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Mathematical communication skills in the context of linear equations: A study on students' proficiency and self-esteem

Krida Singgih Kuncoro [1, 2 a *], Betty Kusumaningrum [1, 3 b], Denik Agustito [1 c], Fajar Meirani [4 d], Ega Sri Lestari [1 e]

[1] Universitas Sarjanawiyata Tamansiswa. Jl. Batikan UH-III/1043 Yogyakarta, 55167, Indonesia
[2] Universitas Pendidikan Indonesia. Jl. Dr. Setiabudhi No. 229 Bandung 40154, Indonesia
[3] Universitas Negeri Yogyakarta. Jl. Colombo No. 1, Yogyakarta 55281, Indonesia
[4] Utrecht University. Heidelberglaan 8, 3584 CS Utrecht Netherlands
[a] krida.kuncoro@ustjogja.ac.id; [b] betty.kusumaningrum@ustjogja.ac.id; [c] agustito@ustjogja.ac.id;
[d] f.fajarmeirani@students.uu.nl; [f] egasrilestari4165@gmail.com
* Corresponding Author.

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Abstract: This research aimed to analyze the mathematical communication skills of eighth-grade students in junior high school regarding the topic of linear equations. The population of this study consisted of eighth-grade students in one of the schools in Yogyakarta. Prior to selecting the subjects, a self-esteem questionnaire was administered, and then six students were randomly chosen, with three students having high self-esteem and three students having medium self-esteem. The selected students were then given an interview and a written test on mathematical communication skills. The data collected for this study included the results of the written test and the interviews. Based on the data analysis conducted, it was found that among the six selected students, SP1 was able to answer the questions using written text, drawing, and mathematical expressions, but their communication of the answers was not accurate. SP2 exhibited higher mathematical communication skills compared to the other subjects. SP3 had low mathematical communication skills, SP4 had moderate communication skills, SP5 had low mathematical communication skills, and SP6 could be considered to have moderate communication skills. Therefore, teachers are expected to provide students with the freedom to solve problems according to their own understanding and ideas.

Keywords: Linear Equations; Mathematical Communication Skills; Self-Esteem; Students' Proficiency

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INTRODUCTION

Education is recognized as a crucial element in the personal development of individuals, serving as a foundation for their present and future (Akkari & Maleq, 2020). It encompasses a deliberate and well-planned effort to create a learning environment that facilitates the active development of various aspects, including spirituality, self-control, personality, intelligence, and necessary skills, both for individuals themselves and for the betterment of society, nation, and country (Indonesia, 2003). Within the educational landscape, formal schooling, particularly in schools, plays a pivotal role in achieving these educational objectives (OECD, 2019).

Mathematics, being one of the core subjects taught in schools, holds immense significance in producing well-rounded and competent students (NCTM, 2000).

In our daily lives, we encounter mathematics in various forms, from routine transactions to engaging in diverse activities. As such, developing mathematical skills becomes imperative for students to accomplish their desired learning outcomes (Kilpatrick et al., 2001). In the process of learning mathematics, students are not only expected to think critically, formulate formulas, and solve mathematical problems but also to effectively communicate their ideas and reasoning (Belecina & Ocampo Jr, 2018; Brendefur & Frykholm, 2000). Communication, defined as the transmission of messages from sender to receiver to achieve specific objectives (Shannon, 1948), holds paramount importance in the classroom setting, where teachers impart knowledge to students. Throughout the learning journey, students are required to convey their ideas and concepts proficiently, both verbally and in written form (Pourdavood et al., 2020). This ability is known as mathematical communication skills, which serve as a fundamental goal in the learning process (Tong et al., 2021). It is an indispensable skill that every student should possess to effectively articulate their mathematical ideas and thoughts (Wilkinson, 2018). In the realm of mathematics education, students are expected to convey their ideas using symbols, diagrams, graphs, and other visual representations to clarify the nature of problems, utilizing mathematical language such as linear equations, diagrams, and graphs (Uyen et al., 2021).

Mathematical communication skills play a pivotal role in the process of learning mathematics (Chasanah & Usodo, 2020; Gravemeijer et al., 2017). During mathematics lessons, teachers frequently engage students by posing questions that require them to identify, analyze, master, and express their opinions while solving the given problems (Utami et al., 2022; NCTM, 2014). However, despite the importance of mathematical communication skills, many students struggle to develop them fully, resulting in noticeable deficiencies. The level of mathematical communication skills among students in Indonesia remains relatively low. According to the mathematics achievement scores, Indonesian students scored an average of 386, while the international average stands at 500, placing them at 38th among 42 participating countries (OECD, 2019). These scores clearly indicate that students' mathematical abilities are still categorized as low, with a proficiency limited to basic mathematical problem-solving, while grappling with more complex ones.

The low scores can be attributed to students' difficulties in comprehending complex situations, leading to an inability to solve mathematical problems systematically as required. These challenges are also evident when students employ mathematical symbols and structures, and present their ideas. Written communication poses a particular challenge for many students. Therefore, it becomes crucial for teachers to unpack the meaning embedded in mathematical symbols to enhance mathematical communication within the classroom (Güçler, 2014). This observation aligns with the reality observed during direct research in classrooms and the collection of mathematics assignments at a junior high school in Yogyakarta during the Field School Introduction, where many students exhibited low mathematical communication skills in their mathematics learning.

