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Students' Mathematical Communication Skills on Straight-Line Equation Using PMRI and Collaborative Learning

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Abstract

The study aims to examine students' mathematical communication skills on the material of straight-line equation through video-assisted learning using the Indonesian Realistic Mathematics Education (PMRI) approach and collaborative learning. The type of research is descriptive qualitative research with participants consisting of 20 students in the eighth grade of junior high school in the Palembang District, South Sumatera Province. This study comprised three meetings. The initial two meetings were dedicated to learning process using video material with PMRI and collaborative learning. The third meeting was utilized for result evaluation through testing. Data were collected through written tests, observations, and interviews using the descriptive data analysis approach. The findings of the study reveal that the combination of the PMRI approach, collaborative learning, and video learning on the material of straight-line equation has a fairly effective application. The students' skills to communicate mathematically are identified. The most frequent indicator is expressing mathematical ideas, while the least frequent indicator is drawing conclusions. Students' mathematical communication skills can be improved by using learning video in conjunction with PMRI and collaborative learning during the learning process.

Keywords: Mathematical Communication Skill, Straight Line Equations, PMRI, Collaborative Learning, Teaching and Learning Video

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INTRODUCTION

Communication skills have an important role in learning mathematics. NCTM (2000) explains that communication is fundamental in mathematics because it is a way for students to present mathematical ideas orally or in writing. This is in line with a study by Lara-Porras et al. (2019) which argued about how important mathematical communication is for a successful mathematical performance in the future. The skill to effectively communicate mathematical concepts plays a crucial role in students' understanding of the relevance of mathematics in their daily lives, especially in today's modernized world (Zakkia et al., 2021). Based on the Regulation of Minister of Education and Culture of the Republic of Indonesia Number 37 of 2018 (2018), one of the competencies students must have in learning mathematics is the ability to communicate mathematical ideas. With good communication, students can understand the intent and purpose of a problem so that they can solve a problem correctly (Purwasih et al., 2023; Murtafi'ah et al., 2022). One of the mathematical topics that requires mathematical communication skills is the straight-line equation.

Based on the current Freedom Curriculum, straight-line equation is one of the materials in mathematics learning for eighth grade in the odd semester in Indonesia. The material of straight-line equation needs to be mastered by students because it is used as prerequisite material for mastering

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further material, such as quadratic functions, linear programming, and so on (Situmorang & Zulkardi, 2019; Sari et al., 2022). In daily life, it has practical implications such as determining the slope value of a building, calculating the distance and time based on a speed, predicting the price of an item within a certain period, and estimating the population of an area (Nusantara & Putri, 2018). Therefore, students need to have good mathematical communication skills in learning mathematics, including in the material of straight-line equation to understand and solve a problem correctly.

On the other hand, many students still consider straight-line equation as a difficult material because it is related to graphs, Cartesian space, and algebra (Sejati, 2020). Moreover, the learning process of the straight-line equation tends to be centered on the teacher, and the material is taught directly by introducing mathematical notations, formulas, and graphs (Sari et al., 2022). This causes learning to be meaningless because students do not feel the practical use of the material and how it directly affects problems in everyday life. Further, the importance of mathematical communication skills is also not well-represented. Field observations show that students' mathematical communication skills in learning mathematics, especially on the straight-line equation material, are still relatively low. Students do not understand mathematical ideas in straight-line equation problems and are unable to convey their ideas or thoughts to others. This can be seen from the mistakes made by students, namely language errors regarding mathematical symbols and understanding of the questions given, causing students not to understand the information stated and asked in straight-line equation problems (Fathimah & Sutama, 2017; Gowasa, 2022; Sari et al., 2022). This is because students are neither yet able to convey their ideas or construct arguments well, nor express a situation or problem in the form of symbols, diagrams, or mathematical models.

Efforts to enhance mathematical communication skills in the straight-line equation material can be made by using an appropriate learning approach. One approach that can be used is the Indonesian Realistic Mathematics Education or Pendidikan Matematika Realistik Indonesia in Bahasa (PMRI) (Khairunnisak, et al, 2022). It is a modified version of Realistic Mathematics Education (RME) that is adjusted to align with the cultural nuances and educational requirements specific to Indonesia. This is what differentiates it from the original framework of RME. PMRI is an approach that aligns with the Freedom Curriculum which emphasizes the importance of making mathematics relatable and applicable to students' everyday experiences, ensuring its relevance to their lives (Putri et al., 2022; Deda & Maifa, 2021). According to Melati et al. (2017), there is an increase in mathematical communication skills using the PMRI approach, particularly the ability to present mathematical statements verbally and in writing, pictures, sketches, or diagrams. Thus, the PMRI approach can be used in mathematics learning to enhance mathematical communication skills.

