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Analyzing Eighth-Grade Students' Mathematical Communication Skills in Solving Exponential Problems

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Abstract

This study examines the mathematical communication skills of eighth-grade students in solving exponential problems. Effective mathematical communication enables students to articulate ideas clearly through writing, drawings, or symbols. A descriptive qualitative method was used, involving three students with high, medium, and low math abilities. Data were collected via problem-solving tasks and semi-structured interviews to analyze students' strategies and thought processes. Results revealed notable differences in skills: high-ability students developed accurate models but lacked consistency, medium-ability students had a sufficient foundation but struggled with contextual interpretation, and low-ability students relied on basic operations without grasping the problem's context. These findings emphasize the need for adaptive learning approaches tailored to students' abilities to enhance mathematical communication. Study limitations include a small sample size and narrow topic focus. Future research should explore broader samples and topics to deepen insights, contributing to the development of more responsive math teaching methods that effectively foster mathematical communication skills.

Abstrak: Penelitian ini menganalisis keterampilan komunikasi matematis siswa kelas VIII dalam menyelesaikan masalah pada topik bilangan berpangkat. Keterampilan komunikasi matematis memungkinkan siswa untuk mengekspresikan ide dan konsep matematis secara jelas, baik melalui tulisan, gambar, maupun simbol matematis. Metode penelitian yang digunakan adalah pendekatan kualitatif deskriptif dengan melibatkan tiga siswa dari kategori kemampuan matematika tinggi, sedang, dan rendah. Data dikumpulkan melalui tugas pemecahan masalah dan wawancara semi-terstruktur untuk mengeksplorasi strategi serta proses berpikir siswa dalam mengekspresikan ide matematis. Hasil penelitian menunjukkan variasi signifikan dalam keterampilan komunikasi matematis siswa. Siswa dengan kemampuan tinggi mampu menyusun model matematika yang akurat, meski masih membutuhkan peningkatan konsistensi. Siswa dengan kemampuan sedang memiliki dasar pengetahuan yang cukup tetapi kesulitan dalam memaknai informasi kontekstual, sedangkan siswa dengan kemampuan rendah cenderung langsung menggunakan operasi dasar tanpa pemahaman mendalam terhadap konteks permasalahan. Temuan ini menyoroti pentingnya pendekatan pembelajaran adaptif untuk meningkatkan keterampilan komunikasi matematis sesuai tingkat kemampuan siswa. Keterbatasan penelitian ini mencakup jumlah sampel yang kecil dan fokus topik yang terbatas. Penelitian lanjutan disarankan untuk melibatkan sampel yang lebih besar dan berbagai topik matematika untuk memperkaya hasil. Temuan ini memberikan kontribusi penting bagi pengembangan metode pembelajaran matematika yang lebih responsif terhadap kebutuhan siswa dan mendukung pengembangan keterampilan komunikasi matematis secara efektif.

Kata Kunci: Komunikasi matematis, bilangan berpangkat, SMP, Matematika, pemecahan masalah

INTRODUCTION

Mathematical communication is a crucial skill in mathematics education, enabling students to express ideas, organize thoughts, and deepen their understanding of concepts (Umar, 2012). It entails using mathematical language to convey ideas clearly and effectively, both orally and in writing (Andriani, 2020; Lubis et al., 2023; Maulyda et al., 2020; Qohar, 2011). This skill includes relating mathematical concepts across contexts and expressing real-world situations mathematically (Fay et al., 2022). Developing mathematical communication skills in schools enhances students' problem-solving abilities by fostering connections between concepts, recognizing errors, and evaluating solutions (Puspa et al., 2019; Suharto & Widada, 2019).

Mathematical communication skills encompass explaining concepts, using correct notation, interpreting representations, and drawing logical conclusions (Fay et al., 2022; Rohid et al., 2019). The National Council of Teachers of Mathematics identifies three core aspects of these skills: expressing ideas, understanding and evaluating mathematical concepts, and using precise terminology (Lutfianannisak & Sholihah, 2018; NCTM, 2000). Common indicators for assessing these skills include articulating ideas through writing and visuals, interpreting mathematical concepts accurately, and using correct notation (Turmuzi et al., 2021). Additional indicators involve connecting concepts with tangible objects and describing everyday situations in mathematical language (Lubis et al., 2023).