Based on the findings of direct research, it was evident that students lack mathematical communication skills, particularly when confronted with word problems. Many students struggle to follow step-by-step instructions based on the given problem information. They often fail to develop the habit of systematically writing down what is known and identifying the question before attempting to solve the problem, resulting in a misunderstanding of the problem and a lack of comprehension of the underlying concepts (NCTM, 2014).

Given the aforementioned background, there is a clear need to delve deeper into the examination of students' mathematical communication skills, specifically in the context of linear equations. The present study aims to explore and analyze the proficiency of eighth-grade students' mathematical communication skills in relation to linear equations. By investigating students' abilities to communicate their mathematical ideas and concepts effectively, this research aims to contribute to understanding the factors that influence students' mathematical communication skills and provide valuable insights for enhancing mathematics education in Indonesia.

While previous studies have examined mathematical communication skills, there is a research gap regarding the specific focus on linear equations and their relationship with students' proficiency in mathematical communication. By narrowing the scope to linear equations, this study seeks to address this research gap and shed light on the unique challenges and opportunities presented in this particular mathematical context. Additionally, the incorporation of self-esteem as a variable in the analysis adds a novel dimension to the investigation. The influence of self-esteem on students' mathematical communication skills has been relatively underexplored, and this study seeks to bridge that gap by examining the potential interplay between self-esteem and mathematical communication proficiency.

Understanding the factors that contribute to students' mathematical communication skills and their self-esteem in the context of linear equations can have significant implications for mathematics education. By identifying areas of improvement and developing strategies to enhance mathematical communication skills, educators and policymakers can work towards fostering a more effective learning environment that nurtures students' mathematical abilities and self-confidence. Additionally, gaining insights into the relationship between self-esteem and mathematical communication skills can inform interventions that aim to boost students' self-perception, motivation, and overall engagement in mathematics learning.

The importance of mathematical communication skills cannot be overstated, as they play a vital role in the learning process and students' overall mathematical proficiency. This study aims to analyze and explore the mathematical communication skills of eighth-grade students in the context of linear equations while also considering the influence of self-esteem. By addressing the research gap in this specific area, this research aims to contribute to the existing body of knowledge and provide practical insights for enhancing mathematics education in Indonesia.

METHODS

This study's research type is descriptive quantitative research (Fisher & Marshall, 2009). The study aims to describe the results of mathematical communication skills of eighth-grade students at a junior high school in Yogyakarta during the Field School Introduction, specifically focusing on linear equations and whether the criteria are met. The subjects were selected through the completion of a self-esteem questionnaire by 22 students, from which six subjects were chosen, including three with high self-esteem percentages and three with moderate self-esteem percentages.

The instruments used in the study were a test of mathematical communication skills and online interviews. The selected subjects were given a written test to assess their mathematical communication abilities, with the test focusing on the topic of linear equations. This study utilized three indicators of mathematical communication ability, specifically written text, drawing, and mathematical expression (Ansari, 2003). After completing the test, the students underwent an interview to further strengthen their mathematical communication. The data collection technique involved testing to assess how students solve problems related to linear equations according to the established indicators. The researcher conducted unstructured interviews, asking questions that broadly covered the research topic. The self-esteem categories of the students are presented in Table 1.

Table 1. Self Esteem Category

Range	Category
$85\% < \% < 100\%$	Very High
$70\% < \% < 84\%$	High
$55\% < \% < 69\%$	Moderate
$40\% < \% < 54\%$	Low
$25\% < \% < 39\%$	Very Low

The data analysis technique in the study involved three stages: (1) Data reduction, which involved collecting essential information and organizing the obtained data. (2) Data presentation, which involved presenting the information in an easily understandable way, as the data collected were in the form of concise descriptions. This included the presentation of students' work and the results of the interviews. (3) Verification stage involved drawing conclusions based on the data obtained. The validity of the data was tested through credibility, data dependency, and data transferability tests. Triangulation technique was employed in this study, which involved comparing the data collected through essay-based tests on the topic of linear equations with the same source, followed by cross-checking through interviews.

RESULTS AND DISCUSSION

Results

The results of the study revealed important insights into the mathematical communication skills of eighth-grade students in the context of linear equations. The data collected through the written essay test and the interview provided valuable information about the students' learning outcomes and their performance in the mathematical communication skills assessment. The mathematical communication skills test focused on the topic of linear equations and was administered to the six selected students. The names of the participants can be found in Table 2. It is important to note that the results presented here are specific to the sample of students from the selected junior high school in Yogyakarta. Further research with a larger and more diverse sample would be beneficial to gain a broader perspective on the mathematical communication skills of eighth-grade students in the region.