In addition to critical thinking and problem-solving, creativity, and collaboration, communication skills are one of the four skills or competencies (the 4Cs) that everyone must have to compete in the 21st century (Suyitno et al., 2021). For this reason, this research is supported by the lesson study for learning community (LSLC). The application of lesson study is intended to build a learning community

(Suwartono et al., 2022; Zainal et al., 2024; Hobri, & Susanto 2020). The application of learning with the learning community approach can shape student competencies, including the abilities to express ideas, ideas, conduct discussions, and express opinions (Hobri, & Susanto 2020). LSLC makes it possible for these abilities to be applied as an effort to improve students' mathematical communication skills.

In this era of information and technological development, teachers are advised to take the challenge to innovate in designing interesting learning for students, especially for delivering good materials. One of the effective new ways to learn is by using learning videos, in which the material is illustrated in a video and can be shared through forums or online learning platforms (Fuady, 2016; Suryani, 2016). Using learning videos can improve cognitive thinking and develop an understanding of straight-line equation (Siwi & Puspaningtyas, 2020). In addition, Hadi (2017) also shows that video is effective in increasing the students' learning motivation, as well as improving their learning outcomes.

In this regard, numerous previous researchers have analyzed mathematical abilities using the PMRI and LSLC, including representation skills using PMRI and LSLC (Adiansyah & Alpiana, 2021), mathematical reasoning abilities using PMRI and LSLC (Octriana, 2019), and problem-solving abilities using PMRI and LSLC (Kurniawan, 2020). Additionally, studies on the use of instructional videos in mathematics education, particularly on topics such as linear equations, have been conducted by previous researchers, such as "The effect of video learning media on fourth-grade students' mathematical learning achievement on fractions" (Yusriza, A., & Kowiyah (2023), and "Use of learning video media to improve mathematics learning results about space building" (Machmudah, 2020). Furthermore, "Students' mathematical reasoning ability on system of linear equation in two variables using video media, PMRI, and collaborative learning" has also been explored. However, there is still limited research on the use of instructional videos in teaching linear equations using PMRI and LSLC. The novelty of this research lies in its utilization of distance learning through instructional videos with the PMRI and LSLC approaches. Therefore, this study aims to examine students' mathematical communication skills in the straight-line equation material using PMRI and LSLC assisted by learning video.

METHODS

Research Type

The type of research is descriptive qualitative research. This research was conducted following the LSLC framework, consisting of the Plan, Do, and See stages. Research using this method aims to describe the conditions that occur during the research.

Research Subject

This research focuses on describing the mathematical communications skills of grade 8 students in a junior high school in Palembang District, South Sumatera Province, consisting of 20 students.

Research Procedures

This research is conducted following the LSLC framework, consisting of the plan, do, and see stages. Research using this method aims to describe the conditions that occur during the research. The plan stage commences prior to the actual implementation of the study, involving the development of research instruments, validation through expert review, and revision of questions through individual (one on one) and small group sessions. In the do stage, the learning implementation stage is divided into three parts, namely asynchronous (scheduled pre-learning), synchronous (scheduled learning), and asynchronous (scheduled post-learning) learning. The research is further conducted in three meetings, with the first and second meetings focusing on the learning process using video learning with PMRI and collaborative learning, and the third meeting aimed at testing the results. In the see stage, the focus is on analyzing and redesigning the lessons based on the findings and experiences gained during the "*Do*" stage.

Data Collection

Data were collected through written tests, observations, interviews, and descriptive data analysis approaches. The test questions consist of three items and have a level of difficulty equivalent to the analysis. Interviews were conducted with three students of different abilities: high, medium, and low. Observations were conducted when students were in the learning process to see what indicators appeared. The students' responses were assessed based on indicators of mathematical communication skills, as outlined in Table 1.

