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Analysis of Mathematical Communication Skills to Students Based on Problem-Solving Construction

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Abstract
This research aims to systematically analyze students' mathematical communication skills based on the given problem-solving construction from the given math problems. The students involved in this study are class IX SMPN 1 Mangarabombang. The type of research applied is qualitative research with a descriptive approach. The research instruments are Mathematical Ability Test, Mathematical Communication Skills Guidelines, and Interview Guidelines. In this study, triangulation techniques were used to check the validity of the data that had been obtained. Data analysis techniques in this study use model with the following stages: 1. Data Reduction, 2. Data Presentation, and 3. Making Conclusion. The results show that mathematical communication skills can be demonstrated by mathematical modeling, representation of ideas, development of the ability to use mathematical object devices, and connecting algebraic expression to mathematical ideas. To realize this, the researcher understood and mastered mathematical concepts to support solving the given problems. Understanding, in this case, is characterized by indicators not only knowing mathematical concepts but knowing at the time when they are used and how to apply them. Then mastery is to place the mathematical concept in the context of the problem.

Keywords: mathematical communication skills; construction; problem-solving

I. Introduction

Modern mathematics careers now require conceptual skills such as critical thinking, modeling, and content application (Zeeuw et al., 2013). The need for skills becomes a learning target needed by learners for self-development. In other words, mathematics is no longer primarily understood as a collection of abstract concepts and procedural skills to be mastered but primarily as a set of human resource-making and problem-solving activities based on the mathematical modeling of reality (Corte et al., 2000).

One of the abilities needed by learners to support the fulfillment of active construction activities is mathematical communication skills. The National Council of Teachers of Mathematics revealed that mathematical communication is an essential competency in mathematics and mathematics education (National Council Of Teachers Of Mathematics, 2000). NCTM also formulated that the purpose of mathematics learning is: (1) learning to communicate, (2) learning to reason, (3) learning to solve problems, (4) learning to associate ideas, (5) formation of positive attitudes toward mathematics. Thus, good mathematical communication skills are needed so that all problems of a mathematical

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nature can be solved by students and poured into mathematical ideas.

Communication is referred to in mathematics learning in mathematical communication. According to Yulianto & Sutiarso (2017), mathematical communication can be interpreted as a student's ability to convey something he/she knows through dialogue or related events. The transferred message contains mathematics materials students learn, for example, concepts, formulas, or strategies for solving a problem (Dewi & Sopiany, 2017; (Nasrullah; Baharman, 2017; Nasrullah & Baharman, 2018)). The parties involved in the communication events in the classroom are teachers and students. How to transfer the message can be orally or in writing. National Council of Teachers of Mathematics (2000) states that mathematical communication skills are the ability to organize mathematical thoughts, communicate mathematical ideas logically and clearly to others, analyze and evaluate mathematical thoughts and strategies others use, and use mathematical language to express ideas precisely. Mathematical communication skills are the ability to convey mathematical ideas/ideas, both orally and in writing, and the ability to understand and accept other people's mathematical ideas carefully, analytical, critical, and evaluative to sharpen understanding (Nasrullah, Suradi, et al., 2021; Tahmir, 2015; Tahmir et al., 2020).

One of the mathematical materials loaded with terms, logos, images, and symbols is the material of quadratic equations. According to Lutfianannisak & Sholihah (2018), using those tools can make the student able to solve math problems well, as long as they understand the function. It becomes more problematic for students, although they understand the function. They cannot explain what they are doing and communicate the target of their work. Therefore, it is not uncommon for junior high school students who cannot solve math problems, including the problem of quadratic equations, because they cannot understand the meaning of terms, images, or symbols in the problem (Ahmad & Nasution, 2018).

Research results presented by Farokhah et al. (2019), where the focus is on the ability to represent mathematical problems in the form of symbols, pictures, manipulative objects, and other mathematical ideas, show that not many students can use mathematical objects well so that students dominate the group who cannot use mathematical objects. That is why teachers should train students in mathematical representation skills because students have difficulty solving problems and writing equations correctly (Utami et al., 2019, Nasrullah, Alimuddin, et al., 2021).