Table 2. List of Research Subjects' Names

No	Name of Research Subject	Research Subject Code (SP)	Self-Esteem Categories
1	ANS	SP1	High
2	DRF	SP2	High
3	CI	SP3	Medium
4	JDD	SP4	Medium
5	EVP	SP5	Medium
6	FYRN	SP6	High

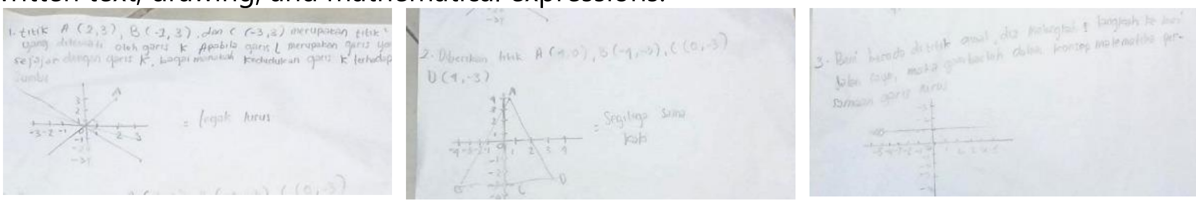
In Table 2, the data also presents the distribution of self-esteem categories among the students. The self-esteem categories are divided into different ranges, indicating the students' self-esteem level. This information provides insights into the overall self-esteem levels within the student population. The table serves as a visual representation of the findings and allows for a comprehensive understanding of the distribution of self-esteem among the students.

The following data description and analysis were obtained based on the test results of seventh-grade students at one of the junior high schools in Yogyakarta in solving mathematical communication ability tests on the topic of linear equations. The test aimed to assess the students' mathematical communication skills specifically related to linear equations. The students were presented with questions and expected to demonstrate their understanding and ability to effectively communicate mathematical concepts. The test provided valuable insights into the students' strengths and weaknesses in mathematical communication.

After analyzing the data, several patterns and trends emerged. It was observed that the majority of students faced difficulties in expressing their mathematical reasoning and articulating problem-solving steps clearly. Many students also struggled with understanding the given mathematical problems, resulting in incorrect interpretations and solutions. Furthermore, the analysis revealed that a significant number of students exhibited limited proficiency in using mathematical language and symbols to accurately convey their ideas. They often relied on incomplete explanations and lacked precision in their mathematical communication. On the other hand, a smaller percentage of students demonstrated strong mathematical communication skills, fluently expressing their thought processes and displaying a clear understanding of the concepts.

Communication Ability Test of Subject SP1

The findings from the assessment of subject SP1's mathematical communication ability are depicted in Figure 1. The figure presents the outcomes obtained from the test, providing a visual representation of SP1's proficiency in effectively communicating mathematical concepts. This assessment involved evaluating various aspects of mathematical communication, such as written text, drawing, and mathematical expressions.



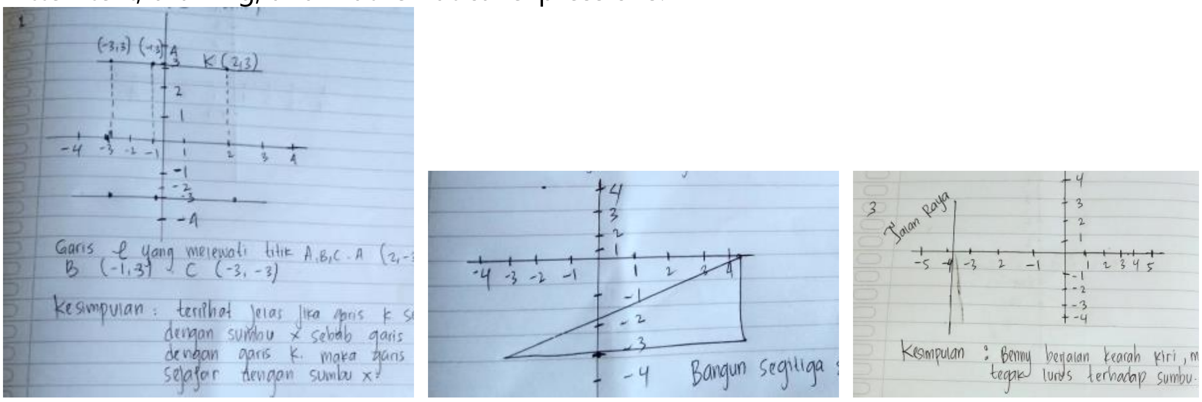
(a) Question number 1 (Written Text) (b) Question number 2 (Drawing) (c) Question number 3 (Mathematical Expression)

Figure 1. Communication ability test of subject SP1

Based on the students' mathematical communication test results in Figure 1, it can be seen that SP1 drew a Cartesian coordinate without explanation. From the student's answer, it is evident that the student did not understand the question at all, especially in creating the requested coordinate points as stated in the question. In Figure 1(b), it is apparent that the student was unable to connect the coordinate points. The student also struggled to determine whether the lines formed by the points were perpendicular or parallel to any axis. As a result, the answers provided were incorrect. In question number 2, it is noticeable that the student was unable to provide reasons for their answer. The student only drew the requested points, but it turned out that the coordinate points chosen by the student were also incorrect, and the same applied when connecting the coordinate points, leading to incorrect answers. Similarly, in Figure 1(c), the student's answer was completely incorrect, and the student was unable to provide reasons for their answer. In their response, the student also struggled to determine the known coordinate points, indicating confusion regarding coordinate points. Therefore, the answers obtained were incorrect, and the student did not grasp the taught material at all. These findings are supported by the test results and interviews conducted, which revealed that SP1 was able to answer questions using written text, drawing, and mathematical expressions and was able to communicate their answers. However, there were still inaccuracies, as SP1's answers were incorrect, and it was challenging for them to effectively communicate their answers in line with what was learned in class. During the interview phase, SP1 was able to provide answers and reasons for their responses.