Table 1. Mathematical communication indicators and descriptors

Mathematical Communication Indicator	Descriptor
Expressing mathematical ideas	Students describe the information mentioned in the given problem and solve the problem using the appropriate steps and calculation.
Converting real objects, pictures, and diagrams into mathematical ideas and vice versa	Students express mathematical ideas of the problem in the form of drawings, graphs, or mathematical symbols.
Drawing conclusions at the end of solution	Students show the conclusions at the end of the problem-solving process.

Table 1 outlines the indicators and descriptors of mathematical communication skills. For the initial indicator, the assessment focuses on students' ability to identify the known (stated) and unknown information in the given problem, followed by solving it with accompanying steps and calculation. The researchers aim to assess students' comprehension on the problem's information. The second indicator involves expressing information in various forms such as graphs, tables, and charts. Lastly, the third indicator evaluates students' capability to articulate conclusions at the end of the problem-solving process. The researchers are interested in examining whether students can appropriately solve the problems to completion.

Data Analysis

This study aims to analyze and describe the mathematical communication skills of grade 8 students in junior high school on the straight-line equation material using PMRI and collaborative learning assisted by learning video. After the written test was carried out, students' answers were checked and given a score according to the assessment rubric created for later analysis. Analysis of this observation data used a descriptive method by describing mathematical communication skills that emerge during learning, based on video recordings (recorded meetings) and field notes. The results of the interviews in the form of recordings were then converted into interview transcripts. Next, several conversations were studied and sorted based on which mathematical communication skills were identified among students. Finally, conclusions were drawn in the form of a clear descriptions of the mathematical communication ability indicators.

RESULTS AND DISCUSSION

The Plan Stage

In the plan stage, the researchers with teachers in the mathematics subject teaching team in Palembang collaboratively developed learning designs in the form of lesson plans, learning videos, worksheets for sharing tasks and jumping tasks and communication skills test questions based on the characteristics and principles of PMRI and LSLC. Then, the researchers and the teachers determined the research subjects and the model teacher for the implementation stage, as well as arranged a schedule of implementation activities (the do stage), observations, and reflection (the see stage). The planning activity was conducted collaboratively in several meetings involving three mathematics teachers and three researchers.

The Do Stage

In the do stage, learning was carried out three times. The first meeting was held on November 18, 2020 with 18 of 20 students attending, the second meeting was held on November 25, 2020 with 20 of 20 students, and the third meeting was conducted on November 26, 2020 with 16 students attending. Learning process was carried out following the lesson plans designed collaboratively by teachers and researchers using the blended learning model, the PMRI approach, and the LSLC system. According to studies by Rahayu et al. (2017), Putri et al. (2022), and Deda & Maifa (2021), learning mathematics using the PMRI approach starts from real things or experiences of students and emphasizes the process of doing math skills, discussing, and collaborating, thus helping students to find their discoveries and ultimately use mathematics to solve problems individually or in groups.

The learning implementation stage was divided into three parts, namely asynchronous (scheduled pre-learning), synchronous (scheduled learning), and asynchronous (scheduled post-learning) learning. During asynchronous (scheduled pre-learning) learning, students were asked to watch the learning video, take notes of important things, and make an inventory of problems by observing the learning video to be discussed in the scheduled learning activities. The learning video begins with contextual problems as the starting point for learning. The context aims to make it easier for students to understand the material and create meaningful learning. In accordance with Panhuizen & Drijvers (2020), learning begins with contextual problems as a starting point, followed by directly involving students to construct their knowledge through previous knowledge, then finally representing the problems in a way that is easier for students to understand. This aims to allow students to learn more meaningfully and reduce the tendency for them to learn mechanically.

In synchronous (scheduled) learning, there were three activities, namely: introduction, core activity, and closing. In the core activity, after students joined their groups, the teacher assigned a sharing task about filling in a pool with water, and a jumping task about increasing the savings of the first meeting. In the second meeting, the sharing task is about the increase of COVID-19 positive cases, while the jumping task applies the context of seesaw. When working on jumping tasks in either the first or second meeting, more than half of the students had difficulty solving problems. However, this means the problem in the jumping task can be considered successful. According to Sato (2014), the success of the jumping task can be seen from the small number of students who can solve the problems correctly. In working on the sharing and jumping tasks, students were directed to collaborate in groups and write the results of discussion in their respective group. During the ongoing discussion process, the teacher acts as a motivator, encouraging students to be active in learning.