For this reason, the use of mathematical communication can be reviewed from the level of mathematical ability possessed by students. This problem follows the explanation by Suryaningtias et al. (2022) that students with high mathematical ability can use notation/symbols in solving problems, make no mistakes in representing mathematical models into graphs, and understand concepts effectively, clearly, and concisely. Students with mathematical skills do not use notation/symbols in solving problems, make mistakes in presenting mathematical models into graphs, and do not understand concepts effectively, clearly, and concisely. While students with low mathematical ability do not use notation/symbols in solving problems and make mistakes in presenting mathematical models into graphs.

The following indicators or activities are classified as mathematical communication according to Sumarmo (in Nasrullah & Baharman, 2017): 1) State a situation, image, diagram, or real object into a language, symbol, idea, or mathematical model. 2) Explain mathematical ideas, situations, and relations orally and in writing. 3) Listen, discuss and write about mathematics. 4) Reading with an understanding of a written mathematical representation. 5) Re-express a mathematical description or paragraph in its language. The National Council of Teachers of Mathematics (2000) states that mathematical communication standards emphasize teaching mathematics to students' ability to: 1) Organize and consolidate their mathematical thinking through communication. 2) Communicate their mathematical thinking coherently (logically arranged) to their friends, teachers, and others. 3) Analyze and evaluate mathematical thinking and strategies used by others. 4) Use the language of mathematics to express mathematical ideas correctly.

One of the types of research related to students' mathematical skills study is PISA. PISA is a form of ability and knowledge evaluation designed for 15-year-old students and held every three years (Siew et al., 2015). One of the objectives of the Program for International Student Assessment (PISA) is to assess students' mathematical knowledge in solving problems in everyday life. The competencies measured in the cognitive realm in PISA are thinking and reasoning, argumentation, communication, modeling, problem-solving, representation (representation), and using symbols and operations (using symbolic and operations) (Gunawan, 2018). From this explanation, the results of mathematics learning reviewed in this case are the ability of students to solve mathematical problems shown through what form is done, what is used, what is developed, and what is obtained (Nurlaili et al., 2020; Nufus et al., 2021). From this reviewed result, the mathematical construction skills can be analyzed in depth to see what kind of mathematical skills students have.

Based on the above explanation, this article attempts to trace students' mathematical communication skills based on the given problem-solving construction from the given math problems, such as what students and how mathematical communication skills are demonstrated through built-up completion. For that, pay attention to the explanation in the text description.

II. Research Method

This study is qualitative research with a descriptive approach. This research aims to systematically describe the mathematical communication skills of students of class IX SMPN 1 Mangarabombang. The instruments used in the study were the mathematical ability test, the mathematical communication skills guidelines, and the interview guidelines. The mathematical ability test is the result of the development of researchers by involving expert validators who understand the character of student mathematics communication. The tests used in this study used the rubric of judgment. The indicators of students' mathematical communication skills in this study are as follows:

Table 1.
Indicators of students' mathematical communication skills

No	Indicator
1	Describe and state the problem situation in writing or drawing properly and correctly.
2	Use mathematical symbols and terms well and precisely in presenting mathematical ideas in writing.
3	Connect algebraic expressions to mathematical ideas

(Samawati & Ekawati, 2021)

In addition to mathematical communication skills tests, the study also involved an interview instrument, a semi-structured interview guideline. In this study, triangulation techniques were used to check the validity of the data that had been obtained. The triangulation used in this study is source triangulation. Data analysis techniques in this study use model with the following stages: In this section, data on the results of students' mathematical ability tests are collected and selected for follow-up with interviews. Using the developed test guidelines, students' work results are checked so that each student sees their math ability. After that, they were interviewed based on a communication skills guide that contained the indicators that had been compiled and also the interview guidelines. This process then contains

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data whose content contains the results of students' work and their arguments in support of the answers given, from the description of the written answer and the passage of the argument, which is connected with the description of other answers put forward by the learner. Furthermore, this strand of description is connected to draw conclusions and formulate appropriate answers to the problems of this study (Huberman & Miles, 2002).