Communication Ability Test of Subject SP2

The results of evaluating subject SP2's mathematical communication ability can be observed in Figure 2. The figure illustrates the outcomes derived from the assessment, visually portraying the level of proficiency in effectively conveying mathematical concepts for SP2. The evaluation encompassed the examination of different facets of mathematical communication, including written text, drawing, and mathematical expressions.



(a) Question number 1 (Written Text) (b) Question number 2 (Drawing) (c) Question number 3 (Mathematical Expression)

Figure 2. Communication ability test of subject SP2

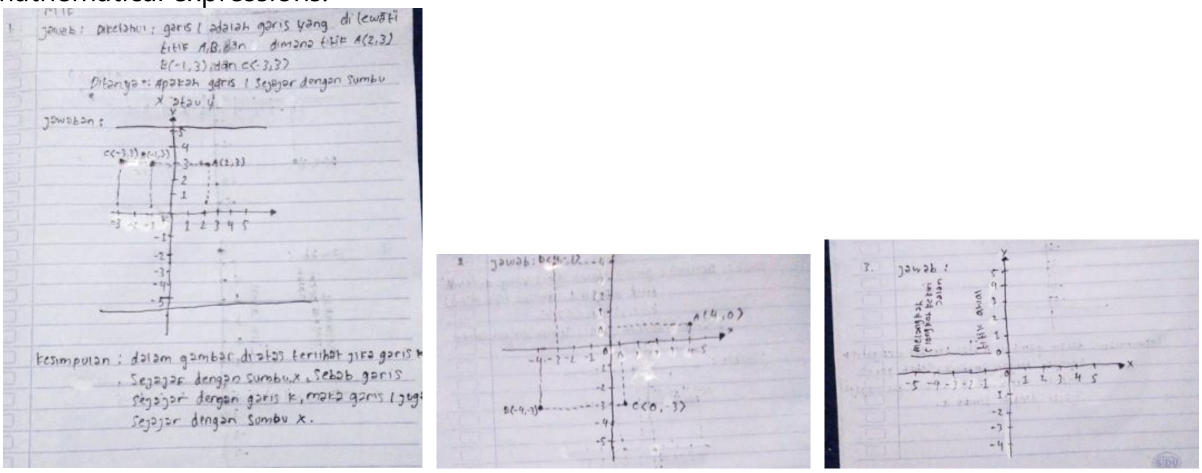
Transcript of the interview with subject SP2.

R : What is meant by Cartesian coordinates?
SP2 : Cartesian coordinates in mathematics are used to determine points in the Cartesian plane using two numbers and are usually written in the form (x, y).
R : How many positions of points are there on the Cartesian coordinate plane? List them!
SP2 : There are four: quadrant I, quadrant II, quadrant III, and quadrant IV
R : Which one from the x and y-axis on the Cartesian coordinate plane is called the abscissa and the ordinate?
SP2 : The x-axis is called the abscissa, and the y-axis is called the ordinate.
R : How many types of lines are there on the Cartesian coordinate plane? What are they?
SP2 : There are four: straight lines, parallel lines, intersecting lines, and coincident lines.
R : If the points on the Cartesian coordinates are already determined, how do you connect those points?
SP2 : By following the given points and drawing lines to connect them.
R : Can the x-axis and y-axis be drawn as lines?
SP2 : Yes, they can.

In Figure 2 (a), it can be observed that SP2 accurately depicted and wrote down several key points from the question, such as drawing the Cartesian coordinate and noting important details and conclusions. The student was able to provide reasoning for their answer and accurately illustrate it. In question number 2, the student's answer was correct. They responded in accordance with the question, although they did not provide any reasoning or necessary points in writing. The student's answers aligned with the question's requirements, and they were able to accurately depict the requested shape using the given coordinate points. In question number 3, which stated, "Beny is at the starting point and takes five steps towards the left side of the highway. Illustrate it in the concept of linear equations!" the student was able to draw a conclusion from their answer but failed to explain the reasoning behind it. From the drawing made by the student, it is evident that they understood the concept and purpose of the question and were able to work on it in detail. This proficiency is also reflected during the online interview, where SP2 successfully answered all the questions, demonstrating proficiency in written text, drawing, and mathematical expression. They effectively communicated their answers, providing reasoning and noting important points from the questions. Based on the interview, SP2 consistently provided appropriate responses.

Communication Ability Test of Subject SP3

Figure 3 illustrates the results of evaluating subject SP3's mathematical communication ability, as indicated in the assessment. The figure visually represents the level of proficiency in effectively conveying mathematical concepts for SP3. The evaluation involved examining different indicators of mathematical communication, including written text, drawing, and mathematical expressions.