Mathematical communication skills are essential for students to comprehend and apply mathematical concepts in real-world contexts (Harianja et al., 2020). These skills enable students to express, interpret, and evaluate mathematical ideas through various representations (Puspa et al., 2019; Rohid et al., 2019). Effective mathematical communication not only supports academic achievement but also enhances critical thinking and adaptability in social contexts (Annisak & Wandini, 2023; Siregar, 2018). However, students' abilities to communicate mathematically often vary, influenced by their confidence levels and overall proficiency (Aprisal & Abadi, 2018; Fay et al., 2022).

Factors such as collaborative learning, teacher feedback, and digital tools can improve mathematical communication (Anisa et al., 2023). Nonetheless, studies indicate that students frequently struggle with written communication, especially in translating word problems into mathematical models (Azizah et al., 2020). Research highlights that many students encounter difficulties with specific aspects of communication, such as drawing and mathematical expression (Utami et al., 2021; Zulhelmi & Anwar, 2021). Numerous studies report low levels of mathematical communication skills among students, underscoring the need for targeted improvement (Rusyda et al., 2020; Sari et al., 2017).

Numerous studies have explored students' mathematical communication skills across educational levels and math topics, including linear algebra for college students, exponents for high school students, and data presentation for junior high students (Anderha & Maskar, 2020; Maryati et al., 2022; Purnamasari & Afriansyah, 2021). Findings indicate that many students need help to meet the expected indicators of mathematical communication skills. For instance, although Anderha and Maskar (2020) observed strong communication skills in some high school students, many still needed help effectively understanding and expressing mathematical ideas. Purnamasari and Afriansyah (2021) found that seventh-grade students' skills in data presentation were notably low, particularly in visual interpretation and data analysis. Similarly, Yullatifa et al (2022) showed that while high-ability nineth-grade students met more communication indicators, students with intermediate or low abilities struggled to do so.

Research by Ismayanti and Sofyan (2021) on eighth-grade students revealed that those with lower mathematical skills struggle to meet mathematical communication indicators, highlighting an urgent need to identify factors that influence these skills and design more effective learning strategies. While much research has examined mathematical communication skills across educational levels, gaps remain—particularly at the junior high level and on specific topics like exponential. Most existing studies, such as those by Anderha and Maskar (2020) and Maryati et al. (2022), focus on high school students and overlook targeted strategies to enhance communication skills for younger students.

This study addresses this gap by analyzing mathematical communication among eighth-grade students, specifically on exponential, a topic underrepresented in prior research. Recognizing the documented challenges faced by junior high students in mathematical communication (Ismayanti & Sofyan, 2021; Purnamasari & Afriansyah, 2021), this study aims to investigate how these students articulate their mathematical communication skills in solving exponential problems. As part of a broader research initiative, this study will provide insights into students' mathematical communication abilities based on their skill levels, contributing valuable information for the development of tailored instructional strategies.

METHOD

This study employs a descriptive qualitative approach to explore the mathematical communication skills of eighth-grade students in solving exponentiation problems. The qualitative approach enables an in-depth exploration of students' thought processes as they develop and communicate mathematical ideas. This method provides a comprehensive view of how students articulate mathematical concepts verbally and in writing, as well as their use of symbols, diagrams, and notation in problem-solving. The research focuses on assessing students' experiences based on mathematical communication indicators as outlined by Lubis et al. (2023): 1) expressing mathematical ideas and relationships through diverse representations in writing; 2) linking objects or images to mathematical concepts; and 3) using mathematical language or symbols to describe everyday situations.

The study was conducted at a well-regarded junior high school in Sulawesi, Indonesia, chosen to represent students' mathematical communication skills in an academically strong environment. From a population of 27 students, three were selected through purposive sampling to represent varying levels of mathematical ability—high, medium, and low. This selection, informed by teacher recommendations and preliminary observations, ensures diverse perspectives in the data collected. The three participants are expected to provide detailed insights into how students communicate mathematically, particularly in solving exponentiation problems, allowing for a broader mapping of mathematical communication patterns. This approach enables analysis of the participants' use of notation and symbols, argument structure, and expression of ideas in both oral and written forms.

