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Students' Mathematical Communication Skills and Their Relation to Self-Confidence in Learning Exponents

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ABSTRACT

Mathematical communication skills are essential for students to understand, construct, and express mathematical ideas. However, studies linking these skills with affective factors such as self-confidence remain limited, particularly in learning exponents. This study aimed to examine the relationship between students' self-confidence and their mathematical communication skills in exponent learning. A qualitative case study design was applied to 53 eleventh-grade students at SMA Negeri 1 Pringgasela. Data were obtained through a mathematical communication test, a validated self-confidence questionnaire, and in-depth interviews. The results show variations in communication skills across self-confidence levels. Students with high self-confidence communicated ideas more comprehensively through oral, written, and visual representations. Students with moderate self-confidence demonstrated adequate but restricted forms of representation, while those with low self-confidence struggled to articulate ideas consistently. These findings emphasize the significant role of affective factors in shaping mathematical communication. The study suggests that instructional strategies should not only focus on conceptual mastery but also foster students' self-confidence through collaborative activities, discussions, and presentations. This contributes practically to classroom practice and theoretically to the integration of affective and cognitive aspects in mathematics learning, particularly in the context of exponents.

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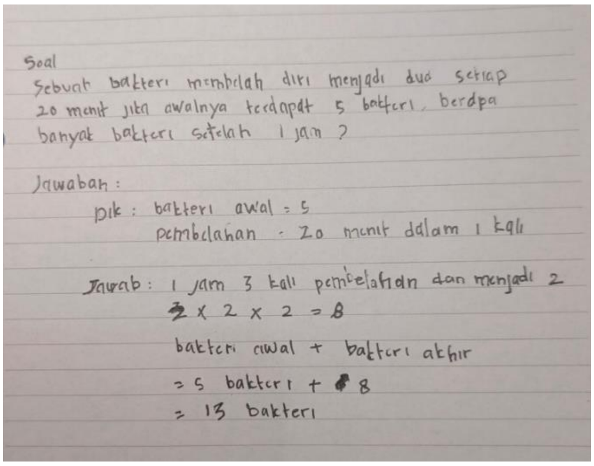
Introduction

In the era of globalization, students are required to master various competencies and skills to live in the 21st century, where numerous challenges and opportunities arise from technological and informational advances (Belli & Annurwanda, 2024). Communication is one of the essential skills that students must possess in mathematics learning, enabling them to express and share ideas with their peers. This ability is commonly referred to as mathematical communication skills.

Mathematical communication skills involve the exchange of ideas, concepts, or information related to mathematics. Schoen et al. argue that mathematical communication is not merely about expressing ideas in writing; rather, students are expected to develop the ability to read, speak, illustrate, listen, and collaborate (Sri Solihah & Asep Amam, 2021). These skills allow students to explain, understand, and apply mathematical concepts clearly and effectively. According to Nur Rohmah (2022), mathematical communication is the ability of students to convey ideas either in written or oral form, underscoring its importance in mathematics education.

Despite its importance, students' mathematical communication skills remain far from optimal in practice. This is evidenced by the low achievement of Indonesian students in the Programme for International Student Assessment (PISA) 2018, where Indonesia ranked 72nd out of 77 participating countries. Conducted by the Organisation for Economic Co-operation and Development (OECD), PISA assesses the skills and competencies of 15-year-old students worldwide. One of the domains assessed is mathematical literacy, which includes the ability to analyze, reason, and communicate ideas effectively, as well as to formulate, solve, and interpret mathematical problems across various forms and contexts (Sherli Pitrah Dewi, 2022). Findings from previous studies consistently highlight that students' mathematical communication skills are still underdeveloped.

Research conducted by Fazriawati & Irvandi (2023) demonstrated that the topic of exponents is particularly effective for assessing students' mathematical communication skills. Moreover, the understanding of exponential functions as a crucial aspect of mathematical communication has been extensively explored in semiotic studies and mathematical modeling activities (Pessoa da Silva & Werle de Almeida, 2018).