III. Results and Discussion

Result of Research

To measure students' mathematical communication skills with the given problems related to the topic of quadratic equations, which include indicators (1) The ability to describe and state problem situations in the form of writing or drawings properly and correctly; (2) The ability to use mathematical symbols and terms precisely and adequately in presenting mathematical ideas in writing; (3) The ability to connect algebraic expressions to mathematical ideas, the problem was developed as follows. 1) Ani attached a rectangular colored paper to his book, with a difference in length and width of 2 cm and an area of 24 cm^2. Draw the Rectangle and then calculate the length and width of the colored paper used by Ani! 2) Riki and Bayu worked together to paint the walls within 12 minutes. If Riki works alone, it takes 10 minutes longer than Bayu takes. How long does it take for Riki and Bayu to paint the walls each?

Figure 1 shows in addition to the narrative statement that the student used to convey his idea to solve a given problem. This student used mathematical modeling and flat wake images based on the given information in the form of symbols. Pay attention to the student's response for Problem 1

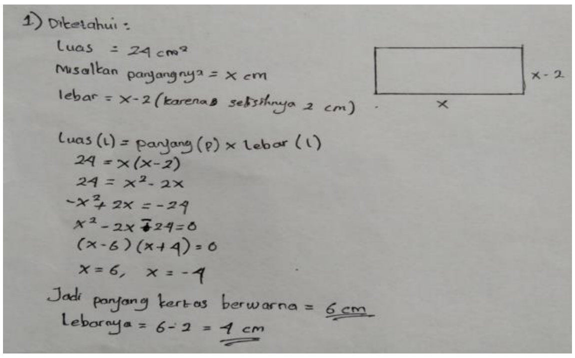

Figure 1. Problem solving construction number 1

Observer : What information is known from question number 1?
Student : That's the area of the rectangle = 24, the length for example x cm, the width = x-2 cm
Observer : What is asked of this?
Student : The length and width asked
Observer : Why is it long x cm and wide x-2 cm?
Student : Because it is not yet known how long it is, so it is written with x, while it is x-2 cm the wide size based on the explanation that the difference is 2 cm.
Observer : Why not that length x - 2 cm?
Student : Hmm... because if the width must be smaller, the width is written x-2 cm.

From the interview results, to build the solution to the problem given, students' focus on current problem information begins with the area of the formed shape, namely the rectangle. Based on this shape, a projection is made for each part of the Rectangle where there is a section of Length and Width, in this case, which is used "the length, for example, x cm, the width = x – 2 cm." When confirmed with the question Why is it long x cm and wide x – 2 cm? ", this student answered, "Because it is not yet known how long it is, so it is written with x, while it is x-2 cm the size of the width based on the explanation of the problem that the difference is 2 cm". From this answer students' understanding of the use of variables is well developed. Even when confirmed with the question "Why not that length?" x – 2 cm, the student commented, "Hmm... because if the width must be smaller in size, so the width written x-2 cm". This statement ensures that the student understands the difference in length and width in solving this problem.

If you look at the construction of the above answer, the flat wake image is helpful as a supporter of mathematical modeling to show how the final answer is obtained. The manipulation of mathematical modeling involves various mathematical concepts such as similarity, multiplication, quadratic equations, factorization, zero forming equations, addition, and subtraction.

From this interview excerpt, drawing a rectangular flat build is essential because of the information listed on the problem. It supports problem-solving so that it is easy to determine the x value. In other words, the use of images can facilitate constructed problem-solving steps. Next, the conversion from the rectangular flat build area formula is directed to build the quadratic equation.

In addition, the importance of understanding symbols supports the construction of a given problem-solving. Pay attention to the explanation of students in the interview excerpt as follows.