Data for this study were gathered using two primary techniques: problem-solving assignments and semi-structured interviews. The problem-solving task included three questions specifically crafted to assess students' mathematical communication skills on the topic of exponentiation, requiring them to express their mathematical ideas through various forms of representation. Following the completion of these tasks, semi-structured interviews were conducted to delve further into students' understanding and strategies used in problem-solving. This interview format allowed researchers the flexibility to adapt questions based on student responses, enabling a more detailed and in-depth collection of information.

After data collection, analysis proceeded through four stages: data presentation, data reduction, data interpretation, and conclusion drawing (Miles et al., 2014). In the data presentation stage, responses from problem-solving tasks and interviews were organized according to key aspects of mathematical communication, including concept explanation, the use of mathematical notation and symbols, and the construction of logical, coherent arguments, creating a structured format for further analysis. During data reduction, irrelevant information was filtered out, leaving only data directly related to the indicators of mathematical communication skills being studied, allowing researchers to concentrate on significant information and avoid analyzing excessive or unrelated data.

In the data interpretation stage, the researcher develops a narrative based on the collected and analyzed data, interpreting findings by relating them to mathematical communication theory and compiling an in-depth description of students' mathematical communication characteristics. This process includes exploring relationships between mathematical communication indicators and examining how these indicators appear in students' responses. The final stage is conclusion drawing, where the researcher synthesizes findings and enhances validity through triangulation. This step involves comparing data from problem-solving tasks with interview data to ensure accuracy and reliability. Triangulation is crucial for maintaining data consistency and reducing subjective bias during analysis.

RESULTS AND DISCUSSION

Results

The characteristics of students' mathematical communication skills in solving exponential problems are presented in **Table 1**.

Table 1. Characteristics of Students' Communication Skills

Category	Characteristics		
	S-01 (High)	S-02 (Moderate)	S-03 (Low)
Understanding Mathematical Ideas in Writing	Able to clearly and structurally write mathematical expressions based on problem information, connecting relevant details with appropriate mathematical statements or expressions, and constructing accurate mathematical models from known data	Able to write mathematical expressions that reflect the relationship of understanding information to the basic idea, but has difficulty fully interpreting the problem's intent, often resulting in inaccuracies	Unable to write mathematical expressions aligned with problem information, directly jumping to calculations using basic addition and multiplication without explaining their meaning
Connecting Real-World Contexts to Mathematical Ideas	Able to convert problem information into relevant mathematical expressions, sometimes misunderstanding the problem's specific aim, which impacts the solution steps and final result, and needs greater precision to ensure expressions align precisely with the question	Writes mathematical expressions based on information provided in the problem but often misinterprets data, leading to calculation errors	Writes mathematical expressions based on provided information but often misinterprets data, resulting in calculation and answer errors
Representing Contextual Events in Mathematical Models	Accurately represents problem information within a mathematical model but lacks consistency in solving the problem fully; not all aspects are addressed thoroughly	Limited in representing problem information in a mathematical model; often misinterprets data, showing difficulty in following structured, accurate problem-solving procedures	Unable to represent problem information in a mathematical model, interpreting problems subjectively and using symbols and operations without contextual explanation, leading to entirely incorrect answers

Based on **Table 1**, significant differences were found in the mathematical communication skills of students, corresponding to their levels of mathematical ability. In understanding mathematical ideas, there was a clear distinction among the three participants. Students in the high category (S-01) are able to write mathematical expressions clearly and in a structured manner, consistent with the information provided in the problem. S-01 demonstrates the ability to connect relevant information to precise mathematical statements or expressions and to construct accurate mathematical models. In an interview, S-01 stated,

> "I try to understand all the information in the question first, then I write down the steps to solve it."

An example of S-01's solution to the first problem is presented in **Figure 1**. **Figure 1** illustrates how S-01 approaches the first problem by interpreting it through both discussion and mathematical expressions, establishing relationships that align with mathematical concepts. Based on this interpretation, S-01 proceeds with solution steps, linking the problem's requirements to relevant mathematical concepts. These findings suggest that students in the high category demonstrate a strong ability to represent mathematical ideas in writing, showing a mature understanding of mathematical structures and symbols within the context of exponential.