Question:
A bacterium divides itself into two every 20 minutes. If initially there are 5 bacteria, how many bacteria will there be after 1 hour?
Answer:
Let: initial bacteria = 5
Division: 20 minutes for 1 time
Solution:
In 1 hour there are 3 divisions, and it becomes 2 × 2 × 2 = 8
Initial bacteria + final bacteria =5 bacteria + 8 = 13 bacteria

Figure 1. Students' responses from the preliminary observation

The results of the preliminary observation conducted by the researcher are consistent with the findings of Sherli Pitrah Dewi (2022), and Fazriawati & Irvandi (2023), which revealed that students' mathematical communication skills remain low. Based on students' written responses, one student demonstrated partial ability to express mathematical ideas. In writing, the student was able to identify and record important information from the problem and perform the initial calculation ($2 \times 2 \times 2 = 8$), indicating the ability to organize thought processes. However, the student failed to express the correct mathematical relationship by using addition ($5 + 8$) instead of multiplication (5×8). This suggests a significant weakness in expressing ideas visually, as the student could not imagine how each initial bacterium divides and multiplies.

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Such an error, if articulated orally, would likely reflect the same conceptual weakness, indicating that the difficulty lies not only in writing skills but also in a deeper understanding of the exponential concept. Hence, the problem relates not only to cognitive processes but also to broader influencing factors.

Several factors can affect students' mathematical communication skills, including a deep understanding of mathematical concepts, mastery of symbols and notation, reasoning and problem-solving abilities, and the ability to clearly and accurately express mathematical ideas both orally and in writing (Hapsoh, 2022). Furthermore, mathematical communication skills are also influenced by self-confidence (Azzahra, 2023). Self-confidence refers to an individual's belief in their own abilities and qualities. In the context of mathematical communication, it refers to students' belief in their ability to understand, process, and communicate mathematical ideas orally and in writing. Thus, students need to strengthen their self-confidence as part of improving their mathematical abilities.

Self-confidence is essentially the belief within individuals that any life challenge must be faced with action (Fitriyani, 2024). According to Bandura, self-confidence reflects an individual's perception of their ability to motivate themselves, which is manifested in actions aligned with task demands (Sri Solihah & Asep Amam, 2021). Similarly, Sunarti et al. (2022) emphasize that self-confidence is a belief in oneself that an individual is capable and assured in making decisions and taking actions to complete academic tasks.

A considerable number of studies have examined students' mathematical communication skills, with most reporting low performance. For example, Anisa & Rini (2022) investigated senior high school students' communication skills in solving linear programming problems in relation to self-confidence. Popi et al. (2022) explored the influence of self-confidence on the low communication skills of students at SMA Negeri 1 Kawali in the 2021/2022 academic year. In addition, Shofiyana Noor & Rochmad (2023) examined junior high school students' mathematical communication skills based on self-confidence in a Problem-Based Learning setting supported by STEM modules. However, to date, no study has specifically investigated the relationship between mathematical communication skills and self-confidence within a single study using exponent learning as the main context and involving eleventh-grade senior high school students as participants. This gap underscores the urgency of the present study.

This study not only seeks to confirm previous findings but also aims to provide new contributions by analyzing in greater depth how varying levels of self-confidence (high, moderate, and low) influence specific aspects of students' mathematical communication skills in exponent learning. In short, this research addresses the existing gap by investigating the mathematical communication skills of eleventh-grade students in the context of exponent learning, with a focus on their levels of self-confidence.