Observer : Furthermore, what mathematical symbols and terms are used to solve problem 1?
Student : This is, for example, area (A), length (p), and width (l), the same x as the value of the unknown length.
Observer : According to my sister, is the use of mathematical symbols and terms important in solving problem 1?
Student : Yes, it is.
Observer : Why is it important?
Student : Because... Ee... because it is necessary to use symbols, otherwise using symbols means that they cannot be done.

Following the explanation, students emphasize that using symbols becomes part of the process of manipulating quadratic equations that have been built. The manipulation process involves several mathematical concepts so that the common problem solving achieves the expected answer.

Observer : What formula is used in solving problem number 1?
Student : The formula finds the area from that formula so that the quadratic equation is obtained.
Observer : Try to explain the process of describing the formula until it obtains the quadratic equation?"
Student : First, I first write the formula that is area = length x width, then I enter the area of 24, the length x and width x – 2, so I write 24 equals to x times x – 2 obtained 24 = x2 - 2x, subsequently, obtained x2 - 2x +-24 = 0, that is the quadratic equation.
Observer : What is it “x” = 6 and x = -4?
Student : Hmm... Those are the roots of the solution.
Observer : Please explain; how does it get the roots of the solution?
Student : The way, the equation is x2 - 2x + 24 = 0, I do factorization, then find a number that if multiplied equal to -24, if added up to produce -2. So, I get (x - 6) (x + 4), therefore -6 if multiplied by 4 equals -24, if -6 + 4 equals -2
Observer : On the answer sheet, you obtain the root of the solution of the quadratic equation that is x = 6 and x =-4. From those two numbers, which is chosen as the length of the colored paper? Why?
Student : The x = 6, because of the size of the Length, if the -4 is impossible because the size of the length does not have a negative number
Observer : Continue the width how?
Student : The width is that x-2, because x is 6, so 6 – 2 = 4, so the width is 4

This interview shows that the concept used is not only about broad concepts, quadratic equations, and factoring but also arithmetic concepts. Even more than that, it can be seen that the concept of integers also plays a role in determining which is suitable to solve this problem, whether negative numbers can be used in this case or even do not solve the problem discussed. In other words, at the end of the settlement, students must determine the best solution to solve the given problem. Pay attention to the student's answer form problem 2 below.

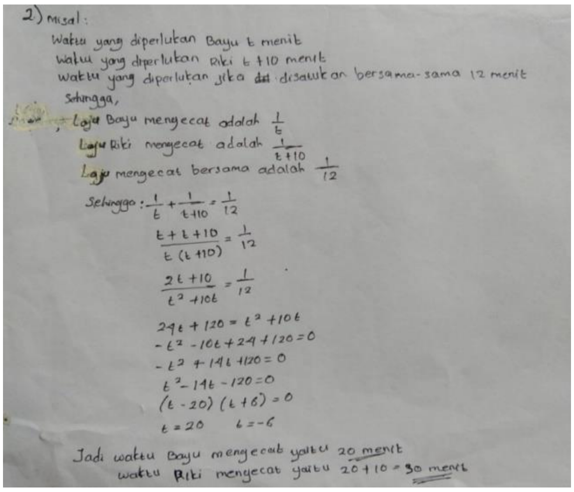

Figure 2. Problem solving construction number 2

For problem number 2, which is visible, students do not use drawings in problem-solving construction. However, the construction of mathematical models with various manipulations is carried out to determine the expected completion. As a first step, the student wrote down information in the form of providing that the time needed by Bayu is t minutes, the time Riki takes is t + 10 minutes and the time needed if painting together is 12 minutes. Then associate the problem is the problem with the concept of speed. Here is an excerpt of the interview with the student.