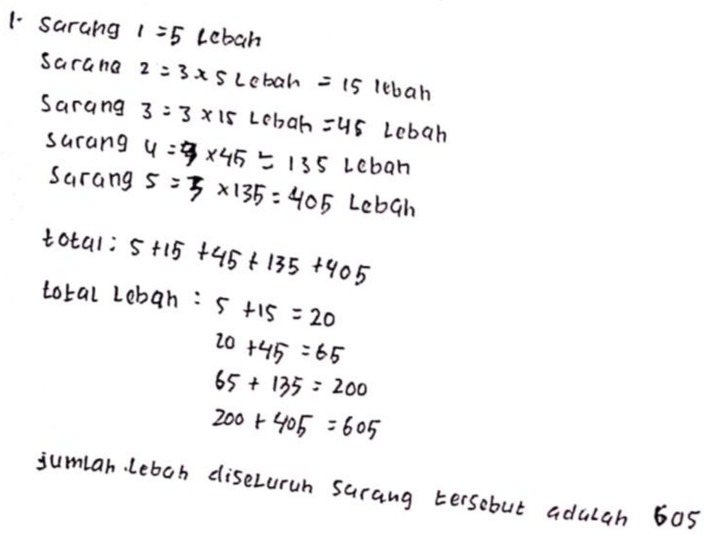

Figure 1. S-01's Answer to the First Problem

In contrast, students in the medium category (S-02) can only write mathematical expressions that reflect basic relationships. However, S-02 needs help to fully grasp the question's intent, leading to inaccurate answers. S-02 expressed,

> "Sometimes I am not sure if the steps I am taking are right or not, so I just write what I understand."

An example of S-02's response to the first problem is shown in **Figure 2**. **Figure 2** shows that S-02 attempted to interpret the problem by creating a mathematical model that connects the information with mathematical expressions. However, S-02 needed to have understood the bee growth pattern, assuming it increased by five times instead of the correct threefold pattern. This misunderstanding led to errors in the final answer. These findings suggest that, while S-02 has a foundational grasp of representing mathematical ideas, more interpretation of complex instructions is needed to ensure accurate solutions.

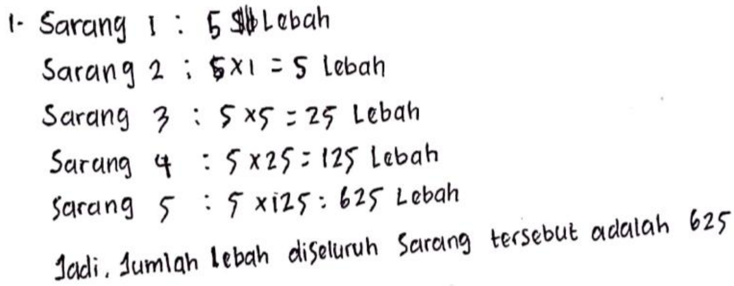

Figure 2. S-02's Answer to the First Problem

In contrast, students in the low category (S-03) displayed significant difficulty in writing mathematical expressions aligned with the problem's information. Rather than developing a mathematical model to represent the problem, S-03 directly performed calculations using basic operations, such as addition and multiplication, without regard for the appropriateness of meaning or context. Interviews supported these findings, with S-03 stating,

"I am just trying to guess what needs to be calculated."

Figure 3 shows an example of S-03's problem-solving steps. As shown in **Figure 3**, S-03 immediately begins solving the problem with numerical operations, bypassing initial steps that would indicate an understanding of the problem's information. The operation pattern chosen by S-03 needs to align with the problem's requirements, highlighting inaccuracies in the approach. These findings suggest that S-03 has yet to develop a strong understanding of mathematical structures and representations, which impacts its ability to solve exponential problems accurately.

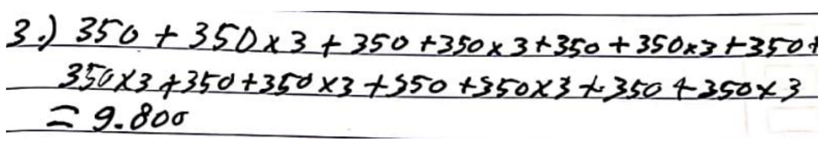

Figure 3. S-03's Answer to the Third Problem

In terms of connecting real-world contexts with mathematical ideas, S-01 demonstrates a strong ability to convert problem information into relevant mathematical expressions. However, S-01 sometimes needs help to fully grasp the specific purpose of the question, leading to occasional inaccuracies in the final answer. S-01 stated,

"Sometimes I understand the problem but do not always know how to get an accurate answer."