Method

Type of Research

Method employed in this study was descriptive qualitative research with a case study design, as it aligned with the objective of describing students' mathematical communication skills in relation to self-confidence in learning exponents. Type of research employed in this study was qualitative research with a case study approach. A case study is defined as an in-depth description and analysis of a bounded system, namely a system in which one case is interconnected with others (Oktaviana, 2022). The qualitative research process involves several essential steps, such as formulating research questions and procedures, collecting specific data from participants, analyzing the data inductively from particular themes to broader themes, and interpreting the meaning of the data (Triana, 2020b). The rationale for adopting a qualitative approach in this study was to explore more carefully and deeply, as well as to gain a comprehensive understanding of students' mathematical communication skills in exponent learning in relation to their self-confidence.

Subjects

Subjects in this study were determined through a two-stage selection process. In the first stage, subjects were selected based on self-confidence questionnaire scores, which were categorized into three groups: high, moderate, and low. From these results, an initial number of subjects was identified for each category. In the second stage, to obtain the final representative subjects, one student was chosen from each self-confidence category (high, moderate, and low) according to their mathematical communication tendencies as reflected in the exponent test. The selection of one student from each category was intended to provide a comprehensive picture of the relationship between self-confidence and mathematical communication skills across different confidence levels. Thus, the final subjects in this study consisted of three students.

Instruments

Instruments used in this study included a self-confidence questionnaire, a mathematical communication skills test based on exponent material, and semi-structured interviews.

Questionnaire

Self-confidence questionnaire used in this study was adopted from a previous study and had been validated by a lecturer at UIN Mataram. It was developed based on four indicators: (1) belief in one's own abilities, (2) acting independently in decision-making, (3) having a positive self-concept, and (4) being confident in expressing opinions. The questionnaire consisted of 20 statements, each with four response options. The blueprint of the self-confidence questionnaire used in this study is presented in Table 1.

Table 1. Indicators and Sub-Indicators of Self-Confidence

No.	Indicator	Sub-Indicator
1	Belief in one's own abilities	Not easily influenced by others. Willing to make choices when facing opposing opinions.
2	Acting independently in decision-making	Able to study independently. Able to solve problems without assistance from others.
3	Having a positive self-concept	Persistent when working on mathematics problems. Optimistic about success in learning mathematics. Willing to accept criticism and suggestions from others for self-improvement.
4	Confidence in expressing opinions	Willing to express opinions during group discussions. Willing to propose solutions to mathematical problems during discussions. Willing to present or communicate the results of discussions.

Test

Test used to measure students' mathematical communication skills in exponent learning was developed based on three indicators: (1) the ability to express mathematical ideas orally, in writing, and visually; (2) the ability to understand, interpret, and evaluate mathematical ideas both orally, in writing, and through other visual forms; and (3) the ability to use mathematical

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symbols and notations to represent mathematical ideas. An example of one of the test items used in this study is presented in Table 2.

Table 2. Mathematical Communication Skills Test Instrument

Indicator	Task	Task Characteristics
Ability to express mathematical ideas orally, in writing, and visually	Context: To observe the growth of a bacterium on its host, a researcher takes a section of the infected host and monitors it for the first 2.5 hours. Initially, there are 30 bacteria. The bacteria divide into two every 30 minutes.	a. Model the bacterial growth function for each phase. b. Draw the graph of the bacterial growth.

Interview

In this study, the researcher employed unstructured interviews to explore in-depth information related to the research subjects. The interviews were used to strengthen the data obtained from students regarding their process of completing the mathematical communication skills test. The interviews were conducted with three students who demonstrated a tendency to be able to answer the mathematical communication test items.

Procedures

Data collection procedure in this study was carried out using three main techniques: questionnaires, tests, and interviews. The self-confidence questionnaire was used to measure students' confidence levels and consisted of 20 statements with four response options on a Likert scale. This questionnaire was administered to all students as respondents. After completing the questionnaire, the researcher distributed a mathematical communication skills test on exponent learning. The test, in the form of open-ended questions, was designed to assess students' mathematical communication skills based on the indicators from the National Council of Teachers of Mathematics (NCTM). Furthermore, unstructured interviews were conducted with three students selected as research subjects. The interviews served to obtain deeper insights into the students' process of solving the test items and functioned as supporting data. The subjects were chosen based on test results that reflected their mathematical communication skills in accordance with the categories of self-confidence (high, moderate, and low).