In the third meeting, the communication skills test was carried out through a Zoom meeting. There were 16 students who attended the meeting and participated in the test. After the implementation of the do stage, the researchers, the model teacher, and the observers conducted reflection activities (the see stage). In this stage, the model teacher expressed their impressions and comments during teaching. Meanwhile, the observers conveyed their findings on the learning activities that had been carried out. Based on the observations and students' works, the following results are obtained.

The First and Second Meeting

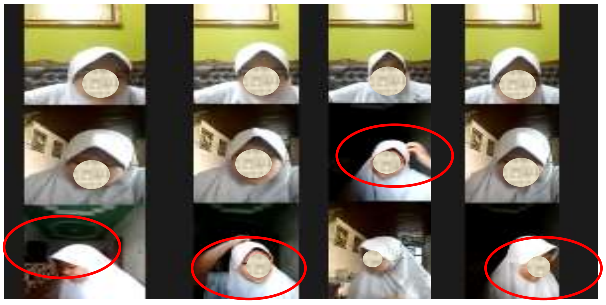

Figure 1. Subject A (marked with a red circle) when collaborating in the group

Based on the results of observations in group discussions in Figure 1, subject A appeared confused, silent, and restless while her friends attempted to solve a problem, indicating a lack of understanding of the problem's meaning. This highlights a deficiency in subject A's mathematical communication abilities, consistent with the findings of Fathimah & Sutama (2017), who suggested that poor mathematical communication skills can result in misunderstandings of question sentences, leading to confusion about the information mentioned and what is asked in the questions. With encouragement from the teacher, subject A felt braver to ask questions and engage in discussions with her peers regarding the problems. Subsequently, her friends assisted in clarifying the concepts until subject A gained comprehension.

The following is the result of subject A's work on the jumping task.

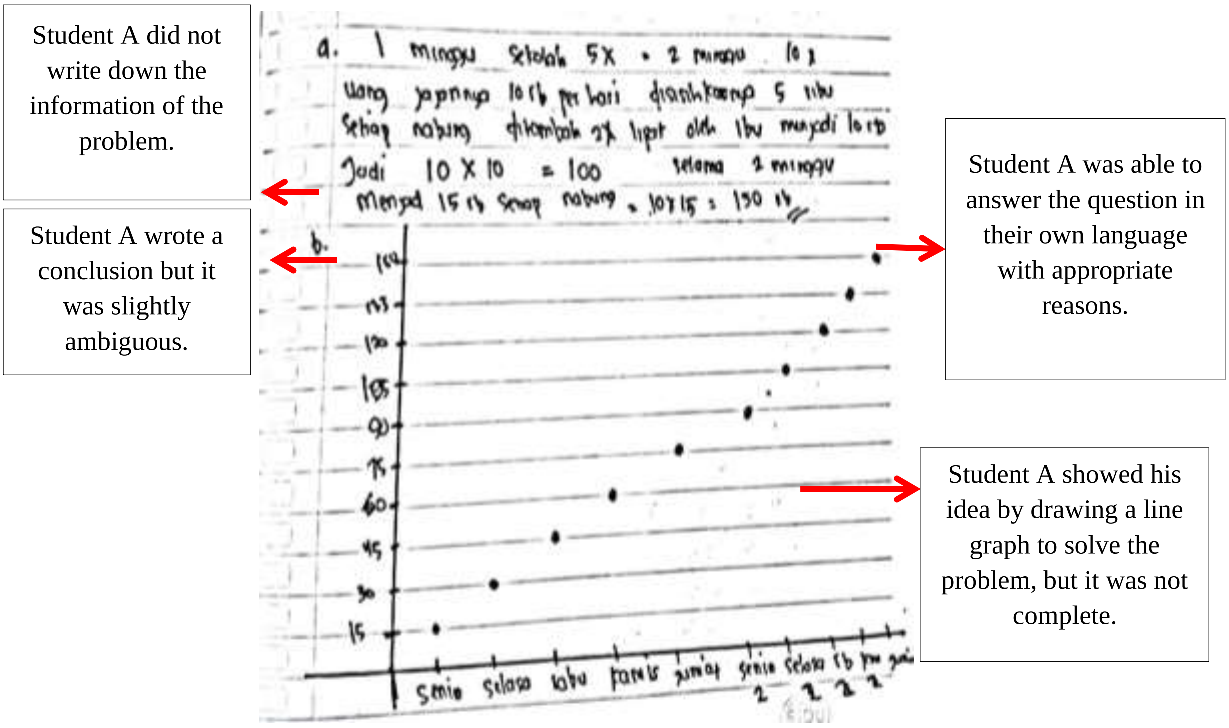

Figure 2. Subject A's jumping task answer

Based on subject A's answer in Figure 2, it can be inferred that there has been an improvement in subject A's mathematical communication skills even though they are not yet at their peak level. This can be seen from the solution which reflects the indicator of mathematical communication skills. After a written test of mathematical communication skills, the following results were obtained.