(a) Question number 1 (Written Text)

(b) Question number 2 (Drawing)

(c) Question number 3 (Mathematical Expression)

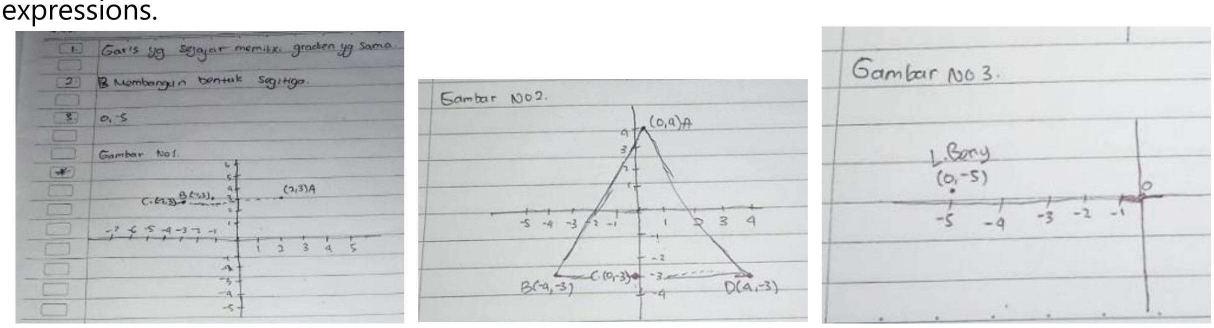
Figure 3. Communication ability test of subject SP3

In the student's response, as shown in Figure 3(a), it is evident that the student can answer the question correctly and in detail. The student is able to determine the coordinate points on the Cartesian coordinate plane. Furthermore, the student can connect the given coordinate points to form a straight line and draw a conclusion based on the answer provided. In question number two, the student was asked to determine the geometric shape that would be formed based on the given information. In Figure 3(b), it can be observed that the student was only able to identify the location of the coordinate points but could not connect them as specified. In question number 3, as seen in Figure 3(c), the student managed to place the known coordinate points; however, they were unable to connect the given coordinate points on the Cartesian plane and failed to provide reasoning and conclusions in their own answer.

The results of the communication test from this subject align with the findings of the interview conducted. It is apparent that SP3 can answer all the questions, but when it comes to drawing, the student struggles, indicating difficulty in effectively communicating what they have learned during the test. Nevertheless, based on the interview, the student is capable of providing answers and their reasoning.

Communication Ability Test of Subject SP4

The assessment outcomes of subject SP4's mathematical communication ability are depicted in Figure 4, providing a visual representation of their proficiency in effectively conveying mathematical concepts. The evaluation encompassed the examination of various indicators of mathematical communication, such as written text, drawing, and mathematical expressions.



(a) Question number 1 (Written Text) | (b) Question number 2 (Drawing) | (c) Question number 3 (Mathematical Expression)

Figure 4. Communication ability test of subject SP4

Transcript of the interview with subject SP4.

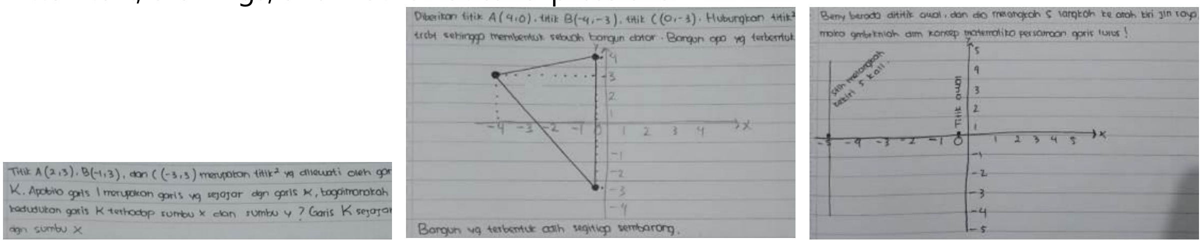
R : What is meant by Cartesian coordinates?
SP4 : A cartesian coordinates system is a plane that collects points using two numbers, often referred to as the x-coordinate and the y-coordinate.
R : How many positions of points are there on the Cartesian coordinate plane? List them!
SP4 : There are four positions: quadrant I, quadrant II, quadrant III, and quadrant IV.
R : Specify which one from the x-axis and y-axis on the Cartesian coordinate plane is called the abscissa and the ordinate.
SP4 : X is the abscissa, and y is the ordinate.
R : How many types of lines are there on the Cartesian coordinate plane? What are they?
SP4 : There are two: parallel lines and perpendicular lines.
R : If the points on the Cartesian coordinates are already determined, how do you connect those points?
SP4 : They can be connected by drawing lines from the given coordinate points.
R : Can the x-axis and y-axis be drawn as lines?
SP4 : Yes, they can.

In question number one, the students were asked to determine the equation of a line based on mathematical concepts. In Figure 4(a), it can be observed from the student's responses that they were able to answer the question correctly. The student was able to identify the given coordinate points and connect them on the Cartesian plane. However, the student struggled to provide reasoning to support their answer and draw conclusions from it. In question number two, the students were asked to determine the geometric shape formed by the given coordinate points. In Figure 4(b), it is evident that the student was able to identify the coordinate points on the Cartesian plane, but they made errors in connecting the points. As a result, the formed shape was incorrect, as it should have been a right triangle instead of what is shown in Figure 4(b). Question number three involved Beny's position after taking a specified number of steps in a given direction. In Figure 4(c), it is apparent that the student was unable to understand the intention of the question and provided an answer that was different from what was requested. It is evident that the student only identified the coordinate point instead of the distance/steps specified in the question.

