The analysis results of the three phases will produce innovative didactic designs. In the stages of the learning process, besides the need to master the material, a teacher also needs to have the ability to create didactic relationships between students and teaching materials to create an ideal didactic situation for students. Therefore, the relationship between teaching materials and students is conveyed through teaching material. Teaching materials are materials used by teachers or instructors in implementing classroom learning (Alaidi et al., 2020; Kosasih, 2021; Magdalena et al., 2020; Nurdyansyah, 2018b). Preparing teaching materials should pay attention to the characteristics of students, using language that is easily understood by various students' abilities. Suitable teaching materials can provide the abilities of each student with low, medium, and high abilities. However, based on the results of an interview with a high school mathematics teacher, it was stated that not all students had teaching materials because the teaching materials available in the library were insufficient to be borrowed by students. Practical and minimalist teaching materials can widen students' knowledge of teaching materials.

The module is one of the printed teaching materials practically used by students. The use of the module is intended for independent learning purposes. PBL steps are expected to be able to minimize students' mathematical reasoning problems. Therefore, this research aims to discover the learning obstacles that students experience and design teaching materials in the form of valid modules. The module created was implemented in the The Eleventh. Application of this teaching material hopes that students' mathematical reasoning abilities improve.

RESEARCH METHOD

This research used the qualitative method because the results will be interpreted as the result of module implementation designed as a whole process, starting from the creation process to the findings from the limited module result trials in the classroom.

At the same time, the research design was DDR. The subject of this research was the eleventh-grade students to identify the learning obstacles and design the teaching material implementations. The techniques used by researchers in collecting data are written tests and questionnaires. The instruments in this research were tests of mathematical reasoning abilities (written tests) and validation sheets. Data analysis in research by way of descriptive analysis.

RESULTS AND DISCUSSION

Results

This research obtained results in the form of 31 students' answers who answered five questions to identify student learning difficulties or learning obstacles, and the following results were obtained in Table 1.

Table 1. Recapitulation of test results.

No.	Answers			Obstacles
	True	Nearly True	False	
1	5	6	20	Students have difficulty showing questions in a picture
2	0	5	26	a) Students need help remembering trigonometry identities. b) Students need help manipulating trigonometric identities that should be changed.
3	0	2	29	a) Students have difficulty presenting a right triangle DEF, which has sizes three times, four times, and so on in pictures. b) Students have difficulty associating the relationship between the two triangles.
4	0	5	26	a) Students have difficulty in determining the side of the known angle and hypotenuse. b) Students need help determining the proper proof to prove the conclusion is right or wrong.
5	0	7	24	a) Students need help in distinguishing trigonometric equations and trigonometric identities. b) Students need help in determining the proof of trigonometry identity, with the final result of the proof being 2.

From all students' answers, an average value of 28.06 is obtained. After identifying learning obstacles, didactic and pedagogical anticipation and prediction of student responses that will emerge are needed. The anticipation made is poured into a didactic situation. This didactic situation is included in the design of teaching materials in the form of a trigonometry mathematics module. The module is validated by a validator with a validation score above 87.00%. This figure is a very valid criterion.

Implementation of valid modules in class uses problem-based learning that makes students active and work together in groups. Then, after learning, a final test is carried out in the form of questions that are the same as the questions for identifying learning obstacles. The overall student answers obtained an average value of 80.4. Table 2 shows the overall results of student answers.

Table 2. Recapitulation of the competency test results.

No.	Indicators of mathematical reasoning ability	Answers		
		True	Nearly True	False
1	Ability to present mathematical statements orally, in writing, pictures, and diagrams	13	18	0
2	Ability to manipulate mathematics	29	0	2
3	Using patterns and relationships to analyze situations and generalizations	20	9	2
4	Conclude a statement	27	2	2
5	Ability to make conjectures	24	1	6

Discussion

Learning obstacles from the five questions are related to indicators of mathematical reasoning abilities. One example of the questions given is:

1) A child plays with a kite. The thread length used is 15 meters, and the child's height is 1.5 meters. Suppose the angle formed between the thread and the horizontal line is 300. Then, calculate the kite's height from the ground.
2) Change $\tan^2 x + \csc^2 x - \cot^2 x$ into ^2x sec.