Table 2. Results of student achievements on each indicator

Indicators	Number of Students Answering the Question		
	1	2	3
Expressing mathematical ideas	40%	55%	50%
Converting real objects, pictures, and diagrams into mathematical ideas and vice versa	60%	45%	0%
Drawing conclusions at the end of solution	30%	0%	35%

Table 2 shows that students' mathematical communication skills are considered low because none of the indicators of communication skills reach above 70% or 80%. Some of these indicators are in the range below 50%. The indicators include expressing mathematical ideas in question number 1; converting real objects, pictures, and diagrams into mathematical ideas and vice versa in questions number 2 and 3; and drawing conclusions at the end of solution. In other words, the most fulfilled indicator is the ability to express mathematical ideas. Half of the students are able to write down the information stated in the questions given. The least frequent indicator is drawing conclusions. Based on the interviews, students stated that they often forgot to write down the conclusion at the end of the solution. The following section will descriptively discuss students' difficulties in each indicator based on the answers they provided in the test.

1. A mask manufacturer reported that the number of masks sold between October 1-9, 2020 increased with an average of 65 pieces per day. On October 1, a total of 460 masks were sold. If the sales increase at the same average rate, calculate the total number of masks sold by the mask manufacturer on October 8, 2020. Please draw a line graph showing the mask sales from October 1-9, 2020.

Figure 3. Test question number 1

Figure 3 depicts problem number 1. In this problem, students are asked to calculate the total masks sold on October 8, 2020, and draw a line graph of mask sales as of October 1-9 2020. Figure 4 is the work of subject A.

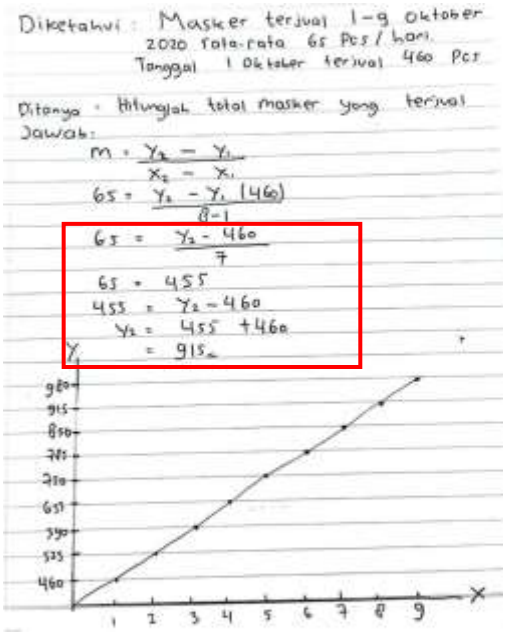

Figure 4. Subject A's answer to test question number 1

Based on Figure 4, it can be concluded that student applied their understanding of the concept of straight-line gradient to the problem given. The student also demonstrated indicators of mathematical communication skills. There was only a little error in the student's work, as indicated by the red box in the image of the student's answer. The following is a conversation between the researcher and student. (Note: R = Researcher, A = Student A).

R : *What information is known from question number 1?*

A : *Between October 1-9, an average of 65 masks were sold per day, and on October 1, 460 masks were sold.*

R : *How did you solve the problem?*

A : *Using the gradient formula, ma'am. So, 65 is the slope, y_1 is 460, x_1 is 1. What you want to look for is the 8th mask, so y_2 is what you are looking for. x_2 is 8. Just apply the formula, ma'am.*

R : *Why does this say 65 = 455?*

A : *Uh yes ... it was a mistake, ma'am. 455 is the result of 65 times 7.*

R : *Then what is the conclusion?*

A : *I forgot to write it down, ma'am. The total masks sold on October 8, 2020 were 915.*

Based on the conversation between the researcher and the student, the researcher assessed that the student understood the meaning of the question and showed indicators of mathematical communication skills verbally and in writing. There was only a writing error in the calculation and he admitted it during the interview. Figure 5 shows question number 2 given to students.