Based on the results of the communication test and the conducted interview, it can be concluded that SP4 was able to communicate their answers and successfully complete all the questions effectively. Additionally, during the interview, the student was able to provide accurate answers and appropriate reasoning.

Communication Ability Test of Subject SP5

Figure 5 presents the assessment results of subject SP5's mathematical communication ability, visually depicting their competence in effectively conveying mathematical concepts. The evaluation involved analyzing diverse indicators of mathematical communication, including written text, drawings, and mathematical expressions.



(a) Question number 1 (Written Text) (b) Question number 2 (Drawing) (c) Question number 3 (Mathematical Expression)

Figure 5. Communication ability test of subject SP5

Transcript of the interview with subject SP5.

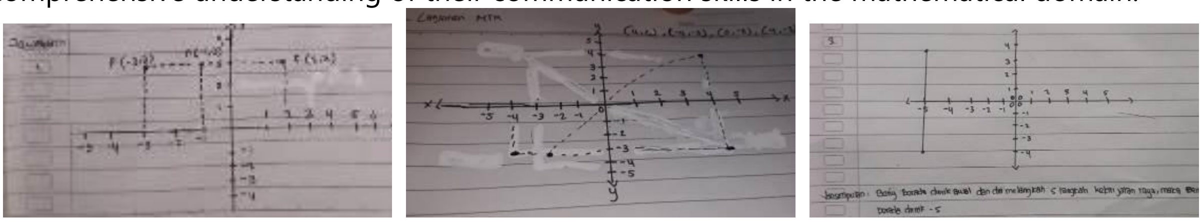
R	:	What is meant by Cartesian coordinates?
SP5	:	A collection of points on the Cartesian plane
R	:	How many positions of points are there on the Cartesian coordinate plane? List them!
SP5	:	There are four: quadrant I, quadrant II, quadrant III, and quadrant IV.
R	:	Specify which one from the x-axis and y-axis on the Cartesian coordinate plane is called the abscissa and the ordinate.
SP5	:	
R	:	How many types of lines are there on the Cartesian coordinate plane? What are they?
SP5	:	Perpendicular lines and non-perpendicular lines.
R	:	If the points on the Cartesian coordinates are already determined, how do you connect those points?
SP5	:	By drawing lines that follow the given points.
R	:	Can the x-axis and y-axis be drawn as lines?
SP5	:	Yes, they can.

Based on the students' communication test responses for question number 1, it is evident from Figure 5(a) that the student did not attempt to solve the problem at all, as their answer was blank. It is clear that the student did not understand the question. Question number 2 involved given points A (4,0), B (-4,-3), C (0,-3), and D (4,-3), where the students were asked to connect these points and determine the shape formed. In Figure 5(a), it can be seen from the student's responses that they were unable to correctly identify the X-axis and Y-axis of the given coordinate points. For example, in point A (4,0), the student placed four on the y-axis instead of the X-axis, and vice versa. As a result, the student made mistakes in placing the coordinate points on the Cartesian plane, and consequently, the connected points were incorrect.

Question number 3 stated, "Beny is at the starting point and takes five steps to the left of the highway. At which point is Beny located after taking the specified steps? Illustrate it using the concept of a straight line in mathematics!" In Figure 5(c), it can be observed that the student's answer was correct, indicating their ability to determine the coordinate point as requested. Based on the students' responses, it can be concluded that they understood the questions' intention. However, SP5 is still unable to effectively communicate their understanding, as evidenced by their answers not aligning with the questions. Additionally, the interview results show that the student still lacks understanding and struggles to communicate, with incorrect or no responses. Therefore, it can be inferred that SP5 has a low level of mathematical communication ability.

Communication Ability Test of Subject SP6

The proficiency of subject SP6 in effectively conveying mathematical concepts is represented in Figure 6, showcasing their mathematical communication ability assessment outcomes. The evaluation encompassed the analysis of various indicators of mathematical communication, such as written text, drawings, and mathematical expressions, to provide a comprehensive understanding of their communication skills in the mathematical domain.



(a) Question number 1 (Written Text) (b) Question number 2 (Drawing) (c) Question number 3 (Mathematical Expression)

Figure 6. Communication ability test of subject SP6

Transcript of the interview with subject SP6.

R	:	What is meant by Cartesian coordinates?
SP6	:	The cartesian coordinate system is used to determine the position of each point in the Cartesian plane using two numbers, usually represented as (x, y) for that point.
R	:	How many positions of points are there on the Cartesian coordinate plane? List them!
SP6	:	There are four: quadrant I, quadrant II, quadrant III, and quadrant IV.
R	:	Specify which one from the x-axis and y-axis on the Cartesian coordinate plane is called the abscissa and the ordinate.
SP6	:	The x-axis is called the abscissa, and the y-axis is called the ordinate.
R	:	How many types of lines are there on the Cartesian coordinate plane? What are they?
SP6	:	There are 7: perpendicular lines, non-perpendicular lines, intersecting lines with the x-axis, intersecting lines with the y-axis, parallel lines, non-parallel lines, and lines coinciding with a point.
R	:	If the points on the Cartesian coordinates are already determined, how do you connect those points?
SP6	:	By drawing lines from one point to another.
R	:	Can the x-axis and y-axis be drawn as lines?
SP6	:	Yes, they can be drawn as lines.