Analysis

This study employed the interactive analysis model of Miles and Huberman combined with a thematic analysis approach. The process did not merely separate the data but also integrated it from three main sources: questionnaires, tests, and interviews (Belli & Annurwanda, 2024). In the data reduction stage, information from each source was simplified and categorized. The self-confidence questionnaire data were grouped into high, moderate, and low categories, while data from the mathematical communication test and interviews were condensed into key points. In the data presentation and thematic analysis stage, the integration of data took place. Rather than being presented separately, the data were connected for each subject. For instance, the responses of a high self-confidence subject on the test were analyzed alongside their interview statements. This analysis sought to identify patterns or themes to understand how levels of self-confidence influenced the way students communicated mathematical ideas. Finally, in the conclusion-drawing stage, the findings from the three data sources were combined. In this way, the study's conclusions became more robust and valid, supported by evidence from multiple perspectives.

Results

In this study, the researcher categorized the types of self-confidence by distributing a questionnaire to the students. Based on the self-confidence questionnaire results, 53 students were classified into three categories: high, moderate, and low. The categorization of students based on self-confidence is presented in Table 3.

Table 3. Results of the Self-Confidence Questionnaire

Category	Number of Students
High	8
Moderate	42
Low	3

Based on Table 3, among the 53 students who participated in the study, the questionnaire results revealed significant variations in self-confidence levels. The majority of students, 42 or 79.25%, demonstrated a moderate level of self-confidence. This indicates that most students possessed a fairly stable belief in their abilities, though not outstanding. Meanwhile, the high self-confidence group included only 8 students or 15.09%, and the low self-confidence group was the smallest, with only 3 students or 5.66%. These data provide an initial overview that most students were in a balanced psychological state, which may influence how they respond to academic challenges.

Subsequently, the researcher analyzed students' mathematical communication skills through the results of the mathematical communication test, examined in relation to the self-confidence questionnaire results. The research subjects selected were students who demonstrated a tendency to answer the mathematical communication test items on exponent material and who represented the three self-confidence categories: high, moderate, and low. The research subjects are presented in Table 4.

Table 4. Research Subjects

No.	Student Initials	Total Questionnaire Score	Level of Self-Confidence
1	SAP	63	High
2	AL	59	Moderate
3	MFA	26	Low

Test and Interview Results

Students' Mathematical Communication Skills with High Self-Confidence

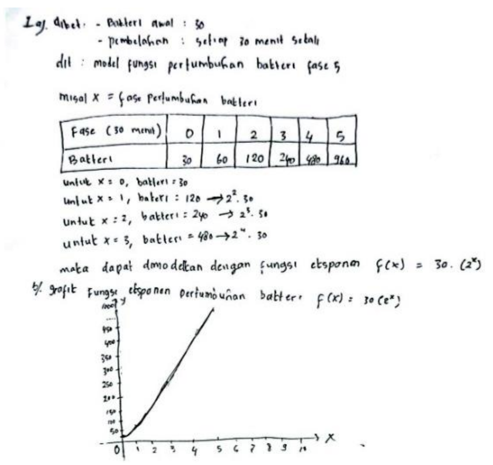

Figure 2. Component 1 of SAP's Response

Example: Initial bacteria = 30
Division occurs every 30 minutes.
Thus, the model of bacterial growth at phase 5 is constructed as follows:

Phase (x, 30 minutes)	0	1	2	3	4	5
Number of Bacteria	30	60	120	240	480	960

Let x represent the growth phase of the bacteria.
For $x = 0$, the number of bacteria $= 30 \times 2^0 = 30$.
For $x = 1$, the number of bacteria $= 30 \times 2^1 = 60$
For $x = 2$, the number of bacteria $= 30 \times 2^2 = 120$
For $x = 3$, the number of bacteria $= 30 \times 2^3 = 240$
For $x = 4$, the number of bacteria $= 30 \times 2^4 = 480$
For $x = 5$, the number of bacteria $= 30 \times 2^5 = 960$

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Hence, the bacterial growth can be modeled using the exponential function:

$$f(x) = 30 \cdot (2^x)$$

The graph of the exponential growth function is given by:

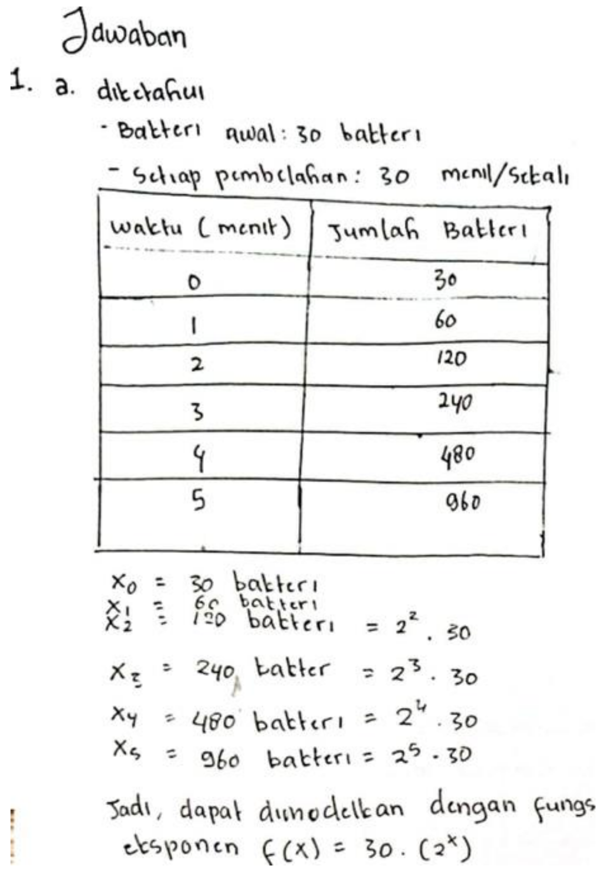
$$f(x) = 30 \cdot (2^x)$$

Based on the Figure 2, SAP began the problem-solving process by identifying and recording the key information provided. This included the initial number of bacteria (30), the rate of division (every 30 minutes), and the variable being asked (the bacterial growth function model at the 5th phase). SAP also demonstrated initiative by assigning “x” as the representation of the bacterial division phase, which served as an essential first step in mathematical modeling. The student then systematically constructed a table to visualize and simplify the calculation of the number of bacteria at each division phase. This strategy proved effective in organizing the data and understanding the growth pattern. Following this, SAP successfully formulated an accurate exponential function model in accordance with the problem’s requirements on bacterial growth. Furthermore, SAP articulated mathematical ideas both in written and visual form through the table, indicating a strong conceptual understanding. In addition, SAP’s success in illustrating the exponential function graph of bacterial growth, $f(x) = 30(2^x)$, highlights a comprehensive ability to represent and interpret mathematical relationships. Overall, these steps consistently demonstrate that SAP possesses strong skills in expressing mathematical ideas both analytically and visually.