Question 1 with indicators of ability to present mathematical statements orally, in writing, pictures, and diagrams, and question 2 with indicators of ability to manipulate mathematics. The results of student answers to the two questions will be displayed in Figure 1 and Figure 2.

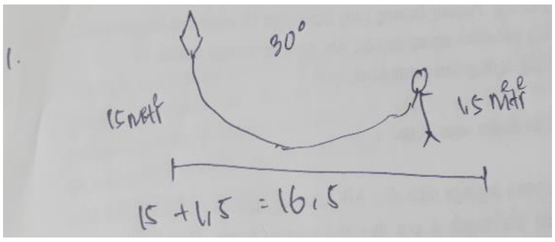

Figure 1. Student' answer to question number 1.

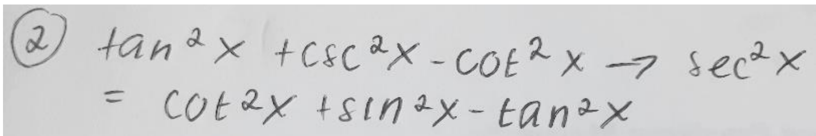

Figure 2. Student' answer to question number 2.

The two pictures show that students still have difficulty presenting images and manipulating trigonometric identities. Therefore, the didactic situation created, which has been displayed in the module, is in Figure 3.

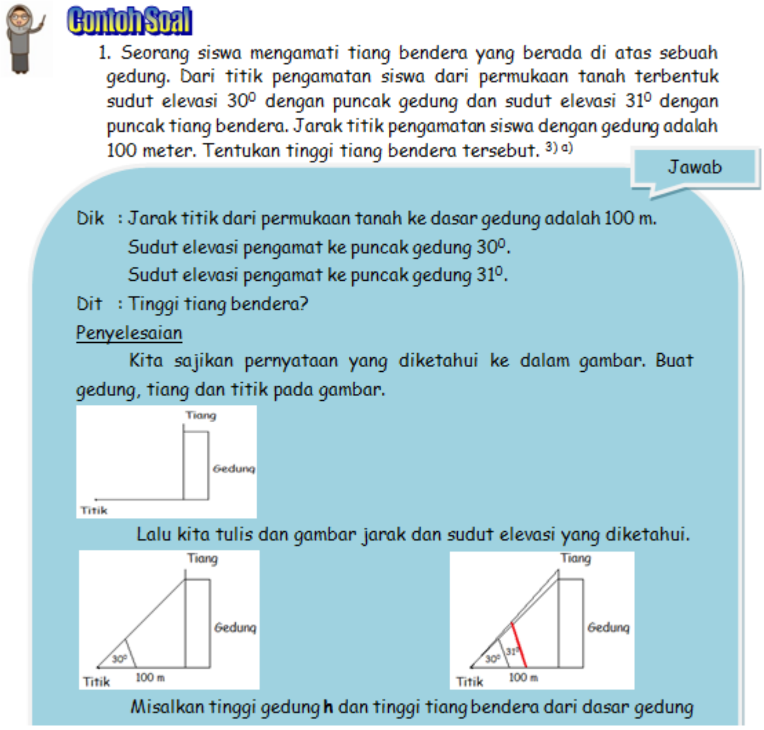

Figure 3. Example question number 1.

Figure 3 shows how to present the question statement in pictures and how to answer it systematically.