Observer : What information is known from question number 2?
Student : Riki and Bayu work together to paint the walls within 12 minutes; if Riki works alone, it takes 10 minutes longer than Bayu. So, I suppose the time needed Bayu is t minutes, the time needed Riki is t + 10 minutes, and the time if painting together is 12 minutes.
Observer : What is being asked about it?
Student : Time to paint each
Observer : Why does it take a minute while the time needed Riki t + 10 minutes?
Student : Because of the explanation in question, Riki is longer, 10 minutes longer than Bayu.
Observer : Try to explain; why can sister write down the time for Bayu to paint is 1/t?
Student : Because it is necessary to know how fast Bayu paints the walls, so it is time t, remembering the learning of IPA if you want to know the speed divided by time, the time is t, it means divided into 1/t.

Referring to the above explanation, this student has understood what will be solved in this problem. Therefore, what is needed is well outlined in the identification section of the given problem information. In identifying the problem, the interpretation and representation of the information are presented using mathematical reasoning shown through the formula 1/t. The symbol t is understood as time with units of minutes. Reasoning about this time develops according to the information understood; therefore, its interpretation is indicated by the following statement.

"Riki and Bayu worked together to paint the wall within 12 minutes; if Riki worked alone, it would take 10 minutes longer than Bayu needed. So I suppose the time needed Bayu is t minutes, the time needed Riki is t + 10 minutes, and the time if painting together is 12 minutes."

To determine the answer to the question, "How long does it take for Riki and Bayu to paint the walls, respectively? "This student-constructed the following idea.

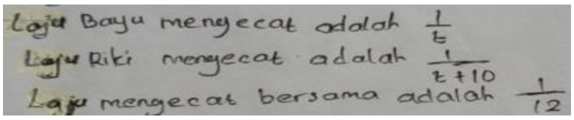

Figure 3. Interpretation of the concept of speed

From this image, to determine how much time it will take for Riki and Bayu, the students relate to the concept of speed even though it is inversely proportional to time. However, the timing of such a painting is understood as a part related to speed. As in the following statement.

Because it is necessary to know how quickly Bayu paints the wall, it is time t, remembering the learning of the natural science, if you want to know the speed divided by time, the time is t, means divided into 1/t. This is based on the understanding that what is discussed is time, then preparing a problem-solving plan begins by constructing the required mathematical model. Interestingly, this student tries to relate the concepts he acquired when studying the subject of IPA. In other words, there is the experience of learning from other subjects involved in crafting problem-solving.

Next is constructing some logical arguments about speed, as shown in figure 3. The three arguments are related to each other even though the sum of the first and second arguments is the same as the third. This later became the basis for the manipulation of the mathematical model developed. The manipulation of mathematical modeling involves various mathematical concepts such as similarity, multiplication, quadratic equations, factorization, zero forming equations, addition, and subtraction. The use of these concepts is not much different from that used in solving problem number 1. In addition, both contained in problem 1 for the second problem also produce alternative answers that invite logical arguments of students to determine the answer precisely. However, the complete answer meets the completion construction based on mathematical manipulation. However, some answers do not support the right solution to the problem. Both of these issues contain these challenges. The explanation of the construction steps of solving the developed problem is as follows.

Observer : Why is it added up $\frac{1}{t}+\frac{1}{t+10}=\frac{1}{12}$? Why not use multiplication?

Student : Because if working together means in numbers, it is appropriate to add up, right?

Observer : Iya is right. To sum up, try to explain the process of elaborating the addition of fractions and factoring of the quadratic equation you wrote?

Student : First, I match the denominator on the left and then work on how to sum fractions. Next, I multiply by 2t + 10 and 12, then 1 time t2 + 10t, so that it becomes 24t + 120 = t2 + 10t. After that, I move the one in the right field to the left-field wall; if moving means multiplied by negative, so that it is obtained -t2- 10t + 24t + 120 = 0, then I divide I mean times with negative numbers (one) all so that it becomes a positive number t2, I continue to get the quadratic equation t2 – 14t – 120 = 0.

Observer : Why do you want to be positive t2?

Student : To facilitate factoring.

Observer : So, how do you factorize it?