Researcher	*How do you model a mathematical function that represents bacterial growth at each time phase?”*
SAP	*I represent x as the phase of bacterial growth*
Researcher	*What strategy do you use to make it easier to solve the problem?*
SAP	*To make it easier for me to solve the problem, I created a table to determine the number of bacteria at each phase. For example, at phase 0 there are 30 bacteria, then at phase 1 there are 60 bacteria, because at each phase the number doubles from the previous phase, and it continues like that until phase 5*
Researcher	*So, what is the function model of bacterial growth at each phase?*
SAP	*It can be modeled with the exponential function $f(x) = 30(2^x)$, as I wrote in my answer sheet.*
Researcher	*If you were asked to draw a graph of bacterial growth in the problem, what information would you present and what would the graph look like?*
SAP	*I would create a graph with the x-axis as the phase and the y-axis as the number of bacteria. Then I would plot points on the graph according to the number of bacteria at each phase—for example, at phase 0 there are 30 bacteria—and connect them accordingly.”*

Based on the interview results, the subject SAP demonstrated strong abilities in expressing mathematical ideas through written, visual, and oral forms. In writing, SAP successfully interpreted and summarized the problem information, as well as introduced variable representations that reflected a solid initial understanding of the problem. SAP’s visual ability was evident when systematically using a table to model bacterial growth and constructing an accurate graph, with appropriately defined x- and y-axes and a curve that illustrated exponential growth. Although there were minor inaccuracies in notation, these did not diminish the substance of the understanding. Orally, SAP’s ability to explain the process indicated a strong comprehension, as reflected in the way inductive reasoning was articulated to arrive at the correct exponential function. Thus, SAP effectively communicated mathematical thinking in multiple forms, fulfilling the indicators of the ability to express mathematical ideas.

Students’ Mathematical Communication Skills with Moderate Self-Confidence



Known:
Initial bacteria: 30
Each division: every 30 minutes

Time (minutes)	Number of Bacteria
0	30
1	60
2	120
3	240
4	480
5	960

$x_0 = 30$ bacteria
$x_1 = 60$ bacteria
$x_2 = 120$ bacteria $= 2^2.30$
$x_3 = 240$ bacteria $= 2^3.30$
$x_4 = 480$ bacteria $= 2^4.30$
$x_5 = 960$ bacteria$= 2^5.30$
Thus, the bacterial growth can be modeled by the exponential function:

$$f(x) = 30.(2^x)$$

Figure 3. Component 1 of AL’s Response

Based on the Figure 3, AL was only able to express mathematical ideas in oral and written forms. The following excerpt presents the results of the interview with AL.

Researcher	*Here, you created a table and wrote X_0, X_1 up to X_5 in the form of multiplication with 30. Then, you concluded that the exponential function is $f(x) = 30(2^x)$. Could you explain how you arrived at this conclusion?*
AL	*Yes. First, I saw from the problem that the initial number of bacteria was 30. Every 30 minutes, the amount doubles. So, at time 0, the number is 30. After 30 minutes (time 1), 30 is multiplied by 2 to become 60. After 60 minutes (time 2), 60 is multiplied by 2 to become 120, and so on.*
Researcher	*Then, how did you transform this into the form 2^x?*
AL	*I noticed that since the initial number of bacteria is 30, that becomes the base. Then, each time it divides, the quantity is multiplied by 2. The number of divisions depends on the time or the ‘phase’ of division. That is why I used 2^x, where x represents the number of divisions*

Based on the interview results, the subject AL demonstrated strong ability in expressing mathematical ideas orally and in writing. This was evident from the ability to present data in a table, identify multiplication patterns, and formulate an accurate exponential function, $f(x) = 30(2^x)$. Orally, AL was able to explain the reasoning process logically and in detail, providing justification for each component of the function, which indicated a deep conceptual understanding. However, there was a significant limitation in visual representation. AL was unable to draw the graph of the exponential function, indicating difficulties in representing mathematical relationships visually despite a solid algebraic understanding. This suggests that AL’s comprehension was not fully developed across all forms of mathematical representation.