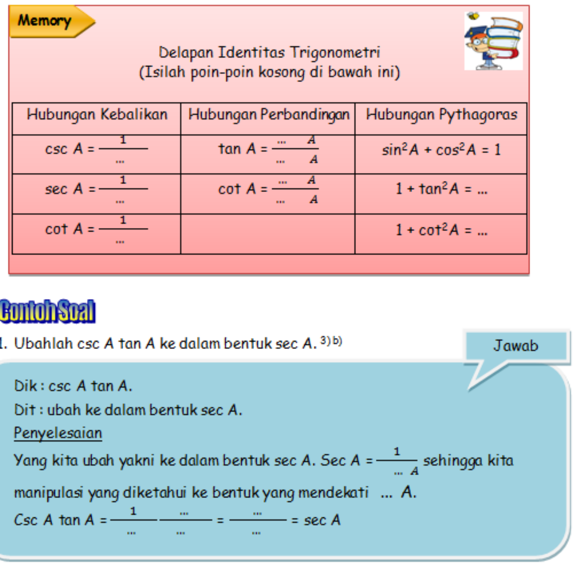

Figure 4. Example Question number 2.

The memory based on Figure 4 reminds students of what they have understood in learning trigonometry identities. From that memory, it can make it easier for students to remember trigonometry identities when answering questions. An example of a question in the module provided a method students should use to answer the question. The students' work on one of the questions is in Figure 5.

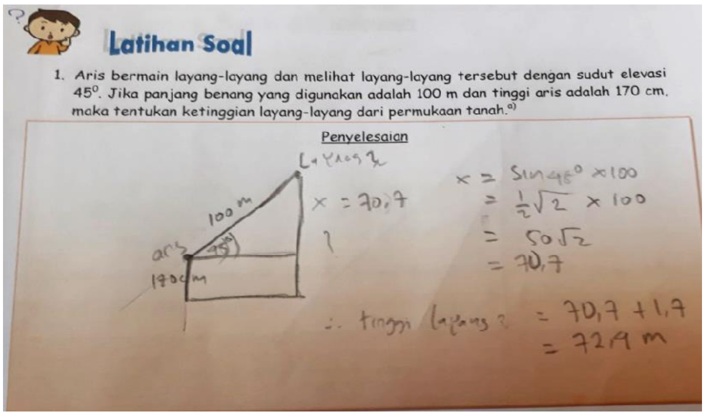

Figure 5. Student' answer to question number 1.

Students answer the question correctly by presenting the correct picture so that substituting values into the formula is appropriate. In the problem in Figure 5, Aris' height is the key to determining the kite's height because the height of something must be calculated from a surface. The student added the height from Aris' observations and Aris' height.

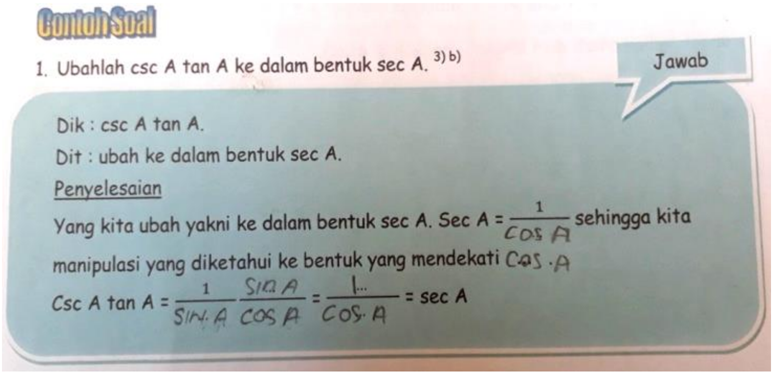

Figure 6. Student' answer to the example.

Figure 6 shows that students follow the steps by changing sec A first into the form$\frac{1}{\cos\cos A}$. It is hoped that the manipulation of csc A tan A is changed first to another form so that with mathematical operations, one can get$\frac{1}{A}$ which became sec A. The two didactic situations made most students answer the competency test questions correctly. The following is one of the student's answers related to indicators of the ability to present mathematical statements orally, in writing, pictures, and diagrams, and the ability to manipulate mathematics.

