Students’ Mathematical Communication Ability in Solving Trigonometric Problems

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Abstract. Mathematical communication ability is a person’s ability to convey mathematical ideas orally or in writing which are presented in the form of graphs, tables, diagrams, symbols, or mathematical models. The purpose of this study is to determine and describe the level of mathematical communication ability of students. This type of research is a qualitative descriptive study. The sampling technique was using a purposive sampling technique. The results showed that the percentage of students’ mathematical communication ability in the text writing indicator, 38% of students were in the poor category, 50% of students were in the moderate category, 11% of students were in a good category, and 4% of students were in the very good category. On the drawing indicator, 7% of students were in the poor category, 57% of students were in a low category, and 36% of students were in the moderate category. 14% of students were in the poor category, 50% of students were in a low category, 18% of students were in the moderate category, 11% of students were in a good category, and 7% of students were in the very good category.

Keywords: Mathematical Communication; Problem; Trigonometry.

1. Introduction

The progress of a nation can be seen from how much a nation produces quality human resources (HR). Quality human resources can be formed with education. Education can provide cognitive abilities and mental readiness for someone to enter society, build social relationships, and have a responsibility as individuals and social beings. Learning is part of the educational process in which there is communication between teachers and students.

Communication means notification, conversation, exchange of ideas, or relationships. In terms of communication, it can be defined as social interaction through symbols and a system of delivering messages from one party to another so that mutual understanding occurs [1]. Communication will make ideas as objects of discussion, improvement, revolution, and reflection [2,3]. The communication process aims to construct meaning, offer ideas, and share ideas. When communicating, these students will learn to explain and convince the ideas as an understanding they have to others[4]. Lim and Chew stated that students capable to efficiently solve problems and also explain math concepts and skills to their friends, teachers, or others through effective communication[5]. Communication abilities in learning mathematics are called mathematical communication ability.

Mathematical communication ability is individual abilities in expressing and pouring information to others based on the thought obtained in the form of sketches, illustrations, and mathematical expressions [6]. NCTM [7] states that are four mathematics communication standards in mathematics learning,
namely: (1) regulating and consolidating mathematical thinking through communication; (2) communicate mathematical thinking coherently and clearly to peers, teachers, and others; (3) analyzing and evaluating the mathematical ideas and strategies of others; and (4) using mathematical language to present mathematical ideas correctly. According to Elliott and Kenney, mathematical communication ability has three aspects, namely writing, drawing, and mathematical expression. These aspects are a person’s ability to express any ideas of mathematical in the form of text, which is called writing; graphs, pictures, diagrams, and tables called drawing; symbols, languages, and math model called mathematical expression[8].

Several other researchers have also admitted the importance of communication ability in studying mathematics. Communication shows how students express ideas and ideas and reflect on their understanding of mathematics to others [9,10]. The ability of mathematical communication ability is needed to learn the language, mathematical symbols and explore mathematical ideas; communication is useful for training students in expressing ideas based on facts, rationally, and convincing others to gain mutual understanding [11]. Baroody said that mathematics can play a role as a language to communicate any idea in a clear, precise, and accurate manner. Mathematics can also play a role in social activities, especially for interaction between students and teachers. Therefore, mathematical communication should be developed continuously beyond only a tool for thinking and looking for patterns to solve problems and find solutions[12,13].

Asiskin [14] mentioned several roles of communication in mathematics learning, namely: (1) able to explore mathematical ideas from various perspectives, promote student thinking, and increase students’ ability to see connections from various mathematical pathways; (2) can be used to reflect and measure students’ mathematical understanding; (3) can promote students to combine and organize mathematical ideas; (4) can improve the construction of mathematical knowledge, social ability, reasoning, and self-confidence; and (5) can promote inclusive mathematical communication.

Previous researchers showed that students’ mathematical communication abilities were still in the low category, Nurjanah’s research results showed the proportion of achievement of communication ability such as students on the indicator of visual mathematical expression ability by 25%, the ability to demonstrate written mathematics visually by 35%, the ability to use mathematical notation by 35%, and the ability to use situation models by 15% [15]. The result of Sari’s Research also showed that the percentage of students’ mathematical communication ability on the indicators of expressing mathematical ideas, situations, and correlations into graphs, pictures, or algebraic expressions was only 35%. The indicator states daily experience into a mathematical symbol or model by 35% and linking pictures or diagrams to mathematical ideas by 53.3%[16]. Further research by Tiffany which shows that the percentage of students can connect pictures, diagrams, graphs into mathematical ideas by 70%, explain mathematical ideas in writing with pictures, diagrams, tables, or algebra by 13.33%, and express everyday language events or mathematical symbols as much as 26.76% [17]. Based on several studies it is known that the mathematical communication ability of students from various schools is still in the low category, so there is a need for more in-depth research on the description of each level of students’ mathematical communication ability.