This finding suggests that while high-ability students like S-01 can relate mathematical concepts to real contexts, they could further benefit from enhancing their rigor sand accuracy in interpreting the intent of the problem to achieve more precise results.

S-02 are generally able to write mathematical expressions based on the provided information. However, they often need to be more accurate with data, leading to incorrect calculations. As S-02 stated in an interview,

"I think I understood, but after trying, the results were wrong."

This statement suggests that while medium-category students can convert data into mathematical expressions, their grasp of contextual information still needs to be improved. Strengthening their ability to interpret data findings accurately could help them relate real-world problems to appropriate mathematical concepts more effectively.

In contrast, S-03 struggle to connect the visual and abstract elements of a problem with the corresponding mathematical concepts. Misinterpretations of problem information directly impact their calculation process, resulting in incorrect final answers. S-03 stated,

"It's hard for me to see how the word problem turns into an equation or formula."

In the interview excerpt, S-03 acknowledged experiencing difficulty in solving problems presented as abstract word problems. This discovery indicates that S-03 faces challenges in understanding the connection between contextual elements and mathematical representations. This difficulty can hinder their ability to relate mathematical concepts to real-life scenarios—an essential skill in understanding exponential concepts.

When it comes to developing mathematical models of contextual events, S-01 demonstrates fairly strong ability, though consistency in solving the entire problem remains an area for improvement. S-01 can translate problem information into an accurate mathematical model, but certain parts of the problem may still need to be fully addressed. These limitations could stem from inconsistencies in following the complete solution procedure or from time constraints affecting thoroughness. Overall, however, S-01 shows a solid understanding of representing exponential problems through mathematical models.

S-02 displays notable limitations in translating problem information into mathematical models. Frequently, S-02 needs to interpret given information, resulting in errors within the solution process. This finding suggests that while students with moderate abilities can recognize some basic elements needed to construct mathematical models, they need help following a structured and accurate approach. Therefore, these students would benefit from more intensive guidance to develop their skills in creating mathematical models from contextual information.

Conversely, S-03 shows an inability to build accurate mathematical models of contextual events. These students often interpret problems subjectively, immediately applying symbols or mathematical operations without considering the context, which leads to incorrect answers. This discovery indicates that students in the low category not only face challenges in connecting real-world contexts to mathematical concepts but also need help with formulating appropriate mathematical models for the problems they encounter.

A triangulation analysis, combining findings from problem-solving results and interview data, reveals consistent patterns. High-category students demonstrate a strong understanding and consistency in grasping mathematical ideas, though they could improve their precision. Medium-category students have a foundational understanding but still face challenges in interpreting contextual data accurately. Low-category students show significant limitations across all aspects, which aligns with the difficulties they reported in interviews.

Discussion

This study revealed significant differences in mathematical communication skills among students with high, medium, and low abilities, which influenced the accuracy and coherence of their answers when solving exponential problems. These findings align with previous research, indicating that mathematical communication skills often vary based on students' mathematical ability levels and confidence (Aprisal & Abadi, 2018). For instance, research by Ismayanti and Sofyan (2021) found that students with lower mathematical skills frequently need help to meet key indicators of mathematical communication. This observation is consistent with the current study, where low-category students demonstrated difficulty in converting contextual problems into appropriate mathematical models, often approaching problems subjectively without following formal procedures. In contrast, high-ability students (S-01 category) were able to construct relevant mathematical expressions, though some inconsistency remained in fully solving the problems.

Similarly, research by Purnamasari and Afriansyah (2021) found that students with intermediate abilities also face challenges in interpreting data and constructing mathematical models. This finding is mirrored in the present study, where medium-category students (S-02) frequently misinterpret question information, leading to inaccurate answers. Overall, this study underscores the importance of improving accuracy in interpreting mathematical data and developing more adaptive learning models to meet the diverse needs of students across skill levels.