Based on the subject's response to question number 1, as seen in Figure 6(a), it can be observed that the student was able to answer the question, but their response was somewhat inaccurate or, more precisely, incorrect. The student was only able to determine the coordinate points but lacked understanding of the subsequent steps to solve the problem. It is evident from the student's answers that they did not fully grasp the intended meaning of the given question. Question number 2 involved the given points A (4,0), B (-4,-3), C (0,-3), and D (4,-3), with the instruction to connect these points and determine the shape formed. In SP6's response, it is apparent that the student was confused in determining the given coordinate points to be placed on the Cartesian plane, resulting in an incorrect shape being formed.

Question number 3 stated, "Beny is at the starting point and takes five steps to the left of the highway. At which point is Beny located after taking the specified steps?" It can be seen from the students' answers and conclusions that they understood the given question, although they opted for a more practical approach without providing a systematic solution. SP6 was able to communicate their understanding, although they seemed a bit uncertain in the written text. Furthermore, based on the interview results, SP6 was able to provide answers without hesitation and provide reasoning for all the interview questions, although their answers were incomplete and not entirely accurate. Despite being able to answer all the interview questions, the students struggled to apply their knowledge to the problem at hand. Therefore, it can be concluded that SP6 has a moderate level of mathematical communication ability.

Discussion

The findings of this study revealed intriguing patterns among the six subjects, shedding light on the complex relationship between self-esteem and mathematical communication abilities. It is evident that self-esteem alone is not sufficient for effective communication, as demonstrated by subjects SP1 and SP6, who exhibited high self-esteem but only moderate mathematical communication skills. This finding aligns with previous research indicating that self-esteem does not always translate into academic achievement or competence in specific domains (Ross & Broh, 2000; Zheng et al., 2020). On the other hand, subjects SP2 and SP4 showcased both high self-esteem and high mathematical communication proficiency, suggesting a positive relationship between self-esteem and communication skills in the context of linear equations. This finding aligns with the self-enhancement theory proposed by (Baumeister et al., 2003), which suggests that individuals with high self-esteem are more likely to engage in adaptive behaviors and demonstrate higher levels of competence.

Interestingly, subjects SP3 and SP5 displayed moderate self-esteem but struggled with mathematical communication. This indicates that self-esteem alone may not be the sole determinant of communication proficiency. Other factors, such as the learning environment, instructional methods, and individual differences, likely play significant roles in the development of mathematical communication skills . Motivational factors, such as task value and academic self-concept, have been shown to interact with self-esteem to influence students' engagement and achievement in mathematics (Kuncoro et al., 2021; Scherrer & Preckel, 2019). It is plausible that these motivational factors also influence communication skills. Students who perceive the value of effective communication in mathematics and possess a positive self-concept in this domain are more likely to invest effort in developing their communication abilities (Hammoudi, 2020; Perera & John, 2020).

This study highlights the intricate relationship between self-esteem and mathematical communication skills among eighth-grade students. It is important to note that the relationship between self-esteem and mathematical communication abilities can exhibit variations across individuals (Magnusson & Nermo, 2018). While some students with high self-esteem may demonstrate strong communication skills in mathematics, others with low self-esteem may struggle to effectively express their mathematical ideas. Conversely, some students with high self-esteem may face challenges in communicating their mathematical thoughts clearly, while those with lower self-esteem may surprisingly excel in this area. These variations highlight the complex nature of the relationship between self-esteem and mathematical communication abilities, suggesting that additional factors such as cognitive processes, prior experiences, and individual learning styles can influence the manifestation of these skills (Pellas, 2014). A comprehensive understanding of these variations can guide educators in tailoring instructional approaches and interventions to address each student's specific needs and strengths, ultimately promoting the development of robust mathematical communication abilities (Roy et al., 2013).

While self-esteem can play a role in fostering confidence and motivation (Masselink et al., 2018), it is not the sole determinant of communication proficiency in mathematics. Educators must adopt a comprehensive approach that considers various factors, including targeted instruction, the learning environment, metacognitive awareness, and individual learning styles, to enhance students' mathematical communication abilities effectively. By doing so, educators can empower students to become proficient communicators in mathematics and foster their overall mathematical understanding and success. Targeted instruction tailored to address specific communication challenges, such as explicit teaching of mathematical vocabulary and presentation techniques, can significantly enhance communication skills. The educational environment, including class size, resources, and teacher-student interactions, also impacts communication proficiency. Furthermore, individual learning styles and preferences affect how students process and express mathematical concepts. Some students may thrive in collaborative group settings, while others may prefer individual reflection and exploration. By acknowledging and addressing these diverse factors, educators can implement comprehensive strategies that promote the holistic development of mathematical communication abilities, moving beyond solely focusing on self-esteem. A multifaceted approach that considers targeted instruction, the educational environment, and individual learning styles alongside self-esteem is vital for nurturing effective mathematical communication skills in students (Di Giunta et al., 2013).