This study aims to determine and describe the level of mathematical communication ability of students in solving trigonometric problems. The novelty of this research is that researchers use trigonometric material to determine mathematical communication ability with high school students as the subject. In contrast to several previous studies that describe the mathematical communication ability of junior high school students in solving Two-Variable Linear Equations and Inequalities [7, 9, 18, 19], Construct a Flat Side Space [20], Pythagoras [13], Triangle [5], Set [21], Algebraic Forms [22], Relationships and Functions [23], Statistics [24]; high school students in completing the material Circle [25] and Dimensional Three [16]; and vocational students in completing the Two-Variable Linear Equation System [26] and the Linear Program [27].
2. Research Methods

This type of research is a qualitative descriptive study. Research using this method aims to describe the conditions that occur during the research. The sampling technique in this study is by using purposive sampling. The subjects of this study were 28 students of class XI IPA. The instrument used was a two-item mathematical communication skill test item with three indicators of mathematical communication ability. The flow diagram in this study as follows in figure 1:

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Figure 1. Research Flow Diagram
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The indicators of mathematical communication ability in this study can be seen in Table 1 as follows:

| Aspect               | Indicator                                                                 |
|----------------------|---------------------------------------------------------------------------|
| Written Text         | State and explain a situation, picture, or mathematical model in the form of mathematical ideas in writing in their language |
| Drawing              | Express a situation or mathematical idea in the form of pictures, diagrams, graphs, or tables |
| Mathematical Expressions | Expressing a situation or mathematical idea into a symbol or mathematical model and solving it |

The rubric to determine the level of students’ mathematical communication ability in this study is a modification of the High School Math Communication GRC Rubric, Maryland Math Communication Rubric, Quasar General Rubric, and Maine Holistic Rubric for Mathematics which are shown in Table 2 below.

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Table 2. Rubric for Assessing Mathematical Communication Ability

| Level  | Written Text         | Drawing                          | Mathematical Expressions |
|--------|----------------------|----------------------------------|--------------------------|
| 0      | No answer            | No answer                        | No answer                |
| Very Poor 1 | Students write explanations in their language but the explanations given are difficult to apply, incorrect and unclear | Students can paint pictures, diagrams, graphs, or tables but it is not true | Students cannot create mathematical models and solve problems using mathematical language (symbols, terms, signs, or formulas) |
| Poor   |                      |                                  |                          |
| 2      | Students write explanations in their language, but the explanations given are only partially correct, incomplete, and unclear | Students can paint pictures, diagrams, graphs, or tables but not clearly or without description | Students can make mathematical models and solve problems using mathematical language (symbols, terms, signs, or formulas) but are still wrong in calculations |
| Average |                      |                                  |                          |
| 3      | Students write explanations using their | Students can paint pictures, diagrams, | Students can make mathematical models and |
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According to Sriwahyuni [28], the percentage of students’ mathematical communication ability can be known by the following formula:

\[
P = \frac{\sum X_i}{Y} \times 100\%
\]

Information:
P: Percentage in each category
\(X_i\): Student who meet level \(i\) on each indicator; \(i = 0,1,2,3,4\)
Y: Many students took the test

### 3. Results and Discussion

The results of the students’ mathematical communication ability test can be seen in Table 3 below:

| Indicator to- | Level of Students’ Mathematical Communication Ability | Total Students |
|--------------|-----------------------------------------------------|----------------|
|              | 0  | 1  | 2  | 3  | 4  |                |
| 1            | 0  | 10 | 14 | 3  | 1  | 28             |
| 2            | 2  | 16 | 10 | 0  | 0  | 28             |
| 3            | 4  | 14 | 5  | 3  | 2  | 28             |

The percentage of categories of students’ mathematical communication ability can be seen in Table 4 below:

| Category of Students’ Mathematical Communication Ability |
|----------------------------------------------------------|
| Poor | Low | Moderate | Good | Very Good |
|------|-----|----------|------|-----------|
| 1    | 0 % | 38 %     | 50 % | 11 %      | 4 %       |
| 2    | 7 % | 57 %     | 36 % | 0 %       | 0 %       |
| 3    | 14 %| 50 %     | 18 % | 11 %      | 7 %       |
3.1 Description of the level of students’ mathematical communication ability

3.1.1 Students with level 0 mathematical communication ability
In the first indicator, there are no students who have level 0 mathematical communication ability.

In the second and third indicators, there were two and four students with mathematical communication ability level 0, respectively. The students’ inability to answer questions can be influenced by several factors, such as a lack of understanding of the concept of trigonometric material or a lack of understanding of the questions given.

3.1.2 Students with level 1 mathematical communication ability
In the first indicator, students with level 1 mathematical communication ability are 10 students. One of the students’ answers can be seen in Figure 2 below:

Based on Figure 2, students have been able to write several steps in their language but they are incorrect and difficult to understand. This can be seen from $K_1$ where students draw an isosceles triangle, even though students should draw a right triangle. Furthermore, in $K_2$ students are known to be able to understand that before looking for $\cos \alpha$ and $\tan \alpha$ they must first find the side using the Pythagoras formula, but students are still wrong in writing formulas and doing calculations. In $K_3$, students did not write the formula to look for $\cos \alpha$ and $\tan \alpha$, which were still wrong in entering the known numbers in the formula $\tan \alpha$.