Student : It is the same way to factor in the number 1, but the difference is from the number I chose, it is if at times obtained -120 if added obtained -14 so that I get it, so"(t - 20) (t+6) t = 20, t = -6

Observer : Between the two numbers, which one is chosen as the time Bayu needs to paint the walls? Why?

Student : When Bayu painted it 20 because it was the same number 1 earlier, a negative number cannot be taken for about time.

From this explanation, students construct answers with mathematical concepts that are well understood and as needed. As is the case when asked in the section "Why is it added up $\frac{1}{t} + \frac{1}{t+10} = \frac{1}{12}$, why not use it multiplication?" in this section, rational use of the concept of addition is based on the statement "Because if working together means added up," in other words the word working together can be represented as a time that it is used together so that the entire time is the result of the sum of the time used.

Another explanation of the need to change to a positive form of the mathematical form t^2- 10t + 24t + 120 = 0 to t^2 – 14t – 120 = 0, taking into account that it is easier to factor if t^2 is not in negative form. After the expected square equation form is obtained, the next is to factor the shape into (t - 20) (t+6) = 0. This form provides a challenge of logical consideration which will be taken because for t - 20 = 0 can mean t = 20 (positive number), but for t + 6 = 0 means t = -6. So, there are 2 answers to t, which are 20 and -6. Of course, it takes logical consideration to determine one of the two appropriate times as a solution to a given problem. As the student explained, "Bayu painted it 20 because it was the same number 1 earlier; a negative number cannot be taken for about time". In this case, the selected time is 20 because time is not a negative number for this problem.

Discussion

The two responses put forward by students to both given mathematical problems show that solving mathematical problems requires a good understanding and mastery of mathematical concepts (Baroody & Coslick, 1993; Nasrullah & Baharman, 2018; Nofrianto et al., 2017). Understanding the concept intended in this case is not just knowing that mathematical knowledge contains the concepts of similarity, multiplication, quadratic equations, factorization, zero-forming equations, addition, and subtraction. However, a good understanding is to know at the time when it is used and how to apply it (Nurlaili et al., 2020), although at first, it is only an experiment that can then be wrong, so it does not support solving the problem built (Hadiastuti & Soedjoko, 2019).

Next is the mastery of mathematical concepts intended, in this case, to place the mathematical concept in the context of the problem at hand (Gravemeijer, 2013; Nofrianto et al., 2017). Not infrequently shown in the framework of solving the problem that is built is appropriate according to the procedures of how the concept is used. However, the construction of such settlements did not match the expected problems given. In both of these cases, the end of the troubleshooting procedure still requires consideration to choose the correct numbers to resolve a given problem.

In general, according to what is seen from the student's responses in this study, the construction performance is shown by using images (e.g., flat wakes) is helpful as a proponent of mathematical modeling to show how the final answer is obtained (Nofrianto et al., 2017; Nurlaili et al., 2020). 2) Figure or formulation as a starting point is part of the representation of ideas for the manipulation of mathematical modeling so that it involves various mathematical concepts that require the ability to describe and state the problem situation in the form of writing or drawing properly and correctly (Nurlaili et al., 2020; Ridwan & Nasrullah, 2015). Furthermore students develop the ability to use mathematical symbols and terms well and precisely in presenting mathematical ideas in writing (Lutfiyana et al., 2021) and connect algebraic expressions into mathematical ideas (Nurjanah et al., 2018; Samawati & Ekawati, 2021; Febrian et al., 2022).

IV. Conclusion

It can be concluded that mathematical communication skills can be demonstrated by mathematical modeling, representation of ideas, development of the ability to use devices of mathematical objects, and connecting algebraic expressions into mathematical ideas. To get this point, the understanding and mastery of mathematical concepts are the main components to support solving the given problems. In this case, understanding is characterized by indicators not only knowing mathematical concepts but knowing when they are used and how to apply them. Then, mastery is to place the mathematical concept in the context of the problem.

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