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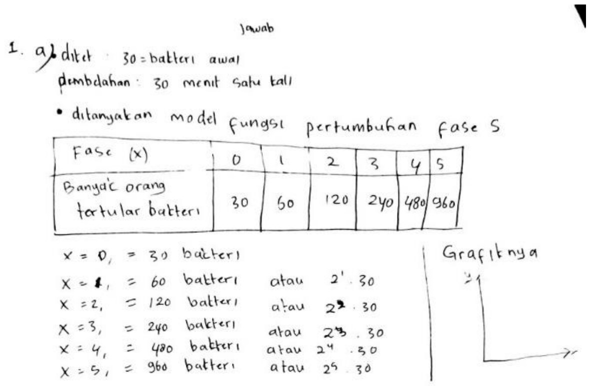
Students' Mathematical Communication Skills with Low Self-Confidence



Given:
Initial bacteria = 30
Division occurs every 30 minutes
It is asked to determine the growth function model up to phase 5.

Phase (x)	**0**	**1**	**2**	**3**	**4**	**5**
Number of infected by bacteria	30	60	120	240	480	960

For $x = 0 = 30$ bacteria
For $x = 1 = 60$ bacteria or $2^1.30$
For $x = 2 = 120$ bacteria or $2^2.30$
For $x = 3 = 240$ bacteria or $2^3.30$
For $x = 4 = 480$ bacteria or $2^4.30$
For $x = 5 = 960$ bacteria or $2^5.30$

Figure 4. Component 1 of MFA's Response

Based on the Figure 4, MFA cannot yet be considered fully capable of meeting the indicators of expressing mathematical ideas in oral, written, and visual forms, as the student did not complete the graph of the exponential function as required in the problem. The following excerpt presents the results of the interview with MFA.

Researcher	*How did you begin identifying the growth pattern? What was the first step you took after understanding the problem?*
MFA	*The first step I took was making a table. I created a column for 'Phase (x)' to show how many times the bacteria had divided, and a column for 'Number of Bacteria' to record the quantity at each phase.*
Researcher	*How did you connect the data in the table with the form* 30.2^x*? What did you notice from the numbers in the table that helped you find the pattern?*
AL	*After filling in the table, I looked at the numbers. From 30 to 60 it was multiplied by 2. From 60 to 120 it was also multiplied by 2. I noticed this consistent multiplication by 2. Then I realized that 60 is* 2×30*, 120 is* $4 \times 30 (2^2 \times 30)$*, 240 is* $8 \times 30\ (2^3 \times 30)$*. So, 30 is the initial value, and the power of 2 with the phase determines the amount.*
Researcher	*I noticed you started drawing the graph but did not finish. Why was it left incomplete?*
MFA	*It was because I wasn't confident with the graph I was drawing, so I decided not to complete it*

Based on the interview results, MFA demonstrated significant strength in written mathematical expression, as shown in the ability to identify key information, organize it in a well-structured table, and consistently recognize exponential growth patterns in multiplicative form. However, the student showed limitations in visual expression, as although the axes were drawn, the data points were not plotted and the growth curve was left incomplete. This indicates that while MFA possesses a solid conceptual understanding, the ability to translate mathematical ideas into visual representations still needs further development.

Discussion

Based on the results of the self-confidence questionnaire and the exponent test presented above, the findings of this study regarding students' mathematical communication skills at different levels of self-confidence (high, moderate, and low) in exponent learning. Students with high self-confidence, such as SAP, demonstrated comprehensive mathematical communication skills. They were able to express mathematical ideas fully across the three modalities: oral, written, and visual. This finding is consistent with international studies reporting that students with high self-confidence tend to express mathematical ideas comprehensively through multiple modalities (Campo-Meneses et al., 2021). Strong self-confidence enables them not only to understand concepts but also to represent their understanding clearly and systematically. This aligns with theories suggesting that self-confidence minimizes anxiety, thereby freeing cognitive capacity to construct logical arguments and choose the most effective representation (e.g., graphs for exponential growth). SAP's ability to construct graphs indicates a deep understanding of multiple representations, shifting from algebraic notation to visual representation seamlessly—an essential skill in mathematics. This result is also in line with Sunaryo et al. (2024). Furthermore, SAP's written solutions systematically captured key problem information, included tables and exponential growth graphs, and were explained clearly and logically. This is supported by Hendriana et al. (2018) and Asri Asi Putri et al. (2018), who argue that students with high self-confidence tend to show initiative and courage in expressing opinions and making decisions in problem-solving.