A deep understanding of the intricate dynamics involved in the relationship between self-esteem and mathematical communication skills is crucial. Such understanding can serve as a valuable foundation for developing effective interventions to enhance students' mathematical communication abilities. Educators can tailor interventions that address specific challenges and capitalize on strengths by comprehending how these factors interact and influence each other. This knowledge can inform the design of instructional strategies, learning materials, and assessment methods that foster effective communication in mathematics (Hendriyanto et al., 2023; Kuncoro & Juandi, 2023). Moreover, understanding these dynamics allows educators to identify and address potential barriers or misconceptions that hinder students' communication proficiency. It also enables the implementation of supportive learning environments that encourage collaboration, critical thinking, and reflection (Martin & Bolliger, 2018). Ultimately, utilizing this understanding in the development of interventions empowers educators to provide students with the necessary tools and opportunities to enhance their mathematical communication skills, leading to improved learning outcomes and increased engagement in the subject.

To address the diverse needs of students, educators should adopt a multifaceted approach that considers both self-esteem and other factors contributing to effective mathematical communication (Mahani, 2019; Maspe et al., 2021). Providing explicit instruction in communication strategies, fostering metacognitive awareness, and creating a supportive learning environment are crucial steps in facilitating the development of communication skills among students with varying levels of self-esteem (Kamid et al., 2020; Noviyana et al., 2020; Rustam & Ramlan, 2017). By tailoring instructional approaches and accommodating individual learning styles, educators can empower students to overcome communication barriers and enhance their overall understanding of mathematical concepts.

These findings emphasize the importance of considering the multifaceted nature of mathematical communication skills. Effective communication in mathematics goes beyond simply conveying answers or solutions; it involves the ability to articulate mathematical concepts, justify reasoning, and engage in mathematical discourse. Therefore, educators should not only focus on improving students' self-esteem but also emphasize the development of specific communication strategies and metacognitive awareness. By providing explicit instruction in communication strategies, such as using precise mathematical language, organizing ideas clearly, and presenting logical arguments, educators can equip students with the necessary tools to effectively communicate their mathematical thinking (Hartinah et al., 2019). Encouraging students to reflect on their communication practices and engage in self-assessment can also enhance their metacognitive awareness, enabling them to identify areas for improvement and actively work toward refining their communication skills (Kuncoro et al., 2022).

Creating a supportive learning environment is equally crucial (Ismiyati et al., 2022; Blazar & Kraft, 2017; Winstone et al., 2017). When students feel safe and encouraged to express their ideas and ask questions, they are more likely to actively participate in mathematical discussions and engage in collaborative problem-solving activities. Educators can foster this environment by promoting a positive classroom culture that values and respects diverse perspectives, providing opportunities for peer collaboration, and offering constructive feedback that focuses on improving communication skills (Doyle, 2018). Furthermore, it is important to acknowledge the unique learning styles and preferences of individual students (Sener & Çokçaliskan, 2018). Not all students learn and communicate in the same way (An & Carr, 2017). Some may prefer visual representations, while others may excel in verbal explanations. By recognizing and accommodating these differences, educators can tailor their instruction to meet the diverse needs of students, thereby facilitating their communication skills development.

Further research is warranted to explore additional factors and interventions that can further enhance mathematical communication skills and contribute to the advancement of mathematics education. As forthcoming investigations within this theoretical framework unfold, it is imperative to further elucidate the significance of particular occurrences, interventions, overarching ramifications, and, notably, their interconnectedness. Educators and researchers need to consider these findings when designing instructional strategies and interventions to enhance mathematical communication skills. Mathematical communication ability, which is currently the main focus as the dependent variable, can be expanded to include broader aspects of students' cognitive patterns. Lastly, we acknowledge that the examination thus far has been confined to a restricted range of significant incidents and specific target demographics. This discernment uncovers numerous avenues for future research, encompassing diverse aspects. It would be valuable to investigate the specific factors that influence mathematical communication abilities, considering a larger sample size, diverse student populations, and longitudinal studies to capture the developmental aspects of communication proficiency.

These findings have important implications for instructional strategies and interventions aimed at enhancing mathematical communication skills. Recognizing that self-esteem is not the sole determinant of communication proficiency in mathematics is crucial. Factors such as targeted instruction, the educational environment, and individual learning styles also play significant roles. By understanding these dynamics, educators can design effective interventions to foster communication skills among students. Further research, with larger sample sizes, diverse student populations, and longitudinal studies, can provide a deeper understanding of the factors influencing mathematical communication abilities and inform evidence-based practices in mathematics education.

CONCLUSION

Among the six subjects examined, there were instances where high self-esteem was associated with high mathematical communication skills (SP2), while in other cases, individuals with high self-esteem demonstrated only moderate mathematical communication skills (SP1 and SP6). Similarly, subjects with moderate self-esteem showed varying levels of mathematical communication proficiency, ranging from low (SP5) to moderate (SP4). This study underscores the complex relationship between self-esteem and mathematical communication skills in the context of linear equations. While there are instances of a positive correlation between high self-esteem and high mathematical communication skills, the findings also highlight variations in the relationship between self-esteem and mathematical communication abilities. Therefore, educators need to adopt an approach that considers both self-esteem and other contributing factors when promoting students' mathematical communication skills. This research provides a basis for the development of effective instructional strategies and serves as a groundwork for further investigation into the factors influencing students' mathematical communication abilities. By addressing these factors, educators can better support students in developing strong mathematical communication skills, ultimately enhancing their overall mathematical proficiency and academic success.

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