2. During the COVID-19 pandemic, many families stocked up on medical masks. One family stocked up 3 boxes of masks. If the family consists of 3 members and each family member uses 2 pieces of masks per day, please sketch a line graph showing the daily stock of masks.

Figure 5. Test question number 2

In Figure 5, students were asked to draw a line graph of the mask stock of a family per day during the COVID-19 pandemic. For problem number 2, none of the students answered correctly and completely. Figure 6 is the result of subject B's work.

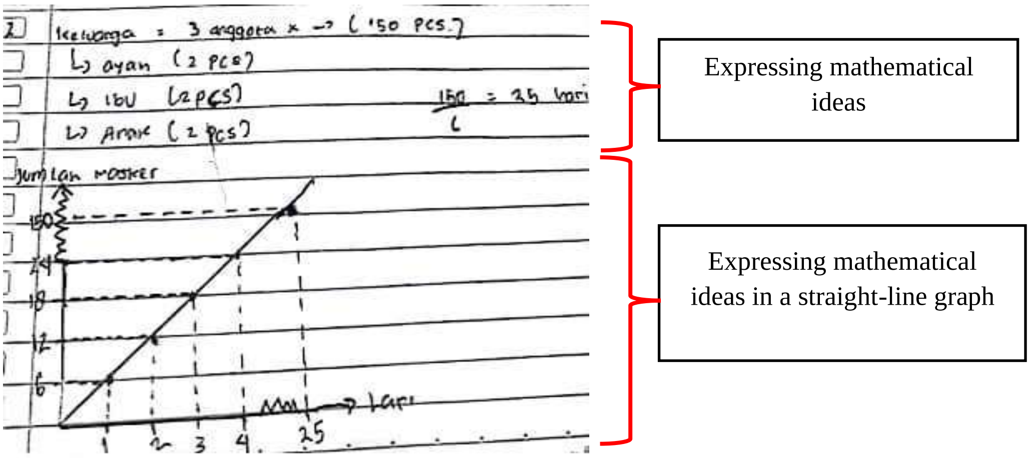

Figure 6. Subject B's answer to the test question number 2

Student B did not completely mention what information was stated in the question (see Figure 6), but they wrote down the calculation and drew a straight-line graph, even though it was not correct. The following is a conversation between the researcher and student. (Note: R = Researcher, B = Student B).

R : *How did you solve this problem?*
B : *Based on the question, there is a family of 3 members consisting of father, mother, and child. They stock 3 boxes of masks. 1 box has 50 pieces of masks, which means 3 times 50, 3 boxes has 150 pieces of masks. Then you just divide it; 150 masks are divided by 6 into 25 days. Each person uses 2 masks per day, so 6 is from 2 masks times 3 people. 6 masks are used a day in total.*
R : *What do you mean by "25 days"?*
B : *The number of days the masks ran out of stock, ma'am. So, 150 masks ran out on the 25th day.*
R : *Then for the graph?*
B : *We can get the result if we wear 6 masks a day. So, we keep adding six every day until day 25. In the graph, x is the day and y is the number of masks.*

Based on the answers and the results of interviews with the student, the researcher assessed that the student did not understand the question, and still did not fully understand the material of drawing graphs. This is indicated by the incorrect written solution to the problem, especially in the straight-line graph. The line graph should show a decrease from left to right.

> 3. In one city, X, the daily increase in positive COVID-19 cases remains constant. On September 3, 2020, and September 8, 2020, the number of positive COVID-19 cases in the city was 20 and 50, respectively. Calculate the total number of positive COVID-19 cases in the city on September 30, 2020?

Figure 7. Test question number 3

Figure 7 shows test question number 3. In this question, students were asked to calculate the number of positive cases of COVID-19 in X city on September 30, 2020. Figure 8 is an example of a student's work.

