Students’ ability to convert a situation into a mathematical model or diagram using problem solving approach

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Abstract. Students' mathematical communication skill needs to be developed through appropriate instructional strategies; one of which is the problem solving approach. One of the indicators of the mathematical communication skill is the ability to state the situation into a mathematical model/diagram. This article aims to describe the development of students’ ability to convert a situation into a mathematical model/diagram using the problem solving approach. This study used mathematical communication skill tests and a semi-structured interview. The data was obtained from the implementation of the quadrilateral learning using the problem solving approach involving six Year 7 students in a junior high school in Aceh Besar, Indonesia that consist of two high, middle, and low-achieving students. The finding shows that students’ ability to convert the situation into a mathematical model/diagram using problem solving approach was varied. High-achieving students can convert the situation into the model/diagram in every lesson. Middle-achieving students can convert the situation into a mathematical model/diagram in the first lesson, but the ability decreased in the second lesson and increased in the following lesson. Low-achieving students could not convert the situation into a mathematical model/diagram in the first and second lesson. However, they were able to do that in the third lesson.

1. Introduction
Mathematical communication is one of the mathematical abilities required in learning mathematics [1,2]. Mathematical communication is the ability to write, read, listen, review, interpret and evaluate ideas, symbols, terms, and mathematical information [3]. Aspects of mathematical communication skill include the ability to express, to interpret and evaluate mathematical ideas, and the ability to use terms, symbols, and structures. The ability to declare, to interpret and evaluate mathematical ideas can be conducted orally, in writing, and by visualization [4]. The ability is essential to model the situation or mathematical problems.

Developing students' mathematical communication begins with familiarizing students with problems related to problem solving activities [5]. Problem solving approach provides an opportunity for students to develop their mathematical communication skills and mathematical ideas [5,6]. Problem solving is a learning approach exposing students to a problem and asking them to solve it. Problem solving approach trains students to understand problems, plan solutions, solve problems, and re-examine the answers [3].

A well-established plan will optimally enhance the efforts to develop students' mathematical communication using the problem solving approach. Also, developing the learning instruments using appropriate procedures is crucial in planning the learning. Good learning instruments need to satisfy
the criteria of validity, practicality, and effectiveness [7]. The practicality and effectiveness criteria are evaluated based on the learning implementation in the classroom.

This article investigates the development of students' mathematical communication skill using formative tests that have been developed. This aims to answer a research question “how is the development of the students’ ability to convert the situation into a mathematical model/diagram using a problem solving approach?”

2. Method

This design research aims to develop learning instruments using the problem solving approach to improve students' mathematical communication skills. The learning instruments developed using ADDIE development model that consists of analysis, design, development, implementation, and evaluation phase. The developed products were a lesson plan, student worksheet and tests for mathematical communication skills of the topic of quadrilaterals. This article focuses on students' ability to convert the situation into a mathematical model/diagram as an indicator of mathematical communication skills.

Data of students’ ability to convert the situation into the mathematical model/diagram was obtained from the effectiveness of the learning instruments, i.e., the increase of the students’ skills measured [8]. The participants were six Year 7 students in one of the senior high schools in Aceh Besar, Indonesia. The ability of the students was varied, high, middle, and low. The students were selected based on the pre-test results and the teacher’s recommendation.

3. Result and discussion

Quadrilateral learning instruments using problem solving approach were developed for five lessons. The first lesson discussed the area and perimeter of squares and rectangles. The second lesson discussed the area and perimeter of parallelograms. The third lesson discussed the area and perimeter of trapezoids. Meanwhile, the area and perimeter of rhombus and kites were presented in the fourth and fifth lessons.

At each end of the learning, students were given formative tests individually. Formative tests were created in the form of descriptions and developed based on the indicators of mathematical ability. The development of the students' skills to convert the situation into the mathematical model/diagram was measured by the tests and clarified by semi-structured interviews. The ability to convert situations into a mathematical model/diagram was identified when the students were able to convert the situation in a problem into a mathematical model/diagram appropriately.

The students were asked to solve a problem about the area and perimeter of the rectangle in the first formative test. The expected answer was that students could draw a rectangle with a length of 30 m and 20 m, $\frac{1}{3}$ parts for the pool, $\frac{1}{2}$ parts for the garden, the remaining for the park. Based on the students' answers, it was indicated that high- and medium-achieving students were able to convert the situation into the mathematical model/diagram. Meanwhile, the low-achieving students were not able to convert the situation into the mathematical model/diagram. The students’ answers in solving the problem of mathematical communication skills based on indicators of the ability to convert the situation into the mathematical model/diagram are shown in Figure 1.

![Figure 1. Examples of students' answers: (a) high-achieving students, (b) medium-achieving students, and (c) low-achieving students.](image_url)
Figure 1 shows that high and medium-achieving students could draw a rectangle with the length of 30 m and width of 20 m as well as the location for the pool, gardens, and parks as specified in the problem. While low-achieving students only illustrated a rectangle with a length of 30 m and width of 20 m without specifying a predetermined part of the problems. This shows that high- and medium-achieving students were able to convert the situation into a mathematical model/diagram. The excerpt from the interview presented as follows.

Teacher: “What should be done to make calculation easier?”
Student: “Illustrates the situation stated in the problem.
Teacher: “Yes, good! Can you convert the situation into diagram so it would be easy to understand?”
Student: “Yes, I can.” (Drawing rectangles, the length is 30 and width is 20 as well as drawing sections for gardens, pools, and parks)

Based on the above explanation, it is indicated that high- and medium-achieving students could convert the situation into the mathematical model/diagram. This means that medium- and high-achieving students satisfy the indicator of the ability to convert the situation into a mathematical model/diagram. Figure 1 also shows that low-achieving students have not been able to convert the situation into the mathematical model/diagram.