In the second indicator, students with level 1 mathematical communication ability are 16 students. One of the students’ answers can be seen in Figure 3 below:

Figure 2. The Results of Student Work with on 1 Mathematical Communication Ability on Indicator 1

Figure 3. The Results of Student Work on Level 1 Mathematical Communication Ability on Indicator 2
Based on Figure 3, students have been able to paint pictures but they are incorrect and incomplete. This can be seen from $K_4$ which shows that students do not write down the two known angles and do not have an idea to find the other angles so that students cannot know that the location of the three children will form a right triangle.

In the third indicator, students with level 1 mathematical communication ability are 14 students. One of the students’ answers can be seen in Figure 4 below:

![Figure 4](image)

Based on Figure 4, students are only able to write formulas and cannot make mathematical models. This can be seen from $K_5$ where students are not able to make mathematical models correctly to solve problems based on the formula that has been written. Furthermore, on $K_6$ students did not write in full how these results were obtained. This shows that students are not clear and complete in solving problems.

3.1.3 **Students with level 2 mathematical communication ability**

In the first indicator, students with level 2 mathematical communication abilities are 14 students. One of the students’ answers can be seen in Figure 5 below:

![Figure 5](image)

Based on Figure 5, students have written several steps but only partially correct and the answers are still incomplete and clear. This can be seen in $K_7$ where students do not write that students will sketch pictures as a first step to make it easier to solve problems. Furthermore, in $K_8$ students did not write down how to find the side length. This shows that students do not write down all the steps clearly and systematically.

In the second indicator, students with level 2 mathematical communication ability are 10 students. One of the students’ answers can be seen in Figure 6 below:
Figure 6. The Results of Student Work on level 2 Mathematical Communication Ability on indicator 2

Based on Figure 6, students have painted a picture by providing information but it is still wrong. Students can imagine that the sketch will form a right triangle after knowing the size of the other angles, but are still wrong in positioning the image so that it matches the size of the known angle. This is indicated by $K_9$ where students at right angles write down the angles of 60°, even though the right angles should be 90°.

In the third indicator, students with level 2 mathematical communication ability are 5 students. One of the students’ answers can be seen in Figure 7 below:

Figure 7. The Results of Student Work on Level 2 Mathematical Communication Ability on the Indicator

Based on Figure 7, students can write formulas and create mathematical models to solve problems but are still wrong in doing calculations. In $K_{10}$, students are not consistent in writing symbols that match their mathematical models. In $K_{11}$, students make calculation errors in finding solutions to problems.

3.1.4 Students with level 3 mathematical communication ability

In the first indicator, students with level 3 mathematical communication ability are 3 students. One of the students’ answers can be seen in Figure 8 below:

Figure 8. The Results of Student Work on Level 3 Mathematical Communication Ability on Indicator 1

Based on Figure 8, students have written all the steps but there is a little language that is unclear and wrong. This can be seen in $K_{12}$ where students do not provide information that the Pythagoras formula
is used to find the side lengths and students also do not write completely what is meant by the front, side, and tilt.

In the second indicator, there are no students who have level 3 mathematical communication ability.

In the third indicator, students with level 3 mathematical communication ability are 3 students. One of the students’ answers can be seen in Figure 9 below:

![Figure 9](image)

**Figure 9.** The Results of Student Work on level 3 Mathematical Communication Ability on Indicator 3

Based on Figure 9, students can write formulas and create mathematical models to solve problems correctly but not completely. In $K_{13}$, students do not provide information and units for the calculation results so that students are not complete in solving problems.

3.1.5 **Students with level 4 mathematical communication ability**

In the first indicator, students with level 4 mathematical communication ability are 1 student. One of the students’ answers can be seen in Figure 10:

![Figure 10](image)

**Figure 10.** The Results of Student Work on Level 4 Mathematical Communication Ability on Indicator 1

Based on Figure 10, students have written all steps using their language correctly, clearly, and completely.

In the second indicator, there are no students who have level 4 mathematical communication ability. In the third indicator, there are 2 students with mathematical communication ability level 4. One of the students’ answers can be seen in Figure 11:
Based on Figure 11, students can write formulas and create mathematical models to solve problems correctly and completely.

4. Conclusions and Suggestions
Based on the research results, in the text writing indicator, 38% of students were in the poor category, 50% of students were in the moderate category, 11% of students were in a good category, and 4% of students were in the very good category. On the drawing indicator, 7% of students were in the poor category, 50% of students were in a medium category, and 36% of students were in the moderate category. 14% of students were in the poor category, 50% of students were in a low category, 18% of students were in the moderate category, 11% of students were in a good category, and 7% of students were in the very good category. This study also supports the results of research by Azizah which shows that students’ mathematical communication ability has not reached classical completeness, which means that only a small proportion has mastered mathematical communication ability. Based on the results of research and field findings, the authors suggest examining in-depth about students’ mathematical communication ability and the factors that influence it, conducting other reviews to determine students’ mathematical communication ability, and conducting research with other materials or subjects and with larger populations.

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