Additionally, this study highlights areas for improvement in constructing mathematical models for contextual events, a difficulty also reported by Azizah et al. (2020) in their research on students' challenges in translating word problems into mathematical models. Here, low-ability students (S-03) tended to rely on basic mathematical operations without creating an appropriate model, revealing a significant gap in understanding the underlying mathematical structure. These findings are consistent with Utami et al. (2021), who noted that students often struggle with expressing mathematical ideas, particularly in contexts that require visual and abstract representations involving deep reasoning.

The study underscores the importance of a more systematic approach to enhancing students' mathematical communication skills. Findings indicate that students in the high category demonstrate strong abilities in converting problem information into relevant mathematical expressions but still require greater precision in interpreting question intent to produce more accurate final results. The need for improvement of this ability suggests that while these students' mathematical communication skills are well-developed, their accuracy could be further refined. This case aligns with the findings of Harianja et al. (2020), which emphasize that effective mathematical communication not only supports academic success but also enhances critical thinking and adaptability in social interactions. Therefore, the results of this study highlight the need for targeted coaching to improve rigor among high-ability students, contributing to more comprehensive problem-solving outcomes.

The study also emphasizes the essential role of collaborative learning and feedback as effective strategies for strengthening mathematical communication skills. Research by Anisa et al. (2023) shows that collaborative learning and teacher feedback have a positive impact on students' ability to articulate mathematical ideas and understand more complex concepts. In this context, the current study recommends implementing more adaptive learning methods, particularly for students facing challenges in developing their mathematical communication skills. Collaborative learning enables students to share ideas and learn from peers, which can lead to overall improvements in mathematical communication skills.

This study also highlights the potential of digital technology to enhance students' mathematical communication skills. Fay et al. (2022) suggest that incorporating technology into mathematics learning provides students with interactive opportunities to explore varied visual representations, which can be especially beneficial for understanding abstract concepts. Consequently, this study recommends using digital devices as learning aids, particularly for low-ability students who may benefit from visual and interactive support in bridging mathematical concepts with real-world contexts.

In sum, the findings of this study emphasize the need for a holistic approach to improving students' mathematical communication skills. Students with high, medium, and low abilities have distinct needs in the math learning process, especially in terms of mathematical communication. Therefore, this study advocates for a differentiated learning approach that aligns with students' ability levels. High-ability students could benefit from additional challenges to improve accuracy. In contrast, medium- and low-ability students may require extended time to thoroughly understand the context and procedures essential for solving mathematical problems.

CONCLUSION

This study aims to analyze the mathematical communication skills of eighth-grade students in solving exponential problems. The results indicate significant differences in mathematical communication skills across students with high, medium, and low ability levels. High-ability students tend to construct precise mathematical expressions and demonstrate a strong capacity to translate contextual information into accurate mathematical models; however, they still face challenges in maintaining consistency and thoroughness throughout the entire problem-solving process. Students with moderate ability exhibit a basic proficiency in expressing mathematical ideas but need help with interpreting contextual data, which often leads to calculation errors. Meanwhile, low-ability students need help in connecting the visual and abstract elements of the problem to relevant mathematical concepts and tend to apply mathematical operations with a deep understanding of the problem's context. These findings offer valuable insights into the diverse learning needs of students based on their ability levels. Accordingly, a more adaptive learning approach is highly recommended to support students in developing their mathematical communication skills effectively.

While this study significantly enhances the understanding of mathematical communication skills among eighth-grade students within the context of exponential, it has several limitations. One major limitation is the small sample size, consisting of only three students with differing ability levels, which may impact the generalizability of the findings, as variations in student characteristics beyond this sample may not be fully represented. Additionally, the study's use of a descriptive qualitative approach provides in-depth insights into students' thought processes. However, it lacks the quantitative measurements that could offer a more precise evaluation of mathematical communication skill levels. Furthermore, the study focuses exclusively on exponential number, a topic with unique characteristics that may not generalize to other mathematical areas.

Given these limitations, further research is recommended to examine students' mathematical communication skills across a larger population and a broader range of mathematical topics, such as algebra, geometry, and statistics. Quantitative research methods, such as surveys or experimental designs, could provide a more objective and comprehensive measurement of students' mathematical communication skills. Additionally, future studies could investigate the effectiveness of various instructional approaches—such as incorporating interactive digital technology, project-based learning, or group discussions—to enhance mathematical communication skills across different ability levels.

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