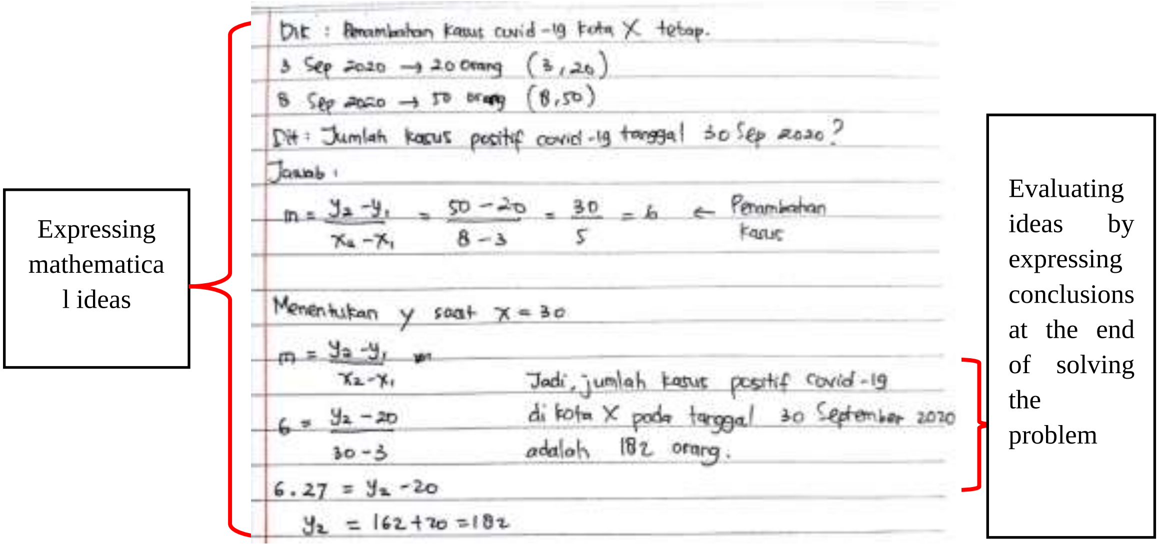

Figure 8. Subject C's answer to the test question

Based on the answer in Figure 8, subject C demonstrated the indicator of expressing mathematical ideas by writing down the information mentioned and what was asked in the question, as well as doing the calculation correctly and completely. In addition, subject C also evaluated the idea by writing a conclusion at the end of the solution (see Figure 8). The following is student A's answer to question number 3 in Figure 9.

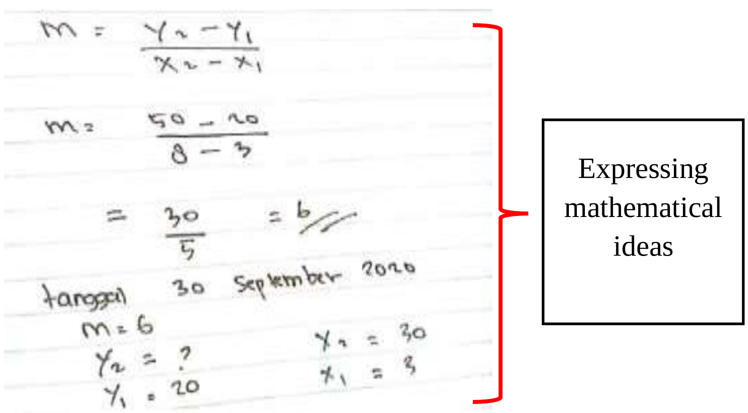

Figure 9. Subject A's answer to test question number 3

In Figure 9, it can be concluded that subject A did not optimally use his mathematical communication skills as seen from his incomplete answer. These findings were justified through conversations between researchers and students. (Note: R = Researcher, A = Student A).

R : *How did you solve the problem?*
A : *It's not finished, ma'am. I should find* y_2*. I ran out of time yesterday.*
R : *What is* y_2*?*
A : *The number of positive cases, ma'am. What was asked in the question.*
R : *So, if we work on this, how do we find* y_2*?*
A : *Using the gradient formula, ma'am. m equals* y_2 *minus* y_1 *per* x_2 *minus* x_1

Based on the answer above (see Figure 9), student A immediately used the gradient formula to find the value of the slope, but he did not write down the information mentioned and what was asked in the question. Based on his work and interview, it appeared that student A's job was not complete. There were still other steps to be resolved, but student A understood how to solve the problem.