Students with moderate self-confidence, such as AL, demonstrated partial or incomplete communication skills. While they were able to communicate in oral and written forms, they failed in the visual aspect (graphing). This suggests that moderate self-confidence is not strong enough to overcome more complex cognitive challenges, such as transforming conceptual understanding into visual representations. Excessive cognitive load may hinder them from completing tasks that require integration of multiple representations. These students may understand concepts but lack the confidence to visualize ideas, revealing a gap between conceptual understanding and visual representational skills. This finding is consistent with Triana (2020a), who reported that students with moderate self-confidence remain weak in formal symbolic representation and visualization.

Students with low self-confidence, such as MFA, showed a striking disparity between cognitive ability and affective performance. While they demonstrated strong conceptual understanding through oral and written communication (explaining patterns and systematic steps), low self-confidence hindered them from completing the visual aspect. MFA's inability to complete the graph due to "lack of confidence" highlights that low self-confidence is not merely a lack of courage, but also a psychological barrier that prevents execution of tasks requiring visual representation. This is consistent with Sukatin et al. (2023), who noted that strong conceptual mastery does not always align linearly with high self-confidence. This gap is also reinforced by Jannah & Rahmi (2025), who found that some students struggle to visually represent mathematical ideas despite being able to communicate them orally and in writing.

Overall, it can be concluded that self-confidence influences students' mathematical communication skills. Students with high self-confidence are more confident in expressing and evaluating mathematical ideas across multiple forms of representation. Students with moderate self-confidence demonstrate adequate abilities but remain hesitant, while those with low self-confidence show strong potential in symbolic aspects but lack the confidence to express ideas visually. This study highlights the crucial role of self-confidence in mathematics learning. By implementing interventions that focus on building students' confidence, teachers can support students in reaching their optimal potential in mathematical communication (Asri Asi Putri et al., 2018).

Conclusion

This study concludes that self-confidence plays a crucial role in shaping students' mathematical communication skills. Students with high self-confidence demonstrated

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comprehensive abilities across oral, written, and visual modalities, while students with moderate self-confidence showed adequate but incomplete skills, particularly in visual representation. Conversely, students with low self-confidence experienced significant difficulties in visualizing mathematical ideas, despite demonstrating solid conceptual understanding through oral and written forms. The study is limited by its small sample size and qualitative case study design, restricting generalizability, and by its focus on a single topic (exponents). Nevertheless, the findings contribute to the literature by providing empirical evidence on how self-confidence influences students' mathematical communication in exponent learning, a context rarely examined in previous studies. Practically, the results underscore the importance for teachers to integrate strategies that not only strengthen conceptual understanding but also actively build students' self-confidence through collaborative tasks, classroom discussions, and visual modeling activities. Future research should expand the scope to larger and more diverse samples using quantitative or mixed-method approaches to examine statistical significance and to design targeted interventions for enhancing visual communication skills in mathematics learning

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Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

Author L.F. was responsible for developing the research instruments, drafting the study, conceptualizing the theoretical framework, collecting and processing data, conducting data analysis, presenting the results and discussion, revising the manuscript, and ensuring consistency throughout the article. Author H.R.P.N. contributed to the development of the theoretical framework and approved the final version of the manuscript. Author Y.N. also contributed to the development of the theoretical framework and approved the final version of the manuscript. The percentage contributions of the authors to the conceptualization, drafting, and revision of this article are as follows: L.F.: 60%, H.R.P.N.: 20%, and Y.N.: 20%..

Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, [L.F.], upon reasonable request.

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