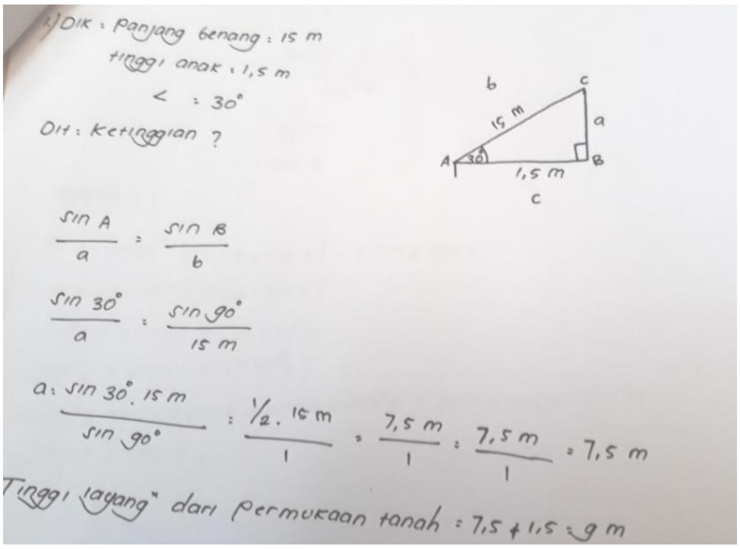

Figure 7. Student' answer to question number 1 after using the module.

Before using the module, students could not present the image correctly (Figure 1). Then, after using the module, students could answer questions correctly and systematically because they could present in Figure 7 and Figure 8 per the question statement (Nanmumpuni & Retnawati, 2021).

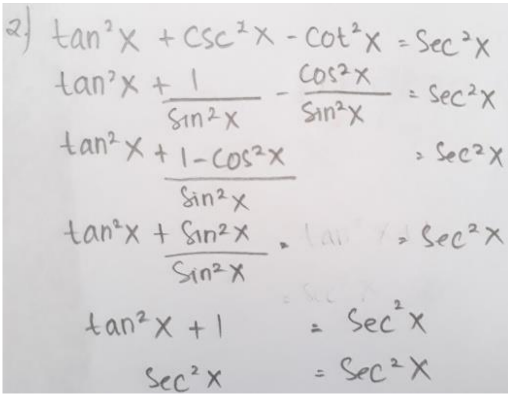

Figure 8. Student' answer to question number 2 after using the module.

Before using the module, the students needed help manipulating trigonometric identities correctly (Figure 2). Then, after using the module, students knew that $\tan^2x + 1 = \sec^2x$, so students only changed $\csc^2x - \cot^2x$ with mathematical operations. The final result was 1. The results of the average students' answers both before and after using the module show that students' mathematical reasoning abilities are better (Samadun & Dwikoranto, 2022).

CONCLUSION

Fundamental Finding: Based on research conducted on eleventh-grade students, the implemented valid module can minimize students' learning difficulties or make students' mathematical reasoning abilities better. Implication: This module will have a function if it is used systematically from the prerequisite material to the core material by using problem-based learning. **Limitation:** The problem-based learning model is very good to apply to learning mathematics and is not limited to trigonometry material.

Future Research: It is hoped that future research can find a more effective method to make it easier for students to change trigonometric identities into other forms and create a more realistic view of presenting problems in pictures.

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***Anggita Maharani (Corresponding Author)**
Department of Mathematics Education,
Universitas Swadaya Gunung Jati,
Jl. Perjuangan No 1, West Java, Indonesia
Email: anggitamaharani@ugj.ac.id

Leo Waldy Yulius Putra
Department of Mathematics Education,
Universitas Swadaya Gunung Jati,
Jl. Perjuangan No 1, West Java, Indonesia