The See Stage

This stage is crucial for reflecting on what worked well and what needs improvement in terms of student learning and understanding. This stage is carried out after conducting the learning according to the lesson plan that has been jointly designed. Reflection activities are conducted in the form of discussions between the model teacher and the observer. The model teacher initiates the discussion by presenting impressions experienced during the implementation of the learning. Subsequently, the observer alternately presents their findings on student activities. All findings and inputs from the see stage are used as materials for revising and improving the planning or implementation stages in the second cycle (Kurniasih, et al., 2020). In this case, the model teacher feels assisted by the presence of learning videos. The worksheets that have been designed are also good and make learning interesting even though it is limited by distance. Distance learning clearly hampers communication between teachers and students, especially due to inadequate facilities and infrastructure.

Expressing Mathematical Ideas

Expressing mathematical ideas is one of the indicators for mathematical communication skills. This indicator refers to students' ability to express their mathematical thoughts or concepts in written form, both in natural language and mathematical symbols. This includes the student's ability to transform verbal or contextual information into appropriate mathematical representations. In this case, students are expected to be able to mention the information stated and asked from the given problem and solve the problem using the appropriate steps and calculation (Table 1). This indicator often appears in students' responses, as shown in Figure 4 and Figure 8. However, there are students who have not written down what is asked correctly. This causes errors in understanding the meaning of the question and the problem solving process as shown in Figure 6. This finding is consistent with a study by Nurhayati & Bernard (2019) who found that students' difficulties in answering the questions are due to their limited understanding of mathematical problems.

Converting Real Objects, Pictures, and Diagrams into Mathematical Ideas and Vice Versa

The second indicator for mathematical communication skills is converting real objects, pictures, and diagrams into mathematical ideas and vice versa. The aspect assessed is expressing the mathematical ideas of a problem in the form of drawings, graphs, or mathematical symbols. Based on the results of students' answers, some students make mistakes in drawing the graphs (See Figure 6). Students lack proficiency in understanding concepts related to linear equations and gradients, identifying points through which a line passes, deriving the equation of a line, and representing linear equations in graphs. As noted by Retnawati (2017), the lack of understanding in one concept causes a lack of understanding in other concepts, which further results in students having difficulty connecting the concepts to one another to solve a problem.

Drawing Conclusions at the End of Solution

The last indicator is drawing conclusions at the end of solution. The aspect that is assessed is showing the conclusions at the end of the problem-solving process. Based on the students' answers, some students did not write down and made mistakes in drawing conclusions. Therefore, this indicator was hardly identified in this study. The mistakes in drawing conclusions tend to be caused by students making mistakes in the calculation and a lack of understanding how to write well-formed conclusions. This phenomenon was also observed in the research conducted by Fitriatien (2019), where students often forget to write down their final answers. Some other students have already reached conclusions, but they are less meticulous, resulting in conclusions that do not align with the intended purpose of the problem. Many errors in drawing conclusions occur because students make mistakes in the preceding stages, leading to inaccurate conclusions.

CONCLUSION

Based on the research that has been done, it can be concluded that after learning with PMRI and LSLC assisted by learning videos is applied, students have demonstrated mathematical communication skills on the straight line equation material. However, not all of the skills have been optimized, as seen from the percentage of the students' test results which show mathematical communication skills indicators of no more than 70% or 80%. Some students have not developed their mathematical communication skills. This may be caused by technical difficulties (e.g. internet connection problems) during distance learning via Zoom, which allows only half of the information to be received. Therefore, students' mathematical communication skills on straight-line equation using PMRI and Collaborative learning are categorized as average or fair. In addition, the use of learning videos is very helpful for improving students' communication skills because the material explanation can be studied repeatedly and the context used in the learning video is easy to understand. Therefore, to develop and improve mathematical communication skills, PMRI learning and LSLC assisted by learning videos can be used to guide students. Nevertheless, while learning videos can be effective, it is important to note that an over-reliance on them might neglect other essential aspects of learning, such as classroom interaction and hands-on activities.

There are limitations to the implementation of distance learning. The dominant factor is that students' mathematical communication abilities appear to be only related to written communication skills. Furthermore, there is limited direct interaction between teachers and students which reduces opportunities for practice and skill improvement, lack of access to additional resources such as textbooks and teaching aids, technological challenges which can hinder student participation in online discussions, teacher difficulties in evaluating and providing feedback effectively, as well as limited student involvement that can affect their ability to develop optimally in mathematical communication skills. Therefore, it is necessary to conduct further research to examine the influence of public speaking skills, discussion groups and mathematics appreciation on mathematical communication skills. In addition, it is recommended that future studies analyze errors in understanding the context and their relationship to students' way of thinking to solve problems, especially in using models.

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