In the second formative test, students were asked to solve a problem about the area and perimeter of parallelograms. The expected answer was that students could draw a parallelogram with the adjacent side lengths of 50 m and 52 m and one of the 50 m sides without trees. Based on the students' answers, it was found that high-achieving students were able to state the situation in the mathematical model/diagram, but the low- and middle-achieving students had not. The answers of low-, medium- and high-achieving students are presented in Figure 2.

![Figure 2](image_url)

**Figure 2.** Examples of students' answers: (a) high-achieving students, (b) middle-achieving students, and (c) low-achieving students.

Figure 2 shows that high-achieving students appropriately described the land of parallelogram with adjacent side lengths of 50 m and 52 m and one of the 50 m sides was not shaded, while the middle-achieving students correctly described the land of parallelogram with adjacent side lengths of 50 m and 52 m, but they incorrectly drew the trees that should be on one side of the 50 m only (as mentioned in the problem). Low-achieving students drew a parallelogram with trees planted inside it with 2 m length without trees. This indicates that only high-achieving students were able to convert the situation in the problem into the mathematical model/diagram that was confirmed in the following interview excerpt.

Teacher: “Can you convert the situation on the problem into the diagram with one of the 50 m side planted no trees?”
Student: “Yes, I can.” (Drawing a parallelogram with adjacent side lengths of 50 m and 52 m, and the 50 m side is without trees)
Teacher: “Why don’t you draw the trees on the 50 m side?”
Student: “Because that side is not planted with trees.”
It can be said that high-achieving students were capable of expressing the situation in the problem into the mathematical model/diagram. That means that they satisfied the indicator of the ability to convert the situation into a mathematical model/diagram. However, the medium- and low-achieving students had not met the indicator yet.

In the third formative test, the students were asked to solve a problem about the area and perimeter of the trapezoid. Based on the students’ answers, it was found that high-, medium-, and low-achieving students were able to convert the situation into the mathematical model/diagram. Figure 3 presents the students’ answers.

![Figure 3. Examples of students' answers: (a) high-ability students, (b) medium-ability students, and (c) low-ability students.](image)

Based on the above explanation, it can be concluded that high-, medium-, and low-achieving students were able to convert the situation in question into the mathematical model/diagram.

In the fourth formative test, students were asked to solve a problem about the area and perimeter of a rhombus. The expected answer was that students could draw a rectangle where a rhombus is in the middle of the rectangle. The students’ responses are presented in Figure 4.

![Figure 4. Examples of students' answers: (a) high-achieving students, (b) medium-achieving students, and (c) low-achieving students.](image)

Based on the above explanation, it can be concluded that high-, medium-, and low-achieving students were able to convert the situation in question into the mathematical model/diagram.
middle of a rectangle. This shows that high-, medium, and low- achieving students could appropriately express the information in the diagram into mathematical ideas as shown in the following interview excerpt.

Teacher : “Before calculating the area of the park outside the pool, did you sketch the park so that it would be easy to understand? Can you show me the sketch?”

Student : “Yes, I can.” (drawing a rectangle in the middle of the rhombus without writing the size)

Teacher : “How to express the mathematics model?”

Student : \( p = 3d_1, 1 = p-2 \)

Based on the above explanation, it can be concluded that the students were able to convert the situation into the mathematical model/diagram.

In the fifth formative test, the students were asked to solve a problem about the area and perimeter of the kite. The students’ answers are presented in Figure 5.

![Figure 5](image_url)

**Figure 5.** Examples of students' answers: (a) high-achieving students, (b) medium-achieving students, and (c) low-achieving students.

Figure 5 indicates that the high-achieving students stated the mathematical model for the area of the rectangle as 432 cm\(^2\), length as 2x, and wide as 3x, while the medium-achieving students described a mathematical model for pas 3x, l as 2x, and L as 432 cm\(^2\). The low-achieving student expressed the mathematical model for the rectangle of ABCD is 432 cm\(^2\), AB as 2x, and BC as 3x. This finding shows that high-, medium- and low-achieving students were capable to accurately describe the information in the diagram into mathematical ideas as revealed in the following interview excerpt.

Teacher : “What is the mathematical model of this problem? ”(Pointing to the problem)

Student : “The area of the rectangle is 432 cm\(^2\), the length equals to 2x, and the width equals to 3x.”

Based on the explanation mentioned earlier, it can be said that high-, medium- and low-achieving students had been able to convert the situations presented in the problems into the mathematical model/diagram. This occurred because the learning provided enough opportunities for the students to express their mathematical thinking [6]. Besides, the problem solving approach might also motivate students to be more active in discussing the problems with their group members. This discussion positively contributes to the students’ ability in converting the situation into the mathematical model/diagram [9].

Based on the results of formative test analysis, students’ ability to convert the situation into the mathematical model/diagram had progressed from the first to the fifth meeting. This suggests that the learning instruments developed met one of the indicators of the effective learning instruments [8].

**4. Conclusion**

The results show that the students’ ability to convert the situation into the mathematical model/diagram improved and it was varied based on their ability. High-achieving students were able to express the situation in the question into a mathematical model/diagram in each lesson. The medium-achieving students were able to express the situation into the mathematical model/diagram in the first lesson, but it decreased in the second lesson and improved in the third lesson. Meanwhile, the low-achieving students had not been able to convert the situation into the mathematical model/diagram in the first and second lesson, but then they could do it in the third lesson.
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